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# Preface

The Association of South-East Asian Nations (ASEAN) Postharvest Seminar series is recognised as the premier forum for discussion of research and development activities by regional postproduction specialists. The seminars are generally held every two years and attract participants from throughout the region and much further afield.

The 19th ASEAN Seminar on Postharvest Technology was special in at least three ways. First, the commodity scope was extended from grain and other ‘durable’ commodities to include also fruits and vegetables, ‘perishable’ commodities whose large postharvest losses in the region demand research and development attention. Second, the seminar was, for the first time, held under the aegis of APEC, the Asia–Pacific Economic Cooperation forum. Third, this was the first ASEAN Postharvest Seminar to be held in Vietnam and, indeed, may have been the largest such gathering so far held there.

The theme of the seminar—Quality Assurance in Agricultural Produce—acknowledged that this is a time in which trade in agricultural produce is playing a vital role in stimulating the economies of the region. The nexus between ‘quality’ and ‘trade’ was a topic of detailed analysis in presentations and discussions during the seminar.

The purpose of postharvest handling is timely delivery of a product that closely matches buyer specifications and meets regulatory requirements. Satisfying customers underpins quality assurance (QA) and other quality systems that aim to provide product of the desired standard. As export markets become increasingly competitive, responsive QA can be crucial for maintaining and expanding markets. In addition, at national and international levels, the deliberations of the World Trade Organization and other policy changes have provided the framework for regional moves to promote uptake and harmonisation of quality standards. Ample coverage of all these issues will be found in the papers in this volume.

We thank the Australian Centre for International Agricultural Research (ACIAR) for sponsoring the seminar and publication of the proceedings, and the Australian Agency for International Development (AusAID) and the Danish International Development Assistance Agency (DANIDA) for supporting the attendance of a large number of regional participants. We thank all presenters and participants, and all those who were involved in organising the seminar — the enthusiastic contributions of both these groups made the event an outstanding success.

Greg Johnson  
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ACIAR Postharvest Technology  
Program

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# Opening Address

Honourable Mr Chairman, ladies and gentlemen:

On behalf of the Ministry of Agriculture and Rural Development (MARD), I would like to welcome the international and local delegates to the 19<sup>th</sup> Association of South-East Asian Nations (ASEAN) and 1<sup>st</sup> Asia–Pacific Economic Cooperation (APEC) Postharvest Technology Seminar organised by the Post-Harvest Technology Institute (PHTI HCMC) in cooperation with the Australian Centre for International Agricultural Research (ACIAR) in Ho Chi Minh City on 9–12 November 1999.

The topics of the seminar have drawn much attention from many people, especially farmers, as the development of postharvest technologies will not only promote commodity agriculture and raise the commercial value of agro-products, but improve conditions for farmers to exploit and use their land reasonably, create more jobs for them and help increase their income. The development of postharvest technologies will be the basis for the firming-up of rural industrial and service areas and thus change the rural economic structure as well as reorganise the labour to speed up the process of industrialisation and modernisation. The development of postharvest technology therefore affects not only the economics but also the society.

The Ministry of Agriculture and Rural Development would like to express its support to the international and local organisers for their good idea of holding the seminar and their hard preparation to ensure its success.

At present, postharvest technologies in Vietnam are still limited: only around 50% of agro-products are processed; most products for export are minimally processed; and some are in raw form.

Even though Vietnam is the second largest rice exporting country, the capacity of rice processing enterprises is just 10 million tonnes/year in total. In the whole country, there are about 100 coffee processors, 40 rubber enterprises, 50 tea plants, 41 sugar factories, 60 cashew nut units and 20 fruit–vegetable processors. To set up agriculture for export, the Government of Vietnam has approved programs of processing development and marketing of agro-products that represent important parts in the total value of agricultural products.

I am glad that hundreds of international and local scientists are taking part in the seminar. This seminar provides a really big forum for the scientists to discuss and communicate new findings in postharvest technologies. This is also a good chance for Asia–Pacific scientists to develop, broaden their cooperation, and exchange experiences for new peaks in science.

With this spirit, I wish the seminar great success and wish all the participants good health and happiness.

Thank you.

Professor Ngo The Dan  
Vice Minister of MARD

# Vietnam's Agriculture in the Context of Regionalisation and Globalisation: Opportunities and Challenges

Bui Thi Lan\*

## *Abstract*

Vietnam is an agricultural country with over 77 million people, 76.5% of them living in rural areas. Agricultural land accounts for 22.2% of the total area of the country. Agricultural production has a great influence on national economic development. Looking back on the national economic development process, particularly of agriculture, it can be outlined as follows:

— Before 1988: the Vietnamese economy had been operating under the centralised planning mechanism. All the land and materials for agricultural production were under State ownership. Agricultural production was centrally planned by the Government of Vietnam (GOV).

— Since 1988: the GOV launched the campaign for economic renovation, with the focus on agricultural production. New policies have been introduced. Profound reforms have also taken place in the agricultural sector. With adoption of the renovation policy great achievements have been made in agriculture, among which the most outstanding is food production.

The process of regionalisation is taking place worldwide and is a common trend for all the countries including Vietnam. In 1995 Vietnam became a full member of the Association of South-East Asian Nations (ASEAN) and has participated in most regional organisations and agreements, including the Common Effective Preferential Tariff (CEPT), ASEAN Free Trade Area (AFTA) and the Asia-Pacific Economic Cooperation (APEC) group, and is preparing to join the World Trade Organization. New opportunities are open for Vietnam, e.g. exchange trade, and economic and financial cooperation with member countries including developed countries. On the other hand, the country is facing great challenges as it is bound to implement commitments made when joining these organisations, such as reduction in tariffs and removal of non-tariff barriers. This means that Vietnam's economy in general, and agriculture in particular, will be subject to tougher competition.

The paper also recommends measures to be considered and taken to improve the competitiveness of Vietnam's agriculture.

## Overview of Vietnam's Agriculture

VIETNAM'S agriculture plays a very important role in the country's economy; 76.5% of the population lives in rural areas, 76.88% of the total labour force (42.6 million people) consists of rural labour. Agricultural land covers 22.2% of the total area of the country. The sector provides about 30% of the country's national income. Given these facts it is

obvious that agriculture has a great influence on national economic development.

## Before 1988

The Vietnamese economy operated under a centralised planning mechanism with cooperatives and state enterprises acting as the main economic components. All agricultural sources and materials were under state ownership. Agricultural production was planned by the Government and distribution of the products to farmers was on an average basis. During

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this period, the price of agricultural products did not rely on production costs and market supply–demand rules; consequently, farmers were not encouraged to make efficient use of agricultural resources and therefore the country’s agricultural productivity was very low.

## Since 1988

Recognising weaknesses of the centralised planning mechanism, the Government introduced a series of economic renovations focused on the agricultural sector. Over the past decade, a great number of agricultural renovation policies have been issued and implemented, such as the agricultural and forestry land allocation policy, agricultural and forestry extension policy etc. These policies have brought remarkable achievements in agricultural and forestry production in general and food production in particular. An agricultural annual growth rate has been maintained at around 4.5–5%. As a result, from a country with a food deficit, Vietnam has now become one of the largest exporters in the world of rice, coffee and cashew nuts. The increase of trade turnover from agricultural and forest products for the period from 1989–1999 has been nearly 20% per year.

## Vietnam’s Agriculture in the Context of Regional and Global Economic Integration

### Vietnam’s agriculture and its integration process

The opening up of the Vietnamese economy since the late 1980s is an integral component of the country’s economic renovation and continues to be a centrepiece in the 1990s. Among the main characteristics of this policy are expansion and diversification of trade activities, promotion of large-scale foreign investment flows and integration into the world trade system through joining the Association of South-East Asian Nations (ASEAN) and the Asia–Pacific Economic Cooperation (APEC) group. In 1995, Vietnam became full member of ASEAN. Since then Vietnam has participated in all regional trade agreements such as the Common Effective Preferential Tariff (CEPT) and ASEAN Free Trade Area (AFTA).

The main objective of AFTA is that ASEAN member countries commit to reduce tariffs to 0–5% by

the year 2003 (2006 for Vietnam) and remove non-tariff barriers (NTBs) 5 years after the products’ tariff is reduced. Together with other commodities, agricultural, forestry and fishery products are also subject to tariff reduction with the following classifications:

- (1) Inclusion List (IL): commodities subject to immediate tariff reduction;
- (2) Temporary Exclusion List (TEL): commodities which are temporarily exempt from tariff reduction. The time schedule for tariff reduction of those commodities is 1996–2000; and
- (3) General Exclusion List (GEL): commodities of great importance for national security, social morals, human health, historical and cultural values are not subject to tariff reduction and NTB removal when implementing CEPT.

In 1988, Vietnam officially joined APEC and is now negotiating for the accession to the World Trade Organization (WTO), the largest trade organisation in the world. With the entry to ASEAN, APEC and the accession to WTO, Vietnam will on the one hand have opportunities to open up its economic activities with the whole world, but on the other hand it will face very strong regional and international trade competition.

## Opportunities, challenges and recommended measures

### *Opportunities*

By joining regional and global economic integration, some new opportunities are open to Vietnam’s agriculture:

- provoking its comparative and competitive advantages—cheap and abundant labour force, diverse climatic conditions;
- getting new markets for agricultural and forestry products—at present, agricultural products of Vietnam are exported to 50 countries. With the entry to ASEAN, APEC and WTO in the future, Vietnam will be able to enter into other markets;
- having a fairer trade environment according to regional and international trade rules (regional and international anti-dumping policies, dispute settlement mechanisms etc.);
- being introduced to new technologies from developed world agriculture; and
- getting access to greater foreign investment in agriculture and food industries from larger foreign investors.

### *Challenges*

Being a very backward and poorly productive sector, Vietnam's agriculture will face the following challenges while joining agricultural regionalisation and globalisation:

- being exposed to tougher regional and international competition in terms of productivity, quality and price;
- becoming less protected because of reduction in agricultural subsidisation, tariff lines, removal of non-tariff barriers and development of specialised agriculture;
- starting from an inefficient production management mechanism;
- being threatened by agricultural and forestry environment degradation;
- losing traditional farming practices, local crop varieties and animal breeds; and
- having a lack of skilled farmers for making use of increased farming technology, and a surplus of unskilled farmers.

### *Recommended measures*

Some suggested measures to prepare Vietnam's agriculture to integrate well into regional and international agricultural competition are as follows:

- continuing the carefully and determinably agricultural market-oriented economy approach with the focus on improving quality, and reduction of production costs and prices;
- increasing the exportation of value-added agricultural and forestry products through processing industries;
- formulating a competitive strategy of selected agricultural and forestry commodities and investing more in their production and processing;
- applying temporary development subsidisation measures only to selected agricultural, forestry, and fishery commodities considered to be potentially competitive;
- working out incentive investment policies for both local and foreign investments in the agriculture, forestry, fishery and food industries;
- assuring clear legislation for a fairer business environment for all agricultural economic sectors; and
- building a qualified contingent of management staff equipped with good professional knowledge and able to communicate in foreign languages in order to be able to deal with regional and international working and trade negotiations.

# Globalisation and the Benefits of a Broad-based Approach to Postharvest Systems Development

F. Goletti and E. Samman\*

## *Abstract*

The paper is organised in three parts. The first part argues that global trends tend to strengthen the importance of postharvest systems in many developing countries. The global changes are accompanied by the emergence of large domestic and international enterprises in economies previously dominated by small and medium enterprises. The second part argues that a broad-based approach to postharvest and agroindustry development may be more adequate than a large-enterprise model of development to respond to the challenges of rural poverty. The broad-based approach recognises the scope for economies of scale in the long run, but it is also aware that, in the short and medium term, transaction costs, niche markets and intra-industry linkages might actually make small and medium enterprises more conducive to growth than large enterprises. The third part of the paper presents the case of the starch industry in Vietnam—an industry largely characterised by small enterprises that have been able to grow and adapt to rapid change over the past decade. High transaction costs suggest a role for small and medium enterprises in a continuum of firm sizes that include large enterprises and multinational companies. Modelling work shows the employment and growth benefits of a broad-based approach that promotes small and medium enterprises.

OVER the past two decades, global changes in the agrofood industry have affected postharvest systems dramatically—as the structure of the industry has become more concentrated, demand patterns have shifted towards higher value added products, and supermarkets are increasingly the major actors in the farmer-to-consumer chain. Yet, in many developing countries, postharvest systems and agroindustry are still largely characterised by a multitude of small enterprises—often household businesses with little capital, limited access to modern technology, and poor integration with urban and international markets. Under the process of globalisation, these small enterprises are put under pressure by the entry of large domestic and international agribusinesses. It is not clear what the impact of agroindustry globalisation on rural livelihoods and small enterprises has been. The objective of this paper is to understand to what extent globalisation is compatible with a broad-based approach to agroindustrial development. A broad-

based approach implies a balanced structure of expanding small, medium, and large enterprises that can capture different scale economies, niche markets, linkages with urban and international markets, and intra-industry linkages. To this purpose, the paper is organised into five sections including this introduction. The second section shows how current global trends tend to strengthen the importance of postharvest systems in developing countries. The third section argues that a broad-based approach to postharvest systems can be compatible with the globalisation of the agrofood industry. The fourth section presents a case study of the starch industry in Vietnam, a sector where promotion of a broad-based approach is shown to have both equity and growth benefits. The final section briefly summarises the arguments and concludes.

## **The Increasing Importance of the Postharvest Sector**

Presently in developing countries, several global trends highlight the increasing importance of post-

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harvest systems. The first trend is the contraction of the agricultural sector, measured both by a declining portion of the labour force engaged in agriculture and a declining share of agriculture in gross domestic product (GDP). Moreover, the share of agriculture in GDP tends to contract more rapidly than its share in labour, implying a growing surplus of labour in rural areas. In low-income countries, agriculture accounted for 73% of the labour force and 34% of GDP in 1980. In 1990, agriculture's share of the labour force had fallen to 69%, while in 1995 it only accounted for 25% of GDP. In high-income countries, in contrast, agriculture accounted for only about 5% of employment and 2% of GDP in 1995 (World Bank 1997). Labour displaced by shrinking agricultural employment usually migrates to the slums of the big cities in search of more remunerative opportunities. High migration rates, coupled with the inability of urban areas to absorb this influx, suggest the need for policy to boost productive rural employment. Postharvest activities such as processing and marketing tend to be labour-intensive (Boeh-Ocansey 1988; FAO 1995); therefore they can employ those who otherwise would leave, while increasing value added in rural areas (see Austin 1995; Fellows 1997). Policies, institutions, and technologies to develop rural agro-enterprise would directly strengthen the rural economy despite agricultural contraction. They would also promote increased agricultural production to provide the raw materials for processing.

A second and related trend is urbanisation. The share of the urban population in developing countries has grown 3.3% annually since 1980, and about 40% of the population of low- and middle-income countries was urban in 1995. In high-income economies, the urban population has become stable at 75% of the total population, indicating that urbanisation in developing countries is likely to continue (see World Bank 1997; FAO 1999). As people live further from where food is prepared, they increasingly rely on transport, storage, processing, and marketing systems for a secure and safe food supply. Reduced time for food preparation (see Kennedy and Reardon 1994) and rising demand for processed food (see Jaffee and Gordon 1993) increase the need to develop healthy, affordable food products and appropriate processing systems. Moreover, urbanisation and the related income growth affect dietary composition. As peoples' incomes increase, the share of calories they derive from starchy staples declines, while consumption of higher value foods increases (Poleman 1994). These higher value foods include fresh and processed fruits and vege-

tables, meats, fish, dairy products and vegetable oils. They tend to have shorter shelf lives than traditional staples, and require a well organised postharvest chain to ensure freshness. Further, advances in the postharvest sector often reduce consumer prices, bolstering food security for the urban poor.

The third trend is toward a more liberalised international trade system and an increasing orientation of developing countries toward export markets as a source of economic growth. This orientation is attributable both to increased surpluses, arising from the introduction of green revolution technology, and to policy changes wrought by structural adjustment programs (SAPs) in much of the developing world. One tenet of SAPs is the promotion of exports through such incentives as currency devaluation and deregulation of trade. Participation in international markets requires relatively sophisticated marketing, information, and transportation networks. Successful competition requires quality control and product standardisation, and improved storage and trade facilities (see Jaffee and Gordon 1993; Johnson 1998).

The fourth trend is a growing interest in redressing gender inequity (see Fleischer et al. 1996). Women have traditionally played an important role in processing, handling and preparing food. In West African countries, for example, the role of women in marketing agricultural products is well known (see Jaffee and Morton 1995). A large part of women's work in postproduction is often in the informal sector, including such tasks as the preparation of traditional foods, and small-scale production of fish, palm oil, cassava, and dairy products (Petritisch 1985). The development of postproduction can play an important role in providing further economic opportunities for women and in channelling their incorporation into formal sector employment. This, of course, requires that such development explicitly take account of the role of women and their comparative advantage in postharvest activity (Petritisch 1985).

The fifth trend is rising concern with environmental issues and sustainable development. Consumers are demanding reduction in pesticide use, organic food products, and biodegradable packaging, and these demands will increase along with rising income. In the United States of America (USA), for example, demand for organic produce rose 14% yearly between 1988 and 1992 (Thrupp 1995). These concerns present opportunities and challenges for postharvest research, to develop alternative technologies for storage pest and disease control, waste treatment from processing plants, aquaculture, livestock feedlotting, and

improved food safety (see Austin 1995; Arnold 1996; Johnson 1998).

To date, traditional postharvest research has focused upon the role of technology as the catalyst for improvement. However, this narrow emphasis should be broadened to incorporate institutional and policy dimensions of the postproduction system that are often critical in allowing the dissemination of technological improvements and in expanding their reach to the most disadvantaged. For instance, in many countries, smallholder farmers face missing or incomplete markets for inputs and outputs. Institutions such as contract farming can overcome this gap by linking processors with smallholder farmers, guaranteeing a stable supply of raw materials to the former and steady markets and prices to the latter. They thus allow smallholders to gain reliable access to markets and prices where transaction costs would otherwise be too high or price outcomes too unpredictable, such as markets for perishables and high-value items in tradable sectors (Minot 1986; Delgado 1998).

## **The Broad-based Approach to Postharvest and Agroindustry Development**

The globalisation of agroindustry over the past decade has been accompanied by consolidation and increasing concentration in market share. This is particularly evident in industrialised countries and is also becoming widespread in developing countries, as a consequence of a more liberalised world trade system and increasing foreign direct investment (FDI) in agroindustry. In the European Union, Viaene and Gellynck (1995) report that the food, drink and tobacco industry has become increasingly concentrated since the early 1980s, while Giles (1999) foresees its further concentration so that as few as 20 major groups will dominate by about 2010. In the United Kingdom, Dolan et al. (1999) describe a dramatic concentration of food retailing in the last three decades, with four retailers accounting for nearly 75% of food sales in 1998. Turning to the USA, Koontz et al. (1993) find a large increase in the concentration of meat packing; this is echoed for lamb (Brester and Musick 1995), beef (Azzam 1998) and pork (Hayenga 1998). Evidence for this trend is growing in developing countries too. In Brazil, Jank et al. (1999) count 143 mergers and acquisitions in the food, beverage and tobacco industry in the 3 years following the 1994 Real Plan. In South Africa,

Kaplinsky and Manning (1998) report that the Gini coefficient for industry rose from 0.78 in 1972 to 0.84 in 1988. In both Kenya and Zimbabwe, five exporters have come to control over 75% of all fresh vegetable exports (Dolan et al. 1999). The Asian Productivity Organization (1992) describes the growing prevalence of large industry in Indonesia from the mid-1970s onward.

At the same time, there seems to be a shift from spot markets to contract farming and vertical integration (see FAO 1997; Schejtman 1998). Notable examples are palm oil production in Malaysia (see Kajisa and Meredia 1997) and fruit production in Latin America (e.g. see Key and Runsten 1999). This shift is partly a result of the higher quality standards that large retailers and supermarkets are requiring from their suppliers in developing countries (Dolan et al. 1999).

Even though this process might lead to higher growth and improved efficiency, there is concern that it might induce a type of development that is neither broad-based nor employment-generating in rural areas, and that therefore it might not contribute to rural development and poverty alleviation. Evidence of the effects of the globalisation of agroindustry on rural areas and small enterprise development in developing countries is very scarce. However they carry important implications for development policy. As the agricultural sector contracts in many developing countries, the labour force in rural areas does not decrease at the same rate. An increasing number of rural households are engaged in activities with low productivity, and rural-urban migration does not seem a solution in the medium term. Therefore, the priority for many developing countries is to generate rural economic activities that increase the income of the rural population. Agroindustry is an obvious candidate for this type of activity, because of its linkages with agriculture and rural development. However, if the development of globalised agroindustry is dominated by a small number of large and capital-intensive enterprises, in the short and medium term, it does not augur well for rural households or small enterprises. Within this context, there is a need to explore alternative policy options to promote broad-based agroindustrial development, without compromising efficiency and the opportunities for growth presented by the global economy.

In many developing countries, postharvest systems and agroindustry are dominated by a multitude of small and medium enterprises (Figure 1A). Under the pressure of changing demand patterns and competition from large domestic or foreign enterprises, there are

serious concerns about the ability of small and medium enterprises to survive in the small and medium term. In the long term (Figure 1B), the distribution of firms engaged in postharvest and agroindustry might well be dominated by large enterprises. As the economy moves from a predominantly rural to a predominantly industrial structure, the consolidation of agroindustry might be optimal on both growth and efficiency grounds. However, in the medium term, there could be important reasons why the promotion of a broad-based approach including small, medium, and large enterprises might be more favourable to growth than a bias towards large enterprises.

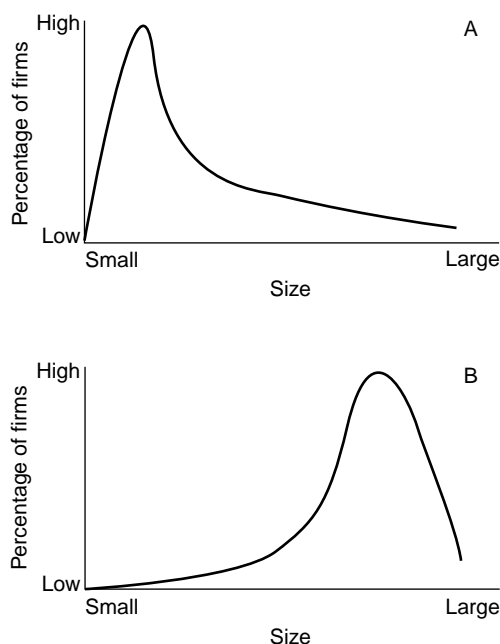
Several facets of globalisation tend to discriminate against small and medium enterprises. In the case of fruits and vegetables, for example, the need to control for high perishability requires specialised production, packing techniques and refrigerated transport. Computer-controlled deep irrigation systems in production, the intensive use of fertiliser and pesticides, sophisticated packing plants that resemble large

modern factories, and temperature and atmospherically controlled storage and transport all contribute to ‘cool chain’ supply systems which allow fresh produce to be supplied to major supermarkets around the world. More generally, marketing products requires highly sophisticated and well-integrated information and transportation networks. The need to comply with aesthetic, hygiene, and health requirements involves investment in research, development, and marketing that small and medium enterprises cannot easily afford.

However, there are also countervailing trends that suggest a new role for small–medium enterprises, in such areas as niche markets that stress product differentiation over cost. Reardon et al. (1999) give examples of product differentiation according to domestic/export, refined/coarse or rich/poor consumer, and give the examples of wheat and coffee in Brazil, maize in urban Mali and milk products in Latin America. Several small European companies have successfully marketed products on the basis of region of origin (see OECD 1995). Niche markets in developed countries more appropriate to suppliers based in developing countries could include organic fruit (Dolan et al. 1999), traditional foods sought by immigrant communities, and other specialised food for which demand is likely to increase as income distribution—and consequent consumption patterns—become more fragmented in the coming years (see Giles 1999). For instance, Giles (1999) projects that in the United Kingdom the food distribution system will become much more fragmented by 2010, owing to a fall in the market share of supermarkets, and increases in food eaten away from home, as well as that bought from discounters and delivered to the home.

An emerging body of work suggests that small-scale firms may be able to compete with their larger counterparts by exploiting two factors. The first is a reliance on external rather than internal economies of scale through some form of networking (e.g. Schmitz 1995). The second is based on the premise that in certain industries mass production is becoming inefficient and being replaced by more efficient production techniques suited to small-scale production (e.g. see World Development 1999). Both factors may apply to the processing industry, although more case studies are needed to substantiate this view.

Nonetheless, there is also evidence to support the argument that in some rural environments, small enterprises might even be more competitive than large enterprises because of:



**Figure 1.** Two extreme cases of the distribution of firm size involved in postharvest systems and agroindustry in developing countries. (A) shows a distribution dominated by small firms and (B) shows a distribution dominated by large firms.



1. more flexibility in adapting to disruptive circumstances and in responding to frequent interruptions in the supply of inputs (e.g. see Sandee 1999 on Indonesia);
2. an input supply that is insufficient to permit substantial economies of scale (e.g. so that large fish plants are operating below capacity in Tanzania—McCormick 1998);
3. better labour flexibility either in utilisation of labour or by combining several business activities which can be frozen or expanded according to market fluctuations<sup>1</sup>;
4. markets that are not large or constant enough to absorb the output of a large plant running at full capacity (e.g. demand for rattan furniture in Indonesia—Smyth 1992). Local production costs will often exceed world prices, militating against exports;
5. managerial problems involved in large-scale production can be very complex and lack of effective coordination can result in input loss; and
6. there may be diseconomies of scale in large-scale plants, especially those which are outside of the plant itself, e.g. if adequate infrastructure is lacking, new roads may be needed, large concentrations of estate workers may require housing, and poor industrial linkages may make the maintenance of a sophisticated, large-scale plant difficult.<sup>2</sup>

Kaplinsky (1990) shows how these problems have led to large-scale sugar processing plants being supplanted by smaller scale models in China, India and Kenya, where production at levels originally envisioned would have doubled sugar production costs.

In conclusion, while long-term trends seem to augur increasing concentration in the agro-processing industry, there are several factors, at least in the short to medium term, that argue for continued small firm involvement. These arguments suggest that a broad-based approach to agroindustrial development might be possible, not only on the grounds of equity, but also of efficiency.

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1. These first three arguments are adapted from Rasmussen et al. 1992.

2. These last three arguments are taken from Kaplinsky 1990.

## **Growth Benefits of the Broad-based Approach: the Case of Starch in Vietnam**

Despite a decade of remarkable growth of the agricultural sector, there is mounting evidence that rural areas in Vietnam are lagging behind urban areas (Nguyen Van Bich et al. 1998). The gap between rural and urban incomes is increasing and the prospects for strong and sustainable growth of non-farm rural income are not encouraging. With 80% of population living in rural areas, these trends—if they continue—risk raising social tensions. In response to these trends and the recent crisis in Asia, the government of Vietnam has recognised the key role of agriculture and rural economy for the promotion of industrialisation and modernisation and its contribution to increasing employment and income of the rural population (see Phan Van Khai 1999).

An example of rural income diversification and industrialisation concerns the starch industry in Vietnam. Ten years ago, starch production was roughly 10% of the total use of cassava. The industry was characterised by low levels of production, serving local markets for noodles and maltose. Since then, the industry has grown rapidly, with newer and larger participants engaging in the production of specialty varieties of starch for industrial, food, and export purposes. In particular, the past few years have witnessed the arrival of a few large-scale foreign and domestic enterprises with significant potential for the development of the starch industry in Vietnam. However, small-scale production of starch continues to dominate. Currently, 90% of the starch processors in Vietnam could be classified as small processors, with less than a 10 t/day capacity.

At the same time, however, as the starch industry develops and modernises, there will be an increasing emphasis on technology and capital within the starch industry. This threatens to crowd out many of the small-scale producers, who may not have the capital resources to compete. While this may be a desirable situation in the long run, it is possible that it is not the most efficient situation in the short or medium term. In an environment characterised by high transaction costs, induced by low levels of infrastructure development and market integration, and poor productivity of cassava, there are gains to be made in enhancing the scale of small-scale starch processors.

We examine the starch industry of Vietnam using data from a household survey undertaken by the Inter-

national Food Policy Research Institute (IFPRI) in collaboration with the International Centre for Tropical Agriculture (CIAT—Centro Internacional de Agricultura Tropical) and the Post-Harvest Technology Institute (PHTI) in Hanoi during 1998 (see IFPRI 1998). After an overview of starch uses in Vietnam, we provide a detailed profile of the Vietnamese starch industry—highlighting the growth experienced in the industry, the structure of firms and end users, and constraints facing the industry. We then discuss the issue of promoting broad-based growth in the starch industry by way of using an industry model to trace the effects of a capital injection into the subsector.

## Overview of starch uses

Starch uses are varied, and are diversifying further with continued global economic development. In Vietnam, root crops, especially cassava, have been the traditional sources of starch for use in food products. Cassava starch is processed into a range of foods, including noodles, crackers and cakes. Cassava starch is also the main raw material for maltose production in northern Vietnam (maltose is, in turn, used by the confectionery industry). All of these traditional uses are found mainly as household enterprises—Vietnam may be a unique example of the development of small-scale maltose production from cassava starch, for example.

Non-food industrial uses of cassava are also found in Vietnam, associated with larger scale enterprises. The textile industry, for example, uses cassava starch for sizing, while the paper industry uses starch for coating high quality types of paper. As these industrial sectors develop, demand for starch is likely to increase. In Vietnam, the recent arrival of a few large-scale starch-producing firms interested in added value

products has resulted in a much more diverse product offering than was found only a few years ago. The production of fermentation products (monosodium glutamate and lysine) has started, for example. The Thai starch industry, which is more developed, has placed substantial effort and resources on a shift towards production of higher valued modified starches from cassava. Cassava starch is seen as the logical raw material for modified starch and for production of sweeteners in Southeast Asia, comparable to maize in North America and potato in Europe. As the starch-using industries develop in Southeast Asia, the range of starch-derived intermediate and end products manufactured from cassava will also expand.

## Profile of the starch industry of Vietnam

In this part, we discuss some of the major highlights of the starch industry, as well as look at some of the constraints within the industry that affect its competitiveness and efficiency.

### *Increasing utilisation of cassava production, but excess capacity in the starch industry*

Up until about ten years ago, starch production utilised roughly 10% of cassava production. Since 1988, an increasing number of participants have started to be involved in starch production, including both rural households and large enterprises. Results from the survey show that at least 24% of total cassava production is currently utilised for starch (Table 1), and this is probably an underestimate, given that the survey under-sampled several regions such as the North East South, where starch production is large. The greatest share is for dry starch production (18.7% of the total). The total starch production (wet and dry) in the survey was found to be 131,450 t, corresponding to more than 477,000 t of cassava.

**Table 1.** Starch production in 1998 and cassava equivalent.

Starch type	Starch production ('000 t)	Cassava equivalent ('000 t)	Share of cassava production (%)
Wet starch	42307	105767	5.3
Dry starch	89143	371429	18.7
Total	131450	477196	24.0

Source: International Food Policy Research Institute/Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)/Post-Harvest Technology Institute (IFPRI/CIAT/PHTI) Survey 1998.

Despite a greater utilisation of cassava production by the industry, one of the major constraints faced by many starch processors is an inability to procure enough cassava to run operations at full capacity. In particular, there is a sizable gap between potential capacity and capacity utilised, a relationship that becomes stronger as firm size gets larger. Larger processors have much higher levels of excess capacity than do smaller processors, which typically operate at 90% or more of total capacity. Simple regression results highlight the relationship between enterprise size and the gap between potential capacity and capacity used, which is significant at the 95% level (Table 2).

High cassava costs contribute to lowering the competitiveness of the industry. Survey results (see Table 3) show that large enterprises pay the highest price for

raw material procured by farmers (Dong 391 per kg) while micro enterprises pay the lowest prices (Dong 285 per kg). High costs are also related to the low productivity of cassava in Vietnam. Current yields only average 7.3 t/ha in the country (Table 4). Perhaps more important than low cassava yields is the wide variance of yields throughout the country. In the North Mountains and Midlands, where most of the production takes place, yields average 6 t/ha, while in the North East South, yields are much higher (10.2 t/ha). In some parts of the North East South (such as Dong Nai), it is not uncommon to see yields of up to 30 t/ha. Variable yield levels make it difficult for larger processors, in particular, to consistently procure adequate quantities of cassava to run operations efficiently.

**Table 2.** Regression results from the estimation of the relationship between capacity unutilised and enterprise size.

Variable	Coefficient value	t-statistic
Constant	49.979	23.921
Enterprise capacity	0.172	3.086

Note: Dependent variable in the regression is percentage of capacity unutilised, defined as the gap between potential capacity and capacity used.

Source: International Food Policy Research Institute/ Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)/Post-Harvest Technology Institute (IFPRI/CIAT/PHTI) Survey 1998.

**Table 3.** Raw material prices and cost.

Enterprise size	Cassava price from farmers (Dong/kg)	Cassava price from traders (Dong/kg)	Raw material as % of total cost
Micro	285	383	94.4
Small	300	342	91.7
Medium	332	367	90.3
Large	391	399	86.5
Average for Vietnam	318	377	87.6

Source: International Food Policy Research Institute/ Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)/Post-Harvest Technology Institute (IFPRI/CIAT/PHTI) Survey 1998.

**Table 4.** Yield of cassava in Vietnam in 1997.

Region	Yield (t/ha)	Production ('000 t)
North Mountains and Midlands	6	704
Red River Delta	8.7	49
North Central Coast	6	251
South Central Coast	8.7	369
Central Highlands	9.3	266
North East South	10.2	283

**Table 4.** (Cont'd) Yield of cassava in Vietnam in 1997.

Region	Yield (t/ha)	Production ('000 t)
Mekong River Delta	7.7	61
Vietnam	7.3 (average)	1983 (total)

Source: Statistical Bureau of Vietnam.

*Increasing size of new entrants, but decreasing returns to scale*

Production of starch in Vietnam is carried out by a variety of enterprises, including very small firms and some large ones. From our survey, we find an industry that is heavily skewed towards smaller enterprises. Micro enterprises (less than 1 t per day) comprise almost 50% of the sample, with small enterprises (between 1 and 5 t per day) making up about 26%, medium enterprises (between 5 and 10 t per day) about 24%, and large enterprises (more than 10 t per day) only 10% of the sample. Among large enterprises, the largest enterprise, VEDAN, has a capacity of 800 t per day. Moreover, the new entrants have increased the size of their operations, as shown by an average processing capacity. This increased from less than 10 t per day previously to 1994 to an average capacity of almost 60 and 80 t per day in 1995 and 1997 (see Figure 2). The regional distribution of enterprises indicates a large predominance of small firms in the north and large firms in the south.

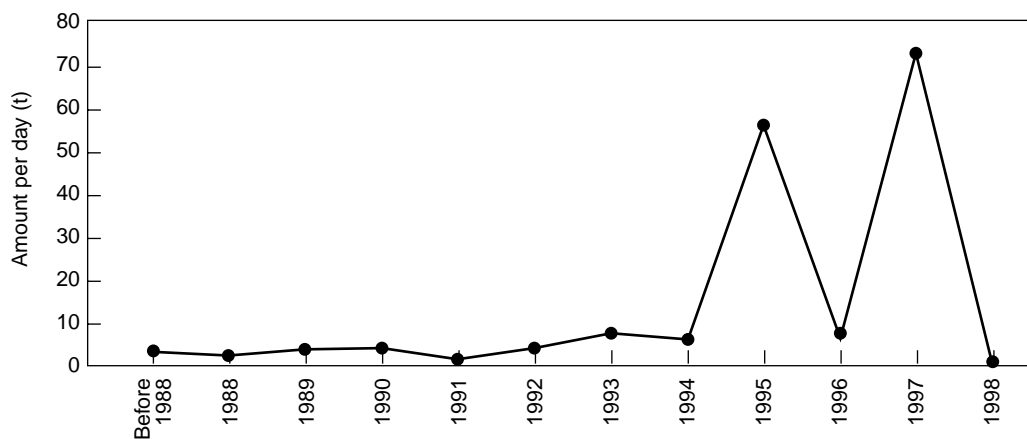
While starch enterprises are getting larger, the industry itself is subject to decreasing returns to scale. This was confirmed by regression analysis of the production function, namely:

$$\ln(q) = a + b \ln(K) + c \ln(L) \quad (1)$$

where  $q$  represents total volume of production (wet starch and dry starch),  $K$  is the value of total capital equipment, and  $L$  is the total number of man-months worked by employees in a given starch factory. The results show that  $a = 0.66$ ,  $b = 0.3$  and  $c = 0.417$  (all statistically significant coefficients), which implies decreasing returns to scale since  $b + c < 1$  for a Cobb–Douglas production equation. Decreasing returns to scale suggest there could be problems in procurement of raw material that prevent firms from expanding to optimal capacity, a fact discussed previously.

*Specialisation of starch production by size*

The survey also points to specialisation of starch production by firm size. The contribution of micro–small–medium enterprises to wet starch production is about 87% in our sample, while they contribute only 13% to dry starch production (Table 5), highlighting a specialisation of small–medium enterprises in wet starch and a specialisation of large enterprises in dry starch. This is to be expected, since dry starch is more capital-intensive than the production of wet starch. There is also specialisation in terms of the markets served by varying sizes of starch operations. Smaller starch enterprises process starch for mainly the noodle industry, with the more



**Figure 2.** Average capacity of new entrants in the starch industry.

advanced processors producing starch for Vietnam's maltose industry. By contrast, the larger enterprises are targeting their starch for a wide range of food and non-food uses, including the paper industry, monosodium glutamate, pharmaceuticals, and textiles.

Interestingly, small enterprises have maintained their network of sales despite competition from large enterprises in traditional wet starch markets (i.e. noodles, maltose). This can be partially attributed to the nature of the markets serviced by smaller enterprises. Sales of wet cassava starch by smaller enterprises encompass a much smaller distance than those serviced by larger enterprises. Smaller enterprises maintain their markets by servicing a local clientele that is removed from where larger operations exist. High transaction costs—in terms of poor infrastructure, impediments in moving raw materials, and established marketing channels with small enterprises—are likely to hamper the ability of large enterprises to move into markets served by smaller enterprises.

#### *Increased demand for starch in Vietnam and export markets*

The opportunities of cassava processing for the local food industry and other non-food uses has induced a dramatic increase in investment by small and large enterprises, with an average annual rate of

78% over the period 1988 to 1997 (see IFPRI 1998). An additional reason for this strong growth of investment and production is the linkage with world markets. Starch in Vietnam is an exportable commodity. During 1998, more than 21,000 t were exported to countries such as Singapore, Taiwan, the Philippines, Indonesia, and Malaysia. The export prices of starch are much higher than domestic prices, partly reflecting the better quality of exported starch. On average, export prices were almost \$300/t, compared with less than \$200/t for domestic starch.

#### *Greater capital availability by large processors relative to small processors*

Different enterprises have quite different capital equipment, as shown by a very small value of equipment for micro–small enterprises (about \$50), while for large enterprises the average value is about \$363,000 (Table 6). The small enterprises, however, have a much more efficient use of capital equipment, as shown by an output–capital ratio of 9.3 t per million Dong of capital equipment versus 0.6 t of starch for large enterprises. Two capital constraints nonetheless affect the Vietnamese starch industry. While small enterprises may utilise capacity more efficiently (given its relative scarcity), the quality of the capital used is not comparable to that used by larger enterprises. Most small processors manufacture starch with

**Table 5.** The relative contributions of small and large firms to starch production in Vietnam.

	Wet starch production (‘000 t)	Share of wet starch production	Dry starch production (‘000 t)	Share of dry starch production
Small enterprises	36961	87%	11522	13%
Large enterprises	5346	13%	77621	87%
Total	42307	100%	89143	100%

Note: small enterprises denote firms with a capacity of less than 10 t/day.

Source: International Food Policy Research Institute/ Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)/Post-Harvest Technology Institute (IFPRI/CIAT/PHTI) Survey 1998.

**Table 6.** Average value of equipment and assets (thousand Dong).

Enterprise size	Value of equipment	Value of all productive assets
Micro	808	6760
Small	1354	4429
Medium	17749	350209
Large	4729007	5979160
Average for Vietnam	491512	671398

Source: International Food Policy Research Institute/ Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)/Post-Harvest Technology Institute (IFPRI/CIAT/PHTI) Survey 1998.

only the bare minimum of equipment, using graters and pumps for most operations. By contrast, large enterprises have access to sedimentation tanks, dryers, and complete starch systems. Moreover, throughout the industry, the majority of the starch industry is working with locally manufactured equipment, or old equipment from Russia and China, which is of quite low value and inappropriate for producing high quality starch.

Both constraints point the need for not only improved capital access but for a channelling of capital resources into modernising equipment and operations. Yet the survey points out that access to credit is quite limited for both small and large enterprises (Table 7). Large firms have better access to bank credit, but the large firms are also the ones that express a bigger gap between obtained credit and credit requirements (the requirement–obtained credit ratio is almost 7).

*Greater efficiency in cost structure among smaller enterprises*

A different cost structure for various firm sizes partly explains the greater efficiency of smaller enterprises (see Table 8). For micro enterprises, for example, rental equipment is a large share of their cost (35%) while this is negligible for large enterprises.

Large enterprises spend more than 68% in electricity and labour, while medium enterprises allocate only 47% to these two items. A regression of average cost over firm size confirms the hypothesis of greater efficiency at smaller scale.

$$\ln(\text{average cost}) = 4.14 + 0.21 * \ln(\text{capacity}) \quad (2)$$

In the above regression, the coefficient on capacity is significant at the 1% level ( $t = 5.58$ ).

*Greater environmental concerns related to starch production*

Finally, the production of starch is polluting the environment, causing serious problems in water quality at the community level. In the absence of sewage systems and water purification systems, the starch processors have no other choice but to dump the residues and the polluted water into the village streets and inadequate sewage system. Both households and community leaders indicate this as one of the most serious problems, particularly for small enterprises (see IFPRI 1998).

*Discussion*

It is clear that the starch industry demonstrates the potential of rural industrialisation, where low-value agricultural commodities such as cassava are processed into high-value commodities such as starch

**Table 7.** Access to credit.

Enterprise size	Credit (million Dong)	Share of credit from bank (%)	Requirement ratio <sup>a</sup>
Micro	5.1	78	2.5
Small	14.9	89	1.1
Medium	21.4	83	3.5
Large	108	94	6.9

<sup>a</sup> Note: the requirement ratio is the ratio between the credit deemed necessary to conduct operations smoothly and the actual credit obtained.

Source: International Food Policy Research Institute/ Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)/Post-Harvest Technology Institute (IFPRI/CIAT/PHTI) Survey 1998.

**Table 8.** Share of operation costs (excluding raw materials).

Enterprise size	Electricity and fuel (%)	Labour (%)	Transport (%)	Rental equipment (%)	Other (%)
Micro	29	9	9	35	18
Small	2	21	12	25	20
Medium	21	26	13	1	39
Large	40	28	7	0	25
Average for Vietnam	38	27	8	2	25

Source: International Food Policy Research Institute/ Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)/Post-Harvest Technology Institute (IFPRI/CIAT/PHTI) Survey 1999.

to be used in a variety of industries. There is evidence of growth in the industry, in terms of the quantity of cassava utilised by the industry, but also procurement bottlenecks among larger enterprises. This manifests itself in terms of the industry facing decreasing returns to scale. Given that new entrants to the starch enterprises are getting larger, this constrains the development of the industry. At the same time, however, it points to a significant role to be played by small and medium-sized starch enterprises in Vietnam. These firms are running at much higher levels of capacity with fewer constraints in terms of raw materials or market access. Yet these firms tend to operate at lower levels of technology and capital and are more prone towards having problems with pollution. By providing greater levels of capital and technology to small and medium enterprises, there could be efficiency gains in the industry as a whole given the high transactions costs that beset the starch industry. This will be examined more carefully in the next section.

### **Policy options: the optimal allocation of credit to starch enterprises**

This section looks at alternative policy options to promote the starch sector, highlighting the role of capital availability among small and large enterprises. As identified in the previous section, one of the major impediments to the starch sector is limited access to credit. Both large and small enterprises face difficulties in obtaining credit to finance their procurement activities as well as capital investment. It is unclear, however, how a credit injection to the starch sector should be targeted—i.e. should credit be directed at small or larger enterprises? To answer this question, we develop a sector model used to describe the starch industry. We then run a number of simulations to test the most efficient allocation of capital to the sector.

#### *Starch industry model for Vietnam (SIMV)*

In order to evaluate the effects of alternative policies on prices, production, income, and trade, we have built a sector model of the starch industry in Vietnam (SIMV). The model includes four commodities (food, feed, wet starch, and dry starch), five types of agents (farmers, feed producers, wet starch processors, dry starch processors, and end users). It is an aggregate model (i.e. does not allow for regional variation and trade) and incorporates international trade in feed and dry starch. The list of equations and the description of the model can be found in Appendix 1.

#### *Policy simulations*

To examine the impact of an injection of credit into the starch sector, we conduct three simulations with SIMV. In all cases, we consider a 10% increase in the total value of capital equipment as a proxy for the credit injection. We note that the total value of capital equipment in the starch sector (with the exception of the large enterprise VEDAN) is roughly \$21 million, so that a 10% increase implies an injection of about \$2.1 million to the capital available in the sector. It should be noted that this expansion of credit should not be considered a subsidy. Rather, we consider this investment as a type of loan that could generate enough income to be repaid at market interest rates. In the case of small enterprises, we assume the credit injection will translate partly to an increase in the average capital of each processing unit and partly to an expansion of the size and number of small enterprises.

The simulations differ in how capital is distributed among enterprises. In the first scenario, we examine the effects of a 10% increase in the value of industry capital equipment to the entire sector, or to small enterprises and large enterprises alike. The second simulation takes the same amount of capital and allocates it only to small enterprises. In essence, this is akin to increasing the size of small enterprises and transforming them into ‘larger’ enterprises. In the case of the third simulation, we increase the capital of large enterprises only. The goal of this exercise is to see whether the income benefits from targeting credit injections into the starch subsector are more beneficial when geared differentially (i.e. towards small or large enterprises) or when the sector is treated equally.

#### *Results*

The results of all three scenarios are summarised in Tables 9A–9C. In the first simulation, we consider an equal distribution of capital to small and large enterprises. Total income increases \$640,000, or 1.7%. Production of wet and dry starch increases by 1.2% and 3.3%, respectively. At the same time, wet starch income is reduced slightly, as prices fall (–1.5%) more than production rises. Dry starch income is buoyed by higher production and the prospect of export markets. Since dry starch has an export outlet, prices do not fall; rather, excess production is channelled into 4,500 t of exports. In the cassava market, income rises slightly (1.4%), supported by higher retail prices owing to a greater demand for starch. As expected, higher cassava prices reduce feed income marginally (–0.9%). Overall, despite the growth in export markets, it should be noted that the effects of the sector

are not very large. Given the difficulty in ensuring a good recovery rate for investment loans, it is unclear whether this policy would make much of a difference.

When we examine the second simulation, we see a much different story. Total income rises by nearly 11% (or \$4 million). The injection of credit boosts the income of small starch processors for both wet and dry starch. Wet starch income for small processors increases almost 9%, while dry starch income rises an incredible 167%. The capital injection causes a significant increase in wet starch production by small processors. This in turn causes an increase in overall wet starch production (37%) and a significant fall in prices (-33%). Overall wet starch income declines as a result, which affects large processors more than small processors. Large processors suffer from higher input prices and low wet starch prices, while small processors increase production due to the capital injection. Since large processors comprise a larger share of total wet starch income, their income (as well as wet starch income as a whole) falls considerably. In the dry starch industry, there is enormous expansion, as small processors expand production into the dry starch sector. While the model does not dynamically capture a change in capacity for starch enterprises, expanding into dry starch production would necessarily imply a need to increase enterprise size, given the technology needed to enter this market. Exports rise by 137% to 52,000 t. Farm income rises considerably (10%), as demand for cassava boosts production and prices. This in turn reduces feed income (6%). Given that the benefit to the sector is a rise in income of \$4 million, a credit injection packaged as a \$2.1 million loan (or 10% of the value of capital equipment), would imply easy repayment over a short period of time.

When capital is increased only for large enterprises, the sectoral income benefits are not very large (only 1.5% for the sector as a whole, 1.2% increase for farm income, and 4.4% increase for the dry processors). Indeed, the effects here are similar to those in the first simulation. The implication for the three policies

clearly suggests greater benefits to stimulating small enterprises.

## Conclusions

The paper has argued that global trends including the contraction of agriculture, urbanisation, and the liberalisation of domestic and world markets tend to strengthen the importance of postharvest systems in many developing countries. The global changes have, however, witnessed the emergence of large domestic and international enterprises in economies previously largely dominated by small and medium enterprises. The paper has argued that a broad-based approach to postharvest and agroindustry development may be more adequate than a large-enterprise model of development to respond to the challenges of rural poverty. The broad-based approach recognises the scope for economies of scale in the long run, but it is also aware that, in the short and medium-term, transaction costs, niche markets and intra-industry linkages might actually make small and medium enterprises more conducive to growth than large enterprises. Since not much empirical evidence is available on this issue, this paper has presented the case of the starch industry in Vietnam, an industry largely characterised by small enterprises that have been able to grow and adapt to rapid change over the past decade. The broad-based growth process is important because of its implications for rural development in countries characterised by a large rural population and where the income gap between urban and rural areas is growing. The analysis of micro-efficiency and transaction costs suggests a role for small and medium enterprises in a continuum of firm sizes that includes large enterprises and multinational companies. Modelling work has shown that a broad-based approach that promotes small and medium enterprises has benefits not only in terms of employment but also in terms of growth.



**Table 9A.** Results of the starch industry model for Vietnam (SIMV) simulation: 10% injection of capital to small and large processors.

	Amount	Change	Percentage change
<b>Cassava market</b>			
Production ('000 t)	2007.87	8	0.4
Food consumption ('000 t)	297.64	-2.4	-0.8
Farm price (Dong/kg)	282.76	2.81	1
Retail price (Dong/kg)	350.76	2.81	0.81
Farm income (US\$ million)	26.17	0.36	1.41
<b>Feed market</b>			
Production ('000 t)	302.3	-2.44	-0.8
Farm price (Dong/kg)	1011.0	0	0
Retail price (Dong/kg)	1256.0	0	0
Feed consumption ('000 t)	190.7	0	0
Exports ('000 t)	111.6	-2.44	-2.14
Value exports (US\$ million)	11.27	-0.25	-2.14
Feed income (US\$ million)	4.21	-0.04	-0.86
<b>Wet starch market</b>			
Retail price (Dong/kg)	1181.82	-18.08	-1.51
Total production ('000 t)	41.3	0.5	1.22
Small processor production ('000 t)	28.46	0.31	1.08
Large processor production ('000 t)	12.84	0.19	1.53
Total consumption ('000 t)	41.3	0.5	1.22
Intermediate consumption ('000 t)	29.32	0.35	1.22
Processor price (Dong/kg)	1086.82	-18.08	-1.64
Total income (US\$ million)	0.69	0	-0.33
Small processor income (US\$ million)	0.4	0	-0.63
Large processor income (US\$ million)	0.29	0	-0.25
<b>Dry starch market</b>			
Retail price (Dong/kg)	2442.0	0	0
Total production ('000 t)	141.35	4.52	3.31
Small processor production ('000 t)	12.67	0.36	2.89
Large processor production ('000 t)	128.68	4.17	3.35
Total consumption ('000 t)	114.76	-0.04	-0.04
Total income (US\$ million)	6.46	0.32	5.16
Small processor income (US\$ million)	0.37	0.02	4.89
Large processor income (US\$ million)	6.08	0.3	5.19
Processor price (Dong/kg)	1990.0	0	0
<b>Starch exports</b>			
Value exports (US\$ million)	7.98	1.37	20.73
Total export income (US\$ million)	1.85	0.32	20.74
Quantity exports ('000 t)	26.59	4.57	20.73

**Table 9A.** (Cont'd) Results of the starch industry model for Vietnam (SIMV) simulation: 10% injection of capital to small and large processors.

	Amount	Change	Percentage change
<b>Production shares (%)</b>			
Cassava for food	14.82	-0.18	-1.2
Cassava for feed	54.35	-0.66	-1.2
Cassava for wet starch	1.49	0.01	0.83
Cassava for dry starch	29.33	0.82	2.89
<b>Income shares (%)</b>			
Farm income	69.74	-0.23	-0.32
Feed income	11.21	-0.29	-2.56
Processing income	19.06	0.52	2.81
Wet Starch income	1.85	-0.04	-2.09
Dry Starch income	17.21	0.56	3.37
Small processor income	2.07	0	0.2
Large processor income	16.98	0.52	3.14
<b>Total income</b>			
Total income (US\$ million)	37.52	0.64	1.74

**Table 9B.** Results of starch industry model for Vietnam (SIMV) simulation: 10% injection of capital to small processors only.

	Amount	Change	Percentage change
<b>Cassava market</b>			
Production ('000 t)	2055.91	56.05	2.8
Food consumption ('000 t)	283.71	-16.33	-5.44
Farm price (Dong/kg)	299.98	20.03	7.15
Retail price (Dong/kg)	367.98	20.03	5.76
Farm income (US\$ million)	28.42	2.62	10.16
<b>Feed market</b>			
Production ('000 t)	288.15	-16.59	-5.44
Farm price (Dong/kg)	1011.0	0	0
Retail price (Dong/kg)	1256.0	0	0
Feed consumption ('000 t)	190.7	0	0
Exports ('000 t)	97.45	-16.59	-14.55
Value exports (US\$ million)	9.84	-1.68	-14.54
Feed income (US\$ million)	3.99	-0.25	-5.91
<b>Wet starch market</b>			
Retail price (Dong/kg)	807.27	-392.63	-32.72
Total production ('000 t)	56.03	15.22	37.31

**Table 9B.** (Cont'd) Results of starch industry model for Vietnam (SIMV) simulation: 10% injection of capital to small processors only.

	Amount	Change	Percentage change
Small processor production ('000 t)	47.61	19.45	69.1
Large processor production ('000 t)	8.42	-4.23	-33.45
Total consumption ('000 t)	56.03	15.22	37.31
Intermediate consumption ('000 t)	39.78	10.81	37.31
Processor price (Dong/kg)	712.27	-392.63	-35.54
Total income (US\$ million)	0.57	-0.13	-18.59
Small processor income (US\$ million)	0.44	0.04	8.94
Large processor income (US\$ million)	0.13	-0.17	-57.15
<b>Dry starch market</b>			
Retail price (Dong/kg)	2442.0	0	0
Total production ('000 t)	165.92	29.09	21.26
Small processor production ('000 t)	33.32	21.01	170.59
Large processor production ('000 t)	132.6	8.09	6.5
Total consumption ('000 t)	113.77	-1.03	-0.9
Total income (US\$ million)	7.91	1.77	28.8
Small processor income (US\$ million)	0.95	0.6	167.3
Large processor income (US\$ million)	6.95	1.17	20.27
Processor price (Dong/kg)	1990.0	0	0
<b>Starch exports</b>			
Value exports (US\$ million)	15.64	9.04	136.78
Total export income (US\$ million)	3.63	2.1	136.8
Quantity exports ('000 t)	52.15	30.12	136.79
<b>Production shares (%)</b>			
Cassava for food	13.8	-1.2	-8.02
Cassava for feed	50.6	-4.41	-8.02
Cassava for wet starch	1.98	0.5	33.58
Cassava for dry starch	33.63	5.12	17.96
<b>Income shares (%)</b>			
Farm income	69.51	-0.45	-0.64
Feed income	9.76	-1.74	-15.14
Processing income	20.73	2.19	11.81
Wet starch income	1.39	-0.5	-26.61
Dry starch income	19.34	2.69	16.18
Small processor income	3.42	1.35	65.08
Large processor income	17.31	0.84	5.12
<b>Total income</b>			
Total income (US\$ million)	40.89	4.01	10.87

**Table 9C.** Results of starch industry model for Vietnam (SIMV) simulation: 10% injection of capital to large processors only.

	Amount	Change	Percentage change
<b>Cassava market</b>			
Production ('000 t)	2006.53	6.66	0.33
Food consumption ('000 t)	298.04	-2	-0.67
Farm price (Dong/kg)	282.29	2.34	0.83
Retail price (Dong/kg)	350.29	2.34	0.67
Farm income (US\$ million)	26.1	0.3	1.17
<b>Feed market</b>			
Production ('000 t)	302.71	-2.03	-0.67
Farm price (Dong/kg)	1011.0	0	0
Retail price (Dong/kg)	1256.0	0	0
Feed consumption ('000 t)	190.7	0	0
Exports ('000 t)	112.01	-2.03	-1.78
Value exports (US\$ million)	11.31	-0.21	-1.78
Feed income (US\$ million)	4.21	-0.03	-0.71
<b>Wet starch market</b>			
Retail price (Dong/kg)	1196.45	-3.45	-0.29
Total production ('000 t)	40.9	0.09	0.23
Small processor production ('000 t)	27.9	-0.26	-0.92
Large processor production ('000 t)	13.0	0.35	2.78
Total consumption ('000 t)	40.9	0.09	0.23
Intermediate consumption ('000 t)	29.04	0.07	0.23
Processor price (Dong/kg)	1101.45	-3.45	-0.31
Total income (US\$ million)	0.7	0	0.38
Small processor income (US\$ million)	0.4	-0.01	-1.29
Large processor income (US\$ million)	0.3	0.01	2.34
<b>Dry starch market</b>			
Retail price (Dong/kg)	2442.0	0	0
Total production ('000 t)	140.65	3.82	2.8
Small processor production ('000 t)	12.24	-0.07	-0.58
Large processor production ('000 t)	128.4	3.9	3.13
Total consumption ('000 t)	114.79	-0.01	-0.01
Total income (US\$ million)	6.41	0.27	4.44
Small processor income (US\$ million)	0.36	0.01	1.42
Large processor income (US\$ million)	6.05	0.27	4.65
Processor price (Dong/kg)	1990.0	0	0

**Table 9C.** (Cont'd) Results of starch industry model for Vietnam (SIMV) simulation: 10% injection of capital to large processors only.

	Amount	Change	Percentage change
<b>Starch exports</b>			
Value exports (US\$ million)	7.76	1.15	17.4
Total export Income (US\$ million)	1.8	0.27	17.41
Quantity exports ('000 t)	25.85	3.83	17.4
<b>Production shares (%)</b>			
Cassava for food	14.85	-0.15	-1
Cassava for feed	54.46	-0.55	-1
Cassava for wet starch	1.48	0	-0.09
Cassava for dry starch	29.21	0.7	2.45
<b>Income shares (%)</b>			
Farm income	69.75	-0.21	-0.31
Feed income	11.25	-0.25	-2.17
Processing income	19.0	0.46	2.5
Wet starch income	1.87	-0.02	-1.15
Dry starch income	17.13	0.49	2.92
Small processor income	2.04	-0.03	-1.49
Large processor income	16.96	0.49	3.0
<b>Total income</b>			
Total income (US\$ million)	37.43	0.55	1.48

## References

- Arnold, M. 1996. Harvest and postharvest problems in agriculture, forestry and fisheries—the CGIAR contribution to research. Consultative Group on International Agricultural Research (CGIAR) Document No.: SDR/TAC:IAR/96/5.
- Asian Productivity Organization (APO) 1992. APO Seminar on promoting agribusiness for higher productivity, Jakarta, Indonesia, 4–14 August.
- Austin, J.E. 1995. Reflections on IDB strategy for agricultural and rural development. Mimeo.
- Azzam, A.M. 1998. Competition in the US meatpacking industry: is it history? *American Journal of Agricultural Economics*, 80, 96–106.
- Boeh-Ocansy, O. 1988. Small scale food industries: improving performance in developing countries. *Food Policy*, November, 334–337.
- Brester, G.W. and Musick, D.C. 1995. The effect of market concentration on lamb marketing margins. *Journal of Agricultural and Applied Economics*, 27, 172–183.
- Delgado, C.L. 1998. Sources of growth in smallholder agriculture in Sub-Saharan Africa: the role of vertical integration with processors of high value-added items. International Food Policy Research Institute (IFPRI). Paper presented at the Inter-Conference Symposium of the Association of Agricultural Economists, Badplaas, South Africa, 10–16 August.
- Dolan, C., Humphrey, J. and Harris-Pascal, C. 1999. Horticultural commodity chains: the impact of the UK market on the African fresh vegetable industry. IDS Working Paper 96. Sussex, Institute of Development Studies (IDS), University of Sussex.
- FAO (Food and Agricultural Organization of the United Nations) 1995. Food for consumers: marketing, processing and distribution. WFS 96/TECH/4: Provisional Version. Rome, FAO.
- FAO (Food and Agricultural Organization of the United Nations) 1997. The state of food and agriculture. Rome, FAO.
- FAO (Food and Agricultural Organization of the United Nations) 1999. FAO Fact-File, on the Internet. <<http://www.fao.org/NEWS/FOTOFILE/PH9740-e.htm>>
- Fellows, P. (ed.) 1997. Traditional foods: processing for profit. London, Intermediate Technology Publications.
- Fleischer, G., Waibel, H. and Dirksmeyer, W. 1996. Future priorities in postharvest systems development—the role of GASGA. In: Group for Assistance on Systems Related to Grain After-Harvest (GASGA) Executive Seminar No. 8, Systems approach in post-harvest activities, 12–13 June 1996. Montpellier, France, Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD).
- Giles, J.A. 1999. New structures, new customers and new strategies: implications for food safety. Paper presented at the Postharvest Convention 1999 held at Silsoe College, Cranfield University, Bedford, 24 March.
- Hayenga, M. 1998. Cost structures of pork slaughter and processing firms: behavioral and performance implications. *Review of Agricultural Economics*, 20, 574–83.
- IFPRI (International Food Policy Research Institute) 1998. Starch industry development as a strategy for agrofood based rural industrialization. Washington DC, Markets and Structural Studies Division, IFPRI, December 1998.
- Jaffee, S. and Gordon, P. 1993. Exporting high-value food commodities. Washington DC, World Bank Discussion Papers.
- Jaffee, S. and Morton, J. (ed.) 1995. Marketing Africa's high-value foods: comparative experiences of an emergent private sector. Washington DC, The World Bank.
- Jank, M.S., de Paula, S.R.L. Filho, P.F., Leme, M.F.P. and Nassar, A.M. 1999. Multinationals and intra-industry concentration: the case of Brazilian agribusiness exporters. Paper presented at the American Agricultural Economics Association (AAEA) Preconference on Agroindustrialization, Globalization and Economic Development, Nashville, Tennessee, 6–7 August.
- Johnson, G.I. 1998. Postharvest technology in Asia: ACIAR's framework for collaborative research and development. Mimeo.
- Kajisa, K. and Meredia, M. 1997. Transformation versus stagnation in the oil palm industry: a comparison between Malaysia and Nigeria. Michigan State University Staff Paper 5.
- Kaplinsky, R. 1990. The economics of small: appropriate technology in a changing world. Exeter, Short Run Press.
- Kaplinsky, R. and Manning, C. 1998. Concentration, competition policy and the role of small and medium-sized enterprises in South Africa's industrial development. *Journal of Development Studies*, 35, 139–161.
- Kennedy, E. and Reardon, T. 1994. Shift to non-traditional grains in the diets of East and West Africa: role of women's opportunity cost of time. *Food Policy*, Volume 19 (February).
- Key, N. and Runsten, D. 1999. Contract farming, smallholders and rural development in Latin America: the organization of agroprocessing firms and the scale of outgrower production. *World Development*, 27, 386–401.
- Koontz, S., Garcia, P. and Hudson, M. 1993. Meatpacker conduct in fed cattle pricing: an investigation of Oligopsony Power. *American Journal of Agricultural Economics*, 75, 537–48.
- McCormick, D. 1998. Enterprise clusters in Africa: on the way to industrialization? IDS Discussion Paper 366. Sussex, Institute of Development Studies (IDS), University of Sussex.

- Minot, N. 1986. Contract farming and its effect on small farmers in less developed countries. Working paper No. 31. East Lansing, Michigan, Department of Agricultural Economics, Michigan State University.
- Nguyen Van Bich, Nguyen Xuan Nguyen, Chu Tam Quang and Tran Huu Quang 1998. Differences in economic development in urban and rural areas. Viet Nam Socioeconomic Development, No. 13, Spring 1998.
- OECD (Organization for Economic Cooperation and Development) 1995. Niche markets as a rural development strategy. Paris, OECD.
- Petritisch, M. 1985. Women's participation in manufacturing in developing countries, with emphasis on agro-industries. United Nations Industrial Development Organization: Paper prepared for Expert Group Meeting on Women in Agro-Industries, Vienna, Austria, 14–18 October 1985.
- Phan Van Khai 1999. Socioeconomic development in 1998 and major orientation for socioeconomic development in 1999. Government Report presented at the 4<sup>th</sup> Session of the 10<sup>th</sup> National Assembly on 28 October 1998. Hanoi, Vietnam, The Gioi Publisher.
- Poleman, T.T. and Thomas, L. 1994. Income and dietary change: international comparisons using purchasing-power-parity conversions. Cornell Agricultural, Resource and Managerial Economics (ARME) Working Paper No. 94–1.
- Rasmussen, J., Schmitz, H. and van Dijk, M.P. 1992. Introduction: exploring a new approach to small-scale industry. IDS (Institute of Development Studies, University of Sussex) Bulletin 23 (2), 1–7.
- Reardon, T., Condon, J., Bush, L., Bingen, J. and Harris, C. 1999. Food and agriculture standards: their new roles and impacts on farming and agroindustry in developing countries. Paper presented at the American Agricultural Economics Association (AAEA) Preconference on Agroindustrialization, Globalization and Economic Development, Nashville, Tennessee, 6–7 August.
- Sandee, H. 1999. Clustered small enterprise under economic distress: the impact of the Indonesian crisis on small industry clusters, with reference to agroindustries. Paper presented at the American Agricultural Economics Association (AAEA) Preconference on Agroindustrialization, Globalization and Economic Development, Nashville, Tennessee, August 6–7.
- Schejtman, A. 1998. Agroindustria y pequeña agricultura: experiencias y opciones de transformación. CEPAL/GTZ/FAO, ed., Agroindustria y pequeña agricultura: vínculos, potencialidades y oportunidades comerciales. Santiago de Chile, Naciones Unidas.
- Schmitz, H. 1995. Collective efficiency: growth path for small scale industry. *Journal of Development Studies*, 31, 529–566.
- Smyth, I. 1992. Collective efficiency and selective benefits: the growth of the rattan industry in Tegalwangi (Indonesia). *IDS (Institute of Development Studies, University of Sussex) Bulletin*, 23(2), 51–56.
- Thrupp, L. 1995. Bittersweet harvests for global supermarkets: challenges in Latin America's agricultural export boom. Washington DC, World Resources Institute.
- Viaene, J. and Gellynck, X. 1995. Structure, conduct and performance of the European food sector. *European Review of Agricultural Economics*, 22, 282–95.
- World Bank 1997. *World Development Report 1997*. New York, Oxford University Press.
- World Development (journal) 1999. Special issue on clustering and industrialisation.

**Appendix 1.** Description of the starch industry model for Vietnam (SIMV).

The model below is a linear programming model designed to examine the effects of various policies and exogenous shocks on the starch subsector. The following is a list of the endogenous variables in the model. All quantities are denoted in '000 t:

Variable	Description	Number of variables
$q_G^s$	Total supply of commodity G	4
$q_G^d$	Total demand of commodity G	4
$q_{c,G}^d$	Demand for cassava by commodity G	4
$q_{wet,N}^s$	Supply of wet starch from group N	2
$q_{dry,N}^s$	Supply of dry starch from group N	2
$q_{wet,W}^d$	Demand for wet starch by end user W	5
$q_{dry,D}^d$	Demand for dry starch by end user D	8
$p_G^F$	Farm price for commodity G (Dong/kg)	4
$p_G^R$	Retail price for commodity G (Dong/kg)	4
$X^{feed}$	Exports of feed	1
$X^{dry}$	Exports of dry starch	1
$M^{feed}$	Imports of feed	1
$M^{dry}$	Imports of dry starch	1
$Y^{farm}$	Farm income (US\$ million)	1
$Y^{feed}$	Feed income (US\$ million)	1
$Y^{wet,N}$	Wet starch income for group N (US\$ million)	2
$Y^{dry,N}$	Dry starch income for group N (US\$ million)	2
Total		47

The exogenous variables used in the model are listed below:

Variable	Description
$z$	Exogenous shift parameters
$\mathfrak{S}$	Conversion rate of the number of cassava roots required to generate one unit of feed or starch
$p^x$	Export price (US\$/t)
$p^M$	Import price (US\$/t)
MKT	Marketing margins (Dong/kg)
TC	Transportation costs (Dong/kg)
NER	Nominal exchange rate
$\Theta_{G,(N)}$	Profit share for commodity G (for starch, differs by processor size, N, as well)
$\mathfrak{N}^N$	Initial proportion of dry starch produced by group N



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The labels used are defined as follows:

Label	Definition
c	Cassava
food	Cassava as food
feed	Cassava feed
wet	Wet starch
dry	Dry starch
G	All commodities (cassava as food, feed, wet starch, and dry starch)
XG	Exported commodities (feed and dry starch), a subset of G
N	Size of processor (small or large)
W	End users using wet starch (intermediate uses, noodles, maltose, other food and glucose)
D	End users using dry starch (noodles, maltose, other food, glucose, monosodium glutamate, pharmaceuticals, textiles, and paper)

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The first block of equations describes the cassava market. The supply of cassava roots (equation A1) is simply a function of the farmer price for cassava and exogenous supply shocks, such as technology.

$$\ln(q_c^s) = \beta_c^s + \epsilon_{c,c}^s \ln(p_c^F) + \ln(z^c) \quad (A1)$$

Since cassava is used as an input for food, feed, and starch, we model each market separately (equations A2 through A5). Cassava demand for food (equation A2) is assumed to be a function of retail cassava prices and exogenous changes in demand. Cassava demand for feed (equation A3) and dry starch (equation A5) is assumed to be the root equivalent of the total supply of feed and starch, respectively. In the case of wet starch (equation A4), demand for cassava by wet starch is the root equivalent of the net supply of starch. Since a proportion of wet starch is used as an intermediate input in the production of dry starch, we must subtract intermediate uses in order to obtain net demand. Total demand for cassava roots (equation A6) is simply the sum of the demand for cassava from food, feed, and starch.

$$\ln(q_{c,food}^d) = \beta_{c,food}^d + \epsilon_{c,food}^d \ln(p_c^R) + \ln(z_{food}^d) \quad (A2)$$

$$q_{c,feed}^d = \mathcal{I}_{c,feed} q_{feed}^s \quad (A3)$$

$$q_{c,wet}^d = \mathcal{I}_{c,wet} (q_{wet}^s - \Phi q_{wet,interm}^d) \quad (A4)$$

$$q_{c,dry}^d = \mathcal{I}_{c,dry} q_{dry}^s \quad (A5)$$

$$q_c^d = q_{c,food}^d + q_{c,feed}^d + q_{c,wet}^d + q_{c,dry}^d \quad (A6)$$

The second block of equations models the feed market. Feed demand (equation A7) is a function of retail feed prices and exogenous changes in meat demand. Feed supply (equation A8) depends on input prices (i.e. the retail price of cassava) and output prices (i.e. the producer price for feed).

$$\ln(q_{feed}^d) = \beta_{feed}^d + \epsilon_{feed,feed}^d \times \ln(p_{feed}^R) + \ln(z^{meat}) \quad (A7)$$

$$\ln(q_{feed}^s) = \beta_{feed,c}^s + \epsilon_{feed,c}^s \times \ln(p_c^R) + \epsilon_{feed,feed}^s \ln(p_{feed}^F) \quad (A8)$$

The third block of equations focuses on the market for wet starch. The supply of wet starch (equation A9) is differentiated by the size of the processing unit (small or large). While both groups face the same prices, they have different initial endowments of capital and starch. Total supply of wet starch (equation A10) is the sum of small processor supply and large processor supply.

$$\ln(q_{wet,N}^S) = \beta_{wet,N}^S + \epsilon_{wet,N,c}^S \ln(p_c^R) + \epsilon_{wet,N,wet}^S \ln(p_{wet}^F) + \mathcal{I}_{wet,N}^S \ln(K^N), \quad (A9)$$

$$q_{wet}^S = q_{wet,small}^S + q_{wet,large}^S \quad (A10)$$

Wet starch demand (equation A11) depends on the various demands by different users of wet starch (e.g. noodle factories, maltose factories). End-user demand for wet starch is a function of the retail price of wet starch as well as the retail price for dry starch, which can be a substitute for wet starch. Wet starch demand is also affected by exogenous shifts in demand for end-user products, such as noodles or maltose. Total wet starch demand is the sum of wet starch demand by end users (equation A12).

$$\ln(q_{wet,W}^d) = \beta_{wet,W}^d + \epsilon_{wet,W,wet}^d \ln(p_{wet}^R) + \beta_{wet,W,dry}^d \ln(p_{dry}^R) + \ln(z^W), \quad (A11)$$

$$q_{wet}^d = \sum_W q_{wet,W}^d \quad (A12)$$

The fourth block of equations is for dry starch supply and demand. These are similar to the relationships in wet starch. Dry starch supply is a function of cassava retail prices and the producer price for dry starch as well as the capital endowment for small and large processors (equation A13). Total dry starch supply is the sum of supply from small and large processors (equation A14). Dry starch demand depends on the individual demand from the different end users for dry starch (equation A15). For noodles, maltose, other food, and glucose, dry starch demand depends on the retail price of both wet and dry starch and on exogenous shocks on those end products, since both types of starch can be used as in input. For textiles, paper, pharmaceuticals, and monosodium glutamate, dry starch demand is function of only dry starch price and exogenous shifters.<sup>3</sup> Total dry starch demand is the sum of the individual end-user demand for dry starch (equation A16).

$$\ln(q_{dry,N}^S) = \beta_{dry,N}^S + \epsilon_{dry,N,c}^S \ln(p_c^R) + \beta_{dry,N,dry}^S \ln(p_{dry}^F) + \beta_{dry,N}^S \ln(K^N), \quad (A13)$$

$$q_{dry}^S = q_{dry,small}^S + q_{dry,large}^S \quad (A14)$$

$$\ln(q_{dry,D}^d) = \beta_{dry,D}^d + \epsilon_{dry,D,wet}^d \ln(p_{wet}^R) + \beta_{dry,D,dry}^d \ln(p_{dry}^R) + \ln(z^D), \quad (A15)$$

$$q_{dry}^d = \sum_D q_{dry,D}^d \quad (A16)$$

The fifth block summarises the trade and price relationships within the cassava, feed, and starch markets. Cassava and wet starch are assumed to be non-tradable, so that total supply equals total demand (equations A17 and A19, respectively). Since there are exports of feed and dry starch, we model these markets such that supply equals demand plus net exports (equations A18 and A20).

$$q_c^S = q_c^d \quad (A17)$$

$$q_{feed}^S = q_{feed}^d + X^{feed} \Phi M^{feed} \quad (A18)$$

$$q_{wet}^S = q_{wet}^d \quad (A19)$$

$$q_{dry}^S = q_{dry}^d + X^{dry} \Phi M^{dry} \quad (A20)$$

Domestic prices (equation A21) are defined such that the difference between retail and farm prices is the marketing margin. In addition, farmer prices plus transportation costs and marketing margins must be at least the level of the export price (equation A22).

$$p_D^R = p_G^F + MKT + TC \quad (A21)$$

$$p_{XG}^F + MKT + TC \geq p_{XG}^R \frac{NER}{1000} \quad (A22)$$

Similarly, the retail price must be less than or equal to the import price plus any marketing margins and transport costs (equation A23).

$$p_{XG}^R \leq A \left[ p_{XG}^M \frac{NER}{1000} \right] + MKT + TC \quad (A23)$$

The last block defines income for farmers, feed processors, and starch processors. Farm income (equation A24) is the value, in US\$ million, of cassava at producer prices multiplied by the profit share for cassava farmers (currently set at 0.53). Feed income (equation A25) is the product of the profit share (0.15) for feed processors and the value of feed supply. Since

<sup>3</sup>. In the case of monosodium glutamate, pharmaceuticals, textiles and paper—which only use dry starch—we assume that in equation A15,  $\epsilon_{dry,D,wet}^d = 0$ .

a portion of feed is exported, we value domestic consumption at farmer prices and exports at the world price for feed. Wet starch income (equation A26) is defined as the value of wet starch production for small and large processors, each of whom has a different profit share (0.15 for small processors, 0.24 for large processors). Dry starch income (equation A27) is similar to feed income, in that exports are valued at the world price while domestic consumption is valued at the producer price.<sup>4</sup>

$$Y^{farm} = p_c^F p_c^S \Theta / NER \quad (A24)$$

$$Y^{feed} = \left[ p_{feed}^F q_{feed}^{TM} \Phi X^{feed} \right] \Theta^{feed} / NER \quad (A25)$$

$$p_{feed}^X X^{feed} \Theta^{feed} / 1000$$

$$Y^{wet,N} = \left[ p_{wet}^F q_{wet,N}^S \Theta^{wet,N} / NER \right] \quad (A26)$$

<sup>4</sup>. For this discussion, we have omitted the equations for total starch income, which are simply equations 26 and 27 summed over the group, N.

$$Y^{dry,N} = \left[ p_{dry}^F q_{dry,N}^{TM} \Phi X^{dry} \right] \Theta^{dry,N} / NER \quad (A27)$$

$$p_{dry}^X X^{dry} \Theta^{dry,N} / 1000$$

The model is written in GAMS (General Algebraic Modeling System) using mixed complementarity programming (MCP). With MCP, the programmer specifies an equal number of equations and variables. In addition, each inequality of the form  $f(x) \leq 0$  is explicitly linked to a complementary variable  $\rightarrow$  such that  $-f(x) = 0$ . Intuitively, when an inequality becomes binding, it effectively increases the number of equations in the system. In order to preserve the balance between the number of equations and the number of endogenous variables, a new variable must also enter the system by becoming positive. In this model, this only occurs with imports and exports. For example, when the price relationship between the export price and farm price becomes binding (i.e. farm price plus marketing costs equals the export price), an equation for exports (namely,  $X > 0$ ) enters the system, thus allowing for external trade.

# Quality Assurance: the Concept and its Evolution

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## *Abstract*

The objective of quality assurance is to build quality into processes of a system to prevent quality problems in products or services. Its application to agribusiness, especially in postharvest technology, can contribute to greater profitability and customer satisfaction. This paper presents the view that quality embraces wider activities than the quality of a product. It considers the evolution of the concept of quality and its translation into legal obligations for all stakeholders including designers, producers, packers, traders and users.

QUALITY management seeks to create prosperity through human endeavour. It is a form of business management committed to customer satisfaction through continuous improvement. Since business culture varies from country to country and from company to company, there is no set standard form of a good quality management program. Each single program must be planned and implemented on the basis of the nature of its activities and environment. A quality management program cannot function as an entity isolated from the daily managerial activities of an organisation, nor can management be insulated from the requirements of a quality system. However, there are a number of guidelines available for the preparation, implementation and maintenance of a quality management system leading to certification. The ISO 9000:1994 series is the most recent international standard to provide basic guidelines for quality management system certification. ISO 9000:2000, which is currently in draft form, will soon be published.

Over the years, there have been significant changes in the social responsibility of business, such as the legal obligations to protect the employees and the environment while supplying high quality and safe products. An example is the European Community, which had made compliance with the quality ISO 9000 series of standards necessary for suppliers to that community. This was put into effect and enforced in 1992 (Marquardt 1997).

Again, the environmental ISO 14000 standards introduced in 1996 could also be used as a non-tariff barrier to international trade (Rosenbaum 1997) through the requirements of eco-labels (Wilson 1999). To increase assurance in environmental quality, the European Union has recently introduced a number of standard procedures for sustainable agriculture. These standards have been addressed in two publications edited by Van den Brink et al. (1995) and Roling and Wagemakers (1998). It is envisaged that this trend may have far reaching consequences in agribusiness as the capacity to meet these standards is virtually non-existent in many Third World countries. For this very reason, environmental factors must be addressed during strategy formation and implementation (James et al. 1999).

Yet again, compliance with workplace health and safety (or work environment) standards is legislated in many countries, and has already had a profound impact on business activities worldwide (Window 1996).

A critical issue for agriculture is the food safety standard HACCP (Hazard Analysis and Critical Control Points) or food quality assurance, which has also been incorporated into legal requirements that apply to the food industry in the United States of America (USA) (Tisler 1997), Canada (Anon. 1998) and the European Union (Anon. 1996). The position of legal requirements in applying standardised HACCP uniformly to the Australian food industry is unclear at the point of writing, as the Australian authorities are leaning towards a number of local standards such as HACCP-based quality assurance and the SQF 2000

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Quality Code: 1997. In New South Wales alone, there are at least three types of systems recognised by the authorities (Kellam 1995).

It has now become clear that governments in many countries have imposed regulations and even legislation to ensure acceptable quality and safety of foodstuffs supplied to their people. The quality concept and its management system evolve accordingly under government intervention.

## History in Brief

Quality has been associated with the acceptable performance of products from very early times. The precision of fit of the stones in the Egyptian pyramids indicates well-developed production methods and measuring procedures.

In the Middle Ages in Europe, the craft guilds were self-regulating organisations composed of master craftsmen, journeymen and apprentices. Each guild laid down detailed regulations governing the quality of its products. "Quality assurance was informal; every effort was made to ensure that quality was built into the final product by the people who produced it" (Evans and Lindsay 1996).

In the early 1900s, F.W. Taylor (1856–1915) developed a systematic approach for work improvement through the application of knowledge, the use of standard tools and conditions, and the use of motivation with appropriate rewards. He argued that product quality control was the responsibility of inspectors. Since then, quality control departments were created in organisations and the workers were cut off from direct involvement in work improvement.

In the 1920s there was a re-emergence of interest in quality through measurement. Statistical tools and the PDCA (plan, do, check and act) cycle were developed by Dr Shewhart (1891–1967). At Bell Telephone Laboratories, new methods and theories of inspection for maintaining and improving quality were being developed. The early pioneers of quality assurance such as Walter Shewhart, Harold Dodge, George Edwards, W. Edwards Deming and Joseph Juran were members of this group. It was here that the term 'quality assurance' was coined (Evans and Lindsay 1996).

In the 1930s, following the development of British Standards, the application of statistical methods to production was introduced. In Australia, the Standards Association of Australia (SAA) was formed in 1929.

The American Society for Quality Control (ASQC), the Australian Laboratory Accreditation System (testing), and many worldwide societies were established in this period.

The Second World War led to an emphasis on statistical quality control with the Military Standard. After the war, Juran and Deming, along with other industrial experts, contributed to Japan's industrial rehabilitation with the application of quality control methods.

From a management perspective, Armand Feigenbaum wrote "Total Quality Control" in 1957 which impressively brought together all the organisational and managerial ideas relating to quality. Feigenbaum introduced total quality control as an organisation-wide responsibility and cost of quality as a means of quantifying the benefits of its application. In 1970, the Categories of Quality Costs were defined by ASQC.

Deming (1900–1990s) extended Shewhart's ideas into management theory, covering concepts and principles of quality, a system approach to work, distinguishing common and special causes and so on. During the same period as Deming, Juran (1900–1990s) put forward the theory of the quality trilogy — planning, control and improvement.

A well-documented account of the historical development of quality has been given by Banks (1989). But he could not foresee the trends of the 1990s. In Australia, for example, the State Government of Queensland in 1987 passed legislation that required a level of quality assurance as a basis for bidding for Government contracts, and the other States and Federal Government established similar standards of endorsement. The European Community followed in 1992, and Hong Kong considered it in 1998. Oddly enough, Australia then retreated from this position for internal political and commercial reasons.

More recently, the European Community has further strengthened its requirements through the CE Mark system (Kolka 1997; Lemmel 1999) which is concerned with product quality and safety entering the European Community. Since the World Trade Organization is fostering open trade throughout the world, there is emerging among market economies a need to ensure that consumers in any country are protected in both the quality and safety of the products they purchase. Legislation in these markets will be aimed at providing that protection.

## Evolution of the Meaning of Quality

The interpretation of the term 'quality' has evolved along with the growth of managerial thinking. From the historical Guild approach to measurable specifications, quality was defined as 'fitness for use'. In the 1960s, the USA Consumer Product Safety Act and similar legislation around the world gave impetus to quality in a product being seen as 'fitness for its purpose', which considered the customer's expectations. But as products and services became more diverse and complex, the notion of 'conformance to requirements', then 'conformance to agreed requirements', seemed to embrace both the needs of the customer as well as the need of the supplier to have some objective criterion to know when acceptable quality had been achieved. Finally, the ISO 8402:1987 definition embraced many of these aspects with "the totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs".

According to ISO/CD2 9000:2000, quality means "achieving sustained customer satisfaction through meeting customer needs and expectations within an organisational environment committed to continual improvement of efficiency and effectiveness". Quality control, quality assurance and continual improvement are integral parts of a quality management system focused on the fulfilment of quality requirements.

## Quality Concept and Principles

The quality system is a management-led process; it requires leadership and total commitment from senior management to provide an appropriate infrastructure to support the implementation of such a system. As Crosby (1979) states, "the purpose of quality management is to set up a system and a management discipline that prevents defects from happening in the company's performance cycle". To achieve this, it involves fundamental change in both company culture and the technologies employed by the business.

Combining the teachings of the quality theorists with practical experience, one can identify a number of critical factors in the total quality management (TQM) implementation process that are common to sound management theory. Based on Porter and Parker (1993), these include the commitment of management, strategy and structure, communication, training and education, employee involvement, a focus on processes, and application of quality technologies. This is in accord with critical factors identified in the

Malcolm Baldrige National quality Award (Anon. 1992), such as leadership, information analysis, strategic quality planning, human resource development, process quality, and customer focus and satisfaction.

Clearly, these concepts of quality are based on the early work of Shewhart, Deming, Feigenbaum, Crosby, Ishikawa and Taguchi. It is an organisation-wide approach to control, monitor and direct all resources towards the attainment of corporate goals. Although their approaches differ in techniques and emphasis (Ghobadian and Speller 1994), they all have a common objective—continuous improvement in both quality and business performance through customer satisfaction, a culture of total involvement, the application of statistical tools, policy and marketing. These elements must be fully and simultaneously integrated leading the way to quality improvement through the system.

## ISO 9000 Standards and TQM

The ISO 9000 Standards reflect a narrow and static inspection philosophy emphasising conformance to specification and system maintenance. The certification of ISO 9000 and quality audits provide indications that the organisation has achieved the minimum requirements of the standards.

Total quality management systems constitute structured systems and managerial activities. These include a mix of people issues and an understanding of systems and tools of improvement. The people issues are related to leadership. A critical role of leadership is the determining of the organisation's mission, vision and guiding principles. Clearly, people are the key to quality; it is determined by the senior managers with the involvement of the whole organisation. Therefore one of the primary conditions for the successful implementation of TQM is a quality culture; this emerges from the values, beliefs, attitudes and prejudices inherent in all the people in the organisation. These attributes, along with the technology and traditional methods of work, are the prime determinants of the culture of an organisation. To imbue everyone in the organisation with a quality philosophy focused on alignment of strategies, structures and functions with environmental demands, means achieving a culture change in management behaviour.

There are important ISO requirements common to the philosophies of TQM. These include management responsibility, training, process control, statistical techniques, a quality system and internal quality audits

(Smith and Angeli 1995). Therefore, the interrelationship between ISO 9000 and TQM can be illustrated by the following equation (Lim and Niew 1995; Smith and Angeli 1995):

$$\text{TQM} = \text{People (culture)} + \text{tools (technique for improvement)} + \text{system (ISO 9000)} \quad (1)$$

It is indisputable that conformance to technical standards is only part of the total process of satisfying customers while making a profit. ISO 9000 is an integral part of TQM; it acts as a concrete foundation on which to build a quality organisation. It provides guidance in the application of quality improvement tools, techniques, the application of performance measures to the whole system, and provides a structured approach to the deployment of an appropriately trained workforce.

ISO 9000 is at the basic end of the quality management spectrum, with a focus on survival in the marketplace. This standardisation loop does not of itself constitute all the factors necessary for business success (Fuchsberg 1992; Wenmoth and Dobbins 1994; Cooper 1995; Spenley 1995) although some organisations claim that the installation of their ISO 9000 certified system or TQM program has improved their business performance (Deming 1982; Garvin 1988; Teare et al. 1994).

## **Evolution from Quality Management to a Total Business System**

To ensure competitiveness, business strategists have been concerned with the alignment between the internal and external environments in which they compete (Miles and Snow 1985; Mintzberg and Waters 1985; Johnson and Scholes 1997) although external forces are in a state of continuous change. Quality practitioners are not usually concerned with alignment issues during the implementation of quality programs. They focus on operational effectiveness (Porter 1996; Ahire 1997) and are usually concerned with the compliance to certification or quality award requirements.

In a turbulent environment, technical standards and TQM systems are not, and were not intended to be, a sufficient strategy to address the growing complexity of doing business. While some argue that TQM by itself cannot succeed unless it is integrated with other time-based philosophies such as just-in-time, total quality control, total production management, group technology and design for manufacturability (Miyake et al. 1995; Youssef et al. 1996), others point out that

quality means little in business unless it is fully incorporated into business strategy (Brown and van der Weile 1996; Liston 1996; Seghezzi 1997; Collins and Hill 1998; Wong et al. 1998). One might conclude that the failures were most likely associated with the lack of strategic links. At the same time, experience clearly shows that the application of business strategies has not in itself ensured excellence; hence the important perspective promoted in this paper is that the business strategy must have a conscious quality dimension if it is to contribute to improved performance and competitiveness.

The evolution of quality in business has been summed up into four paradigms by Miller (1993); he suggested quality control was followed by quality assurance, then TQM, and finally what he calls 'quantum quality', where learning, creativity, values and sustainability are keynotes for business. Each phase was an improvement based on a response to cultural, political, social and economic environments. It is now evident that the way TQM, or even quantum quality, was understood and implemented in the 1980s or 1990s will become less useful in response to competitive demands in the 21<sup>st</sup> century. The key to increase the speed of design, development, procurement, manufacturing and systems integration must be identified within a specific time-frame, since the requirements may be subject to change on short notice under government intervention. Clearly, the quality paradigm has now moved into a new dimension as proposed by the authors. This is what we call 'business systems integration'. It involves meeting stakeholders' expectations through the alignment of corporate strategies with operations functions and compliance with legal obligations; it is founded on innovation and learning, knowledge creation, organisational agility, improvement of stakeholder values through system capability, competency and safety.

Under government and community intervention, there are at least three (if not more) technical standard systems that need to be incorporated into a business plan in order to comply with the legal and regulatory requirements. For example, the implementation of ISO/CD2 9001:2000 needs to address ISO 14001 and AS/NZS 4804 for a manufacturing firm, whereas companies involved in food production or food-related activities may be required to address ISO 14001, AS/NZS 4804 and HACCP. Similar requirements have been addressed in the CE Mark system. In their recent publications, Mangelsdorf (1998) and Seghezzi (1997) strongly support the harmonisation of

these technical standards under one management system, although integration methodology is not yet available.

In response to the needs for integration, many companies in the United Kingdom have made attempts to achieve a fully integrated, single management system covering quality, environment, and health and safety, but with little success (Hillary 1997). These include the initial attempts made to integrate HACCP with TQM for retail and food service programs and the guide to integrate ISO 9001/2 with HACCP for the food industry (Bolton 1997).

In Australia, the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) has published a number of HACCP-based quality assurance standards, e.g. AS 4461: 1997 for hygienic production of meat for human consumption. AS 4461:1997 (Anon. 1997) is essentially the replica of ISO 9002, except that the entire clause 4.9 (process control) is replaced by the seven principles of HACCP. However, these standards are far from adequate and are not able to comply fully with the requirements of the current legislation and regulations.

More recently, Wong et al. (1998) have put forward a total business system (TBS) covering the integration of quality (ISO 9001), environment (ISO 14001), agriculture and food safety (HACCP), workplace health and safety (AS/NZS 4804) and business strategies. All the technical standards described in this model are sub-systems of the total business system. This model (Figure 1) is a self-generating, 'double loop' learning process which contains a consistent set of principles, procedures and techniques. It provides an umbrella under which all the requirements of stakeholders can be implemented synchronously under a single auditable management system. These include:

- financial goals for the firm; and
- non-financial goals for the satisfaction of customers, suppliers, employees, regulators, the global community, social groups and ecology.

Undoubtedly, the 21<sup>st</sup> century quality management system is going to be different from what it was in the 1980s or 1990s. It will require an appropriate culture of quality improvement to be introduced to a globally competitive organisation.

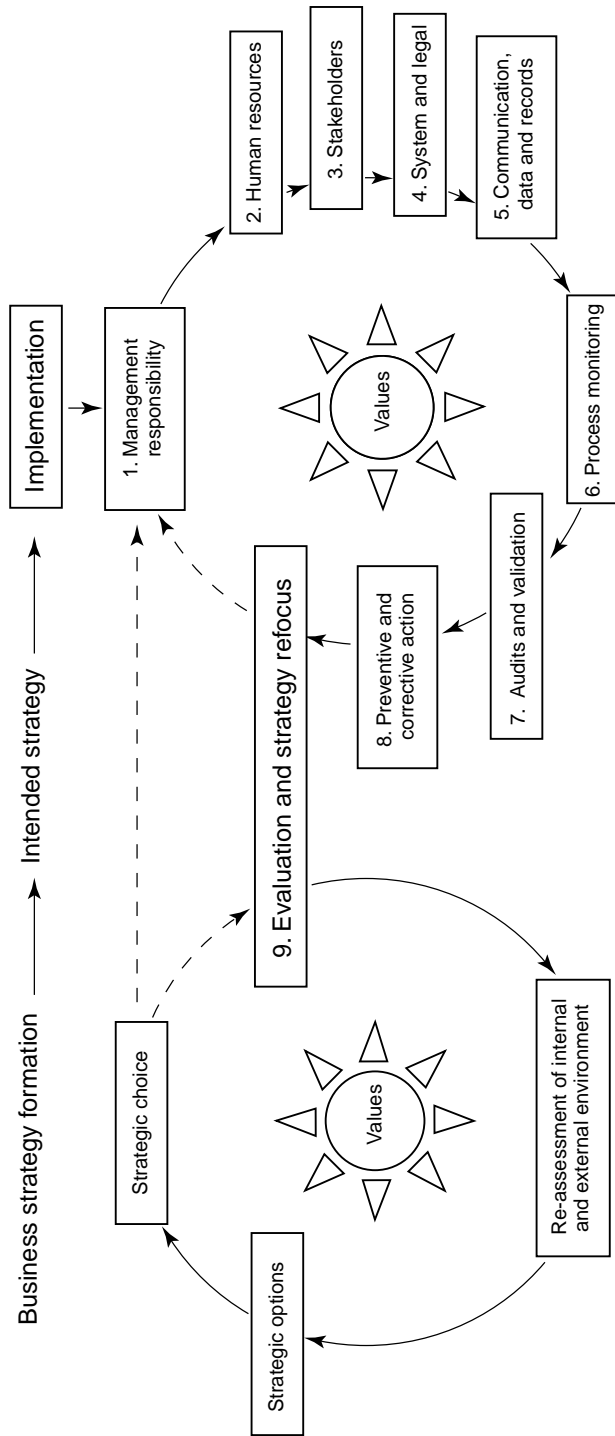
## Impact and Legal Implications of Standards and Regulations on Trade

There is an increasing demand in the global marketplace for regulation regarding the supply of high quality and safe products. Companies that fail to implement ISO 14001 to protect the environment, ISO 9000 series standards for quality, or the HACCP standard for food quality and safety will be unable to compete in Europe, the USA, Canada, Australia, Japan and elsewhere. Under the Food Act in the United Kingdom and Australia, poor quality may result in serious consequences of liability. In the USA, the sale of poor quality products could lead to product liability litigation and insurance difficulties (Helms and Hutchins 1992). The breach of workplace safety, product safety and environmental safety has recently proven to be costly to some national and international organisations (The Courier-Mail, Brisbane, Australia—June 04, 05 and 18; August 11 and 12 1999).

More recently, a complex and comprehensive regulatory product certification framework has been introduced into the European Union (Lemmel 1999). This is commonly known as the European Union Conformity Assessment Requirements or the 'CE Marking' system. These New-Approach directives contain a set of essential requirements covering safety, health and environmental components. In these directives, manufacturers (or producers), importers, distributors, assemblers and installers bear liability for product failures. Failure to take measures, or corrective measures, to comply with a directive will amount to a serious breach of Community law. It appears that the European Union has intensified its certification procedures beyond traditional procedures. The intention is to improve and maintain the reliability and safety of products marketed in the European Community.

It is generally accepted that to achieve a 'Due Diligence' defence, one must actively observe the principles of the relevant international standards or equivalent legislation as discussed. Clearly, businesses now have to be adept in complying with appropriate standards and regulations, and still be able to make a solid profit. Commercial growers who do not comply fully with the appropriate standards or legislation should be aware of the risks. Similarly, agricultural scientists who are the product designers providing advice on the growing of crops and post-harvest treatments should also be aware of their legal obligations.





**Figure 1.** The total business system (TBS) model: the incorporation of integrated International Standards Organisation (ISO) standards into business strategy.

It is now apparent that environmental, quality and safety standards have a significant impact on competitiveness and corporate strategy (Porter and van de Linde 1995a,b; Rao 1996; Rugman and Verbeke 1998). Similarly, standards and legislation should have significant impact on agrifood production processes (pre and postharvest) and business decision making.

The above issue is further supported by the new ISO standards (ISO/CD2 9001:2000), and the United Nations Industrial Organization (Wilson 1999). It appears that a new conceptual framework, which is capable of embracing national legal requirements and international standards under a single management system, must be developed to address these requirements. However, firms do not succeed on operations and procedures alone—these operational procedures must be incorporated into the business strategy framework.

## Discussion

It has now become evident that as business competition is getting tougher under the intervention of standards and legislation, the production or service design (including crop production, postharvest treatment, processing, packaging, distribution etc.) will have to be evolved according to the market perceived quality or expectation. The intention of the change is an attempt to improve productivity through adaptation. Therefore, some of the common quality rules in the 1980s and 1990s are becoming less useful as the quality evolution movement continues (Miller 1993; Wong et al. 1998).

This implies that the attainment of TQM philosophy may no longer guarantee a competitive position in the 21st century—we must go beyond TQM. It is further evident that if ISO standards or TQM programs are not incorporated into business strategies, their implementation can be regarded as irrelevant. Likewise, business strategies will be difficult to realise without quality programs. This means different business strategies call for different quality strategies. Clearly, these two elements must be used interactively and this problem can be overcome by the use of the total business system framework presented by Wong et al. (1998; see Figure 1).

It is becoming very clear and widely accepted that quality is heavily dependent upon the guiding principles of values, culture and ethos (Duncan 1972). Culture, beliefs and values also guide the daily operational behaviour of a company. As consumers are

always guided by habit or expectation, the very values and ethos of a company must be evolved accordingly.

The above concluding remarks further confirm that technical standards, legislation and strategies must be fully integrated into the existing production plan or research program should we wish to succeed in business against the complexity of the changing global business environment.

## References

- Ahire, S.L. 1997. Management science—total quality management interfaces: an integrative framework. *Interfaces*, 27, 91–105.
- Anon. 1992. The Malcolm Baldrige National Quality Award 1992. Application Guidelines. United States of America, National Institute of Standards and Technology.
- Anon. 1996. Seafood exporters to the European Union (EU). <<http://ifse.tamu.edu/alliance/seafood.html>>.
- Anon. 1997. AS 4461: 1997 Australian Standard for hygienic production of meat for human consumption. Standing Committee on Agriculture and Research Management (SCARM) Report No. 54 (2nd edition). Melbourne, Commonwealth Scientific and Industrial Research Organisation (CSIRO) Publishing.
- Anon. 1998. Food safety enhancement program (FSEP). <<http://www.cfia-acia.agr.ca/english/food/haccp/manual/01-01.html>>.
- Banks, J. 1989. Principles of quality control. New York, John Wiley, 3–26.
- Bolton, A. 1997. Quality management systems for the food industry: a guide to ISO 9001/2. London, Blackie Academic and Professional, 193p.
- Brown, A. and van der Wiele, T. 1996. Integrating quality and business planning using a self-assessment matrix. In: Kanji, G.K., ed., Total quality management in action. London, Chapman and Hall, 148–152.
- Collins, L.K. and Hill, F. 1998. The significance of business process reengineering in organisational change strategies: some survey findings. In: Ho, S.K.M., ed., ISO 9000 and total quality management: Proceedings of the third international conference. Hong Kong, Hong Kong Baptist University.
- Cooper, P. 1995. How standards achieve efficiency. *Management*, May, 20–22.
- Crosby, P.B. 1979. Quality is free. New York, McGraw-Hill.
- Deming, W.E. 1982. Quality, productivity and competitive position. Cambridge, Massachusetts Institute of Technology (MIT), Centre for Advanced Engineering Study, 373p.
- Duncan, R.B. 1972. Characteristics of organisational environment and perceived environmental uncertainty. *Administrative Science Quarterly*, 17, 313–327.
- Evans, J.R. and Lindsay, W.M. 1996. The management and control of quality, 3<sup>rd</sup> edition. New York, West Publishing Company, 767p.
- Fuchsberg, G. 1992. Quality programs show shoddy results. *Wall Street Journal*, May 14, B1.

- Garvin, D.A. 1988. *Managing quality: the strategic and competitive edge*. New York, Free Press.
- Ghobadian, A. and Speller, S. 1994. Gurus of quality: a framework for comparison. *Total Quality Management*, 5, 53–69.
- Helms, M. and Hutchins, B.A. 1992. Poor quality products: is their production unethical? *Management Decision*, 30, 35–46.
- Hillary, R. 1997. Total environment management. <<http://www.mcb.co.uk/services/conference/jan97/tqm/tqasia/theme11.htm>>.
- James, P., Ghobadian, A., Viney, H. and Liu, J. 1999. Addressing the divergence between environmental strategy formulation and implementation. *Management Decision*, 37: 338–347.
- Johnson, G. and Scholes, K. 1997. *Exploring corporate strategy*, 4<sup>th</sup> edition. London, Prentice Hall, 507p.
- Kellam, J. 1995. Food safety and standards: trade practices and product liability. In: *Food Safety and Standards Conference*, 11–12 July 1995, organised by IBC Conferences Pty Ltd, Melbourne.
- Kolka, J. 1997. The European Union and conformity assessment. In: Peach, R.W., ed., *The ISO 9000 handbook*, 3<sup>rd</sup> edition. London, Irwin, 605–628.
- Lemmel, M. 1999. Guide to the implementation of directives based on new approach and global approach. European Commission, Directorate-General III (Industry), unpublished draft.
- Lim, T.E. and Niew, B.C. 1995. *Quality management systems: assessment to ISO 9000:1994*. Singapore, Prentice Hall, 420p.
- Liston, A. 1996. Planning for excellence. In: Kanji, G.K., ed., *Total quality management in action*. London, Chapman and Hall, 102–107.
- Mangelsdorf, D. 1998. Evolution from quality management to an integrative system in modern business. *Total Quality Management*, 9, S164–S166.
- Marquardt, D.W. 1997. Background and development of ISO 9000 standards. In: Peach, R.W., ed., *The ISO 9000 handbook*, 3<sup>rd</sup> edition. London, Irwin, 10–30.
- Miles, R.E. and Snow, C.C. 1985. *Organisational strategy: structure and process*. New York, McGraw-Hill, 274p.
- Miller, W.C. 1993. *Quantum quality*. Quality resources. New York, White Plains.
- Mintzberg, H. and Waters, J.A. 1985. Of strategies, deliberate and emergent. *Strategic Management Journal*, 6, 257–272.
- Miyake, D.I., Enkawa, T. and Fleury, A.C.C. 1995. Improving manufacturing systems performance by complementary application of just-in-time, total quality control and total productive maintenance paradigms. *Total Quality Management*, 6, 345–363.
- Porter, L.J. and Parker, A.J. 1993. Total quality management—the critical success factors. *Total Quality Management*, 4, 13–22.
- Porter, M.E. 1996. What is strategy? *Harvard Business Review*, Nov–Dec, 61–78.
- Porter, M.E. and van de Linde, C. 1995a. Green and competitive. *Harvard Business Review*, Sep–Oct, 120–134.
- Porter, M.E. and van de Linde, C. 1995b. Toward a new conception of the environment–competitiveness relationship. *Journal of Economic Perspectives*, 9, 97–118.
- Rao, S.M. 1996. The effect of published reports of environmental pollution on stock prices. *Journal of Financial and Strategic Decisions*, 9, 25–32.
- Roling, N.G. and Wagemakers, M.A.E. 1998. *Facilitating sustainable agriculture*. Cambridge, Cambridge University Press, 318p.
- Rosenbaum, S.W. 1997. ISO14000: legal advantages of replacing command and control regulation. *Practice Periodical Of Hazardous, Toxic And Radioactive Waste Management*, 1, 124–126.
- Rugman, A.M. and Verbeke, A. 1998. Corporate strategies and environmental regulations: an organizing framework. *Strategic Management Journal*, 19, 363–375.
- Seghezzi, H.D. 1997. Business concept redesign. *Total Quality Management*, 8, s36–s43.
- Smith, J.A. and Angeli, I.I. 1995. The use of quality function deployment to help adopt a total quality strategy. *Total Quality Management*, 6, 35–44.
- Spenley, P. 1995. *Step change total quality: achieving world class business performance*, 2<sup>nd</sup> edition. London, Chapman and Hall, 189p.
- Teare, R., Atkinson, C. and Westwood, C. 1994. *Achieving quality performance: lessons from British industry*. London, Cassell, 172p.
- Tisler, J.M. 1997. FDA's application of HACCP to retail food systems. <<http://vm.cfsan.fda.gov/~dms/haccpret.html>>.
- Van den Brink, W.J., Bosman, R. and Arendt, F. (ed.) 1995. *Soil and environment: contaminated soil*, volume 1. Proceedings of the 5th international FZK/TNO conference on contaminated soil, 30 Oct–3 Nov 1995, Maastricht, The Netherlands. London, Kluwer Academic Publishers, 1,662p.
- Wenmoth, B. and Dobbins, D. 1994. Experiences with implementing ISO 9000. *Asia Pacific Journal of Quality Management*, 3(3), 9–27.
- Wilson, S.R. 1999. The impact of standards on industrial development and trade. *Quality Progress*, July, 71–75.
- Window, J. 1996. *Planning occupational health and safety*. 4<sup>th</sup> edition. Sydney, CCH Australia Limited.
- Wong, W.C., Ogle, I.F. and Mansour, P. 1998. Total business system: a generic model for the integration of international standards and business strategies. *Proceedings of Pan Pacific Qualcon*, 98, 185–193.
- Youssef, M.A., Boyd, J. and Williams, E. 1996. The impact of total quality management on a firm's responsiveness: an empirical analysis. *Total Quality Management*, 7, 127–144.

# New Food Processing and Preservation Technology

A. Noguchi\*

## *Abstract*

Variable shelf life and increasing competition require the food industry to have more technological innovation in food processing and preservation. This paper outlines several types of new food processing and preservation technologies which are playing a leading role at present and will do so in the future. These technologies include membrane technology, low-temperature technology related to chilling and freezing, use of electromagnetic waves, extrusion cooking, high-pressure cooking, and Ohmic heating.

## **Membrane Technology**

TO CONCENTRATE a liquid or separate components from a liquid, distillation, extraction, adsorption, filtration etc. are generally used. The method of using pressure in the concentration process and performing molecular-level filtration is an energy-saving technique known as membrane technology. Food processors are now using various kinds of membranes, which include: fine filtering membranes capable of separating microbe-like fine particles from about several  $\mu\text{m}$  to  $0.1 \mu\text{m}$ ; ultrafiltration membranes capable of filtering finer components as well as such biopolymers as protein and starch; reverse osmosis membranes (Figure 1) capable of permeating only water and concentrating salt, sugar, amino acids, aromatic constituents, biopolymers or other solutes; and electric dialysis membranes capable of isolating electrolytes by potential differences.

## **Reverse osmosis concentration**

This method was developed for desalinating seawater into fresh water. It uses synthetic high polymer membranes, such as cellulose acetate and polysulfone, and concentrates liquids by removing water using pressure. Semi-permeable membranes placed between water and a liquid cause the water to move into the liquid side, but if a pressure higher than

the osmotic pressure ( $50\text{--}100 \text{ kg/m}^2$ ) is applied to the liquid, the water in the liquid moves to the water side. Since the latter phenomenon is opposite to normal permeation, it is called reverse osmosis. Characteristics of the reverse osmosis concentration method are: energy consumption is small because no phase change occurs; formation of heat-induced flavour and discoloration do not take place in the product; and there is no great loss in the nutritive value and flavour. Since this method employs no heat, there is a need to prevent the growth of microorganisms during the concentration process. It reduces the volume of food, thus making it easier to transport the product, and is widely adopted mainly in the production of fruit juice, soup and other food categories in which flavour is regarded as most important.

## **Ultrafiltration**

Ultrafiltration membranes have a greater pore diameter than those used for reverse osmosis through which low molecular weight solutes can pass. Since the difference in osmotic pressures arising in filtration is smaller, these membranes generally can separate high-polymer substances with low pressures of  $3\text{--}10 \text{ kg/m}^2$ .

## **Application of membrane technology to food production**

As noted above, reverse osmosis and ultrafiltration membranes filter substances differently, according to molecular weights. Thus, the combination of these two

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membranes has many applications. For example, cheese whey contains salt and cannot easily be used as food as is. However, ultrafiltration can collect protein from the whey first, then by concentrating the filtrate by reverse osmosis and desalinating it by electric dialysis, lactose can be separated. Both the protein and lactose can be used to make food. Table 1 shows the principal applications of membrane technology to food production in Japan.

## Low-temperature Technology Related to Chilling and Freezing

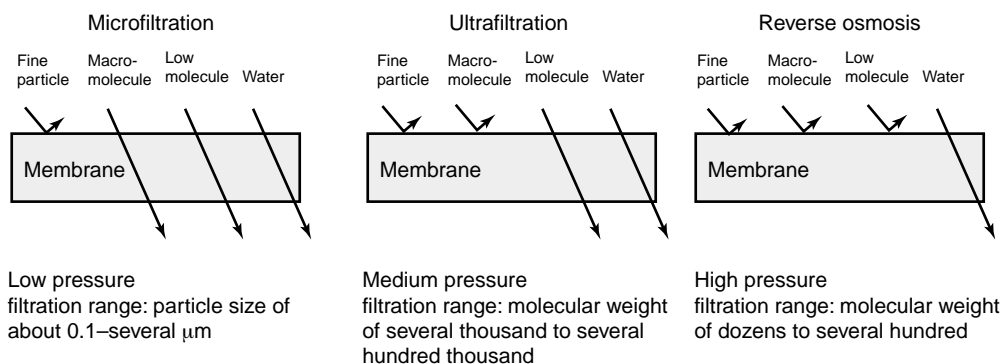
Since low temperatures can keep food quality stable, a variety of techniques have been developed to use low temperature positively for food processing and distribution. For example, freeze-drying, freeze-concentration and freeze crushing are widely used in food processing, and freezing and chilling are used for food storage and distribution.

## Frozen storage and chilled distribution

Because microorganism growth is reduced at low temperatures, freezing and cold storage are often used for perishable food. Japan imports from Asian countries a large quantity of frozen vegetables, mainly such root vegetables as carrot, taro and lotus root. It also imports partly processed food, such as skewered chicken and eel, in a frozen or chilled state. Chilled beef, vegetables etc. are also transported from Australia.

## Freeze-drying

This is the method of freezing food etc. and warming it in a vacuum state, thus drying it. Since the food is dried under a low temperature and under vacuum conditions, the loss of its colour, flavour, nutritional constituents etc. is small. This method can make products with good restorative properties. It is now adopted for the production of many prepared foods and their ingredients. For example, coconut milk is turned into flour by freeze-drying.



**Figure 1.** Comparison of microfiltration, ultrafiltration and reverse osmosis.

**Table 1.** Examples of the application of membrane technology.

Microfiltration	Ultrafiltration	Reverse osmosis
<ul style="list-style-type: none"> <li>• Bottling (aluminium canning)</li> <li>• Removing microorganisms from draft beer and wine brewing</li> </ul>	<ul style="list-style-type: none"> <li>• Clarifying apple juice</li> <li>• Brewing draft sake (rice wine)</li> <li>• Separating soybean protein</li> <li>• Refining enzymes</li> <li>• Collecting proteins from cheese whey</li> </ul>	<ul style="list-style-type: none"> <li>• Concentrating fruit juice, egg white, coffee, cheese whey</li> <li>• Brewing wine, low-alcohol beer</li> <li>• Processing soybean whey</li> <li>• Treating liquid waste from starch processing</li> <li>• Collecting valuable components from animal blood</li> </ul>

## Freeze-concentration

If an aqueous solution is partly frozen into a sherbet state, its solutes remain an aqueous solution in a concentrated form rather than being taken into the ice. Freeze-concentration is the method of making use of this phenomenon to separate ice from a concentrated solution by a centrifugal or column process and thus further concentrating the solution. This can be called an energy-saving technique because it uses less latent heat than that of heating concentration. This method has another good characteristic—because the concentration is performed at a low temperature, only small qualitative changes occur. It is now applied to the concentration of fruit juice, coffee and other products.

## Use of Electromagnetic Waves

‘Electromagnetic waves’ is the generic term meaning the waves transmitted in space as the changes in the electric field over time. The wave having the shortest wavelength is the  $\gamma$ -ray, followed by the x-ray, ultraviolet rays, visible rays, infrared rays and radio waves (Figure 2). In food processing, electromagnetic waves are extensively used mainly as the means of sterilisation and heating. Seen from the sterilisation action,  $\gamma$ -rays, X-rays and ultraviolet rays have great energy and can directly destroy the molecular structure of the object and sterilise it. These are cold sterilisation techniques using no heat. Infrared rays and microwaves (radio waves) impart vibrational energy to molecules, thus causing heat generation and sterilising the product with this heat.

## Sterilisation using irradiation

Sterilisation through irradiation is effective even for those objects hard to sterilise with heat, such as plastic

containers, dried food and grains. It is considered that this method is highly effective, energy-saving and very safe (the Recommendations on Safety by the joint committee of International Atomic Energy Agency (IAEA), Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) 1981). The accelerated electron beam, a type of radioactive ray, has a weak transmissivity, yet a high dose ratio, and so can kill bacteria in a short time.  $\gamma$ -rays and X-rays have strong transmissivity and studies have been conducted as to the irradiation methods which take advantage of this characteristic. Examinations from practical standpoints are also being made regarding the type of microorganisms and sterilisation effects, changes in food constituents and so on.

In Japan, irradiation is employed mainly for the sterilisation of food containers, medical appliances etc. and the de-budding of potato. It is internationally accepted that irradiation is the technology that could have a relatively great effect on the food industry.

## Sterilisation using ultraviolet rays

Ultraviolet rays are known as sterilising rays, especially the wavelength of 254 nm. This wavelength has the capacity to damage the genes and nucleoproteins in the cell and has strong sterilising power. Formerly, this ray was used by pharmaceutical and food producers, hospitals etc. to reduce microorganisms in the air and to sterilise food, surfaces of utensils and drinking water. High-output ultraviolet ray lamps have recently been developed and for use in sterilisation of food and packaging materials for aseptic packaging systems and for other purposes.

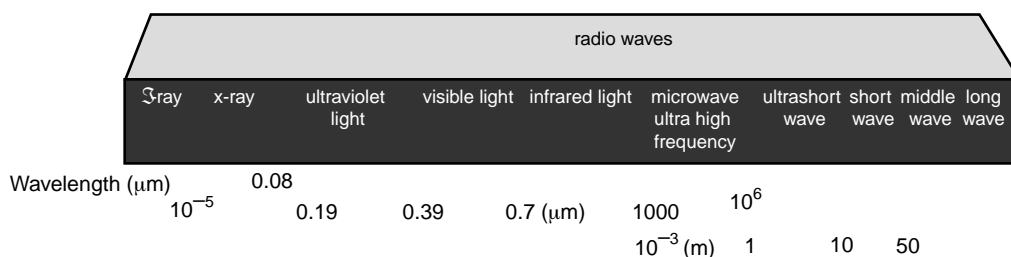


Figure 2. Types and wavelengths of electromagnetic waves.

## Infrared heating

As a result of recent technological innovation in ceramics etc., good infrared ray radiating units with high energy conversion rates and different wavelength characteristics have been developed in succession, and these units have begun to be used in the food processing area. New radiating units are capable of efficiently radiating infrared rays of a wavelength of about 25–30  $\mu\text{m}$  and the rays radiated are converted into heat on the surface of food. The rays do not heat metal, air etc. and so show good energy efficiency. The infrared ray is expected to penetrate the food to some extent, too. In Japan, this method is now widely applied to the cooking of food etc.

## Microwave heating

Microwaves are the radio waves with a high frequency (300 MHz–30 GHz), and those of 915 MHz and 2,450 MHz are used in Japan for food preparation. The most common application of microwave heating is microwave ovens for household and business uses. If food and other dielectrics are subjected to microwaves, the water and other polar molecules (dipoles) contained in the food etc. vibrate heavily and generate heat.

Microwave heating has many good characteristics. Its heating rate is high and so is its heating efficiency.

It can heat uniformly even sponge-like and paste-like food and food with complicated shapes. It can selectively heat the food containing moisture or other constituents. The microwave heating unit is easy to operate and control and highly safe, making it possible to keep the working environment clean. This method is employed for the sterilisation and drying of food, coagulation of protein paste food, thawing of frozen food, reheating of precooked foods, and killing of grain insects. Recent applications include the sterilisation of food containing much moisture, such as semisolid food and highly viscous food, and high-temperature sterilisation under pressure.

## Extrusion Cooking

Extrusion cooking is the technology of using a unit called extruder to make food, food materials, feed and so on. As shown in Figure 3, this unit is composed of a feeder (which feeds materials), a barrel, screws, dies, a heater or cooler, and a motor part. Of these, the screws are the most important parts in terms of performance. Different numbers or shapes of screws produce different physical and chemical phenomena within them, and by making the most of their diverse functions, various types of units have been invented and adopted. Generally speaking, twin-screw extruders, i.e. those equipped with two screws, can handle a wider range of moisture contents of the

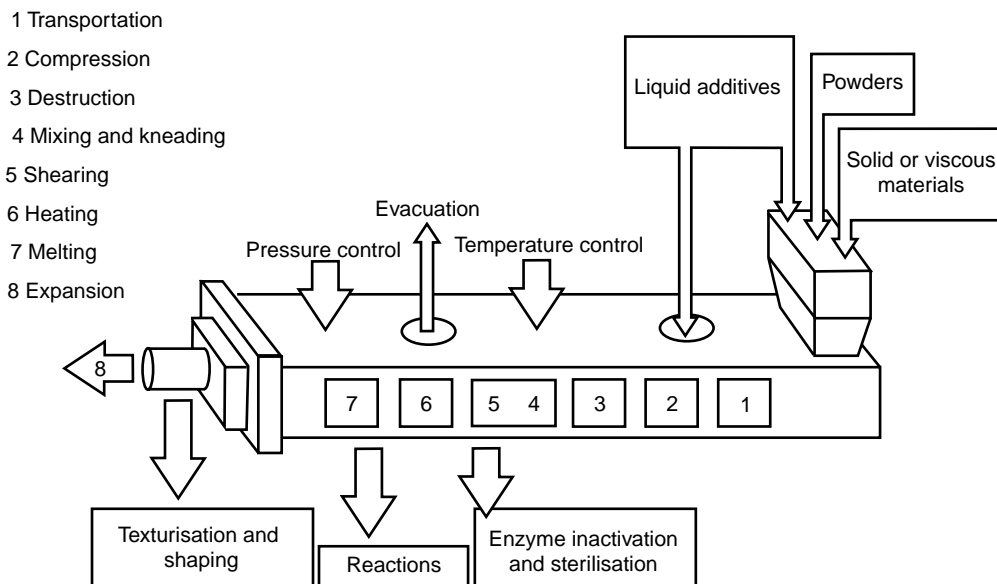


Figure 3. The extruder and its functions.

materials (5–95%) and can realise more diverse processing forms than single-screw models. The materials fed to the barrel from the feeder are sent to the end of the barrel with the screws, during which time they are compressed, mixed and sheared. Around the end of the barrel, the materials are melted under high temperature and pressure and molded or swollen when discharged from the dies. Using this process, starch is gelatinised within a short time and its molecules are sometimes modified, while protein is dissociated or cross-linked, and thus texturised.

This technology can cover many unit operations of food making. Thus it improves the efficiency of the production process and saves energy consumption and space. Extrusion also offers the potential for using new food materials which cannot be handled by conventional food processing techniques. Considering future food production, extrusion cooking is very promising.

### High-pressure Cooking

If a high pressure of 300–600 MPa is applied to food, protein is denatured, starch is gelatinised, and enzyme reactions and aging are inhibited or accelerated depending on the conditions (Figure 4). It has been known that these phenomena can be used to process or

sterilise food and to make tasty products with no qualitative losses caused by heating. When a high pressure of several hundred MPa is applied, most microorganisms will be killed but their sensitivity to pressure differs according to the species and such environmental conditions as pH, temperature and solute concentration.

While usual bacilli will be inactivated or killed at 300 MPa or so, yeast and moulds show a stronger resistance to pressure and will be killed at 400 MPa. Cocci, such as micrococcus, streptococcus and staphylococcus, are more resistant to pressure and a pressure of 600 MPa or more and a temperature of 60°C or more are needed to kill them. The high-pressure cooking units available today do not have adequate capacity to apply a high pressure of 600 MPa or more repeatedly and it is difficult to design a machine to perform continuous processing. Combined with the problems of heat-resistant spores, pressure-tolerant enzymes etc., this has been a serious obstacle to wide application of high-pressure cooking. For the time being, this technology will gradually be applied to the processing of food such as fish and meat products or starch gelatinisation and to the simple and easy sterilisation of food with an intermediate moisture content.

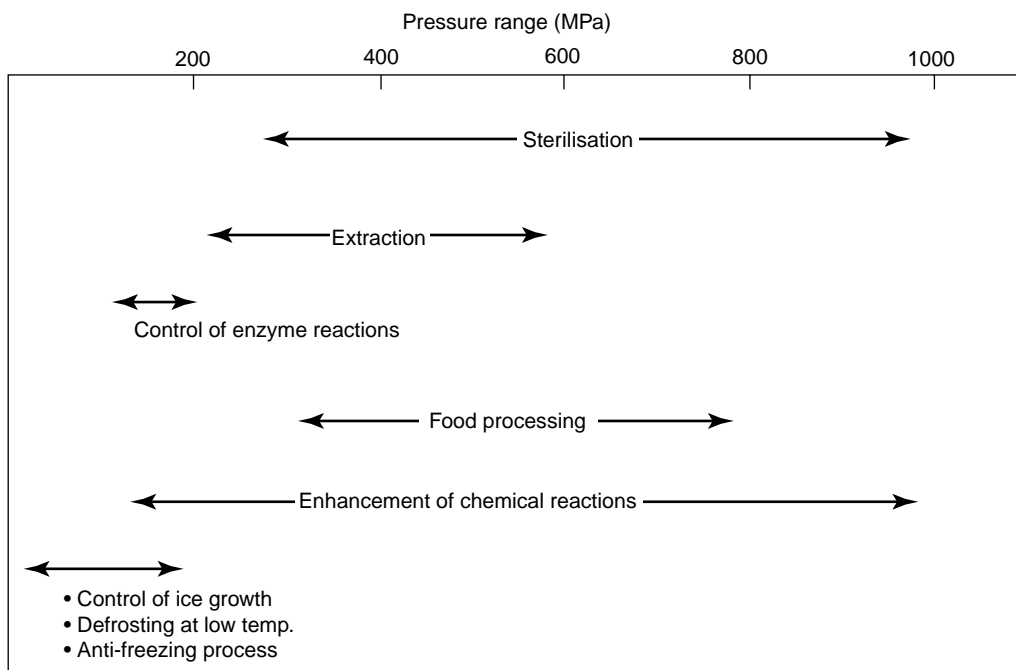


Figure 4. The effect of pressure and its applications.



## Ohmic Heating

The method of passing electricity through food to heat it (Figure 5) has long been used for the production of bread, breadcrumbs, fish products, tsukudani (small fish boiled down in soy sauce and sugar) and so on. In the West, this system was developed into the method of continuously heating and sterilising thick fruit juice and juice-containing particles and in 1986 APV Co. succeeded in the commercialisation of a unit for sterilising fruit juice etc. using this method. Recently this system has become applicable to liquid food with many particles making it possible to use this unit for almost all types of food.

Ohmic heating (also known as Joule heating) unit has several good characteristics. It requires a shorter heating time than other systems. Compared with scraping-type heat exchangers, it can supply more uniform heating for solid-liquid and highly viscous food. It is possible to adjust the heating rate by the addition of salt or a change in the applied voltage. The unit consists of a pump, tubes, and an electrode. In Ohmic heating, parts of the food having different electric conductivity are heated to different degrees. Therefore, it not only is a sterilising method but also has the potential for selective heating.

## Retort-packaged and Aseptically Packaged Food

Traditional techniques of sterilising food by heating to prevent it from secondary contamination and to preserve it for long periods include those used for canned food and sausage. However, a relatively long time is required for sterilisation in these methods, and food quality is liable to be reduced. To minimise the quality loss caused by heat and to raise sterilisation effects, hot water and retort sterilisation techniques have been introduced using small plastic bags and containers which can transfer heat efficiently. The retort-packaged food is generally heated until its centre reaches 121°C, and this temperature is maintained for 4 min or more. Food treated in this way can then be maintained for long periods at room temperature. To meet recent consumer demands for retort-packaged foods with more natural features and better taste, sterilisation has been made at a higher temperature for a shorter time, or at an ultra-high temperature. On the other hand, there has been a trend toward retort-packaged foods without preliminary evacuation of contents and a low temperature treatment at 110°C. Efforts are being made to make materials aseptic and secure commercial asepsis under less strict heating conditions.

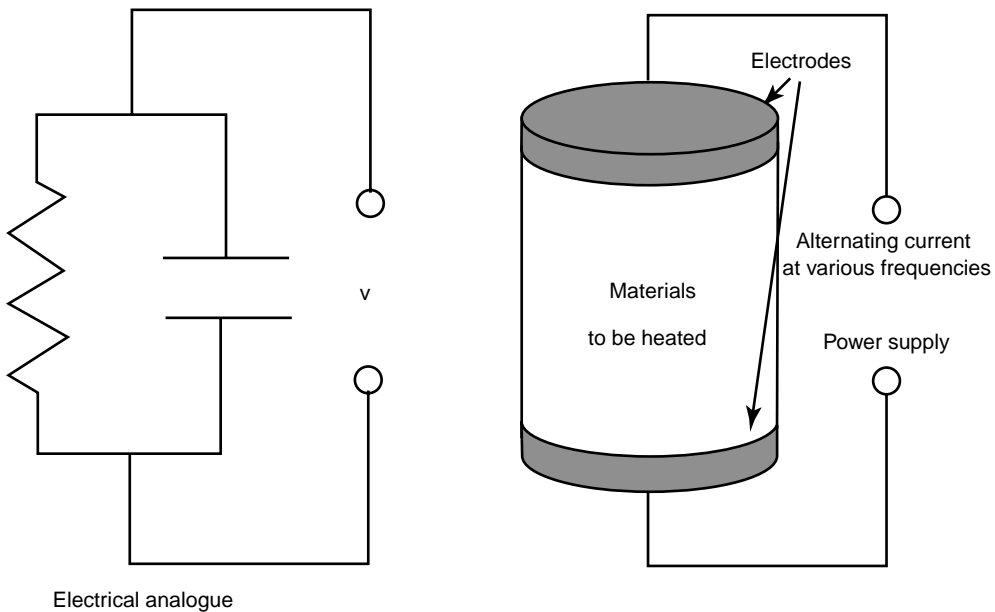


Figure 5. The principle of Ohmic heating.

Aseptically packaged food has a number of advantages. It does not require a long sterilisation time. Unlike retort sterilisation, it needs no heat-resistant packaging materials, and large-size containers (such as drums) can be used. In addition, this food can be kept at room temperature for a long period. Because of this, it has attracted much attention from the aspects of both food quality improvement and energy saving and many projects have been carried out regarding its technical development. While various aseptic packaging techniques, including Tetrapack and Purepack, have been developed and technically established (mostly for liquid food), technical development activities are still continuing for the aseptic packaging of solid food (clean packaging, semi-aseptic packaging).

There are two main types of aseptically packaged food. One of them is the food whose storage period is

extended under low-temperature conditions, e.g. sliced ham and sliced cheese. The other is the food which can be distributed at room temperatures, e.g. aseptically packaged rice, by making the materials as free as possible from contaminating microorganisms, sterilising by cooking and successive pH control, applying deoxidisers, and packaging in an aseptic room or through other treatments. It is an advanced technology to keep packaged solid foods aseptic and a new system is being introduced to cook the materials by heat in a heat-resistant container like a retort package.

In the general trend toward better quality food, new technical development activities are erasing the boundary between retort sterilisation and aseptic packaging.

# Standards and Quality Assurance Systems for Horticultural Commodities

**Ma. C.C. Lizada\***

## *Abstract*

Standards play a critical role in ensuring product safety and defining the competitiveness of horticultural produce. Workable standards and their application will be instrumental in:

- developing a culture of quality in horticultural enterprises and the consuming public;
- assuring safety and quality in horticultural perishables;
- expediting horticultural trade by serving as a common language and basis for pricing;
- ensuring success in the pooled marketing of products from associations of small farmers;
- adopting appropriate systems and applying technologies to meet market expectations and requirements;
- enhancing the image of the horticultural enterprises as reliable suppliers of quality products; and
- protecting the consumer from defective products and those that pose a risk to human, animal and plant health and the environment.

The above contributions of workable standards in assuring quality throughout the handling chain and in designing quality assurance systems for horticultural produce will be illustrated with specific examples. The paper will also emphasise the importance of considering the production–marketing continuum in formulating standards.

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# Postharvest Handling Status and Problems of the Pacific Island Countries

E. Cocker\*

## Abstract

The significance of proper postharvest handling is recognised globally for its ability to minimise losses. Growers, exporters, packers, inspectors, distributors, carriers, and warehouse operators need to be aware of proper methods and techniques of postharvest handling. Significant losses will continue to occur in the Pacific Island countries for as long as non-technical personnel in the produce export industries remain unaware of the elementary principles of postharvest handling.

PACIFIC ISLAND countries have suffered greatly from poor market support infrastructure to ensure proper handling after harvest — there has been a chronic lack of understanding of the basics of produce physiology and produce–environment interactions, and the practicalities of postharvest handling, storage, and transport. Recommendations for regional groundwork to develop commercially practicable standards for exportable produce have yet to be made. As a result, there are high levels of losses and wastage of export produce.

## Background

An absence of accurate diagnosis, coupled with a lack of cooperation between growers and exporters, has led to a degree of misunderstanding amongst growers, extension officers, inspectors, shipping companies, and salesmen of the actual causes of wastage. Hence, little progress has been made towards preventing of damage and wastage.

This is the principal problem in the Pacific region. Qualified technical officers seem to know enough of what the postharvest handling problems are, how to diagnose these problems, and possibly solve them, but that is not enough. Professional technical advice and crucial information are not reaching the rural communities, remote locations, and outer islands, where the majority of growers live. A great number of these

growers do not understand why proper handling of produce after harvesting is extremely important.

Throughout the Pacific Island countries, cooperation between growers, extension officers, and exporters is declining rapidly. This is contributing to low production yields, falling grades, a drop in quality standards, and an increase in wastage. The problem is currently affecting exports in a number of countries: squash from Tonga to Japan; kava from Fiji, Tonga and Vanuatu to the United States and Europe; copra and cocoa from Solomon Islands; ginger from Fiji; papaya from the Cook Islands; rootcrops and watermelon from Tonga; and coffee from Papua New Guinea to Europe.

Compounding the problem are new, 'fly-by-night' exporters who either fail altogether because they do not understand the importance of proper treatment after harvest, or make a lot of money for a short time, then rapidly disappear. We can summarise the major postproduction shortcomings throughout the Pacific Island countries as follows.

- *Lack of understanding of postharvest handling techniques.* Growers and exporters do not understand postharvest handling requirements and techniques, why they are important, and the logistics needed.
- *Lack of consultation and feedback.* There is very little feedback from the exporters to the growers. Growers need to be kept informed regularly of the importance of maintaining quality assurance, what

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the market demand is, competition, price variations, the supply situation, and so forth.

- *High operational costs.* There are few extension offices to help the growers: they cost too much to run, and there are few qualified people to staff them.
- *Lack of technical and marketing information,* poor support infrastructure, and lack of political and bureaucratic support.

### **Lack of Understanding of Postharvest Handling Requirements: Its Significance and Logistics**

In the Pacific, significant losses have occurred and will continue to occur because most of the personnel involved in export development are unaware of fundamental factors such as market requirements and the principles of postharvest handling, and that the produce they are dealing with is living, breathing material that responds to changes in environmental variables such as temperature and humidity and is subject to infection by a range of microorganisms.

Most personnel have little or no knowledge about measures to manage these processes so as to maintain product quality and reduce losses. For example: there is no understanding of, or facilities for, grading, inspection, sorting at packinghouses; water used for cleaning is often heavily charged with fungal and bacterial spores; and foreign matter (such as hair and animal faeces) is often found in export produce.

The significance of proper postharvest handling is so great that, if it is not properly done, it may cause severe losses. While it is understood that overall losses due to poor postharvest handling are often substantial, they are extremely difficult to quantify. Every year there are thousands of kilograms of fresh and perishable produce that are confiscated, rejected, and destroyed because of poor handling and inappropriate treatment after harvesting.

It is estimated that the cause of 90% of the confiscations or rejections of shipments originating from the Pacific is inappropriate handling after harvest, resulting in dirt and mud (introduction of *Salmonella* and *Escherichia coli*); fishy smells; moulds and mites; bacterial and fungal infections; bruising during transport, loading and unloading; animal faeces; spoilage due to improper temperature during storage; spoilage due to poor packaging; and shrinkage due to rough handling.

There have been instances of vanilla containers being confiscated because of fishy smells, and the

presence of hair and other foreign material; containers of ripe coconuts not de-eyed and cracked because of excessive exposure to the sun; containers of improperly cleaned, soil-contaminated taro; containers of yam with bruised skin, rotting, stones, and soil; taro leaves that were excessively dehydrated (moisture loss); containers of kava containing matchsticks, soil, and animal faeces; containers of watermelons spoiled because the wrong cooling temperature was used; containers of frozen cassava thawed because the electrical system on-board the ship was mistakenly switched off; and many more. We cannot afford to continue to incur the losses resulting from errors and mishandling after harvest.

Understanding the logistics of every postharvest handling stage handling is crucial, e.g. the weather, relative humidity, sunrise and sunset, time and season of the year, transportation time, using proper light for inspection, packaging time, and chemical reactions. These are the sorts of factors that most of the inspectors, graders, packers, transporters, and loading people are ignoring. While the logistics from harvesting to transport to packinghouses, cleaning and inspection, grading and sorting, packing and loading and then delivery to the market places is being neglected by most growers, exporters, and shippers, a breakdown in this handling and distribution chain will inevitably cause severe damages and losses to every shipment.

Only by careful attention to all factors in the post-harvest chain will unnecessary losses be reduced.

### **Lack of Feedback from Exporters/ Marketers to Growers, and Inconsistency in the Supply of Quality Produce**

Lack of feedback of information from exporters to growers is a worsening problem. Growers are not being properly advised, either by the extension officers or by the exporters, on factors such as: what quality is needed; the colour and size of produce preferred; when to harvest; where to transport the produce after harvest; the best method of transport; which district to harvest; the anticipated buying price; which cultivars are suitable; where the inspection and trading location will be; the exact date and time of buying; and many other important logistical details.

Unclear messages and misinformation have caused a great deal of frustration and considerable losses to growers. Ginger farmers from the Western District of

Fiji, for example, were prompted in error to harvest their ginger, when it was those from the Central District who should have been asked to do so; growers harvested the white, pink-skin cassava instead of yellow cassava only; growers transported their produce to the Head Office instead of waiting in their own village for the buying team to arrive; growers harvested the large, long yams instead of the 1–2 kg round yams. The result has been a reduction in plantings and less interest in efforts to improve quality. Some growers have switched to unreliable exporters. In addition, the limited supply is being chased by too many buyers (some ‘fly-by-nights’), driving up buying prices and lowering grades and quality standards. Growers can thus quickly become suppliers of low quality produce.

The marketing system must be tightened and constant communication between the local buyers/exporters (assuming they know what the overseas markets requirements are) and the growers is crucial. The success of exports is highly dependent on constant communication and close cooperation between the growers, extension officers and inspectors, and exporters. It is important for exporters to consult growers regularly on quality — what is right and wrong, and what are the specific requirements of the markets. Also, growers must be given a quality assessment of every batch of produce they deliver. Growers need feedback and assessment of how they are performing. They are also prepared to accept criticism made in a spirit of helpfulness.

There is no other solution but to forge much closer links between exporters, extension officers, and growers. It has to be an all-way communication system. For Pacific suppliers to remain in the international scene, they have consistently supply quality produce, and that will entail close cooperation by all parties involved.

There is a growing need for regular, hands-on training in the remote and rural areas. To become committed to production of quality produce, growers must understand what it means. They must be taught proper postharvest handling techniques, and have some knowledge of physiological factors such as respiration, dehydration, temperature, and ethylene production that affect product quality.

## **The Role of Extension Officers**

A lack of extension officers is one of the major impediments to export development in the Pacific region. Growers from remote and outer islands are being dis-

advantaged by poor infrastructural support and lack of proper technical advice on cropping and postharvest handling techniques, crop management, and disease control methods. Lack of technical advice results in considerable wastage of exportable produce at rural and remote areas, while resources, technical expertise, and support facilities are usually well provided at larger centres of population.

Throughout the Pacific region, there are serious concerns about the:

- lack of trained and qualified extension officers;
- poor working facilities for extension officers;
- lack of trained workers in rural and remote areas, including outer islands;
- problems with the electricity supply, inter-island ferry services, communication means, water, and domestic airline services;
- insufficient funding for extension officers to properly execute their duties; and
- abuse of power and improper use of limited resources by extension officers.

When extension officers fail to consult regularly with growers on quality specifications, harvest and postharvest logistics, and transport to the market places, the chain that links the growers, local exporters, importers, retailers, and consumers is broken. This must not be allowed to happen. Growers rely on the help and regular technical and marketing advice of extension officers.

In many cases, extension officers who are highly qualified and motivated to provide all the services needed are unable to do so because they have no transport to allow them to make regular visits to the farmers. A qualified officer alone is not sufficient. The tools and facilities are the other half of the equation to success.

## **Availability of Technical and Marketing Information**

Limited access to much-needed information, which is very costly to obtain, is another setback to growers. In some cases, information is exchanged during kava parties. Such information is usually unreliable, invalid, and may cause frustration to the growers.

An information system is needed that can assure timely delivery of critical technical and marketing information. The information should be in bilingual form. What is needed are details about market opportunities, consumers’ specific requirements, exporters’ and importers’ quality specifications, quarantine

requirements, delivery dates, harvesting dates, diseases and control measures, cropping techniques, varieties that are susceptible to diseases, moisture content requirements, and proper postharvest handling methods. Such information is usually not available, or only so at times when the competition is intense and market demand has dropped. Timely availability of important information is crucial in every aspect of export trade.

It is also noted that 90% of growers in the Pacific are subsistence farmers whose education does not go beyond primary school or the early stages of high school. As a result of this relatively low level of education, there is always a need for closer supervision by extension officers and exporters to ensure productivity and quality production.

### **Government Support**

Government support for the produce export industry, an industry which has the potential to grow substantially, is generally lacking. Governments could facilitate the development of the industry by providing financial support for improved infrastructure (e.g. roads and wharves), processing facilities, and

research, development, and extension services. Governments need to frame market-orientated policies that will foster and promote, among other things, development of a commercial environment conducive to growth and prosperity.

### **Conclusion**

In summary, growers, extension officers, inspectors and exporters must be aware of the basic principles of postharvest handling. They need to talk to each other regularly and to share views, concerns, and expertise. Growers need feedback, respect, and constant dialogue on issues of mutual interest. The implementation of schemes to provide growers with continuing hands-on training on all practical techniques of postharvest handling is strongly recommended. Also recommended are the implementation of a region-wide service for identification of postharvest diseases and disorders, and the regular provision of information on import requirements and quality specifications to growers and exporters.

Improved services by extension officers, together with full support of governments, will help to facilitate healthy growth in export development and trade.

# Quality Evaluation of Some Rice Varieties Being Grown in Vietnam

Nguyen Thanh Thuy and Nguyen Thi Huong Thuy\*

## Abstract

Rice plays an important role in Vietnamese life. This paper describes how Vietnam has become a major rice exporting country and provides detailed statistical information from Ministry of Agriculture and Rural Development sources.

Sixty-five rice varieties—including special traditional varieties (32 and 33 new rice varieties popularly grown in the Red River Delta and Mekong Delta, respectively)—were evaluated for their physical, cooking and processing characteristics. The Vietnamese rice varieties investigated belong to the 'Indica' rice type characterised by long and slender grains, intermediate to high amylose content, medium to soft get consistency, intermediate to moderately high gelatinisation class, and medium to high protein content. When cooked, Vietnamese rice varieties absorb more water, take less time to cook, and expand more to give a flaky and dry cooked rice. Regarding the processing suitability of these varieties, the high amylose content varieties are suitable for noodle-making, whereas lower amylose content varieties can be used widely for different processing purposes such as baby powder food and the extrusion cooking process.

IN VIETNAM, rice is one of the most important foods in the diet of its people, providing 40–80% of calories and about 40% of protein. The irrigated rice culture of Vietnam has proven its long-term stability and in the last 10 years rice production has steadily increased. Along with traditional varieties, new high-yielding and short-duration varieties have appeared and have contributed to this increased annual output.

Vietnam has now become a large rice exporting country (Table 1) with an increasingly large market—currently over 80 countries in 5 continents (see Figure 1).

The export of high quality rice by Vietnam has made much progress but remains low. In 1997, it made up only 20% of the total quantity of rice exported with a price of \$320/t. In contrast, 60% of rice exports from Thailand were of high quality rice.

Recently, the Ministry of Agriculture and Rural Development has set two targets:

- to develop high quality rice varieties and increase the value of exported rice; and

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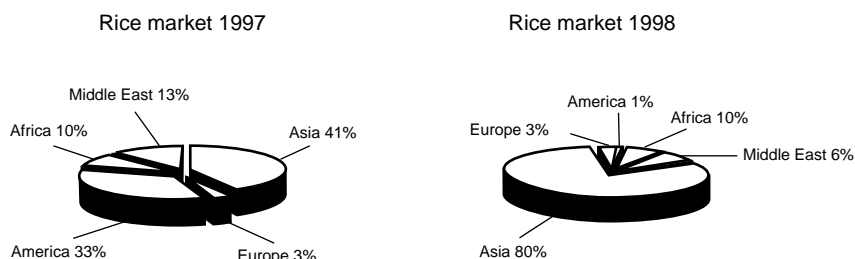
- to decrease production costs and postharvest losses—especially during rice storage, milling and processing.

**Table 1.** Vietnamese rice exports from 1989 to 1998. (Source: Statistical Year Book 1998, and the Ministry of Trade—figure for 1998.)

Year	Quantity exported (million t)
1989	1.40
1990	1.62
1995	1.98
1996	3.00
1997	3.57
1998	3.80

In addition, the Department of Biochemistry at the Post-Harvest Technology Institute has carried out quality analysis and evaluation of rice varieties being grown in two areas—the Red River Delta and the Mekong River Delta.





**Figure 1.** The principal rice export markets of Vietnam.

## Materials and Methods

### Experimental materials

65 rice varieties grown over the two years of 1997 and 1998 were selected, 33 varieties from the Red River Delta and 32 varieties from the Mekong River Delta, the details of which are given below.

#### *Special traditional rice varieties*

The Red River Delta has the varieties ‘Tam Xoan’, ‘Tam Thom’, ‘Tam Ap Be’, ‘Di Huong’, ‘Du Huong’, ‘Nep Cai Hoa Vang’, ‘Nep Ly’ and ‘Nep Dau Huong’.

The Mekong River Delta has the varieties ‘Nang Huong’, ‘Nang Thom Cho Dao’, ‘Nang Thom Som’, ‘Nang Thom Mua’, ‘Mong Chim Trang’, ‘Tai Nguyen’, ‘Tau Huong’ and ‘Nang Thom’.

#### *New rice varieties popularly grown in the Red River Delta*

- Good commercial quality varieties: CR203, ‘Moc Tuyen’, C71, C70, X21 and ‘Tep Lai’.
- Popular high yield varieties: DT10, ‘Bao Thai Hong’, IR17494, CRO2 and IR1561-1-2.
- Newly selected varieties: VD10, VD20 and P4.
- Chinese rice varieties:
  - pure varieties—‘Bac Thom 7’, Q5, Ai32, ‘Khang Dan’ and KC-92-5.
  - hybrids—‘Tap Giao 1’, ‘Tap Giao 4’ and ‘Tap Giao 5’.

#### *New rice varieties popularly grown in the Mekong River Delta*

- Extremely short duration varieties: IR49517-23 (OMCS90) and IR59606 (OMCS94).
- Short duration varieties (group A<sub>1</sub>): OM977-6, VND95-20, TNDB100, OM1706, OM1633, MTL98, MTL99, MTL114 and IR50404.

- Medium duration varieties (group A<sub>2</sub>): IR64, IR62032, IR62030, VND95-19, OM269, OM90-9, OM1726, MTL110, MTL119 and KSB218-9.
- Special aromatic varieties: ‘Khao Dawk Mali’ and ‘Jasmine 85’.

The National Seed Corporation, the Southern Agricultural Science Institute, the Omon Rice Research Institute, the Food Crops Research Institute and the National Center provided rice samples for seed testing. Samples free of foreign matter and empty grains were dried, cleaned and stored before analysis of their physical and chemical characteristics.

### Sample preparation

Husky rice samples were milled in the laboratory using the Satake milling system. Milled rice was then ground into powder using a Tecator grinder with sieving holes of 0.2–0.5 mm.

### Research methods

Rice quality consists of a combination of many factors which vary between different rice varieties. Throughout the world, including Vietnam, rice quality is evaluated according to the four areas set out below.

#### *Milling quality*

- The recovery rate of brown and milled rice is calculated according to the percentage of husky rice weight.
- The rate of whole kernels is calculated according to the percentage of milled rice weight.

#### *Commercial quality*

- The rate of translucent rice is calculated according to the percentage weight of whole kernels.
- The degree of chalkiness is determined using the evaluation method of the International Rice Research Institute (Table 2).

- Grain size (milled rice) is graded according to the length of the grain (L) as shown in Table 3.
- Grain shape of milled rice is according to the ratio of length to width as shown in Table 4.

**Table 2.** Evaluation of rice chalkiness as set out by the International Rice Research Institute in 1981.

Chalky area (%)	Number of chalky spots
Translucent (whole grain)	0 (translucent)
<10	1 (very light chalkiness)
10–20	2 (light chalkiness)
20–30	3 (medium chalkiness)
35–50	4 (chalkiness)
>50	5 (high chalkiness)

**Table 3.** Classification of rice grain size (TCVN 5644-1992).

Classification	Length (L) of rice grain (mm)
Extra long	L B 7
Long	6 AL A 7
Medium	5 AL A 6
Short	L A 5

**Table 4.** Classification of rice grain shape as determined by the length (L) to width (W) ratio (International Rice Research Institute (IRRI) specifications).

Grain classification	IRRI specification
<i>Length</i>	
Extra long	$L > 7.50$ mm
Long	$6.61 < L < 7.50$ mm
Medium	$5.51 < L < 6.60$ mm
Short	$L < 5.50$ mm
<i>Shape</i>	
Slender and long	$L/W > 3.0$
Medium	$L/W = 2.1–3.0$
Bold	$L/W = 1.1–2.0$
Round	$L/W < 1$

### *Eating quality*

Eating quality was evaluated using the following chemical criteria:

- temperature for starch gelatinisation was identified by the alkaline spreading indices method of Little et al. 1958;
- amylose content was evaluated by the method of Juliano (1979a) and Juliano and Perez (1981); and
- the degree of aromaticity was identified by the sensory evaluation method of IRRI (Juliano 1979b).

### *Nutritive quality*

Protein content is evaluated as total protein content using the Micro Kjeldahl method with a converted coefficient of 5.95.

## Results and Discussion

The rice varieties studied are shown in Table 5.

### Milling norms and commercial quality

- Special, traditional and normal rice varieties of the Red River Delta have an average weight per thousand grains ( $W_{1000}$ ) of 18.189 g. Their grain size and shape ( $L = 4.72–5.43$  mm;  $L/W = 1.65–2.56$ ) are smaller than those of special traditional plain rice varieties from the Mekong River Delta ( $W_{1000} = 22.19$ ;  $L = 5.89–6.82$  g;  $L/W = 2.79–3.55$ ).
- Special traditional glutinous rice varieties in the Red River Delta have an average  $W_{1000}$  of 25.99 g and a round grain shape.
- New rice varieties in the Red River Delta have an average  $W_{1000}$  of 22.78 g, an average grain length of  $5 < L < 6$ , and an average slender shape ( $2 < L < 3$ ). Rice varieties in the Mekong River Delta are all long, and 10 out of 24 varieties are extra long ( $L > 7$ ) and the grain type is long and slender ( $L/W > 3$ ). Currently the rice varieties of the Mekong River Delta have the advantage in the export markets.
- 5 of the 62 plain varieties studied have translucency of over 90%. They are: ‘Bac Thom 7’, VD20, ‘Khao Dawk Mali’ (varieties derived from China, Taiwan and Thailand), MTL98 and MTL119. Twenty-three out of the 62 varieties have translucency of over 50% (accounting for 31%). Some varieties in the Red River Delta have comparatively high chalkiness—6 out of 32 varieties have chalkiness of 81.4–100%.

**Table 5.** List of studied rice varieties. (Source: National Crop Testing Company 1998.)

Rice variety	Source	Year of recognition	Duration (days): winter/spring	Duration (days): summer crop	Average yield (Q/ha)
<i>Red River Delta</i>					
CR203	Vegetal Protection Institute	1985	130-140	115-120	40-50
C70	Vegetal Protection Institute	1993	165-175	125-135	50-55
C71	Vegetal Protection Institute	1995	165-175	125-135	50-55
X21	Vietnam Agricultural Science Institute	1996	180-190	115-120	50-60
'Tap Lai'	Local variety, Seed Company of Haiphong	-	180-190	-	50-55
'Moc Tuyen'	Chinese pure variety	-	-	158-160	40-50
DT10	Hanoi Agricultural University No. 1	1985	175-185	115-120	40-45
'Bao Thai Hong'	Chinese purebred variety	-	120-130	110-115	40-45
CRO2	Vietnam Agricultural Science Institute	1994	185-195	135-145	50-55
IR17494 (13/2)	Plant Protection Institute	1989	185-195	130-135	50-60
IR1561-1-2	Plant Protection Institute and Plant Protection Department	-	125-135	110-115	40-50
P4	Food Crops Research Institute	-	170-180	125-130	50-60
VD10	Introduced	-	130-135	105-110	70-80
VD20	Introduced	-	135-140	115-120	55-60
Ai32	Chinese purebred variety, introduced 1992	-	130-135	105-110	50-65
Q5	Chinese purebred variety, introduced 1992	-	135-140	110-115	60-65
'Khang Dan'	Chinese purebred variety	-	130-135	105-110	50-65
KC-92-5	Chinese purebred variety	-	125-130	100-105	55-60
'Tap Giao 1'	Chinese hybrid, introduced 1991	-	130-135	110-120	75-80
'Tap Giao 4'	Chinese hybrid, introduced 1992	-	-	120-125	65-70
'Tap Giao 5'	Chinese hybrid, introduced 1991	-	130-135	110-115	70-75
'Tam Xoan Hai Hau'	Special traditional	-	-	167	32-40
'Tam Xoan Thai Binh'	Special traditional	-	-	145-155	28-40
'Tam Xoan Hai Duong'	Special traditional	-	-	163	35-40

**Table 5.** (Cont'd) List of studied rice varieties. (Source: National Crop Testing Company 1998.)

Rice variety	Source	Year of recognition	Duration (days): winter/spring	Duration (days): summer crop	Average yield (Q/ha)
'Tam Thom Hai Hau'	Special traditional	—	—	163	30–34
'Tam Thom Thai Binh'	Special traditional	—	—	160–165	29–34
'Tam Ap Be'	Special traditional	—	—	167	30–41
'Du Huong'	Special traditional	—	—	160	35–40
'Di Huong'	Special traditional	—	—	160	22–25
'Nep Cai Hoa Vang'	Special traditional	—	—	140–150	35–40
'Nep Dau Huong'	Special traditional	—	—	150–155	37
'Nep Ly'	Special traditional	—	—	150–155	40
<i>Mekong River Delta</i>					
IR50404	South Agricultural Science Institute	1992	95–100	—	55–65
IR62030	Mekong River Delta Rice Research Institute	—	105–112	—	55–60
IR62032	Cuu Long Delta Rice Research Institute	1997	100–105	—	55–65
IR64 (OM98)	Cuu Long Delta Rice Research Institute	1987	105–115	—	60–65
'Jasmine 85'	Introduced	—	105	—	40–60
'Khao Dawk Mali'	Cuu Long Delta Rice Research Institute	1994	100–160	—	35–45
MTL110	Can Tho University	1995	100–110	—	50–55
MTL114	Can Tho University	—	95–100	—	60–80
MTL119	Can Tho University	1993	110–120	—	50–55
MTL98	Can Tho University	1993	100–105	—	50–55
MTL99	Can Tho University	1995	100–105	—	55–60
OM1633	Cuu Long Delta Rice Research Institute	1997	100–110	—	50–80
OM1706	Cuu Long Delta Rice Research Institute	1997	100–105	90–100	50–60
OM1726	Cuu Long Delta Rice Research Institute	—	100–110	—	55–60
OM269 (65)	Cuu Long Delta Rice Research Institute	1993	100–105	—	50–55
OM90-2	Cuu Long Delta Rice Research Institute	1992	105–110	—	45–55
OM90-9	Cuu Long Delta Rice Research Institute	1992	100–110	110–118	50–55

**Table 5.** (Cont'd) List of studied rice varieties. (Source: National Crop Testing Company 1998.)

Rice variety	Source	Year of recognition	Duration (days): winter/spring	Duration (days): summer crop	Average yield (Q/ha)
OM49517-23	Cuu Long Delta Rice Research Institute	1993	90-100	-	50-55
OMCS94	Cuu Long Delta Rice Research Institute	1995	95-100	-	50-60
OM997-6	Cuu Long Delta Rice Research Institute	1994	-	95-100	45-60
TNDB100	Cuu Long Delta Rice Research Institute	1997	-	90-105	50-60
VND95-20	Southern Agricultural Science Institute	-	-	100	50-100
VND95-19	Southern Agricultural Science Institute	-	100-105	-	50-100
'Nang Huong'	Special traditional	-	-	-	-
'Nang Thom Cho Dao'	Special traditional	-	-	-	-
'Nang Thom Mua'	Special traditional	-	-	-	-
'Nang Thom Som'	Special traditional	-	-	-	-
'Tai Nguyen'	Special traditional	-	-	-	-
'Mong Chim Trang'	Special traditional	-	-	-	-
'Tau Huong'	Special traditional	-	-	-	-

## Eating quality

Details of the results obtained in the evaluation of milling quality are given in Appendices 1, 2 and 3. Details of the results for eating and nutritive quality are shown in Appendices 4, 5 and 6.

The main product of rice is cooked rice. The quality of cooked rice is evaluated according to its adhesiveness, stickiness, cohesiveness, and self-drying ability. Rice researchers have found several chemical factors which relate to these characteristics. Among them, amylose content and gelatinisation temperature (GT) are directly proportional to the volume-expanding ability, drying ability, and adhesiveness, and inversely related to stickiness, cohesiveness, and translucency of cooked rice. GT does not much affect the quality of cooked rice, however—according to research results—varieties with high GT always fall below those with low GT.

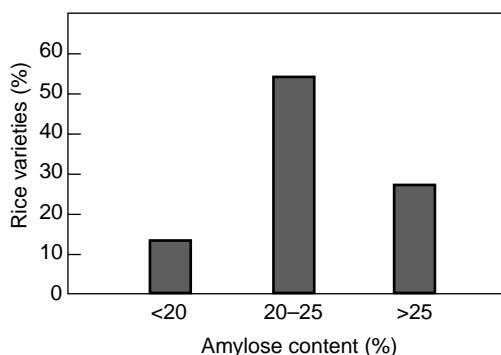
The amylose content and GT for rice from the two areas under investigation are shown in Table 6. Figures 2 and 3 show the percentage of varieties which fall into each category of amylose content and GT.

Grains of rice varieties currently grown have a tendency to be softer and expand more in volume than those surveyed in 1990 (according to the research results of the Post-Harvest Technology Institute). This reflects the demand of consumers for softer cooked rice.

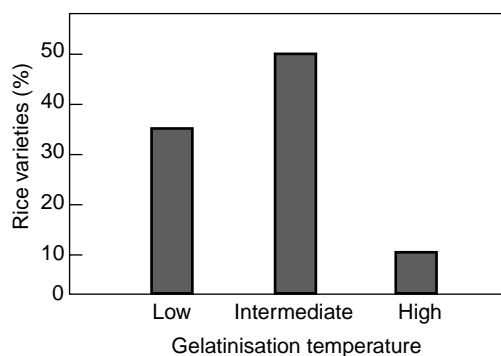
Table 6 shows that:

- Mekong River Delta's rice varieties have a higher average amylose content than those of the Red River Delta;
- most of the rice varieties studied have a low average GT—only 7 out of 62 varieties have high GT; and
- special traditional varieties, especially 'Tam' varieties, have average amylose content (21–23%), average GT, strong aromatic odour and white kernels producing soft and sticky cooked rice. These characteristics of the traditional Vietnamese rice varieties are advantageous in terms of consumer preference.

Glutinous rice varieties, especially 'Nep Cai Hoa Vang', have low amylose content (3.5%), low GT and a very strong aromatic odour.



**Figure 2.** The proportion of rice varieties studied in different categories according to amylose content.



**Figure 3.** The proportion of rice varieties studied in different categories according to gelatinisation temperature.

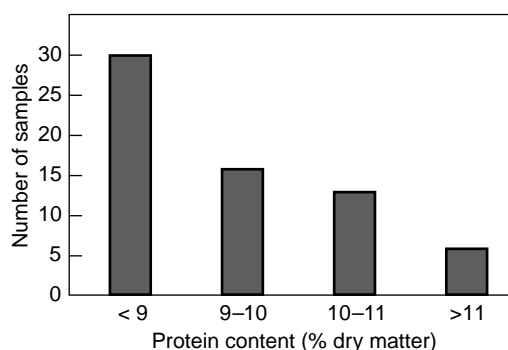
## Nutritive quality

Nutritive quality was evaluated according to the total protein content. Results show that the studied rice

**Table 6.** Amylose content and gelatinisation temperature (GT) of the studied rice varieties.

Zone	Number in sample	Amylose content (%)			GT (°C)		
		<20	20–25	>25	Low	Medium	High
Red River Delta	30	7	12	11	14	15	1
MekongRiver Delta	32	2	22	6	8	16	6

varieties have a protein content ranging from 6.93–11.92%. The total protein content results are presented in Table 7 and Figure 4.



**Figure 4.** The number of rice samples in different protein content categories.

From Table 7, we see that: 4.62% of the studied rice varieties have a total protein content of less than 9%; 24.6% have 9–10%; 20% have 10–11%; and 9.2% have over 11%.

In general, the traditional glutinous rice varieties have a higher protein content (average 9.6%) than plain rice.

## Conclusions

The special traditional ‘Tam’ rice varieties studied are of good quality. They have an average amylose content of 20–25%, a protein content range of 8–10% and have a low or average gelatinisation temperature. Their kernels are white and cooked rice is soft, sticky and has a strong aromatic odour. These characteristics of the special traditional rice collection of Vietnam are advantageous in the marketplace. The natural conditions and climate of the Red River Delta are suitable for growing these rice varieties. Therefore, the expansion and development of export markets should be considered together with policies for strengthening the development of special rice production.

Amid the 65 studied varieties, those in the Mekong River Delta have notable advantages in terms of commercial quality—the grains are long in length, and long and slender in shape, with a comparatively high pro-

portion of translucency. Many varieties are suitable for export. The varieties in the Red River Delta have grains of long length, and long and slender shape. Some have a rather high rate of chalky grains (7 out of 32 varieties have a chalkiness ratio of 81.4–100%). Some have very good translucency, however their grain size makes them not suitable for export. It is uncertain whether this relates to the climatic conditions of the Red River Delta, the local land use habits, or lower investment in study and selection. This problem requires further study.

The protein content in the rice varieties studied ranges from 6.93% (‘Khang Dan’) to 11.92% (‘Jasmine 85’). Varieties containing protein of over 9% account for 57.9% of the total. Glutinous rice varieties have a higher protein content than plain ones.

34 of 62 (54.8%) of the rice varieties studied have an average amylose content of 20–25%. 53 out of 62 (85.5%) have a low or intermediate gelatinisation temperature. This shows that milled rice currently found in the markets of Vietnam—which provides soft, sticky and polished cooked rice—is replacing those varieties characterised by high volume expansion, dry adhesiveness and less adhesion which were popularly grown in 1990 (according to the research results of the Post-Harvest Technology Institute).

## References

- Little, R.R., Hilder, G.B. and Dawson, E.H. 1958. Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal Chemistry*, 35, 111–126.
- Juliano, B.O. 1979a. Amylose analysis in rice—a review. In: *Proceedings of a workshop on chemical aspects of rice grain quality*. International Rice Research Institute (IRRI).
- Juliano, B.O. 1979b. The chemical basis of rice grain quality. In: *Proceedings of a workshop on chemical aspects of rice grain quality*. International Rice Research Institute (IRRI).
- Juliano, B.O. and Perez, C.M. 1981. International comparative testing on the amylose content of milled rice. *Satake*, 33, 157.

**Table 7.** The average total protein content of rice samples tested.

Zone	Number of samples	Protein content (% dry matter)			
		<9	9–10	10–11	>11
Red River Delta	33	21	6	5	1
Mekong River Delta	32	9	10	8	5

**Appendix 1.** Milling quality and commercial quality of special and traditional rice varieties.

Number	Sample	1000 grain weight (g)	Brown rice (% paddy)	White rice (% paddy)	Head rice (%GX)	Translucent rice (%HN)	Size		Shape		Aromatic degree	
							L (mm)	Classification	L/W	Classification		
<i>Rice varieties in the Red River Delta</i>												
1	'Tam Xoan Hai Hau'	18.14	79.98	71.74	98.20	78.22	5.20	Medium	2.44	Medium	1	
2	'Tam Xoan Thai Binh'	19.38	78.39	69.17	96.90	67.16	5.32	Medium	2.49	Medium	2	
3	'Tam Xoan Hai Duong'	19.77	78.84	68.75	93.85	64.40	5.51	Medium	2.53	Medium	2	
4	'Tam Thom Hai Hau'	19.85	76.98	68.03	96.90	69.16	5.12	Medium	2.28	Medium	2	
5	'Tam Thom Thai Binh'	17.58	78.15	68.31	93.60	51.08	5.28	Medium	2.56	Medium	2	
6	'Tam Ap Be'	19.83	77.58	68.95	97.70	58.52	5.32	Medium	2.37	Medium	2	
7	'Du Huong'	17.89	78.53	67.49	88.70	23.28	5.43	Medium	2.50	Medium	1	
8	'Di Huong'	18.66	78.65	68.37	89.90	57.31	4.85	Short	2.29	Medium	1	
9	'Nep Cai Hoa Vang'	25.35	80.03	70.06	92.10	—	4.78	Short	1.67	Rather round	4	
10	'Nep Dau Huong'	27.54	82.07	70.04	86.90	—	4.96	Short	1.74	Rather round	3	
11	'Nep Ly'	25.07	79.60	67.77	94.51	—	4.72	Short	1.65	Rather round	3	
<i>Rice varieties in the Mekong River Delta</i>												
12	'Nang Huong'	21.55	79.10	65.58	82.38	31.27	6.67	Long	3.29	Long slender		
13	'Nang Thom Cho Dao'	21.71	80.20	71.55	82.49	22.62	6.17	Long	3.28	Long slender		
14	'Nang Thom Som'	23.35	81.00	72.95	82.24	34.23	6.27	Long	3.13	Long slender		
15	'Nang Thom Mua'	21.57	80.88	74.08	87.80	39.96	6.30	Long	3.10	Long slender		
16	'Nang Thom'	21.97	19.58	88.50	81.97	56.00	6.70	Long	3.00	Long slender		
17	'Tai Nguyen'	21.39	78.88	67.40	52.92	6.37	5.89	Medium	2.79	Medium slender		
18	'Mong Chim Trang'	24.48	78.78	70.50	37.88	8.13	6.82	Long	3.35	Long slender		
19	'Tau Huong'	21.50	76.50	64.60	82.42	22.82	6.62	Long	3.55	Long slender		



**Appendix 2.** Milling quality and commercial quality of new rice varieties in the Red River Delta.

Number	Sample	1000 grain weight (g)	Brown rice (% paddy)	White rice (% paddy)	Head rice (%GX)	Translucent rice (%HN)	Size		Shape	
							L (mm)	Classification	L/W	Classification
<i>Rice varieties with high commodity quality being grown popularly</i>										
1	CR203	22.03	80.13	71.08	89.26	65.18	5.87	Medium	2.49	Medium
2	C70	23.90	80.95	72.65	81.61	63.70	5.69	Medium	2.50	Medium
3	C71	23.75	79.74	73.68	67.18	53.98	5.68	Medium	2.54	Medium
4	X21	24.97	80.67	68.45	57.96	20.72	5.70	Medium	2.50	Medium
5	'Tep Lai'	19.09	79.30	71.40	53.40	—	5.18	Medium	2.44	Medium
6	'Bao Thai Hong'	22.57	80.75	73.95	78.53	1.50	4.85	Short	1.90	Bold
7	'Moc Tuyen'	21.44	81.08	71.25	91.47	1.20	5.12	Medium	2.04	Medium
8	DT10	22.45	81.13	72.63	68.67	—	6.66	Long	2.59	Medium
9	CRO2	25.58	78.23	68.95	80.67	14.97	6.48	Long	3.00	Medium
10	P4	22.81	80.67	70.52	81.30	43.62	6.39	Long	2.85	Medium
11	IR17494(13/2)	22.44	79.35	69.25	79.19	—	4.69	Short	1.69	Bold
12	IR1561-1-2	23.50	80.50	69.35	75.40	39.50	6.22	Long	2.94	Medium
13	VD10	25.35	77.37	65.95	96.20	81.25	6.30	Long	2.83	Medium
14	VD20	20.55	77.50	66.50	97.50	96.50	5.79	Medium	2.84	Medium
<i>Chinese pure and hybrid rice varieties</i>										
15	'Bac Thom 7'	20.67	78.00	66.80	97.60	98.50	5.35	Medium	2.95	Medium
16	Ai32	22.10	82.16	68.18	65.47	40.16	5.36	Medium	2.37	Medium
17	Q5	26.05	81.02	65.91	64.06	2.60	5.57	Medium	2.27	Medium
18	'Khang Dan'	20.35	80.15	70.18	71.91	59.09	5.43	Medium	2.55	Medium
19	KC-92-5	20.50	78.85	67.92	95.50	- 47.50	5.43	Medium	2.55	Medium
20	'Tap Giao 1'	25.77	80.95	73.31	91.06	55.94	6.24	Long	2.66	Medium
21	'Tap Giao 4'	19.60	78.40	70.79	94.96	74.39	5.84	Medium	2.81	Medium
22	'Tap Giao 5'	25.79	80.82	73.41	96.90	51.66	6.16	Long	2.69	Medium

**Appendix 3.** Milling quality and commercial quality of some of the new rice varieties in the Mekong River Delta.

Number	Sample	1000 grain weight (g)	Brown rice (% paddy)	White rice (% paddy)	Head rice (%GX)	Translucent rice (%HN)	Size		Shape	
							L (mm)	Classification	L/W	Classification
<i>Extremely short duration varieties</i>										
1	OMCS94	24.50	80.90	69.05	86.40	20.60	6.66	Long	3.12	Slender
2	OM49517-23	23.86	77.68	68.90	86.39	49.37	6.71	Long	3.15	Slender
<i>A1 varieties</i>										
3	OM1997-6	26.50	78.57	69.38	90.81	43.23	6.93	Long	3.42	Slender
4	VND95-20	25.90	79.23	70.41	92.30	28.80	7.15	Extra long	3.36	Slender
5	TNDB100	22.10	79.18	70.08	87.70	79.70	6.71	Long	3.42	Slender
6	OM90-2	24.12	79.25	69.70	88.17	29.40	7.15	Extra long	3.56	Slender
7	OM1633	26.75	80.33	69.10	73.13	27.40	6.99	Long	3.39	Slender
8	OM1706	25.48	79.92	71.45	87.60	39.04	6.82	Long	3.31	Slender
9	MTL98	25.56	78.40	70.48	94.48	90.11	6.87	Long	3.15	Slender
10	MTL99	23.16	80.20	70.95	88.12	51.79	6.76	Long	3.36	Slender
11	MTL114	25.65	78.87	70.55	87.45	50.20	6.83	Long	3.15	Slender
12	IR50404	23.85	81.77	71.52	72.80	35.31	6.61	Long	3.14	Slender
<i>A2 varieties</i>										
13	IR64	25.65	79.84	69.70	68.00	33.60	6.98	Long	3.31	Slender
14	IR62030	29.66	81.80	71.38	77.74	33.35	7.21	Extra long	3.28	Slender
15	IR62032	26.08	80.90	71.20	77.97	26.59	6.90	Long	3.37	Slender
16	VND95-19	29.85	80.85	69.62	78.11	12.07	7.15	Extra long	3.20	Slender
17	OM269	25.82	79.27	69.92	54.67	62.16	7.41	Extra long	3.50	Slender
18	OM90-9	23.21	79.50	72.78	74.67	80.36	7.02	Extra long	3.36	Slender
19	OM1726	29.51	81.05	69.43	49.30	28.64	7.36	Extra long	3.45	Slender
20	MTL110	25.50	79.15	69.30	82.33	71.36	7.02	Extra long	3.20	Slender

**Appendix 3.** (Cont'd) Milling quality and commercial quality of some of the new rice varieties in the Mekong River Delta.

Number	Sample	1000 grain weight (g)	Brown rice (% paddy)	White rice (% paddy)	Head rice (%GX)	Translucent rice (%HN)	Size		Shape		
							L (mm)	Classification	L/W	Classification	
21	MTL119	29.94	80.95	70.35	81.49	91.98	7.68	Extra long	3.65	Slender	
22	KSB218-9	25.33	80.50	70.82	94.48	44.24	6.66	Long	3.10	Slender	
<i>Special aromatic rice varieties</i>											
23	'Khao Dak Mali'	24.50	81.23	70.40	88.70	98.20	7.03	Extra long	3.36	Slender	
24	'Jasmine 85'	25.70	80.07	67.37	86.80	80.40	6.92	Long	3.34	Slender	

**Appendix 4.** Eating and nutritive quality of aromatic rice varieties.

Number	Sample	Protein (% dry matter)		Amylose (% dry matter)		GT <sup>a</sup>	
		Classification	ASP <sup>b</sup>	Classification	ASP <sup>b</sup>	Classification	ASP <sup>b</sup>
<i>Rice varieties in the Red River Delta</i>							
1	'Tam Xoan Hai Hau'	10.22	22.66	Medium	5.00	Medium	Medium
2	'Tam Xoan Thai Binh'	10.02	23.17	Medium	5.00	Medium	Medium
3	'Tam Xoan Hai Duong'	8.89	22.92	Medium	5.08	Medium	Medium
4	'Tam Thom Hai Hau'	8.67	22.19	Medium	5.83	Medium	Medium
5	'Tam Thom Thai Binh'	8.75	23.07	Medium	5.00	Medium	Medium
6	'Tam Ap Be'	8.96	22.56	Medium	5.08	Medium	Medium
7	'Du Huong'	8.84	22.83	Medium	5.00	Medium	Medium
8	'Di Huong'	8.90	20.18	Medium	5.76	Medium	Medium
9	'Nep Cai Hoa Vang'	9.03	3.55	Low	6.67	Low	Low
10	'Nep Dau Huong'	10.19	3.49	Low	7.00	Low	Low
11	'Nep Ly'	9.64	3.55	Low	6.00	Low	Low

<sup>a</sup>GT = gelatinisation temperature<sup>b</sup>ASP = alkaline spreading point

**Appendix 4.** (Cont'd) Eating and nutritive quality of aromatic rice varieties.

Number	Sample	Protein		Amylose		GT <sup>a</sup>	
		(% dry matter)	(% dry matter)	(% dry matter)	Classification	ASP <sup>b</sup>	Classification
<i>Rice varieties in the Mekong River Delta</i>							
12	'Nang Huong'	8.12	20.82	Medium		4.92	Medium
13	'Nang Thom Cho Dao'	8.75	21.20	Medium		5.10	Medium
14	'Nang Thom Som'	10.30	20.10	Medium		4.70	Medium
15	'Nang Thom Mua'	9.37	21.00	Medium		4.80	Medium
16	'Nang Thom'	7.92	21.37	Medium		5.18	Medium
17	'Tai Nguyen'	10.40	21.08	Medium		4.90	Medium
18	'Mong Chim Trang'	8.35	21.60	Medium		4.30	Medium
19	'Tau Huong'	10.87	22.46	Medium		4.50	Medium

<sup>a</sup>GT = gelatinisation temperature<sup>b</sup>ASP = alkaline spreading point**Appendix 5.** Eating and nutritive quality of new rice varieties in the Red River Delta.

Number	Sample	Protein		Amylose		GT <sup>a</sup>	
		(% dry matter)	(% dry matter)	(% dry matter)	Classification	ASP <sup>b</sup>	Classification
<i>Rice varieties with high commodity quality being grown popularly</i>							
1	CR203	8.34	26.15	High		4.58	Medium
2	C70	7.62	27.38	High		6.68	Low
3	C71	7.68	25.41	Medium-high		6.00	Low
4	X21	7.62	20.62	Medium <sup>c</sup>		7.00	Low
5	'Top Lai'	8.87	24.87	Medium		5.75	Medium
6	'Bao Thai Hong'	8.19	24.36	Medium		6.00	Low
7	'Moc Tuyen'	8.37	28.26	High		6.00	Low

<sup>a</sup>GT = gelatinisation temperature<sup>b</sup>ASP = alkaline spreading point

**Appendix 5.** (Cont'd) Eating and nutritive quality of new rice varieties in the Red River Delta.

Number	Sample	Protein (% dry matter)	Amylose		GT <sup>a</sup>
			(% dry matter)	Classification	
8	DT10	10.12	25.74	Medium-high	6.00 Low
9	CRO2	9.10	26.08	High	5.00 Medium
10	P4	9.33	12.65	Low	3.40 Medium-high
11	IR17494 (13/2)	7.02	25.26	Medium-high	6.00 Low
12	IR1561-1-2	8.00	25.49	Medium-high	6.75 Low
13	VD10	7.26	14.30	Low	7.00 Low
14	VD20	8.51	17.34	Low	7.00 Low
<i>Chinese pure and hybrid rice varieties</i>					
15	'Bac Thom 7'	11.07	14.96	Low	5.08 Medium
16	Ai32	8.15	26.78	High	7.00 Low
17	Q5	7.50	26.96	High	6.58 Low
18	'Khang Dan'	6.93	26.66	High	7.00 Low
19	KC-92-5	9.37	24.88	Medium	6.00 Low
20	'Tap Giao 1'	8.92	19.90	Low	5.66 Medium
21	'Tap Giao 4'	9.34	18.50	Low	5.33 Medium
22	'Tap Giao 5'	10.23	18.90	Low	5.66 Medium

<sup>a</sup>GT = gelatinisation temperature

<sup>b</sup>ASP = alkaline spreading point

**Appendix 6.** Eating and nutritive quality of new rice varieties in the Mekong River Delta.

Number	Sample	Protein		Amylose		GT <sup>a</sup>	
		(% dry matter)	(% dry matter)	(% dry matter)	Classification	ASP <sup>b</sup>	Classification
<i>Extremely short duration varieties</i>							
1	OMCS-94	9.30	23.20	Medium	2.00	High	High
2	OM49517-23	10.26	22.98	Medium	6.17	Low	Low
<i>A1 varieties</i>							
3	OM997-6	9.37	23.51	Medium	5.92	Medium	Medium
4	VND95-20	10.90	23.19	Medium	4.00	Medium	Medium
5	TNDB-100	9.98	22.23	Medium	3.00	High	High
6	OM90-2	10.68	23.81	Medium	6.00	Low	Low
7	OM1633	9.89	21.69	Medium	2.00	High	High
8	OM1706	8.21	23.09	Medium	4.33	Medium	Medium
9	MTL98	11.05	25.78	Medium-high	4.67	Medium	Medium
10	MTL99	10.10	24.60	Medium	4.83	Medium	Medium
11	MTL114	9.24	26.59	High	2.75	High	High
12	IR50404	9.01	26.50	High	4.80	Medium	Medium
<i>A2 varieties</i>							
13	IR64	11.17	21.57	Medium	2.50	High	High
14	IR62030	8.04	24.15	Medium	7.00	Low	Low
15	IR62032	9.46	20.89	Medium	4.00	Medium	Medium
16	VND95-19	8.16	23.78	Medium	4.42	Medium	Medium
17	OM269	8.70	24.90	Medium	6.30	Low	Low
18	OM90-9	11.60	25.70	High	6.90	Low	Low

<sup>a</sup>GT = gelatinisation temperature

<sup>b</sup>ASP = alkaline spreading point

**Appendix 6.** (Cont'd) Eating and nutritive quality of new rice varieties in the Mekong River Delta.

Number	Sample	Protein (% dry matter)	Amylose		GT <sup>a</sup>
			(% dry matter)	Classification	
19	OM1726	9.34	24.82	Medium	7.00 Low
20	MTL110	7.78	27.53	High	4.67 Medium
21	MTL119	11.21	27.71	High	1.00 High
22	KSB218-9	9.04	24.68	Medium	5.00 Medium
<i>Aromatic varieties</i>					
23	'Khao Dak Mali'	9.10	18.80	Low	6.17 Low
24	'Jasmine 85'	11.92	16.31	Low	6.25 Low

<sup>a</sup>GT = gelatinisation temperature

<sup>b</sup>ASP = alkaline spreading point

# Quality Assurance Systems for ASEAN Fruits (Fresh and Minimally Processed)

G.I. Alexander and B.C. Peacock\*

## Abstract

In Association of South-East Asian Nations (ASEAN) countries, postharvest handling and marketing of fruits have been developing quite rapidly in response to increasing efforts to export fruits to other countries, both within ASEAN and to other countries. A catalyst for these developments has been the ASEAN–Australia Economic Cooperation Program Phase III Project on Quality Assurance Systems for ASEAN Fruits—Fresh and Minimally Processed (QASAF). Within the ambit of the project, each country has developed quality assurance (QA) systems with fruit which they had selected as the subject fruit. A series of projects was undertaken to develop QA systems for the marketing of fresh fruit for local and export markets. A second series of projects was undertaken to develop systems for minimal processing of the selected fruit with a view to achieving an extended shelf life for the product to aid in the penetration of more distant markets.

Brunei Darussalam focused their attention on their local durian varieties, ‘durian otak udang galah’, ‘durian pulu’, ‘durian kuning’ and ‘durian bunga simpur’, which they wished to promote; Indonesia concentrated on ‘Arumanis’ mango which is a popular variety of green-skinned mango; Malaysia used jackfruit which was being used for some limited minimal processing; Philippines chose to work with pineapples for which a minimal processing industry could be developed; Singapore, being an importer of fruit from ASEAN, concentrated on product evaluation and the development of minimal processing systems, including good manufacturing practice (GMP) and Hazard Analysis and Critical Control Points (HACCP) plans; Thailand placed its emphasis on furthering its work on the most common durian (*Durio zibethinus*) in commercial use and which could be used for minimal processing; and Vietnam concentrated attention on dragon fruit—which is a very popular fruit with considerable export potential, mango (‘Cat Hoa Loc’) and longan.

THIS THREE-YEAR project commenced in January 1997 under the auspices of the Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program Phase III (AAECP-III). The ASEAN countries cooperating with Australia in the project were Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. Vietnam joined the project six months after the project’s commencement following Vietnam becoming a member of ASEAN.

The overall goal of the Quality Assurance Systems for ASEAN Fruits (QASAF) project was:

“to develop postharvest handling, minimal processing and food safety systems and implement quality assurance (QA) systems

which will expand marketing opportunities for selected tropical fruits and provide improved returns to fruit producers, marketing agents and processors.”

The project was developed in order to build on the achievements of previous horticultural projects under AAECP in which the capacity of the ASEAN countries was strengthened in the postharvest handling of fruits. The aim of the project was to weld these improved technologies into commercially viable QA systems for the handling and marketing of selected tropical fruits. With increasing interest in minimal processing of fruits and vegetables worldwide, the ASEAN countries were anxious to include minimal processing into the project. This involved the development of new technologies for minimal processing of the fruits selected by the countries for their programs. Minimal processing of fruits had been practised in

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ASEAN over many years but was restricted in scope to fruits for immediate consumption. The minimal processing program in this project was designed to promote a longer shelf life of the processed fruit so that it could be transported and sold in distant markets. This placed strict requirements on the minimal processing procedures to achieve the maintenance of the fresh-like quality and food safety of the fruit over this extended period. These led to the development of QA systems featuring Hazard Analysis and Critical Control Points (HACCP) for the minimal processing of the fruits.

Each country selected fruits for their research and development (R&D) programs in the project. Brunei Darussalam nominated their local durian species as their target fruit. Their Government wanted to stimulate interest in capitalising on many of the local fruits and products in the country and the local durians offered a unique opportunity as they were quite different from the durian species which were produced and marketed by Thailand, Malaysia, Indonesia and Vietnam. Indonesia chose to work with 'Arumanis' mango which is a green-skinned mango with a distinctive flavour. Malaysia selected jackfruit which, being a very large fruit, lent itself very well to minimal processing. The Philippines chose pineapple for their fruit as minimally processed (MP) pineapple seemed to offer opportunities for penetration of markets which were not available to the whole fruit. Singapore, while not a fruit-producing country, played a major role in the project because it was a major market for these ASEAN fruits and could provide information on market requirements for these fruits and their MP products. There was increasing interest, both from Singapore Departmental officers and commercially, in minimal processing of fruits, so programs were developed to meet these desires. Thailand had carried out R&D on their durian during the previous phase of AAACP and wished to extend this work to help access more distant markets and also to develop minimal processing procedures which might offset the disadvantages of the fruit in its penetrating odour and prickly husk and simplify its marketing. Vietnam, because it had not participated in the earlier phases of AAACP and so had not developed experience in many of the postharvest procedures as had the other countries, chose to use a variety of fruits in order to study the postharvest procedures for these fruits, and thus included longan and mango in the list of fruits they studied. However, their main effort was directed at dragon fruit.

## Project Achievements

### QA systems for postharvest handling and marketing of fresh fruits

The main thrust of this section of the project involved the establishment of market descriptions for the fruits for their target markets, the identification of appropriate postharvest handling systems for the fruits, and their integration into commercially acceptable QA systems.

#### *Brunei Darussalam*

Comprehensive market descriptions were developed for the local varieties of durian, namely 'durian pulu', 'durian otak udang galah', 'durian kuning' and 'durian bunga simpur'. A database was prepared on the production, postharvest handling and marketing of local durian.

The primary preharvest and postharvest diseases and pests were determined. The causes of postharvest fruit rots were determined and control measures were developed for these rots. Methods of harvesting fruit were studied as a means of reducing the incidence of fruit rots. It was found that fruit may be harvested at 130 days after emergence of the flower or at least 13 days after the first fruit drop with no disadvantage to fruit quality. Smell was found to be a better indication of maturity than rind colour.

A quality manual was developed to provide complete information on all aspects of the growing, harvesting and marketing of durian to assist the expansion of the durian industry. This included a QA system using improved production and postharvest procedures for the commercial marketing of fresh durian for both the local and export markets.

#### *Indonesia*

'Arumanis' mango is the most popular mango variety in Indonesia. The marketing system was studied and the contribution of each part of the marketing chain to the quality of the end product assessed. This allowed the concentration of the program on those areas which required the greatest attention. An extension program was conducted for farmers to make them more aware of their contribution to the quality of the final product. Posters were prepared to alert farmers to pests and diseases of economic importance and measures to combat them. There is a tendency of farmers to harvest fruit at an immature stage, particularly when the price is attractive, and this problem was also the subject of the

extension program. All these activities were integrated into a quality plan and the support of local government was sought to help the implementation of the plan by farmers, since QA is a new concept which needs active promotion to growers.

Indonesia's quality management team—formed at the production area in Bali—analysed the whole supply chain, from the grower in Bali to the wholesale and retail markets in Bandung. This provided an excellent study of the difficulties which are encountered along the marketing chain so that remedial measures could be developed to help prevent the loss of fruit quality during the distribution process. A series of posters was produced for the information of collectors, transporters and distributors. These were aimed at preventing the most serious problems which were identified along the marketing chain.

These formed parts of the QA system to provide a consistent quality product to the market.

#### *Malaysia*

As the Malaysian program was directed towards the minimal processing of jackfruit, market descriptions and postharvest technologies which would be applicable to minimal processing were studied. Methods of determining maturity indices were evaluated.

A QA system for the postharvest handling of jackfruit was developed covering a flow chart of unit operations, the control of raw materials arriving at the packinghouse, control at the packinghouse plant and cleanliness, control of operations, and control of end products for fresh consumption. A system was established for the control of raw materials received at the packinghouse so that adequate details of the pre-harvest treatment of the fruit received are known. The system also incorporated the development of Good Manufacturing Practice (GMP) at the packinghouse and the use of HACCP for the operation of the plant to ensure that the fruit is not contaminated with microbiological, chemical or physical hazards. The system also provided for the control of the end product for fresh consumption to meet consumer requirements. In the development of QA aids and facilities, Malaysia identified a number of equipment items and record keeping systems which were necessary for the successful operation of the system. The systems which were developed were evaluated commercially with the aid of the commercial collaborators, Federal Land

Development Authority (FELDA) and Federal Agricultural Marketing Authority (FAMA).

#### *Philippines*

The program was conducted in close association with smallholders in order to improve the quality of their pineapple produce. A flotation method was developed to determine the maturity index of the fruit. A simple sizer was developed in the project to make the sorting of fruit by size simpler and more repeatable.

The Philippines developed a QA system for the handling of fresh pineapple and the quality preference was established by consumer and market surveys. The currently used postharvest handling system was documented and an improved QA system was proposed. This involved the placing of the fruit in containers immediately after harvest to prevent bruising and contamination. Sizing was to be carried out and all fruit washed in chlorinated water and checked for maturity and ripeness by flotation in water. Fruit which sank were to be marketed as soon as possible.

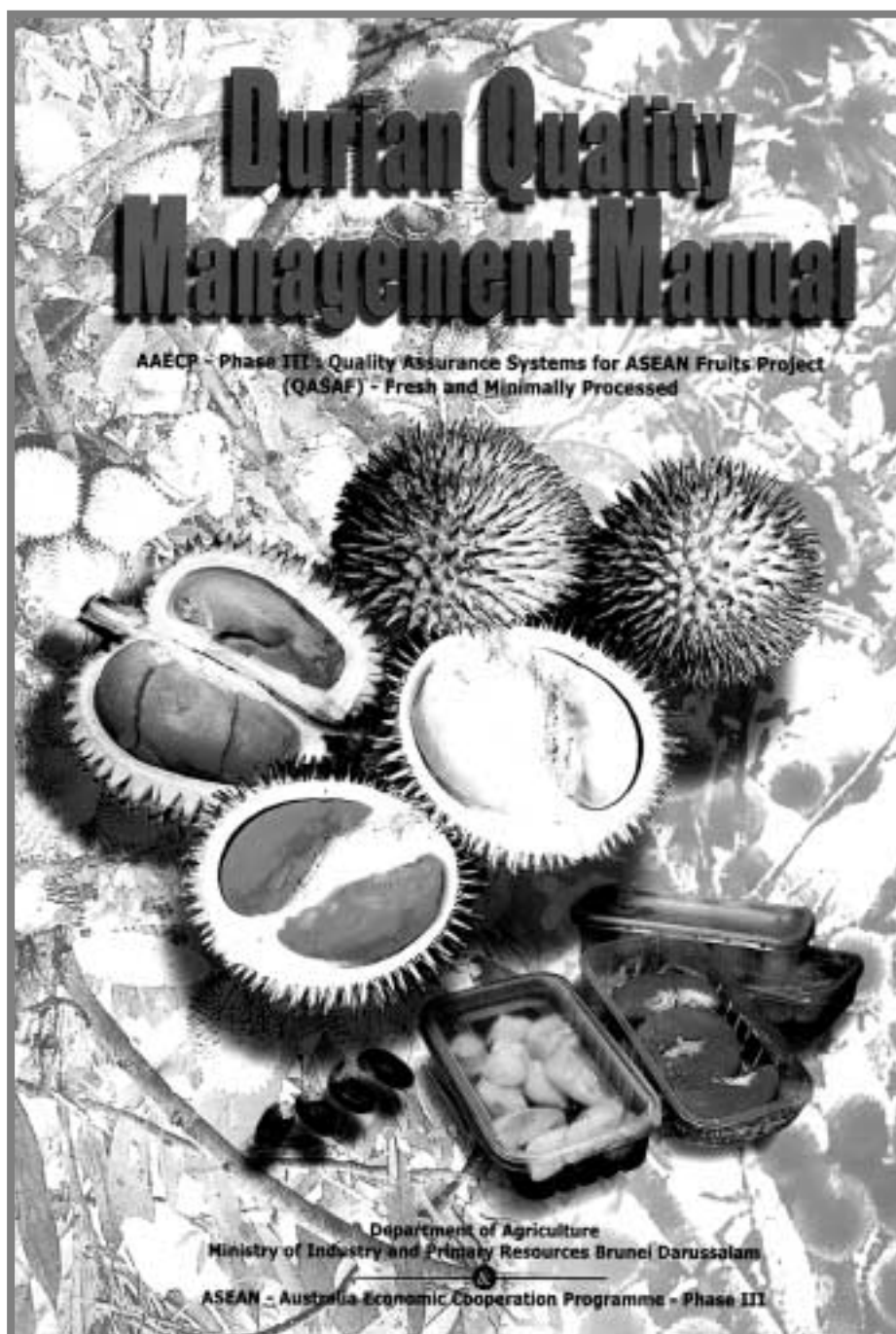
Animated information materials were generated to inform farmers, handlers and service providers. Quality defects were documented to serve as reference in the formulation of grades and standards.

#### *Singapore*

Singapore assisted Vietnam in examining the composition of dragon fruit and residue aspects.

A Good Agricultural Practice (GAP) systems analysis was carried out of the fresh produce handling systems used by National Trade Union Congress (NTUC) Fairprice with the International Standards Organisation (ISO) 9002 as the basis for evaluation. This evaluation was embraced enthusiastically by NTUC Fairprice who decided to adopt QA systems for all their fresh product operations. To date, three of their outlets have received ISO 9002 accreditation.

A training exercise was also carried out with research workers, extension officers, wholesalers, distributors, and supermarket operators in the development of quality plans for wholesale markets, distributors, and wholesalers, supermarkets and other retailers, with an audit trail to identify weaknesses to allow preventive and/or corrective action to be taken.



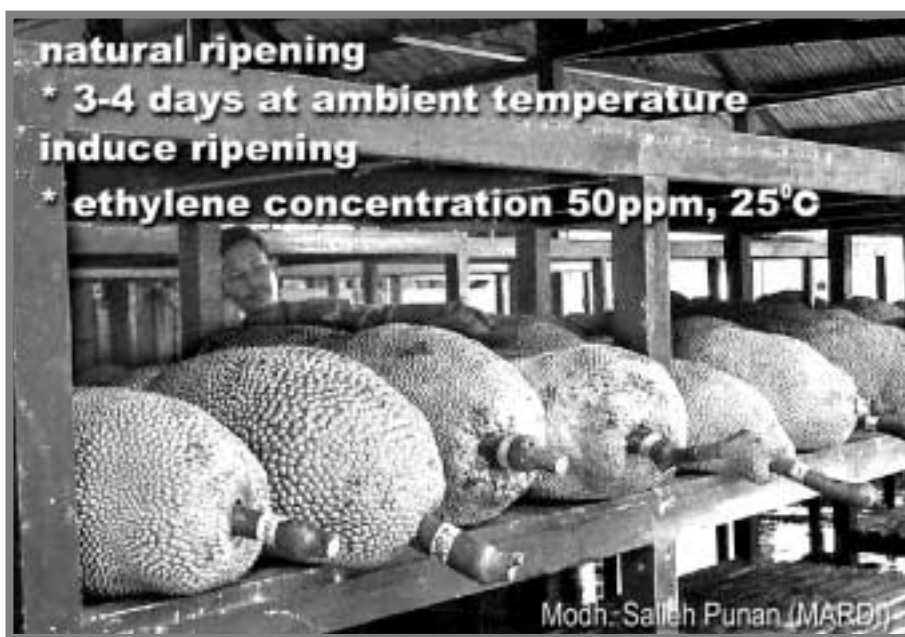
**Figure 1.** Cover page of the Brunei Darussalam Durian Quality Management Manual.



**Figure 2.** 'Durian pulu' for sale at a roadside stall in Brunei Darussalam.



**Figure 3.** A quality team meeting with farmers and collectors in the Buleleng District, Bali, Indonesia.



**Figure 4.** Jackfruit being ripened in the Federal Land Development Authority (FELDA) storage facility before processing, Malaysia.



**Figure 5.** Fruitlets of jackfruit being dissected from the fruit during minimal processing at the Federal Land Development Authority (FELDA) facility, Malaysia.



**Figure 6.** Minimally processed jackfruit in an insulated container lined with thermal freeze packs for transport to market, Malaysia.



**Figure 7.** Durian imported from Thailand on display in a supermarket in Brunei Darussalam.



**Figure 8.** Thai durian being tapped to assess ripeness at the packinghouse.



**Figure 9.** Thai durian being held in a cool room prior to export.

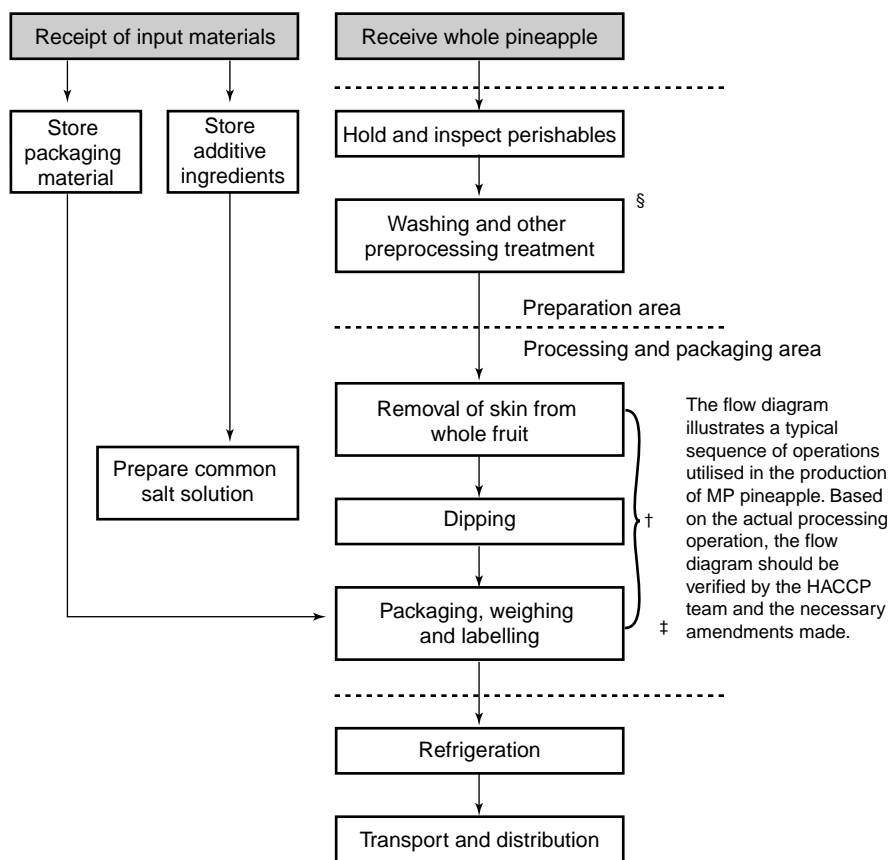


**Figure 10.** Dragon fruit orchard with an immature dragon fruit in the inset, Vietnam.



**Figure 11.** 'Smooth Cayenne' pineapples packed in bamboo baskets at a district market, Philippines.





§ All perishables should not be retained for more than 5 minutes at this stage at 20°C.

† For processing each fruit, the total time for these two stages should not extend beyond 15 minutes at 15°C.

‡ MP pineapples on styrofoam trays are further packed into large plastic baskets for transportation in refrigerated trucks to retail outlets.

**Figure 12.** Process flow chart for minimally processed (MP) pineapple, Singapore.

(Source: P.S. Chong, C.H. Lim and S.T. Chew, Primary Production Department, Singapore.)

### Thailand

Product marketing descriptions on durian were produced based primarily on reports from supermarkets, packinghouse operators and exporters. A postharvest disease control study for the three primary diseases of durian showed that the treatments proposed were effective. A storage study on durian showed that fruit could be stored for three weeks, provided ethylene absorbents were used. Another

study showed that treatment with ethylene was far more effective than any of the ethrel treatments examined in inducing uniform ripening in the fruit.

A QA plan was developed in conjunction with exporter collaborators for the marketing of fresh durian for export markets. A problem which was identified was immature harvesting and a program was instituted to make growers aware of the problem and to take steps to prevent it happening. A flow chart was

prepared of the procedures. A 'Monthong' durian manual was prepared, providing details of defects, misshapen fruit, and packaging and packing methods. Several checks on fruit quality were established at the farm, before and when harvesting, and again on receipt at the packinghouse. The exporters have now accepted that it is necessary to pre-cool the fruit before packing into the container for export. This has been a major improvement as a result of the project as it has allowed the transport of durian over long distances to Hong Kong. Recently, an export shipment of fresh durian has been made to Japan.

An in-country QA workshop carried out at Chanthaburi—involving researchers, extension workers, farmers, packinghouse operators and exporters—allowed the dissemination of much of the research information developed in the project as part of the project's quality plan.

#### *Vietnam*

*Dragon fruit.* Product descriptions were developed based on exporter and importer information. Post-harvest handling surveys were conducted of the marketing system in Binh Thuan Province. Singapore assisted Vietnam in studying dragon fruit composition, nutritive value, physico-chemical characteristics, and certain chemical and microbiological contamination data.

Fruit colour changes were studied, confirming grower reports that dragon fruit showed three distinct changes in colour during development. Fruit development/maturation studies showed that skin colour or days from flowering were quite appropriate indices for harvesting.

A respiration study showed that dragon fruit is apparently non-climacteric and that ethylene or acetylene treatment could not be used to initiate colour development in the fruit. In a storage study, it was found that dragon fruit could be stored for 40 days at 5°C. In a chilling sensitivity study ranging from -2 to 6°C, fruit harvested at 25 days were found to be sensitive to chilling, but by the time the fruit reached 30–35 days the sensitivity had reduced dramatically.

*Mango.* Two surveys were conducted into production and postharvest handling practices for mango in the Mekong Delta. Storage studies using a number of mango varieties showed that mango could be stored for three weeks at 12°C depending on other disease, postharvest treatment and storage factors. A maturation study on the 'Cat Hoa Loc' variety confirmed that 13–14% total solids was an appropriate harvesting index and that specific gravity could be used as a har-

vesting index. A sapburn study on four mango varieties found that two of the varieties were quite sensitive to sapburn and that the other two (including 'Cat Hoa Loc') were not so sensitive.

*Longan.* A preliminary storage study was undertaken using different levels of benomyl and metabisulphide, different storage temperatures, and different types of packing treatment. A maturation study was also undertaken, examining fruit chemical changes and respiratory behaviour. Various SO<sub>2</sub> treatments were examined for fumigating longan and keeping the residues at appropriate levels. Commercial facilities were also examined with a view to keeping residue levels at permissible levels.

## **QA systems for minimally processed (MP) fruits**

#### *Brunei Darussalam*

Studies were carried out on demand and quality requirements for specific local and potential export markets. Draft market descriptions and the optimum maturity and ripeness were developed for MP durian for the local market. The existing procedures and technologies for MP durian were examined. Studies were also conducted into surface sanitation and types of packaging. A flow chart of operations for MP of durian was constructed. The effect of cool storage on storage life of MP durian was studied. The effect of a number of primary packaging materials on shelf life was examined and a suitable secondary packaging film for MP durian was selected.

A HACCP plan for MP durian production was developed and further food safety measures were included in the plan. A Durian Quality Management Manual for Brunei Darussalam for fresh and MP durian was published. The quality management manual will serve as a basis for commercial application of the QA systems. Since durian production is still in its developmental stages, it was not possible to carry out an evaluation of a commercial system. However the QA system incorporating a HACCP plan was reviewed by the Australian consultants during their visits and assessed as to its technical and commercial feasibility.

#### *Indonesia*

A survey was made of minimal processing contaminants and requirements for the local market. The market description of fresh 'Arumanis' mango was developed with support of the field operators and collectors, and the optimum maturity and stage of

ripeness for MP 'Arumanis' mango was established. There is little or no minimal processing of 'Arumanis' mango but a marketing strategy targeting potential consumers was developed. A prototype machine for peeling and segmenting mangoes was produced. The technologies needed for successful minimal processing of 'Arumanis' mango were developed and the treatment procedures for raw materials established. In addition, potential treatments for minimal processing of mangoes prior to packaging were investigated and identified.

A comprehensive QA system incorporating HACCP has been developed for the minimal processing of 'Arumanis' mango. The QA system has allowed the storage of MP 'Arumanis' mango at 5°C for at least 6–9 days. However, because of the need for refrigeration of the product, the system can only be used by the supermarkets and mini-supermarkets which have the capacity to store fruit at <5°C. As a result, the market for MP 'Arumanis' mango is limited to the higher income groups in the community. The economics of development of a MP 'Arumanis' mango industry were assessed.

#### *Malaysia*

The product marketing systems developed for fresh jackfruit were found to be equally applicable for minimal processing and the market description for MP jackfruit was prepared.

Existing minimal processing technologies were reviewed and a flow chart of the operation prepared. The existing system for MP jackfruit was improved in order to meet handling and processing requirements of domestic and export markets. The use of high and consistent quality raw material was found to be very important in achieving a 3-week shelf life at 2°C. Latex production was reduced by the temporary storage of fruit under chilled conditions prior to minimal processing. Various types of primary package were evaluated for suitability in packaging MP jackfruit.

It was found that polystyrene and thermal freeze packing could be used as a secondary packaging system to extend the storage life of MP jackfruit. Suitable modified atmosphere (MA) packages for keeping the product have been established. The use of a water absorbent was found to be effective in minimising moisture condensation.

A survey of existing practices showed that there was a need for improved sanitation during harvesting and handling to reduce contamination. Procedures were developed for the minimal processing of jackfruit

incorporating a HACCP plan and GMP, listing the operations for a minimal processing unit.

Studies showed that thermoform was the best packaging for reducing microbiological deterioration, making product visible, and providing a semi-rigid package to prevent consumer abuse, as well as being stackable.

Raw material specification, end-product specification and minimal processing unit operation are some of the important components in the development of the QA system. The requirements of those components were structured according to the R&D conducted earlier in the project.

The QA system developed was evaluated on a pilot scale. The minimal processing procedure and the QA control measures undertaken in the study contributed to the preparation of high quality end products. However, serious steps should be taken by farmers to overcome the inconsistent sweetness of the fruit. This involves the improvement of cultural practices, fertiliser type and farm management.

The Federal Land Development Authority (FELDA) has already successfully implemented the QA scheme for monitoring MP jackfruit from the farm to marketing. A workshop provided feedback which was adopted in the final QA manual. Economic appraisal of the production of MP jackfruit provided a basis for pricing of the product.

#### *Philippines*

Cooperative studies with farmers established the product marketing descriptions for pineapple for use in minimal processing. A literature search and survey were undertaken of existing systems. These served as a basis for developing processing and packaging technologies for MP pineapples. A suitable primary package was identified and found to be suitable for modified atmosphere packaging of mechanically peeled, whole MP pineapple. A modified atmosphere with 2–8% O<sub>2</sub> was established which could extend the shelf life by reducing oxidation and retarding the growth of microorganisms.

A number of studies highlighted the need to establish a minimum fruit maturity for MP pineapple. It was found that quarter-ripe criteria based on flotation methods were suitable for minimal processing.

A survey on the utilisation of agro-chemicals by pineapple growers and an analysis of pineapple fruit determined the type and level of production contaminants and residues present in MP pineapple.

Suitable packaging materials were identified and used in larger scale trials in combination with chemical treatments to optimise shelf life. Preparation and washing methods were established to reduce the count of the microorganism of concern by 5 log reduction. It was found that *Listeria monocytogenes* may survive, but not grow, in MP pineapple. Shelf life values at 4–25°C were established. Information was gathered to prepare sampling plans for microbiological analyses and to identify bacterial contaminants in MP pineapples. It was found that pathogenic organisms were absent in MP pineapple and control measures were aimed at lowering the aerobic microorganisms, yeast and mould counts of the product. The study showed that strict sanitation was important to produce a product that is microbiologically acceptable.

The washing and chlorination of raw whole fruit which led to a 5 log cycle reduction in *L. monocytogenes* from raw material to MP product was used as the basis for a HACCP plan for MP pineapple. The QA quality requirements were met by determination of the desirable fruit quality for minimal processing, the correct holding conditions for optimum shelf life, and monitoring of consumer acceptance by taste panel and spoilage. The HACCP plan has been made available for commercial use. A training workshop has been scheduled to demonstrate the whole process to approximately 25 participants.

Two runs of MP pineapple were conducted. Packs of MP pineapple cylinders were test-marketed to five-star hotels. The industry collaborator will continue with the supply of the MP product using the HACCP system.

#### *Singapore*

Surveys were conducted of current practices for the minimal processing of fruits, and the contaminants (pesticide and microbiological) and quality changes determined. Various physical and chemical test methods for MP fruits were compiled and validated. A rapid screening method for organophosphorous pesticides was developed and competency was achieved in the use of the Vitek Immuno Diagnostic Assay System (VIDAS) detection system for selected pathogens. The method of isolating and analysing filth from MP fruit samples was refined and adopted. Additional analytical procedures were adopted for use in monitoring the contaminants and quality characters of MP fruits. Two laboratory testing programs were undertaken. Surveys were carried out on jackfruit, pineapple and dragon fruit for pesticide residues.

GMP was studied at a number of MP fruit processors. As a result, a GMP/HACCP guide was developed for MP fruit plants. This was followed by the use of GMP for the set-up of a pilot MP fruit processing plant. A HACCP program was also used at a MP fruit processing plant.

A Good Agricultural Practice systems analysis was carried out at the National Trade Union Congress (NTUC) Fairprice Cooperative Ltd and as a result, NTUC is adopting QA for all its fresh outlets, with three reaching ISO 9002 to date.

#### *Thailand*

The market description for MP durian was established and the existing market chain was studied to produce a flow chart of the marketing system. The optimum level of ripeness was studied in order to test methods for evaluating this quality parameter. It was shown that potassium iodide staining could be used as one measure to determine durian maturity. The raw material characteristics for MP durian were established.

An appealing primary package was designed to prevent formation of water film on the surface of the MP fruit. The package, as designed, is suitable for highly aerobic packaging. No microbial problem was detected. However, this does not mean that MP durian would have less food safety issues.

Shelf life was determined at selected chilling temperatures. Pre-storage and storage technologies were studied to inhibit deterioration with respect to key factors. Processing procedures were developed for the removal and handling of durian flesh. It was found that high velocity air could reduce the effort in dehusking durian and caused less damage to the pulp.

MP durian were surveyed to identify production/postharvest and processing contaminants, and food safety measures were developed to identify these contaminants. Studies on MP durian indicated that durian pulp does not have any residue problems with pesticides of the organophosphate or carbamate groups, or with toxic heavy metals. The project demonstrated that there is a need for hygiene and careful processing of the product to prevent microbial contamination. However, no pathogenic organisms were found in the studies.

The shelf life of the MP product has been determined for selected chilling temperatures. Durian pulp packed in the selected storage system using a tub and PVC film covered with a rigid lid was able to be stored at 2°C and 5°C for 4 weeks. The eating quality was acceptable and it was safe for consumption based

on microbial tests. It was demonstrated that contamination with moulds was the main factor limiting the shelf life of MP durian. The treatments evaluated included SO<sub>2</sub>, metabisulphite, and alcohol vapour. Of these, alcohol vapour offered the best prospects for usage.

Physiological parameters governing these QA systems were characterised. Research showed that, after removal, the pulp continued to ripen similarly to that in the intact fruit. The necessary steps for commercial adoption of QA systems of MP fruit were defined and developed with advice from commercial operators. The QA system incorporating GMP and an initial HACCP plan was evaluated by the Australian consultants in October 1999.

#### *Vietnam*

MP dragon fruit specifications were defined for the local market. Suitable packaging material—packaging film having an oxygen transmission rate (OTR) of 4,000 cc/m<sup>2</sup>/day (21°C)—was selected. Studies were carried out on harvest maturity. Shelf life values at 4°C and 8°C were established. It was demonstrated that the use of fruit with a maturity of 28 days was essential, as the fruit had a pH less than 3.8 which allowed satisfactory storage for 8 days at 4°C.

A draft HACCP plan was developed for the processing of MP dragon fruit and a layout for a minimal processing facility was prepared. A flow diagram was developed combining the minimal processing and food safety procedures for the production of MP dragon fruit.

The QA system which was developed under the project was evaluated commercially by assessing consumer acceptance of the product marketed at the commercial outlet operated by the Post-Harvest Technology Institute (PHTI). The draft food safety guidelines incorporating a HACCP plan were evaluated by the food safety consultants. Based on these evaluations of the HACCP plan and the market acceptance of the product, it is considered that a commercially acceptable product using a QA system incorporating a HACCP plan has been produced.

## Conclusions

The initial projects on the development of QA systems for the marketing of fruit produced some quite significant results. Some of these results were as the result of thorough investigation of the total marketing systems from grower to retailer and identification of the major problem areas. Others utilised major advances in post-harvest technology. Some of the highlights were:

- Brunei assembled all available information on the local durians and related topics to produce a manual for the production and marketing of local durians.
- Indonesia produced a series of posters to illustrate the problems associated with marketing of 'Arumanis' mango over long distances and the methods which can be used to mitigate the effects of these handling procedures.
- Malaysia developed a set of checks and balances for use on farms and in packinghouses so that fruit are presented for marketing in an acceptable condition.
- The Philippines also produced a series of posters to illustrate the effects of handling malpractice and the correct methods of handling the pineapple fruit for market.
- Singapore established quick analytical procedures for fruits so that results can be provided in adequate time for decision making.
- Thailand conducted research which should allow long-distance shipping of durian with trial shipments going to Japan.
- Vietnam carried out a broad program resulting in a longer season for dragon fruit marketing, more consistent quality fruit and wider market penetration.

In the area of minimal processing of fruit, quite significant advances were made in the processing of the fruits, particularly with peeling of the fruits while minimising the risk of damage to the pulp and lowering the level of contamination to acceptable levels. Fruit quality was maintained for quite considerable periods using refrigeration and suitable packaging to prevent damage and provide a modified atmosphere for the product. GMP and HACCP programs were provided and evaluated for their effectiveness. Many of these programs need to be evaluated over time for their general applicability under commercial conditions but considerable progress was made in the project towards these ends. A selection of images taken during the course of the project are shown in Figures 1–12.

# Case Study on Development of a Quality System to Foster the Establishment and Growth of the Durian Industry in Brunei Darussalam

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## Abstract

A quality system has been developed within the durian industry in Brunei Darussalam. This system has been designed to both foster the development of the durian industry in Brunei Darussalam whilst also acting as a model quality system for horticulture in the region.

The Durian Quality Plan that has been developed focuses on a total management approach — commencing with initial site selection through to final product delivery to the customer. The development of the quality system was based on the principles of planning, implementation, monitoring and review, and was a cooperative team effort in every aspect of program design and development.

## Background

THE IN-COUNTRY Quality Assurance (QA) Workshop on Understanding Quality Systems held in Brunei Darussalam on 20–21 August 1997, has provided a springboard for developing QA systems in horticulture. The concept of quality planning for the durian industry as a model for other horticultural industries in the country was used as the selected case study. With assistance from the Project Consultant for the Quality Assurance System for Association of South-East Asian Nations (ASEAN) Fruits (QASAF) Project, the Country Coordinator in Brunei Darussalam for the project conducted quality planning meetings with all persons associated with the durian fruit industry—from production through postharvest management to marketing the fruit. These quality meetings have put into action the theoretical principles elaborated at the workshop.

The whole quality planning process—which was conducted in a series of quality meetings—covered the selection of locations, soils, planting and other pro-

duction criteria, progressing through the whole process of postharvest handling from the farm, through the collector/trader, wholesaler and marketer, to the retailer. In Brunei Darussalam, the intent of the project was to initiate a strong, commercial durian industry rather than to evaluate an existing industry.

## Objectives

The major objectives of the work undertaken to develop the Durian Quality Plan were:

- to develop a quality plan as the foundation for the future development of the QA system;
- to establish an appropriate action plan for future development of the durian quality program, including appointment of a Durian Quality Team;
- to plan an industry over the next 10–20 years; and
- to produce a management tool to aid commercial investors and durian industry operators.

## Formation of the Durian Quality Team

The Durian Quality Team was established to define and prioritise activities required to improve the existing system and carry out the activities defined in the quality plan. Participants involved in the team

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included experts representing production, soil science, crop protection, technical services, growers, extension, postharvest issues, marketers, food technology, and project consultants.

### **Target Audience of the Project**

The audience that the Durian Quality Team targeted with this project included:

- growers in the durian industry;
- all people involved in handling, processing, wholesaling and retailing durian fruit;
- potential investors;
- researchers;
- administrators; and
- ASEAN growers in the durian industry.

### **Activities Involved in the Development of the Durian Quality Plan and Durian Quality Management Manual**

In the development of the Durian Quality Plan, market preferences for fresh and minimally processed (MP) durian were analysed using consumer and market research undertaken by the Food Technology Unit of the Brunei Agriculture Research Centre. These assessments took into account consumer purchasing patterns and other related socioeconomic factors. In turn, draft market descriptions for fresh and MP durian were developed.

A quality plan was created in which all operations involved in the production, distribution and marketing of fresh and MP durian in Brunei Darussalam were encompassed in a flow chart. For each operation, the potential hazards, their causes, potential or actual controls, and critical limits were identified. Specific responsibilities were allocated for monitoring and/or actioning controls and corrective actions, and records were made. Where appropriate controls for hazards were unknown, further actions were decided upon and the necessary inputs determined involving what needed to be done and by whom, and a time frame was developed for carrying out the tasks.

Activities for fresh and MP local durian were identified and prioritised by the Durian Quality Team, and translated into an action plan for 1998–2000.

Based on the Durian Quality Plan, a Durian Quality Management Manual for Brunei Darussalam, for fresh and MP durian, was developed and documented. The structure and content of the manual were developed

during several meetings and discussions involving members of the Durian Quality Team and Project Consultants from Australia, and is an output of the Durian Quality Plan developed earlier.

The Durian Quality Plan and the Durian Quality Management Manual have been reviewed and updated regularly.

For the manual, each member of the Durian Quality Team prepared the procedures and information on all the subjects assigned to them. The first draft was then distributed by the National Country Coordinator to all members of the Team and the Project Consultants for review and comments. After the reviews and ongoing development of sections of the manual, the final document was prepared.

### **Successes of the Project to Date**

A combination of ‘unique’ factors make this project a step forward, including:

- market research was undertaken which provided information and guidelines for the quality planning;
- the diversity of the Durian Quality Team, where members well represented a wide range of expertise;
- the activities were identified and prioritised using relevant criteria;
- an action plan with practical time frames was established—this plan assists in the implementation of quality assurance systems for local durian;
- commercial sectors were involved;
- the style of manual gives practical solutions which allow people to make wise decisions as it provides options, unlike many documents which only provide the technology;
- management and prevention of problems were addressed;
- information to aid people in decision-making is available;
- regular review of the manual and quality plan by the team;
- identification of information that is known and what is not known locally or in ASEAN;
- recent research done on durian has reflected results of market research and the market descriptions that are required; and
- all team members’ contributions were reviewed by the team to ensure the information was complete and could be understood by others.

## **Future Activities—So Where To From Here?**

- Implementation by extension people.
- This case study is being used as a foundation for future development of quality assurance systems for other crops.

- Continuous and regular reviews and updating of the manual.
- The project outcomes and continuing process will be used to highlight areas where further information and research are needed to complement existing knowledge.

After all, quality management is all about continuous improvement; it embraces all aspects of the business or organisation and there is no finish line.



# Postharvest Development for Use in Quality Assurance for Durian

Sonthat Nanthachai\*

## Abstract

The durian (*Durio zibethinus* Murray) is one of the most famous and popular seasonal fruits in Southeast Asia, especially in Association of South-East Asian Nations (ASEAN) countries of which Thailand is the leading producer and exporter of this fruit. In 1998, Thailand produced more than 797,000 t of durian, but exported only 87,400 t of the crop, i.e. only 11% of total production. The main problem regarding the low export volume is a lack of suitable quality assurance (QA) systems for postharvest handling and marketing of durian. Under financial and technical support from the Quality Assurance Systems for ASEAN Fruits Project under the ASEAN–Australia Economic Cooperation Program III, essential postharvest handling technologies are being developed to solve this problem.

## Postharvest Development of Whole Fruit

### Quality requirements for durian fruit in export markets

MEETINGS and discussions were held with exporters to ascertain the requirements of 'Monthong' durian fruit exports to Taiwan and Hong Kong. The results showed that the Taiwanese market needs a more specific fruit size (2.5–4.0 kg) than the Hong Kong market which accepts a wide range of fruit size (2.0–5.0 kg). This is because the Taiwanese want 3–4 fruit in a 10–12 kg container while the Hong Kong market accepts 6–8 fruit in a 18–20 kg box. The two markets are not so strict regarding branding, but specify that the fruit should have more than three well-developed locules and green or slightly yellow skin.

### Marketing description for fresh durian

The information from exporters has led to the preparation of draft quality standards for durian export as follows:

#### *Fruit must be (minimum requirements)*

- intact and sound;

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- clean and free from visible traces of chemicals used;
- free from defects caused by insects and diseases;
- free from mechanical damage; and
- skin green to greenish-yellow.

#### *Classification*

- Extra—fruit contains more than four well-developed locules and has a uniform shape;
- Class I—fruit contains more than three well-developed locules; and
- Class II—fruit contains at least three well-developed locules.

Fruit in all classes should have no wet core when ripe.

#### *Size*

Durian are divided in to three size groups as follows:

- 2.0–3.0 kg
- 3.0–4.0 kg
- 4.0–5.0 kg

#### *Packaging*

- 3–4 fruits in 10–12 kg/box to Taiwan
- 6–8 fruits in 18–20 kg/box to Hong Kong
- identification
  - packer's and exporter's name and address
  - name of produce
  - origin—name of grower, district and/or country
  - commercial specification—class and/or size or number of fruit
  - storage at 14–16°C

### *Shipment:*

Transport by sea: 10 t per reefer container.

## **Maturity**

Fruit maturity is very important for durian marketing. Immature fruit cause a reduction in export volume and a drop in selling price. Several criteria such as peel colour, sweetness and flexibility of the fruit stalk, pulp and seed colour, percentage dry weight of fruit, days from anthesis, and especially the sound of the fruit when tapped are used for judging durian fruit maturity. These criteria, however, can not be applied properly to the large volume of durian for export because of their limitations with respect to speed and accuracy. In addition, some methods are destructive to this expensive fruit. Thus the Department of Agriculture, Kasetsart University and Chiangmai University were given the task of developing a quick and non-destructive test of fruit maturity which could be used at the collecting sites or packinghouse.

## **Appropriate disease control**

The pathogens found in durian during storage were mainly *Phomopsis*, *Laciodiplodia* and especially *Phytophthora* species. Two fungicides are generally used—aliette at 1,000 ppm and thiabendazole at 2,000 ppm—which can control the diseases during 10 days of storage at 14°C. The potential use of both these chemicals at higher concentrations for longer term storage of durian needs further investigation. Ozone application helps to control the mould occurrence on the peel and stem end of durian stored at 15°C and 80% relative humidity for 3 weeks. A preliminary study showed that ozone in combination with fungicide dip is more effective than fungicide dip alone in controlling postharvest diseases on the durian fruit surface.

## **Effect of temperature on storage**

The minimum storage temperature for fully mature ‘Monthong’ durian was previously known to be 15°C. The storage life of durian fruit at 14, 20, 25 and 30°C was 20, 10–15, 7 and 4–5 days, respectively. Fruit harvested at 118 days after anthesis developed chilling injury symptoms at 13.5°C and their storage life at 16.5°C was 2 weeks. Fully mature fruit (125 days after anthesis) could be stored at 13.5°C without chilling

injury for 2 weeks. At 16.5°C, fully mature durian ripened quite fast and could be stored for only 10 days.

## **Effects of ethylene and controlled atmosphere storage**

‘Monthong’ durian stored in air together with ethylene absorbent could be kept for up to 3 weeks, whereas those without absorbent could be stored for only about 2 weeks and were of inferior quality. Under controlled temperatures with 5–7% oxygen, however, there was no difference between fruit stored with or without ethylene absorbent. However, the eating quality of fruit kept under the controlled atmosphere conditions with 10% oxygen was not acceptable due to its off flavour.

## **Precooling for sea transportation**

After packing in the box, the fruit were precooled at 13–15°C using room cooling for 3–4 hours before being loaded into a precooled reefer container and transported by sea at 14–16°C.

## **Commercial application of QA systems involving the improved postharvest procedure**

Postharvest handling practices of durian for sea export are shown in Figure 1.

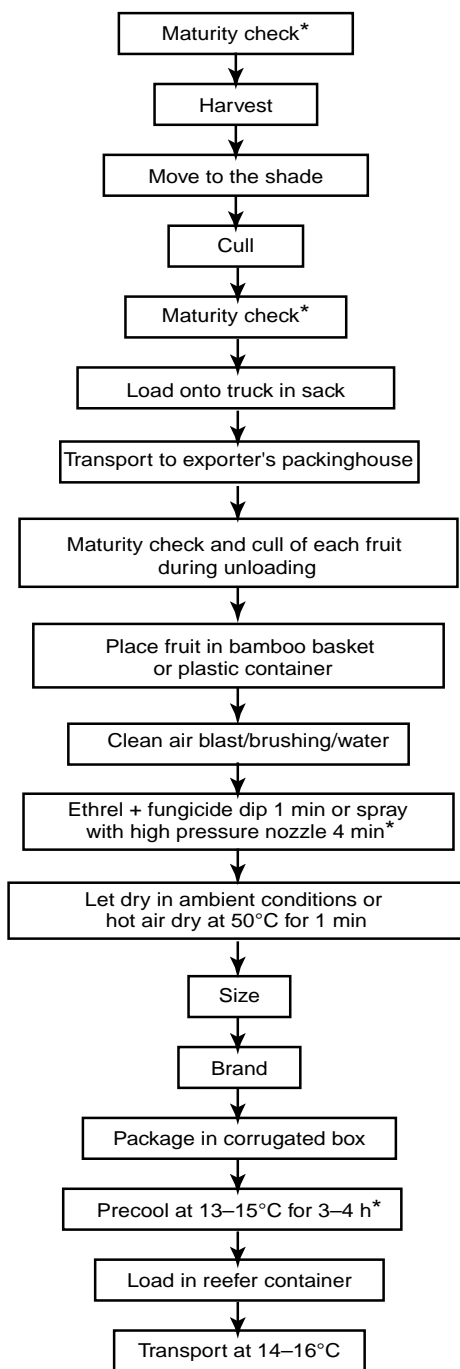
## **Postharvest Development of Minimally Processed Durian**

### **Consumer preference**

The varieties of durian preferred by customers for minimal processing—as ascertained through a consumer questionnaire—were 67% for ‘Monthong’, 32% for ‘Chanee’ and 5% for any cultivar. So the ‘Monthong’ cultivar was selected for use in the quality assurance systems test for minimally processed (MP) durian. The other advantages of this cultivar are its mild odour and firm texture, it is not sensitive to the rainy season and it has a long harvesting period.

### **Marketing description for MP durian**

Information about supermarket requirements led to the set up of a draft product market description for MP durian (chilled) as follows:



\* Critical control points

**Figure 1.** Procedures for the postharvest handling of durian for sea export.

*General description:*

1. Product type MP durian
2. Market Bangkok supermarkets
3. Variety 'Monthong'
4. Marketing period Off-season (October–March)
5. Delivery schedule Every week by truck using cool containers
6. Quantity per delivery.....kg

*Product quality:*

1. *General*  
Pulp with seed packed in white polystyrene tub overwrapped with polyvinyl chloride (PVC) stretch film and covered with PVC transparent rigid lid
2. *Size*  
Medium: 350–400 g net weight  
Large: > 400 g net weight
3. *Characteristics*  
Complete locule, fully developed pulp
4. *Colour*  
Even yellow
5. *Texture*  
Firm, soft
6. *Major defects*  
All packs are to be free of these major defects:  
– incompletely developed pulp  
– disease symptoms  
– mechanical injury—major wound from knife that penetrates pulp in more than one area
7. *Minor defects*  
Locule splitting— incomplete locule without destruction of nearby pulp in the same locule  
Colour—uneven yellow  
Mechanical injury—one wound from knife cutting in one locule  
Surface of pulp—one bruised area
8. *Tolerance*  
Major defects—nil for all grades  
Minor defects—not allowed for premium grade, but allowed for regular grade
9. *Product safety*  
No chemicals are to be used on MP durian. The product at the point of sale is not to contain any physical or biological hazards which may cause injury or illness to consumers.
10. *Packaging*  
Pulp is to be packed in a tub overwrapped with PVC film then covered with a PVC transparent rigid lid. In addition, a water absorber pad may be placed under the pulp to absorb excess water due to condensation caused by any temperature

fluctuations. Covered lid must be sealed with cellotape to ensure that the product has not been opened.

#### 11. Bulk packaging

Tubs are to be packed in fibreboard cartons with slots at either end or at both sides to facilitate forced air cooling. Packages are to be sealed with tape. Packages are to be filled with 12 tubs stacked in 4 columns.

#### 12. Labelling

Package is to be labelled with the brand or showing the production house address, expiry date, grade, variety, weight, storage conditions and recommendations for customers.

#### 13. Special requirements

All packages are to be cooled to 5°C during transportation, storage and display on shelves.

## Maturity

The number of days after anthesis and the sound made when the fruit is tapped are normally used to check durian fruit maturity. MP durian should be 113 days post-anthesis, left at room temperature until a hollow sound can be detected and then left for another day before the pulp is removed. In addition, potassium iodine staining is an effective test of durian maturity—the more mature the fruit, the longer the time taken for a brown stain to develop on the pulp.

## Fruit opening

Durian pulp for MP storage must be ripe but still firm. The pulp from naturally opened fruit will be too soft and opening the fruit with a knife will normally cause damage to the pulp. Ethrel dip, high velocity air, or ethrel together with high velocity air will facilitate fruit opening and cause less damage to the pulp than the regular procedure of using a knife to open the fruit.

## Effect of temperature on durian pulp storage

At storage temperatures of 2°C and 5°C, durian pulp did not show any differences in O<sub>2</sub>, CO<sub>2</sub> or ethylene production. Normally, durian pulp taken from the ripe fruit, then wrapped with PVC film on a foam tray, can be stored at 2°C or 5°C for 3 or 2 weeks, respectively. With carefully operating, however, the storage life of durian pulp could be extended to 4 weeks.

## Effect of SO<sub>2</sub> and radiation on disease control

Direct fumigation of the pulp using 2,000 ppm SO<sub>2</sub>, or placing 200–500 g of sodium metabisulfite in the tray with the durian pulp, can help to inhibit the occurrence of mould for 4 days at room temperature (29–34°C). However, irradiation with gamma rays at 2 kGy seems more promising as no signs of microbes were observed for 5–12 days under ambient conditions. The difference in the length of time that mould was inhibited might be due to the number and species of mould contaminated on the surface of durian pulp.

## Food safety

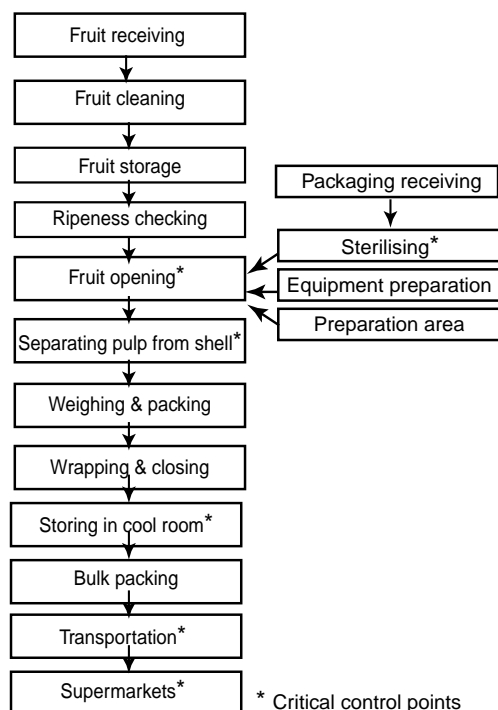
Experiments designed to develop food safety measures for use in QA systems for MP durian were conducted in May–June and June–July of the durian season. The fruit were surface cleaned and cut open using a sterile knife in a room in which the floor and table had been cleaned with antiseptic solution. All packaging materials and trays were sterilised in a 4 × 40 Watt UV-tunnel for 15 minutes. The pulp was checked for microbial contaminants every two weeks until its eating quality was unacceptable. The results of the microbial determination, shown in Tables 1 and 2, indicated that the pulp was safe for consumption throughout the experimental period.

**Table 1.** Microbial determination results of the experiment in May–June 1999.

Storage time	Treatment	Total viable count (colony forming units/g)	Yeast and mould (colony forming units/g)	Coliform (most probable number/g)
0 week	Initial	<10	none	<3
1 week	2°C	<10	none	<3
	5°C	<10	none	<3
2 weeks	2°C	<10	none	<3
	5°C	<10	none	<3
3 weeks	2°C	<10	none	<3
	5°C	<10	none	<3
4 weeks	2°C	<10	none	<3
	5°C	<10	none	<3

## Commercial application of QA systems for MP durian

MP durian production steps for QA systems are shown in Figure 2.



**Figure 2.** Minimally processed (MP) durian production steps for quality assurance (QA) systems.

## Acknowledgments

The author would like to thank the Australian Agency for International Development (AusAID) for financial support to the Quality Assurance Systems for ASEAN Fruit Project under the ASEAN–Australian Economic Cooperation Program III, and Australian Centre for International Agricultural Research (ACIAR) for financial support to attend this meeting. Many thanks to Dr Jingtair Siriphanich, Associate Professor of the Department of Horticulture, Kasetsart University, Miss Apinya Chudhangkura of the Institute of Food Research and Product Development, Kasetsart University, and Miss Benjamas of the Horticulture Research Institute, Department of Agriculture, for their information on QA systems for durian.

**Table 2.** Microbial determination results of the experiment in July–August 1999.

Storage time	Treatment	Total viable count (colony forming units/g)	Yeast and mould (colony forming units/g)	Coliform (most probable number/g)
2 weeks	2°C	none	none	<3
	5°C	none	none	<3
4 weeks	2°C	none	none	<3
	5°C	none	none	<3
6 weeks	2°C	none	none	<3
	5°C	none	none	<3
8 weeks	2°C	none	none	<3
	5°C	none	none	<3

# Quality Assurance System for Dragon Fruit

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## Abstract

Dragon plant (*Cereus undatus* (Haw.)) has been grown on a large scale since 1990 in Vietnam and is an attractive product for foreign consumers. However, the problems that affect the fruit quality have not yet been studied. The establishment of a quality assurance system for the dragon fruit, as part of the "Quality Assurance Systems for ASEAN Fruits" project of the Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program, was carried out in various farms and packing houses in Binh Thuan Province as well as in the laboratory of the Post-Harvest Technology Institute in Ho Chi Minh City (PHTI-HCM). The program involved PHTI-HCM, the departments of Technologies, Sciences and Environment, and Agricultural Extension of Binh Thuan Province, farmers, collectors, transporters, exporters, and importers. The quality standards, and methods of packing, storage, shipping, and handling, have been formulated to meet the requirements of both local and export markets.

In this study, the appropriate pre- and postharvest technologies for dragon fruit were generated and disseminated to the end users. The optimal harvesting times vary between the 25<sup>th</sup> and 28<sup>th</sup> days after flowering for export fruit, and the 29–30<sup>th</sup> days after flowering for local markets. The physico-chemical changes occurring during the fruit maturity period, such as respiration rate, total soluble solids, total acidity, firmness, skin colour, etc., were determined and used for evaluation of shelf life. Translucent flesh, an indicator of fruit chilling injury, was also determined. The chilling sensitivity of fruit depends on the harvesting time. They were more sensitive 25 days after flowering as compared to the rest of the experimental period. Dragon fruit should be stored at 5°C and 90% relative humidity to prolong its postharvest life. Application of potassium permanganate solution (0.2%) can extend the storage life to 40 days. During the postharvest period, common fungal pathogens such as *Fusarium lateritium*, *Aspergillus niger* and *A. flavus* were found and a fungicide mixture (benomyl and copper oxide chloride) was applied to control them.

THE DRAGON plant (*Cereus undatus* (Haw.)) comes from South America. Its fruit has been popular in Vietnam for a long time. In 1990, the Government of Vietnam supported the industry through extension programs that resulted in the export of between about 3,000 to 7,000 t per year between 1992 and 1997. The main importing countries for dragon fruit are China, Hong Kong, Singapore, and Taiwan. Because of its taste, attractive colour, and high nutritive values, the local and overseas markets for the fruit are growing. However, fruit quality is a problem that needs to be improved in order to meet market requirements.

The growing of the dragon plant is very attractive to farmers because they can get more income from

dragon fruit than from crops such as rice, maize, and beans grown in the same area. Therefore, the government is strongly supporting the expansion of the dragon fruit production. The current research, development, and extension programs on postharvest technology focus on: the determination of the best harvesting time; prevention and control of insects such as ants, an unknown pest species of lepidopteran, and fruit fly; the use of plant growth regulators; and methods of handling and storage of the fruits. The work is supported by the Australian Agency for International Development (AusAID) through its project "Quality Assurance Systems for ASEAN Fruits". The results of the project's dragon fruit activities are reported here.

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## Materials and Methods

### Survey and data collection

A survey was conducted in the project site at Binh Thuan Province. Data on farming practices, hazard factors, and the related information on the production and marketing of the dragon fruit were collected and analysed.

Questionnaires on product description were sent to farmers, collectors, importers, exporters, transportation managers, quality managers, wholesalers, retailers, and consumers for their comments, suggestions, and recommendations. The product description was then prepared and disseminated to the parties concerned.

The cooperators were selected from among farmers who attended a training course on postharvest handling and who participated in the quality assurance system of the project.

The participants in the system were:

- Post-Harvest Technology Institute, Ho Chi Minh City;
- Department of Science and Technology and Environment of Binh Thuan Province;
- Department of Agricultural Extension of Binh Thuan Province;
- collector—Ngo Van Tu;
- exporter—Van Loi Company;
- importer—Kien Ping Company, Hong Kong;
- retailers—Coopmart, Super Bowl, Mien Dong supermarket; and
- farmers—Vo Van Tuyet, Le Van Mai, Vo Hong Chien.

### Harvesting index determination

The study was conducted in a three-year-old dragon-fruit production farm at Ham Hiep village, Ham Thuan Nam District, Binh Thuan Province. In the morning on 5 June 1998, 170 flowers on the east side and the same number on the west side of the plants were randomly tagged. Those flowers had opened on the previous evening.

From the 16<sup>th</sup> day (21 June) after the date of flowering, 30 fruit from each side were harvested at 3-day intervals. The harvesting time was 4.00 p.m. and the fruit were transported to the Post-Harvest Technology Institute (PHTI) at 7 a.m. on the following day.

Ten fruit were selected for measuring of their diameters (cm), weights (g), and skin colours (value

( $L^*$ ), hue ( $a^*$ ), and chroma ( $b^*$ ) using the Minolta colour meter).

A separate batch of 10 fruit was placed in the respiration containers for 24 hours and their respiration rates (RR) at harvest time were measured by the continuous airflow method (170 mL/min), using CO<sub>2</sub> analysing equipment (infrared absorption model ZFP YAl) at 22–24°C. The formula of respiration rate is calculated as follows:

$$\text{RR (mg CO}_2\text{/kg/h)} = [(C_1 - C_0) \times L \times 60 \times 273 \times 44 \times 1,000] \div [100 \times 22.4 \times ({}^\circ\text{t} + 273) \times M] \quad (1)$$

where:

$C_1$  = CO<sub>2</sub> concentration (%) of sample;

$C_0$  = CO<sub>2</sub> concentration (%) of control;

$L$  = airflow rate (mL/min);

273 = Kelvin temperature (K);

${}^\circ\text{t}$  = temperature in degrees Celsius;

44 = molecular weight of CO<sub>2</sub>;

22.4 = volume (mole); and

$M$  = sample weight (g).

The last 10 fruit were used for measuring titratable acidity (concentration of citric acid equivalent (mL) per volume of juice), total soluble solids ( ${}^\circ\text{Brix}$ ), total solids content (% dry weight) and specific gravity (g/mL).

With portions of these same fruits, and based on a 10-point hedonic scale, a panel of three judges assessed the pulp-eating quality of the fruit.

### Chilling sensitivity

At 25, 30, and 35 days after flowering, 48 fruit were harvested and held in four cooling cabinets, 12 to each cabinet, at constant temperatures of –2°C, 0°C, 4°C, and 6°C.

The skin colour of two fruit from each cabinet was observed and recorded each day. Then, three days later, two fruit from each cabinet were removed to room temperature. The skin colour, firmness, total soluble solids (TSS), titratable acidity (TA), and eating quality of one fruit was measured. The other fruit was held at the room temperature for three days, then its skin colour, firmness, and TSS were determined using a Minolta Colorimeter CR200b, a penetrometer (with a large head), and hand-held refractometer from Atago, respectively. The TA of the fruit was measured by titration with 0.1 N NaOH and indicated as percentage citric acid. Eating quality was also determined and recorded.

Translucency, which is a symptom of chilling injury, was estimated on a 0 to 5 scale, where 0 is no translucency and 5 is the highest translucency.

## Results and Discussion

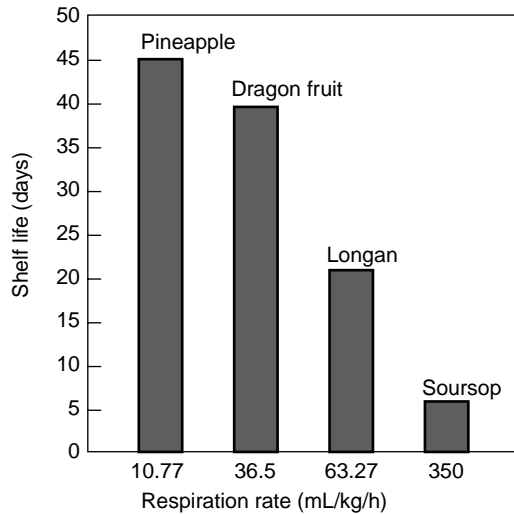
### Harvesting index

#### Respiration rate

Figure 1 shows that the maximum respiration rate of dragon fruit occurred 19 days after flowering. The respiration rate at that time was about 283 mg CO<sub>2</sub>/kg/h. However, on and after the 22<sup>nd</sup> day, these respiration rates fell abruptly and varied between 50 and 120 mg CO<sub>2</sub>/kg/h, perhaps indicating that the fruit had entered the maturation phase. Data show that dragon fruit is a non-climacteric fruit; it has a low respiration rate during the maturation period and should be harvested when ripe for good quality. The relationship between respiration and shelf life is indicated in Figure 2. Dragon fruit's shelf-life can be 30–45 days under optimal conditions.

#### Acidity

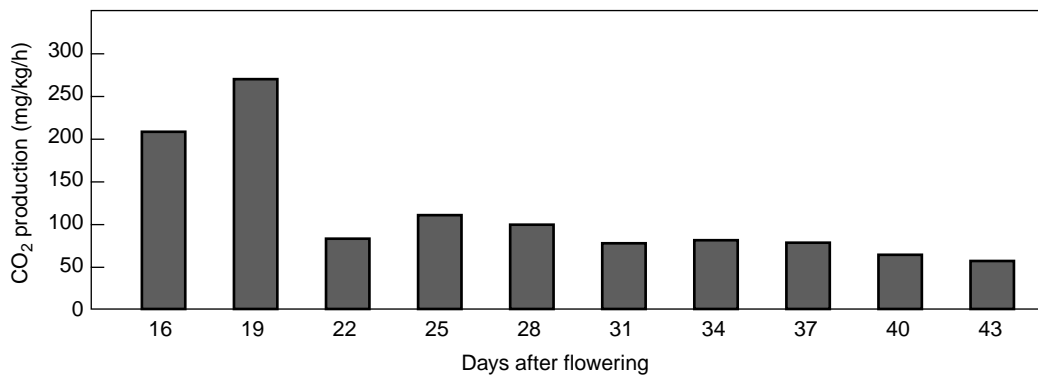
Sixteen days after flowering the acidity of flesh increased for a few days then fell abruptly and remained in low concentrations until harvest. The data show that these values varied from 0.23% to a high of 1.41% at the 16<sup>th</sup> and 22<sup>nd</sup> days after flowering, respectively. However, three days after that, acidity fell to 0.62% and remained below 0.40% for the rest of the observation period (Figure 3). This suggests that during the early stage of fruit development, the process of biosynthesis of organic acids was taking place resulting in an increasing H<sup>+</sup> concentration. An antocyan pigment cycle layer appeared between flesh and skin, then expanded outward and the colour of the skin became red on the 19<sup>th</sup> day.



**Figure 2.** Respiration rate and shelf life of some tropical fruits under the optimal storage conditions.

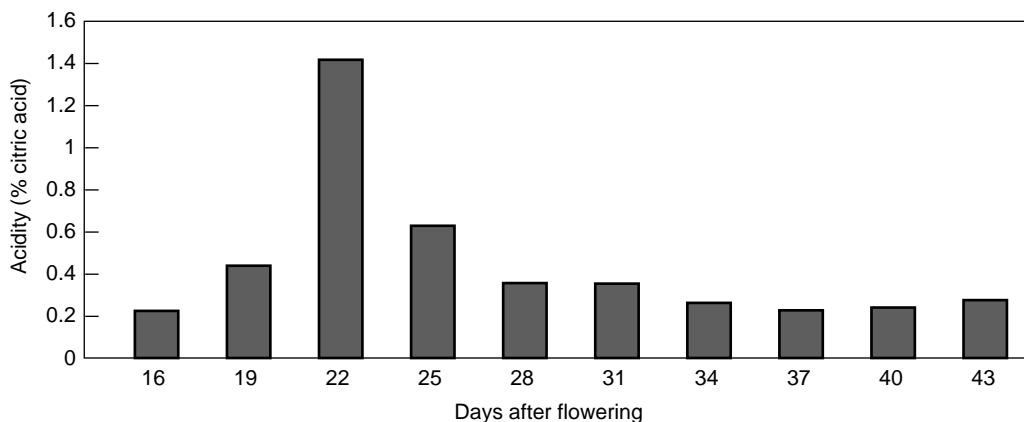
#### Total soluble solids (TSS)

The values TSS of the fruit varied from the lowest (5.4°Brix) on the 19<sup>th</sup> day to the highest one (15.2°Brix) on the 43<sup>rd</sup> day (Figure 4). The data indicate that TSS increased rapidly during the early stages of fruit development. The value of TSS was above 12°Brix when the fruit was 25-days old, and was maintained between 12–16°Brix during the observation period. This is why our farmers wanted to keep the fruit on the tree longer, in order to get sweeter fruit.

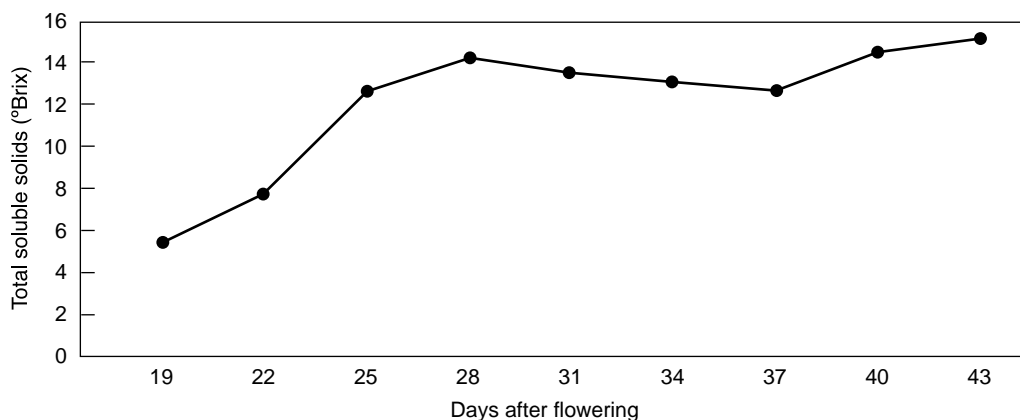


**Figure 1.** Change in respiration rate during fruit development.





**Figure 3.** Change in acidity during fruit development.



**Figure 4.** Change in total soluble solids (TSS) during fruit development.

However, consumers in the international market prefer dragon fruit that are not very sweet. Therefore, the appropriate harvesting date for fruit for export should be based on the TSS/acidity ratio, which is the most important factor indicating the value of the fruit. Normally, the acceptable TSS/acidity values vary, depending on the kind of fruit. For dragon fruit this value may be 40. Figure 5 indicates that the fruit achieved this value at 31 days after flowering. Moreover, the data also indicate that if the market prefers the taste of the fruit either less sweet or sweeter it can be harvested earlier or later than 31 days, respectively.

#### *Firmness*

Figure 6 shows that the firmness fell rapidly between the 16<sup>th</sup> to 25<sup>th</sup> days after flowering, with

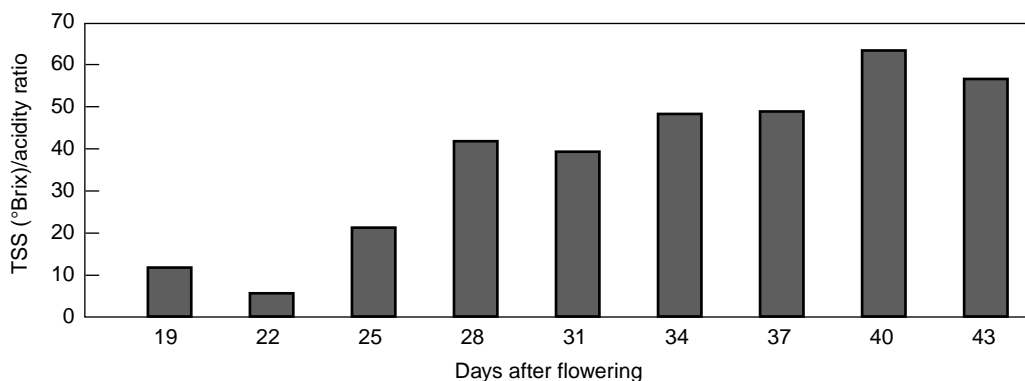
values of 2.4 kg and 0.82 kg, respectively. They then fell to between 0.45 and 0.90 kg for the rest of the observation period. This parameter indicates that the harvesting time should be determined by the softness of the fruit. If the fruit are very soft (firmness <0.90 kg), handling and transportation become difficult. Greater damage will occur and the market value of the fruit will fall.

#### *Change in peel colour*

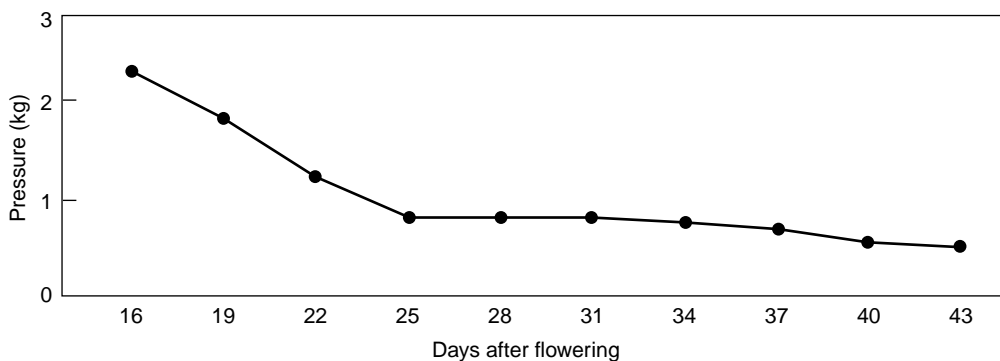
Changes in the colour of the peel of dragon fruit are very difficult to distinguish. However, a standard colour index for the fruit is needed to help the people understand and decide the correct harvesting time. Figure 7 indicates the changes of value ( $L^*$ ), hue ( $a^*$ ) and chroma ( $b^*$ ). The  $L^*$  value varies little, ranging from a low of 44.2 to a high of 53.4. Generally, this

value changed little during the observation period. The values of chroma ( $b^*$ ) were about 52 to 53.5 until the fruit was 22 days old. They then fell to below 15 during the rest of the observation period. Data indicate that value ( $L^*$ ) and chroma ( $b^*$ ) could not be used alone to determine the harvesting time because they changed little. On the other hand, the values of hue ( $a^*$ ) ranged between 18.2–17.6 in the early stage of

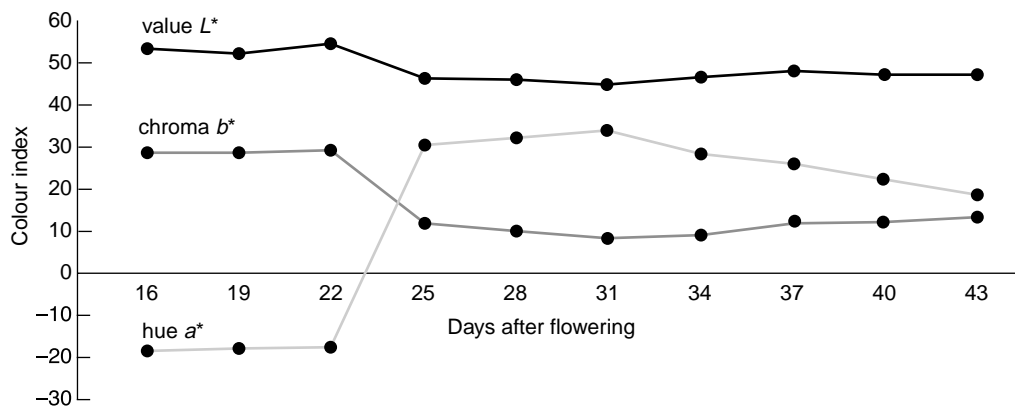
fruit development, but abruptly rose to 30.1 or higher when the fruit was 25 days old. These data are useful for the determination of the appropriate harvesting time in order to have the preferable TSS/acidity ratio. For example, if the selected TSS/acidity ratio is 40, then the values of the three parameters, value ( $L^*$ ), hue ( $a^*$ ) and chroma ( $b^*$ ), should be 44.2, 35.5 and 0.8, respectively.



**Figure 5.** Change in the total soluble solids (TSS)/acidity ratio during fruit development.



**Figure 6.** Change in firmness during fruit development.



**Figure 7.** Changes in the colour of dragon fruit during development.

### Eating quality

The eating quality of fruit was determined using a hedonic scale. Figure 8 shows that the lowest hedonic value was 3.1 when the fruit was 22 days old. This value was 8.1 when the fruit started ripening at 25 days after flowering. The highest score (8.5) was recorded when the mature fruit were 28–31 days old. This coincides with the preferred TSS/acidity ratio as indicated in Figure 5. However, the quality of the fruit was maintained until the 43<sup>rd</sup> day (Figure 8). It has been mentioned above the sweetness or TSS of the fruits was high during that period (Figure 4). At 43 days, the hedonic score was 8.3, which means that some people want to eat a sweeter fruit.

### Fruit development

Figure 9 illustrates fruit development towards and past optimal harvest time.

## Chilling sensitivity

Table 1 indicates that at temperatures of 0C and below, regardless of the age of the fruit, after 17 days of storage, translucency of the fruit was maximal (score 5). When fruit were harvested at 25 days old and stored at 4–6°C the translucency score was 4. When 30–35-day-old fruit were stored at 4 and 6°C, the translucency scores fell to 2 and 1, respectively. It was also observed that at 6°C, the 25-day-old fruit was injured after 7 days of storage, whereas injury to the 30 and 35-day-old fruit was not evident until 17 days of storage. The results indicate that fruit should be

harvested on 30–35<sup>th</sup> day after flowering to avoid chilling damage during storage.

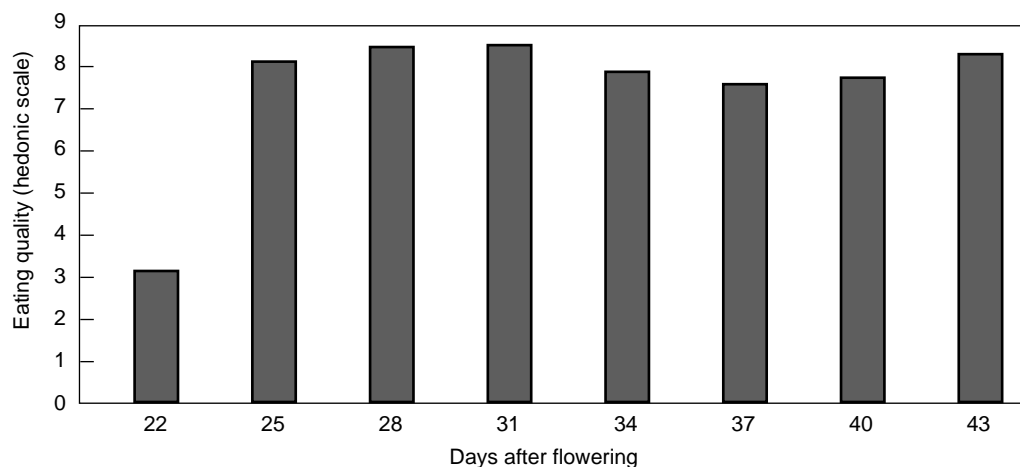
**Table 1.** Effects of storage temperature (°C) and age of dragon fruit on chilling sensitivity (translucency) measured after 17 days of storage.

Temperature (°C)	Days after flowering (age of the fruit)		
	25	30	35
–2	5	5	5
0	5	5	5
4	4	2	2
6	4	1	1

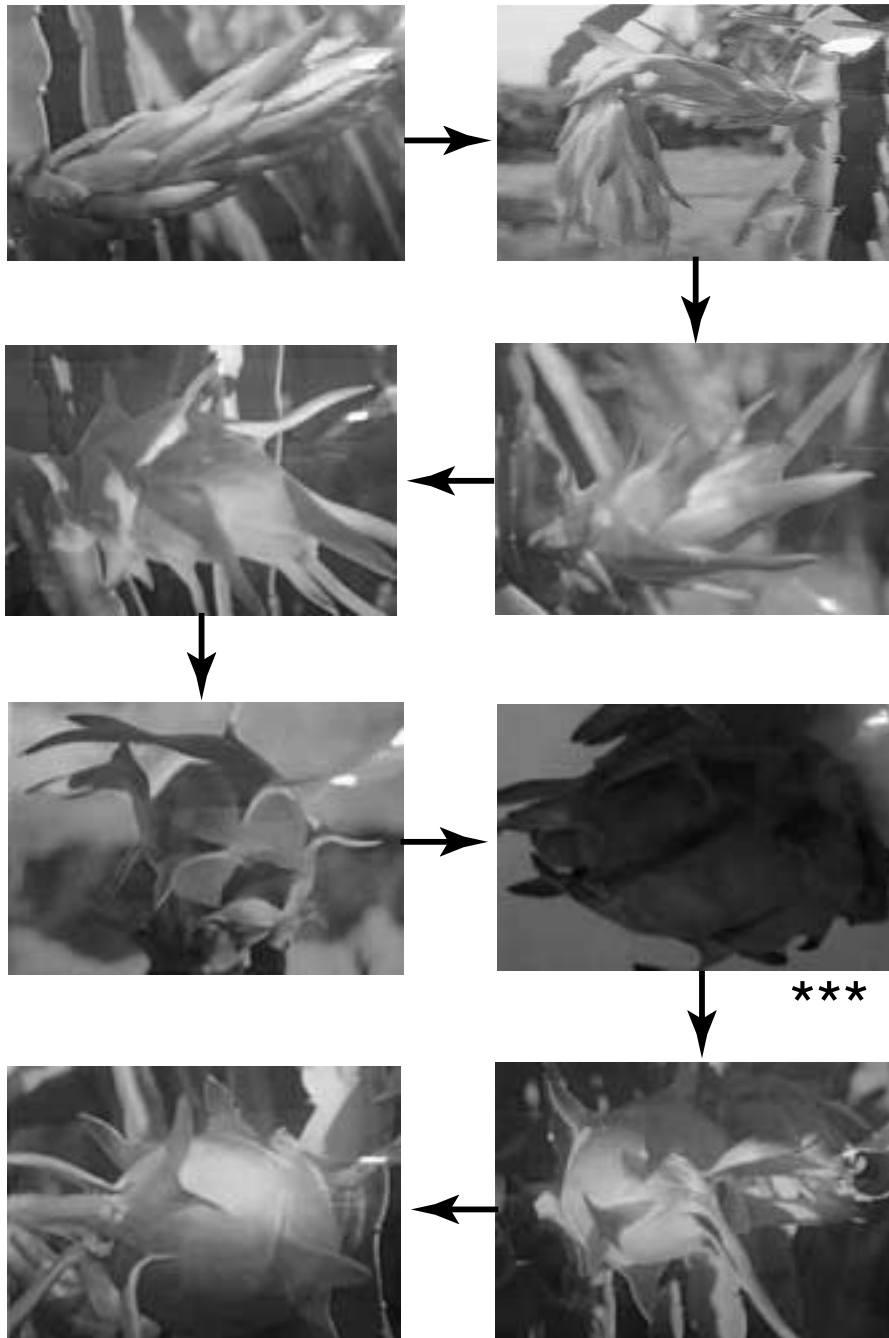
## Fungi on stored dragon fruit

The following species of fungi were found on dragon fruit during storage:

*Alternaria alternata*, *A. cheiranthi*, *Aspergillus avenaceus*, *A. awamori*, *A. clavalus*, *A. flavus* var. *columnaris*, *A. fumigatus*, *A. oryzae*, *A. niger*, *A. tubingensis*, *Curvularia lunata*, *C. oryzae*, *Cladosporium oxysporum*, *Corynespora abelavata*, *Fusarium semitectum*, *F. lateritium*, *Haplariopsis fagicola*, *Mucor hiernalis*, *Penicillium charlesii* and *Syncephalastrum racemosum*.



**Figure 8.** Eating quality of fruit during fruit development.



**Figure 9.** Development of dragon fruit from flowering to harvest. The image marked \*\*\* shows the fruit at optimal harvest time: 28–31 days after flowering; total soluble solids(TSS), 13–14%; titratable acid (TA), 0.3%; TSS/TA 40; colour index 45, 35, 8 ( $L^*$ ,  $a^*$ ,  $b^*$ ); and firmness, 0.87 kg.

## Nutrient composition and residues of pesticides on dragon fruit

Table 2 gives measurements of the composition of the endocarp of dragon fruit examined in this study. In all samples, the main component was moisture (84.0–86.0 g/100 g), with little protein (0.93–1.33 g/100 g) or fat (0.40–1.01 g/100 g). Crude fibre was around 0.88–1.84 g/100 g. Carbohydrate composition was found to be 10.4–12.3 g/100 g. Glucose was present at 4.63–6.39 g/100 g, fructose at 2.16–4.06 g/100 g. There was no maltose or sucrose, but sorbitol was determined at about 0.33 g/100 g.

Table 3 gives the vitamin and mineral composition of the endocarp of dragon fruit. The levels of vitamin C, ranging from 1.0 to 6.3 mg/100 g, were at nutritionally insignificant levels. Thiamin and riboflavin were not detected. The two main minerals found were iron at 1.95–7.4 mg/100 g and potassium at 181.0–321.0 mg/100 g).

Dragon fruit has a lower energy value than banana or jack-fruit but is equal to durian, mango, and pineapple. However, its carbohydrate content is lower than any of those fruits. Some other minerals, such as iron, zinc, sodium, magnesium, are higher than found in other fruits. In particular, dragon fruit is rich in

potassium and is exceeded in this mineral by only banana and jackfruit (Table 4).

Dragon fruit is relatively tolerant of pests and diseases. Dragon plants can grow over a range of soils and climates, but produce the best quality fruit and highest yields when grown on low-nutrient, sandy coastal soils and at high air temperatures, conditions such as are found in Binh Thuan Province of Vietnam. Moreover, pesticides have rarely been used in dragon fruit production, as indicated by the results in Table 5.

## Quality Assurance System

### Quality assurance plan

The quality assurance plan for dragon fruit is shown diagrammatically in Figure 10. Figure 11 illustrates market quality requirements and the defects caused by pests, and improper transportation, cultural, and storage practices. Table 6 shows the hazard analysis—dragon fruit marketing chain in Binh Thuan Province, and Table 7 provides details of appropriate product descriptions for dragon fruit.

**Table 2.** Composition of red dragon fruit (g/100 g edible portion).

Test/sample	1	2	3	4	5	6	7	8	9	10	Average
Fruit weight (g)	351.24	454.31	443.34	358.66	350.88	353.81	357.58	413.94	409.91	444.49	393.82
Moisture	85.60	86.00	85.20	84.30	84.00	85.30	85.50	85.60	85.50	85.60	85.30
Crude protein	1.06	1.33	0.95	0.95	0.96	1.13	1.28	1.11	1.33	0.93	1.10
Fat	0.54	0.44	0.43	1.01	0.73	0.40	0.65	0.57	0.43	0.45	0.57
Glucose	6.10	6.39	5.15	5.62	4.63	5.41	6.25	5.94	5.40	6.14	5.70
Fructose	3.42	4.06	2.36	2.16	3.28	2.47	3.74	3.75	2.98	3.81	3.20
Sucrose	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maltose	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sorbitol	0.47	0.34	0.54	0.39	0.45	0.24	0.23	0.16	0.20	0.25	0.33
Carbohydrate	10.40	10.40	11.90	11.90	12.30	11.40	10.70	10.60	10.40	11.80	11.20
Crude fibre	1.84	1.29	1.06	1.24	1.48	1.19	1.21	1.50	1.75	0.88	1.34
Ash	0.58	0.53	0.47	0.59	0.51	0.62	0.68	0.61	0.60	0.39	0.56
Energy (kcal)	66.40	64.40	63.80	69.50	75.30	67.60	67.40	70.50	65.10	67.10	67.70

Source: Data provided by S.T. Chew, Primary Production Department, Singapore for report to the third meeting of the "Quality Assurance Systems for ASEAN Fruits" project, Jakarta, Indonesia, 1–2 December 1997.

Note: ND = not detected.

**Table 3.** Vitamin and mineral composition of dragon fruit (mg/100 g edible portion).

Test/sample	1	2	3	4	5	6	7	8	9	10	Average
Vitamin C	1.5	3.1	1.9	5.3	6.3	4.1	4.1	1.5	1.0	1.0	3.0
Thiamin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Riboflavin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Niacin	2.8	2.5	2.3	3.1	3.1	2.8	2.4	3.5	3.2	2.3	2.8
Vitamin A	0.0090	0.0078	0.0063	0.0186	0.0123	0.0120	0.0114	0.0117	0.0147	0.0066	0.0111
Calcium	8.0	8.5	7.6	9.9	8.8	11.1	12.8	15.6	11.3	8.3	10.2
Iron	2.41	3.18	2.83	7.4	1.95	3.21	–	4.04	2.47	2.84	3.37
Magnesium	34.5	37.9	38.0	40.6	38.7	41.2	44.3	42.4	42.1	29.5	38.9
Phosphorus	31.8	27.2	25.5	27.3	26.4	24.6	29.8	29.1	30.7	22.8	27.5
Potassium	263.0	267.0	236.0	299.0	241.0	300.0	310.0	321.0	306.0	181.0	272.0
Sodium	6.9	8.9	5.9	13.5	13.0	9.5	10.1	5.8	5.0	10.5	8.9
Zinc	0.29	0.38	0.34	0.42	0.34	0.33	0.26	0.37	0.34	0.38	0.35

Source: Data provided by S.T. Chew, Primary Production Department, Singapore for report to the third meeting of the “Quality Assurance Systems for ASEAN Fruits” project, Jakarta, Indonesia, 1–2 December 1997.

Note: ND = not detected.

**Table 4.** Comparison of the composition of some tropical fruits.

Component	Mangosteen	Banana	Durian	Jackfruit	Mango	Pineapple	Dragon fruit
Moisture (%)	83.4	75.7	81.1	72.0	81.7	85.3	85.3
Energy (kcal)	57.0	85.0	67.0	98.0	66.0	58.0	67.7
Protein (g)	0.5	1.1	2.2	1.3	0.7	0.3	1.1
Fats (g)	0.3	0.2	0.8	0.3	0.4	0.2	0.57
Carbohydrates (g)	14.7	22.2	14.8	25.4	16.8	13.7	11.2
Fibre (g)	5.0	0.5	1.6	1.0	0.9	0.4	1.34
Calcium (mg)	10.0	3.0	8.0	22.0	10.0	17.0	10.2
Phosphorus (mg)	10.0	18.0	38.0	38.0	13.0	8.0	27.5
Sodium (mg)	1.0	1.0	–	2.0	7.0	1.0	8.9
Magnesium (mg)	–	21.8	–	–	8.8	13.0	38.9
Potassium (mg)	135.0	398.0	–	407.0	189.0	146.0	272.0
Iron (mg)	0.5	0.10	0.70	–	0.40	0.50	3.37
Zinc (mg)	–	0.20	–	–	0	0.21	0.35

Source: Data provided by S.T. Chew, Primary Production Department, Singapore for report to the third meeting of the “Quality Assurance Systems for ASEAN Fruits” project, Jakarta, Indonesia, 1–2 December 1997.

**Table 5.** Analyses of the edible (flesh) portion of dragon fruit for pesticide residues.

Tests/sample	1	2	3	4	5	6	7	8	9	10	Average
Organochlorine compounds	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organophosphorus compounds	ND	M = 0.52 ppm	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrethroids	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dithiocarbamates	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-methyl-carbamates	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Source: Data provided by S.T. Chew, Primary Production Department, Singapore for report to the third meeting of the "Quality Assurance Systems for ASEAN Fruits" project, Jakarta, Indonesia, 1–2 December 1997.

Note: ND = not detected.

**Table 6.** Hazard analysis—dragon fruit marketing chain in Binh Thuan Province.

Problem	Probable cause	Potential control measure	Critical limits	Monitoring required	Corrective action	Documents/ records	Further action required
Production: abnormal shape of fruit	Using plant growth regulators (hormones) in the wrong way	Time of application	At least 12 days after flowering	Agro-extensionist to monitor	Follow dose and time of application recommended by supplier	Agro-extensionist to document and show photograph	
Splitting	Irrigation Prolonged ripening of fruit on plant	Time of harvesting	Not more than 35 days after flowering Limited irrigation after ripening	Agro-extensionist to monitor	Follow recommendations of agro-extensionists	Agro-extensionist to document and show photograph	
Bracts not straight; curled down, away from body	Prolonged ripening of fruit on plant Inappropriate consumption plan	Time of harvesting Adjust consumption of fruit	10 days after harvesting under normal conditions	Distributor, wholesaler, and retailer to monitor	Storage technology	PHTI <sup>a</sup> and handler study	
Smoothness of skin	Insects	Chemical and other measures	Under study	Agro-extensionist to monitor	Under study	Extension Centre and Dept of Science, Technology and Environment	Study species of insects and control measures

<sup>a</sup> PHTI = Post-Harvest Technology Institute.

**Table 7.** Product description for dragon fruit.

Description	No. 1 (top quality export fruit)	No. 2 (suitable for selected export and domestic markets)	Not acceptable (unsuitable for No. 1 or No. 2 grade)	Managing the problem
Fungal damage	Nil	Nil	Present	Control aphids in the field. Eliminate sooty mould from the packinghouse.
Insect damage	Lepidoptera damage (min.) Ant damage (min.) Fruit spotting bug (min.)	Lepidoptera damage (blemished) Ant damage (blemished) Fruit spotting bug (blemished)	Lepidoptera damage Ant damage Fruit spotting bug Fruit fly	Monitor to detect infestations in the field. Use suitable control measures (see booklet <i>Controlling insects in dragon fruit</i> for further details).
Skin splitting	Nil	Minimal	Worse than minimal	Harvest fruit before splitting occurs.
Cuts and punctures	Nil	Nil	Cuts Punctures	Harvest fruit gently. Transport fruit gently to prevent damage. Check baskets and crates for rough or sharp edges. Avoid dropping fruit.
Foreign matter	Nil	Nil	Chemical residues Dirt on fruit	Keep harvesting crates and baskets clean and in good condition. Do not place harvested fruit on the ground. Remove any dirt, chemical, insect residue etc. from fruit at the packinghouse.
Bruising			Bruise (pressure mark)	Avoid over-stacking baskets and cartons, which could cause pressure damage and fruit bruising.
Fruit shape	Well shaped	Slightly misshappen		Apply hormone sprays correctly (see booklet <i>Hormone sprays in dragon fruit</i> for detailed information).
Fruit colour	Good, full red colour over entire fruit	At least 70% red coloration on body of fruit and extending into bracts	(Russetted fruit are unacceptable)	Harvest fruit at the correct maturity stage.



**Table 7.** (Cont'd) Product description for dragon fruit.

Description	No. 1 (top quality export fruit)	No. 2 (suitable for selected export and domestic markets)	Not acceptable (unsuitable for No. 1 or No. 2 grade)	Managing the problem
Bract shape and colour	Bracts firm + green at tips + sides	Bract may show yellowing, but be at least light green at the tips and be upright	Yellow bracts Bracts not upright	Apply hormone sprays correctly (see booklet <i>Hormone sprays in dragon fruit</i> for detailed information).
Internal colour + firmness	Flesh shall be white + firm	Flesh shall be white + firm	Milky or translucent flesh not acceptable	Harvest before fruit become over mature Do not store for too long after harvest (maximum 1 week at 20°C and 4 weeks at 7°C).
Green spots	Nil	Up to 3 spots		Apply hormone sprays correctly (see booklet <i>Hormone sprays in dragon fruit</i> for detailed information).
Fruit weight	Extra large: > 500 g Large: >380–500 g Regular: >300–380 g	Extra large: > 500 g Large: >380–500 g Regular: >300–380 g Medium: 260–300 g Small: <260 g		Avoid producing small fruit by using irrigation and optimum fertiliser applications (see booklet <i>Fertilizing dragon fruit</i> for detailed information). Thinning of fruit may sometimes be necessary when crop load is too heavy.

## Conclusions

A system of quality assurance for dragon fruit has been introduced and accepted by dragon plant growers, quality managers, importers, and exporters. The program of quality assurance for dragon fruit could be extended and applied to other fruits, modified as required.

## Acknowledgments

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## Quality assurance plan

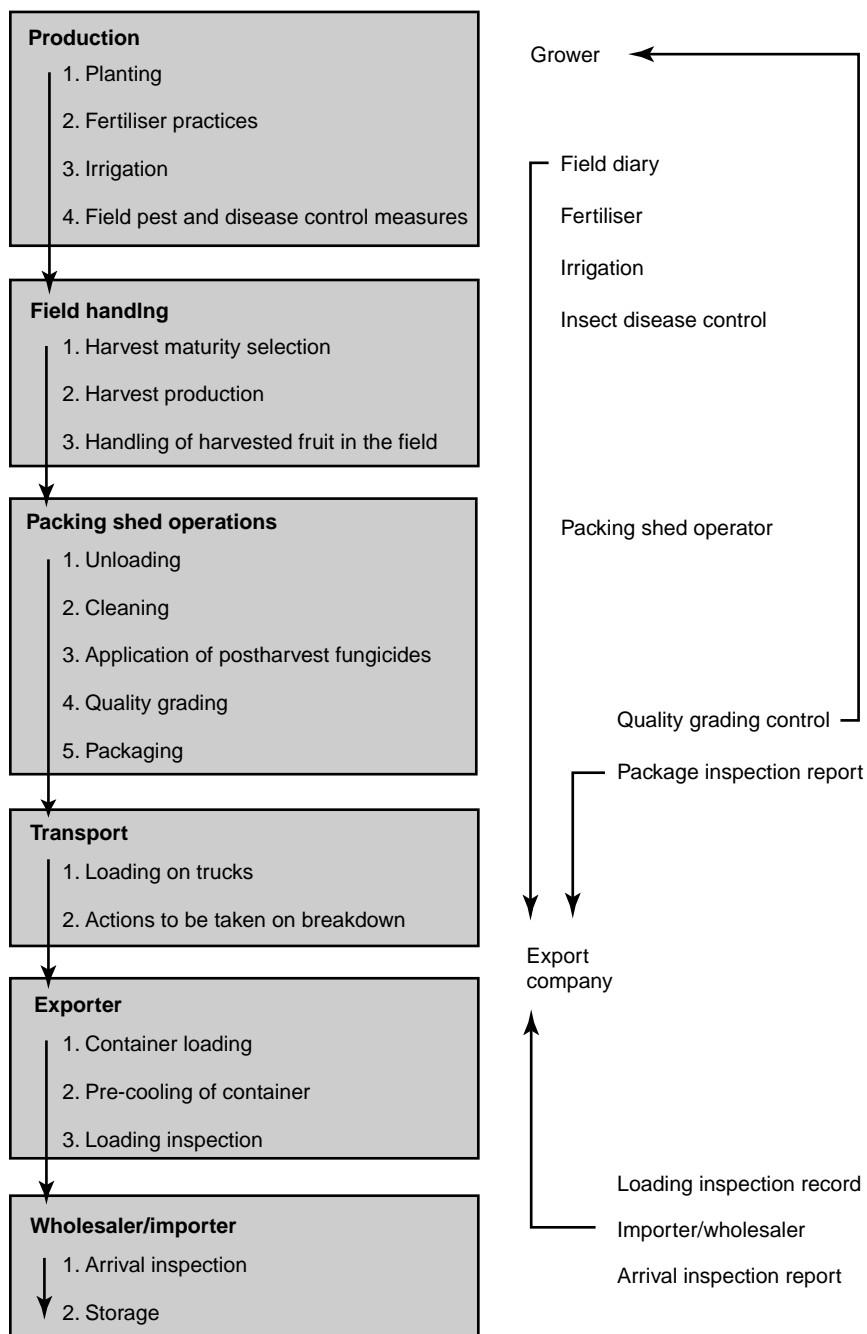


Figure 10. Steps in the dragon fruit quality assurance plan.

Ant damage



Aphid damage



Bruising



Dirt



Yellow bracts



Overripening



Coleoptera damage



Cuts



Puncture



Green spots



Abnormal colour



Chilling injury



### QUALITY MARKET REQUIREMENTS



- Weight: >300 g
- Good shape
- Full red colour
- Firm, hard, and green bracts
- Milky and firm flesh
- Not damaged by disease
- Maximum of 1 spot damaged or green spot caused by insect.

**Figure 11.** Market quality requirements for dragon fruit and defects caused by various agencies and improper practices.

# Establishment of a Quality Assurance System for Minimally Processed Jackfruit

**Mohd. Salleh Punan, Abd. Shukor Abd. Rahman, Latifah Mohd. Nor, Pauziah Muda, Ahmad Tarmizi Sapii, Rohani Md. Yon and Faridah Mohd. Som\***

## *Abstract*

Jackfruit (*Artocarpus heterophyllus*) of Malaysia is commonly consumed as fresh produce and hence is sold as whole fruit, sections/quarters and minimally processed (MP) products. The demand for retailing the fruit as MP products is expanding due to the recent trend of consumers towards ready-to-eat and quality produce. Both domestic and export markets prefer MP jackfruit in their retail outlets, especially at supermarkets, hypermarkets and fast food centres. Hence, there is a need to develop a proper minimal processing technique for the preparation of MP jackfruit. The operation involves harvesting at the right level of maturity, correct in-field handling, sorting, washing, ripening, cutting and removal of the core, taking and selecting individual fruitlets, packing, storage and transportation. These operations should be monitored consistently to ensure the quality and safety of end products. A quality assurance (QA) system has been established and implemented for the processing and management of the product from the point of harvest, postharvest operations and minimal processing, up to the retailing of the end products. The components in the QA system include control of raw materials, postharvest operations, sanitation at the processing plant, minimal processing unit operation and control of end products.

JACKFRUIT (*Artocarpus heterophyllus*) is one of the non-seasonal fruit crops grown widely in Malaysia. Depending on the type or clone, the fruit is consumed fresh, or as canned slices, fruit juice and dried chips. For fresh consumption, the fruit is commonly sold as whole fruit, sections/quarters and minimally processed (MP) produce. Recently, the demand for marketing jackfruit as MP product has been expanding due to the recent trend of consumers towards ready-to-eat and quality fresh produce. The demand is expanding not only within the traditional market outlets, but also in other market sectors such as food services, fast food outlets and food processors (Vinning 1995). The trend is similar in other Association of South-East Asian Nations (ASEAN) countries including Singapore and Brunei, where most of their produce comes from Malaysia. The reason for this trend is understandable, as MP produce offers some advantages, such as ease in serving portions of large

and difficult-to-peel fruit, reduced costs in packaging and transportation, more convenience, maintained freshness, extended shelf life and minimised quarantine barriers in some importing countries (Reyes 1997a).

Product quality is one of the prime factors in ensuring consistent marketing of MP jackfruit. It is well known that quality is a combination of various parameters demanded by consumers such as colour, appearance, shape, size, texture and taste. However, there is no precise measurement or standard unit to identify product quality objectively, since it is always associated with the degree of acceptance by the consumer (Kramer and Twigg 1970). A quality assurance (QA) system was proposed for the horticultural industry by the Natural Resources Institute (1994) to monitor the quality of fresh produce according to consumers' demands. The 'assurance' in QA has been defined as "consistently and reliably delivering products and services that have been predetermined by the markets" (Piccone and Bunt 1997).

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The QA concept is also essential in minimal processing of jackfruit to control variability in production and end-product quality due to differences in growing techniques, seasonal effects, a range of post-harvest conditions, variation in processing techniques and facilities, human factors and market conditions. This paper elaborates the quality system developed for implementation during preparation and distribution of MP jackfruit for both local and export markets. The components of the QA system include control of raw materials, postharvest operations, sanitation at the processing plant, minimal processing unit operation and control of end products.

## Minimal Processing Procedures

Minimal processing of produce results in the breaking of plant cells and liberating oxidising enzymes. The surface of the cut produce is exposed to the surrounding air, thus enhancing contamination by bacteria, yeast and moulds. The main factors limiting the shelf life of MP produce are enzymatic browning, white surface discoloration, microbial spoilage, senescence due to increase respiration and ethylene production, and degradation in nutritional value, texture and flavour (Reyes 1997b). Hence, it is important to ensure that all steps in the process are properly carried out to minimise physical injuries, avoid contamination and maintain high quality of end products. An appropriate procedure for the preparation of MP jackfruit was established for commercial operations. The procedure involves various steps of the operation from harvesting up to market delivery (Figure 1).

## Harvesting

Jackfruit should be harvested at the right stage of maturity. The maturity indices used for whole, fresh fruit can be used for choosing the correct harvesting stage of raw fruit for minimal processing. A maturity study conducted at the Federal Land Development Authority's (FELDA) farm verified that the fruit is fully matured after 14 weeks (100 days) from bagging, which is equivalent to 16 weeks from anthesis. At this stage, the ripened fruit has good eating quality in terms of aroma, texture, sweetness and taste—the total soluble solids (TSS) content has reached about 24°Brix, total sugar about 11–15%, while the total titratable acidity (TTA) is about 0.3%. It is recommended that fruit be harvested in the morning, as field heat is still low and tolerable to the produce.

Harvesting is done by cutting the stalk using a sharp knife and holding the fruit to avoid it dropping.

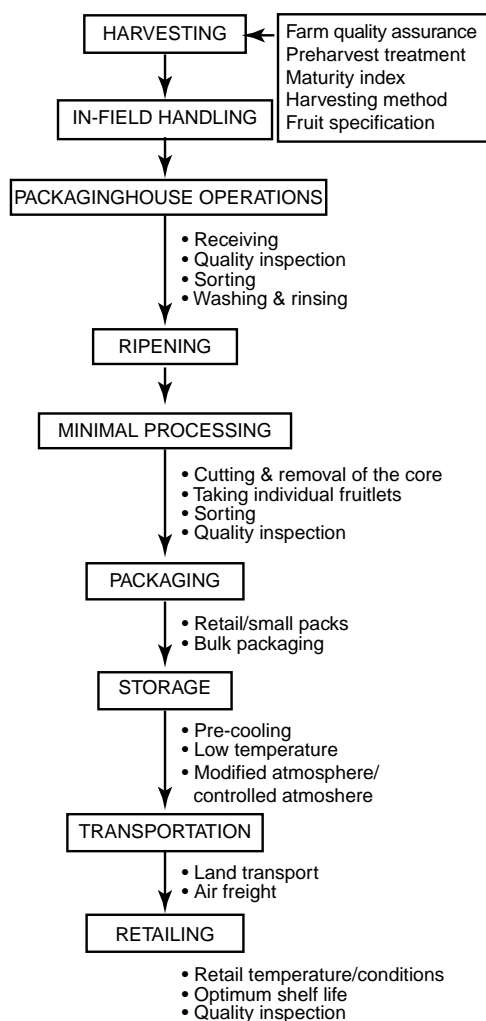


Figure 1. Minimal processing unit operations.

## In-field handling

Harvested fruit should be packed in bulk containers made of either plastic or wood and delivered to the MP plant by lorry or pick-up van.

## Packinghouse operations

Fruit received from farms should be inspected to ensure that the quantity (weight) and the quality meet the required specifications. The fruit should then undergo some minimum postharvest operations prior to minimal processing to ensure maintenance of high quality raw materials for processing. The minimum packinghouse operations include sorting, washing and rinsing. Washing of produce should be done using chlorinated water to remove dirt, foreign matter, latex stains and any field contamination. After washing, produce must be rinsed properly to remove excess moisture from the surface of the fruit.

## Ripening

Prior to the minimal processing, fruit should be ripened fully to achieve optimum aroma, sweetness, taste and eating quality. Fruit should be kept at ambient temperature to allow natural ripening within 3–4 days. However, uneven ripening is a major problem in the natural ripening process, especially for large-sized fruit. An induced ripening method is recommended for jackfruit to achieve more uniform ripening of the fruit. Induced ripening is done by keeping the fruit in a static or closed ripening chamber, equipped with an ethylene gas tank and a flow rate controller. Ethylene gas with a concentration of 50 parts per million (ppm) is flushed into the chamber set at 25°C. After 24 hours, the chamber is opened to allow continuation of the ripening process under ambient conditions. The fruit ripens 3–4 days after the treatment with ethylene gas.

## Minimal processing operation

Fruit ready for minimal processing should be shifted to a hygienic processing room to avoid microbial contamination of the cut surface. Basic operations may include cutting the skin using a clean knife to remove the core, taking individual fruitlets and sorting the fruitlets according to the required size, maturity and colour. Only full fruitlets (not half or partly cut) are recommended for retailing. However, fruitlets with or without seeds can be prepared according to the consumers' preference. Multiple handling of the fruitlets should be minimised during minimal processing to avoid injuries and contamination.

## Packaging

Minimally processed products should be packed properly using a suitable packing material and system. Packaging aims to protect the product from physical and microbiological hazards since their natural protector (the fruit skin) has been removed. The common packaging methods for MP jackfruit include polyethylene bags, polystyrene trays wrapped with polyvinyl chloride (PVC) film and polypropylene containers with lids. Sealing packages may also involve altering the concentration of respiratory gases inside the package to create a modified atmosphere system. Modified atmosphere packaging has also been found to be capable of preserving freshness and extending the shelf life of MP products such as pineapple, pomelo, durian and jackfruit (Anon. 1997).

## Storage

After packaging, MP jackfruit should be kept at a chilled temperature for storage before distribution. A storage temperature of 2°C was found to be suitable for extending the shelf life of MP jackfruit for 3 weeks (Anon. 1997).

## Transportation

MP jackfruit should be distributed using a refrigerated lorry or pick-up van. It is important to maintain the chilled temperature of 2°C throughout the distribution process to avoid deterioration. It is recommended that pre-cooled MP jackfruit be kept in thermal-freeze box to maintain the chilled temperature along the journey to retail outlets. For the export market, air transportation is recommended to ensure fast delivery. Transportation by refrigerated sea-freight may also be viable if the volume of the consignment is large enough and the shelf life of the product is long enough to fulfil the total shipping and distribution periods.

## Retailing

Most of the retail outlets for MP products are supermarkets, hypermarkets, the fast food sector, food service sectors and food processors. It is once again important to maintain the chilled temperature of the product at all outlet sectors to avoid deterioration. The product may be stored temporarily for a period of not more than the expected shelf life. All display racks or shelves in the supermarket or hypermarket should also be equipped with refrigeration facilities.

## QA System in Minimal Processing

The QA system was established as a management tool to support the minimal processing operation for jackfruit. The components in the QA system include control of raw materials, sanitation of processing plants, control of processing operations and control of end products.

### Control of raw materials

#### *Raw fruit specifications*

Fruit brought from farms into the minimal processing plant should comply with the specifications agreed on by the grower/supplier and processor. The specifications shown in Table 1 have been developed based on the Malaysian Standard of Specification for Fresh Jackfruit (SIRIM 1986). The specification can be used as guidelines for quality

inspection of raw fruit at the processing plant. Both processor and producer should agree on the tolerance limits of product quality to be delivered into the processing plant.

#### *Raw material inspections*

A system of inspection of all raw fruit entering the plant should be in place at all times. Inspection facilities such as calipers, balances and thermometers should be provided and used by trained staff. A standard quality form must be prepared and details recorded on it by the inspector. The details of the record include date and time of receipt and inspection, name of supplier, vehicle number, produce temperature on receipt, and condition or quality of produce according to the specifications. A decision of either to accept or reject the consignment must be made based on the inspection analysis.

**Table 1.** Specifications of fresh jackfruit for minimal processing.

Parameter	Specification
Variety	Yellow or orange-coloured flesh
Pest and disease farm control	<ol style="list-style-type: none"><li>1. Control of stem borer by pruning the infested plant parts, filling or injecting with methamidophos (tamaron), monocrotophos (azodrin) or dimethode (rogor)</li><li>2. Control of fruit borer and fruit fly by bagging the fruit, removing rotten fruit and spraying with insecticide</li><li>3. Control of fruit rot by spraying with fungicide</li></ol>
Preharvest practice	Bagging the selected fruit 2 weeks after fruit set
Maturity	100 days (14 weeks) from bagging
Harvesting method	Manually with sharp knife
In-field packaging	Fruit shall be packed in plastic containers, wooden crates or similar protective containers
Labelling	Each container shall be marked with the following information: <ul style="list-style-type: none"><li>• Name of produce/variety</li><li>• Net weight in kilograms</li><li>• Date of harvest/packing</li><li>• Name and address of producer/supplier</li></ul>
Quality requirements	Fruit shall be of similar varietal characteristics, fairly well formed, mature, not over-ripe, reasonable clean or free from stains, dirt and foreign materials, and reasonably free from injury, decay, disease, living and dead insects, moulds and other contaminants
Size classification	Fruit shall be classified according to size: <ul style="list-style-type: none"><li>• Large, weighing 16 kg and above</li><li>• Medium, weighing 8 kg to less than 16 kg</li></ul>

## Sanitation in the processing plant

### *Plant cleanliness and hygiene*

Sanitation in the plant involves consideration of layout design, maintenance of walls, ceilings, floors, doors, plumbing, water supply, refrigeration system, ventilation, glove/boot locker and toilet facilities (Cantwell 1996). The layout for a minimal processing plant can be divided into four main areas: packing-house area, minimal processing area, cold room facilities and management office. The overall cleanliness of the plant should be maintained since it is considered to be food processing plant. Non-splintering and easily cleaned surface materials should be used for work surfaces, walls and floors. Regular washing and cleaning works should be implemented using suitable chemicals and cleaning detergents.

The area in which it is most important to be hygienic—and thus should be monitored most closely—is the minimal processing area, where cutting of fruit, sorting and packing fruitlets are performed. The room should be isolated from other areas to avoid contamination. The room should be provided with a double-door access system to ensure maximum protection from insects and microorganisms. Surfaces for the walls, floor and ceiling of the room should be made from easy-to-clean materials. Washing, cleaning and sanitising should be scheduled regularly before, during and after processing activities. The room should be air-conditioned to control room temperature at about 15–20°C, so as to maintain freshness of produce during processing.

### *Equipment*

All appliances and facilities including knives, scissors, secateurs, containers and the cutting bench must be made from rust-proof materials, such as stainless steel or plastic. Equipment and appliances used in the processing works should be cleaned and sanitised. Basic steps for sanitation involve physical cleaning, pre-rinsing, detergent application, post-rinsing and sanitation using either steam, hot water, chemical detergent or chlorinated water.

### *Staff and workers*

Staff and workers preparing and handling MP jackfruit have a great responsibility to ensure the health and safety of the end users. It is important to ensure that all staff and workers entering the plant—especially the processing area—wear clean apparel, gloves, caps and boots. Changing rooms and lockers for personal belongings should also be allocated to each worker.

## Control of processing operations

### *Production history*

Although production activities at the farm level do not directly influence the minimal processing operations, relevant information should be made available to the processor. This is important to the overall QA system so that corrective actions can be taken to improve the industry. Some of the information to be recorded includes source of fruit, grower's code or name, cultural practices, pest and disease management, and preharvest practices.

### *Work instructions*

Workers and staff involved in the processing plant should be given clear and easy-to-understand instructions in order to carry out their duties properly. The content of the instructions should explain the precise work to be done at every processing step. Work instructions should be made available to the workers either in the form of a manual or display charts.

### *HACCP*

The Hazard Analysis and Critical Control Points (HACCP) standard is well known in the food processing industry as a system of monitoring and controlling quality of processes and product, so that product is not contaminated with microbiological, chemical or physical hazards. The system has been recommended for implementation in the minimal processing of fruits and vegetables (Cantwell 1996; Reyes 1997c). For MP jackfruit, a HACCP worksheet has been established to monitor minimal processing operations right from receiving the raw fruit up to the distribution to retail outlets (Table 2). The guideline was verified commercially at the Federal Land Development Authority's minimal processing plant.

## Control of end products

### *End-product specifications*

The processor/producer and distributor/retailer for each specific market should clearly define end-product specifications. For MP jackfruit, the specifications shown in Table 3 are proposed as guidelines for quality inspection. Both the processor/producer and distributor/retailer should agree on the tolerance limits of end-product quality to be delivered into the market.



**Table 2.** Hazard Analysis and Critical Control Points (HACCP) worksheet for minimal processing of jackfruit.

Operation	Potential hazard(s)	Control measures	CCP (Yes/No)	Critical limit	Tolerance	Monitoring procedure	Corrective action
Receiving raw fruits	Fruit borers, fruit fly and fruit rot	Ensure in-field bagging and discard infected fruit	Yes	Infected area softened	10% area defects	Inspection of infected fruit	Wash with fungicide
	Blemishes, immature and overripe fruit	Discard blemished, immature and overripe fruit	No	Soft fruit, unripe fruit	Flesh too soft	Inspection of the flesh	Proper in-field handling
Washing and rinsing	Contamination due to the use of poor quality and recycled water	Ensure water quality, use 200 ppm chlorinated water and ensure removal of excess water (drying)	No	Fruit rotten	10% fruit defects	Monitor water quality	Replace water regularly
Fruit storage	Spoilage at non-ideal temperature	Cool rapidly (pre-cooling) and store at optimal temperature and humidity	Yes	10–12°C	12 ± 2°C	Record storage temperature continuously	Service coldroom regularly
Ripening	Uneven ripening, overripe	Induce ripening with ethylene gas, monitor ripening stage	Yes	50 ppm ethylene	3–4 days ripening	Detect aroma of ripened fruit	Use proper ripening room
Cutting, removal of individual fruitlets	Microbial contamination (through hands, knives)	Monitor cleaning regime, i.e. sanitiser concentration	No	Unclean appliances	Sanitised daily	Inspection before usage	Wash regularly
	Microbial contamination from peel	Remove all peel, minimise contact with flesh	Yes	Unwashed raw fruit	Flesh in contact	Inspection of flesh quality	Wash raw fruit before cutting
	Spoilage at non-ideal temperature	Operate in hygienic room with temperature at 15–18°C	Yes	Temperature 20°C	Airconditioned room	Record room temperature regularly	Use hygienic processing plant
Packing fruitlets	Contaminated packaging material	Ensure clean package, monitor microbial quality	No	Exposed package	Factory cleaning	Inspection of the package	Wash and dry package
	Spoilage due to incorrect atmosphere inside the package	Test packed sample for leaks, monitor composition of headspace gases	Yes	Modified atmosphere levels	Modified atmosphere limits	Measure head-space gases regularly	Use accurate MAP <sup>a</sup> design
Storage, distribution and retail outlets	Spoilage due to non-ideal temperature and humidity	Monitor storage and handling temperature and humidity	Yes	2–5°C	5 ± 2°C	Record temperature regularly	Service all facilities regularly

<sup>a</sup>MAP = modified atmosphere packaging

**Table 3.** End-product specifications for minimally processed jackfruit.

Parameter	Specification
Variety	Yellow or orange-coloured flesh
Stage of ripeness	Fully ripened but not overripe
Style of cut fruit	Individual fruitlets with or without seeds
Quality of fruitlets	Fruitlets to be of similar varietal characteristics, uniform colour and ripening stage, reasonably uniform size and shape, fairly firm and free from injury or blemish, decay, disease, moulds and other contaminants
Retail packaging	Fruitlets to be packed in polypropylene containers with lids, polystyrene trays shrink-wrapped with polyvinyl chloride (PVC)/stretch film or similar protective containers
Labelling	Each container to be marked with the following information: <ul style="list-style-type: none"><li>• Name of produce/variety</li><li>• Net weight in grams</li><li>• Date of packing/expiring</li><li>• Recommended storage temperature</li><li>• Name and address of packer/supplier</li></ul>

#### *End-product inspection*

A record form should be prepared and completed by trained staff to check end-product quality. The quality should comply with the specifications outlined earlier by the producer. In the case of end-product quality below the specifications, a decision should be made whether to reject the product or return it to the processor for improvement. Quality certification should be stamped on the box of the consignment as a warranty to the distributors and buyers.

#### *End-product management*

End products should be kept under chilled temperature conditions to avoid deterioration and spoilage. It is important to ensure that a 'cool chain' system be used continuously during storage, handling, distribution and retailing of MP products. Temperature in the storage facilities and products should regularly be monitored. Sample analysis should also be scheduled for stored products to evaluate quality and safety levels.

### **Documentation**

An essential element of any QA system is that records are maintained throughout all the processing, handling, storage and distribution stages. Records should be clearly written, dated and signed by the authorised person in charge of the operation. A specially designed form for specific inspection and analysis should be used to assist in standardising all records.

### **Conclusion**

The safety of end product is one of the most important quality aspects to be monitored in MP jackfruit. Monitoring quality can be done using a QA system approach starting from the receiving of raw materials, through processing methods, packaging and storage, and ending with end-product quality at retail outlets. The total QA approach implemented regularly will be able to provide consistent product quality and safety, and hence extend buyers' confidence to consume the produce.

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## References

- Anon. 1997. Annual Report. Serdang, Selangor, Horticulture Research Centre, Malaysian Agricultural Research and Development Institute (MARDI).
- Cantwell, M. 1996. Plant and worker sanitation: a brief review. In: Fresh-cut products: maintaining quality and safety. Davis, University of California.
- Kramer, A. and Twigg, B.A. 1970. Quality control for the food industry. Westport, Connecticut, AVI Publications.
- Natural Resources Institute (1994). Manual for horticultural export quality assurance. Chatham, United Kingdom, Natural Resources Institute.
- Piccone, M. and Bunt, C. 1997. Understanding quality systems. The Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program III: Quality Assurance Systems for ASEAN Fruits (QASAF) Project Workshop, Bangkok, 24–28 March 1997. Brisbane, Palamere Pty Ltd.
- Reyes, V.G. 1997a. Current developments in minimal processing of fruits and vegetables. The Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program III: Quality Assurance Systems for ASEAN Fruits (QASAF) Workshop on Minimal Processing of Tropical Fruits, Kuala Lumpur, 21–23 October 1997. Brisbane, Palamere Pty. Ltd.
- Reyes, V.G. 1997b. Factors limiting shelf life and quality of minimally processed fruits and vegetables. The Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program III: Quality Assurance Systems for ASEAN Fruits (QASAF) Workshop on Minimal Processing of Tropical Fruits, Kuala Lumpur, 21–23 October 1997. Brisbane, Palamere Pty. Ltd.
- Reyes, V.G. 1997c. Preservation technologies and systems for minimally processed fruits and vegetables. The Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program III: Quality Assurance Systems for ASEAN Fruits (QASAF) Workshop on Minimal Processing of Tropical Fruits, Kuala Lumpur, 21–23 October 1997. Brisbane, Palamere Pty. Ltd.
- SIRIM (Standards and Industrial Research Institute of Malaysia) 1986. Specification for fresh jackfruit. Malaysian Standard MS 1055. Shah Alam, Selangor, SIRIM.
- Vinning, G. 1995. Report on a market study of minimally processed tropical fruits. Brisbane, Palamere Pty Ltd.

# Minimally Processed Fruits in Singapore

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## Abstract

A survey was conducted to study the quality and food safety status of minimally processed (MP) fruits in Singapore. As the industry is still in its infancy, produce of this category is not widely available in the market but is slowly gaining in popularity and the increasing demand has hastened its development. Several analytical parameters of quality in fruit products were measured to determine quality changes, including physical examination, pH, ethylene and oxygen gas levels, surface colour, total sugar, total acidity and water activity. For contaminants, pesticide residues were measured and microbiological levels monitored using total plate counts as well as counts of *Escherichia coli*, coliforms, *Staphylococcus aureus*, *Lactobacillus* and PPC (psychrophilic count). Results obtained indicated that MP fruits in Singapore are relatively safe.

MINIMALLY processed (MP) fruits have gained popularity in Singapore since their introduction a few years ago. MP fruits are prepared and packaged for convenient consumption. Other advantages include superior quality over processed fruits. However, the main disadvantage is their increased perishability and shorter shelf life as compared to fresh whole fruits. Minimal processing is defined as "all unit operations such as washing, sorting, trimming, peeling, slicing, coring etc. that might be used prior to blanching in conventional processing" (Rolle and Chism 1987) for the purposes of this paper.

Presently in Singapore, there are five major sectors of producers that are involved in MP fruits. These range from the small-scale fruit stalls that are located in food centres, canteens and hawker centres to large-scale operations such as that of the Singapore Airport Terminal Services in-flight catering centre. The rest include fresh fruit shops, supermarkets and MP fruit processing plants. Currently, all the sectors except the MP fruit processing plants primarily aim to supply MP fruits directly to the consumers. Thus, depending on the storage needs, attention has been focused to varying degrees by the different groups with a view to extending the shelf life of this type of produce. One major obstacle that limits the production of MP fruits is the higher degree of perishability brought about by damage to the fruit tissue during processing.

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A survey was conducted on MP jackfruit and durian from September 1997 to June 1998 to study the quality and food safety status of MP fruits in Singapore.

## Materials and Methods

### Materials

Several samples of MP jackfruit and MP durian were analysed for this study. The samples were either collected from a local MP plant or purchased from wet markets and retail outlets to assess the microbiological and pesticide contamination as well as quality changes in the retail outlets.

### Methods

The microbiological tests undertaken included total plate counts, and counts of *Escherichia coli*, coliforms, *Staphylococcus aureus*, *Lactobacillus* and PPC (psychrophilic count). Total plate counts were determined using the spiral plater system according to the methods described in the Compendium of Methods for Microbiological Examination of Foods, American Public Health Association (APHA) and the Association of Official Analytical Chemists (AOAC) Official Methods of Analysis. Total coliform and *E. coli* counts were determined using the Colitrak method which is based upon the widely used 'most probable number' (MPN) assay as specified in the

Bacteriological Analytical Manual (Food and Drug Administration—FDA/BAM) and AOAC.

The pesticide residue analysis included testing for organochlorine compounds, organophosphorus compounds, pyrethroids, dithiocarbamates (as total CS<sub>2</sub>) and N-methylcarbamates. Organochlorines were analysed by the multi-residue method. The organochlorines were extracted with acetonitrile, the water in the aqueous mixture was salted out, and the organic layer was dried and redissolved in hexane followed by cleaning up with florisol solid phase extraction. The eluent was injected for gas chromatography with an electron-capture detector. The organophosphorus compounds were extracted from the fruit samples with ethyl acetate in the presence of anhydrous sodium sulfate and the filtered extracts were determined by gas chromatography using phosphorous-specific detection. Dithiocarbamate fungicides (Thiram, Maneb, Zineb, Mancozeb, Ferbam, Manam, sodium dimethyl dithiocarbamate and Ziram) were determined as carbon disulfide by the headspace gas chromatographic method with a flame photometric detector. N-methyl carbamates were extracted with acetonitrile, the water in the mixture was salted out and the organic layer was evaporated to dryness. The residue was redissolved in methanol, followed by cleaning up with C18 solid phase extraction. The eluent was injected for high performance liquid chromatography (HPLC) using a machine equipped with a post-column derivation unit, and the carbamates were detected using a fluorescence detector. Pyrethroids were determined by gas chromatography with an electron-capture detector method. All the pesticide residue analysis was done using multi-residue methods as described in Analytical Methods for Residues of Pesticides (Ministry of Welfare, Health and Cultural Affairs, Rijswijk), fifth edition (1988).

For quality changes, pH, physical examination, ethylene and oxygen gas levels, surface colour, total sugar, total acidity and water activity were monitored. Surface colour was measured by using Minolta Chroma Meter CR300 based on the Hunter system. pH was measured using a Fisher Accumet 950 pH meter after calibration at 25°C. Total acidity was determined by a titration method using a standard sodium hydroxide solution. Total sugar (°Brix) was determined by refractometry utilising an Abbe refractometer. Water activity was measured using a LUFT Water Activity Analyser. Both ethylene and oxygen gas levels were obtained by using a TEMAC gas analyser.

## Results and Discussion

### Packaging materials

All of the MP fruits were packed in styrofoam trays with polyethylene film wrapping except for those which were sampled from ready-to-eat, cut fruit stalls in hawker centres and food courts. The ready-to-eat, cut fruit stalls pack the MP fruits in plastic bags or on wooden skewers.

### Physical quality attributes

#### General

Cutting and slicing of fruits has adverse consequences on product appearance. Cut surfaces bring enzymes and substrates together which accelerate browning. Most fruits have an active wound response mechanism, which is triggered by the production of wound ethylene. Ethylene can accelerate colour changes associated with ripening and senescence. Significant surface colour changes were observed for the jackfruit and durian samples. The surface colour darkened from light yellowish-orange to a deep orange colour for the jackfruit within a day. The durian flesh took a slightly longer time to change from light cream to a yellow colour. These observations correlate well with the high level of ethylene gas detected in these samples, which enhances the ripening process. Generally jackfruit were able to maintain good appearance if stored at a refrigerated temperature for a week with a minimum amount of polyethylene packaging, as refrigeration delays senescence and polyethylene packaging reduces dehydration. After 7 days, some fluid had exuded from the jackfruit and 'off' aromas became detectable.

#### MP jackfruit

Eleven samples of MP jackfruit were analysed. The pH ranged from 5.07 to 5.77—which is within the acidic range. The Brix value (dissolved solids) was at a moderate level—13 to 22.5° and the acid content was around 0.08 to 0.29%—which explains the observed pH. The water activity results ranged from 0.94 to 0.99. The oxygen composition in some packages was reduced to as low as 6.3% (high respiration rate, rapid oxygen consumption rate) and in some samples was as high as 19.8% (normal atmospheric oxygen composition is 20.8%). The ethylene results ranged from as low as 300 ppm to as high as above 1,000 ppm (the increase caused by the ripening process).

A series of experiments was also carried out in our laboratory to evaluate the effect of temperature on the respiration rate and ethylene production of MP jackfruit. At 4°C, a significant reduction in both the oxygen uptake and ethylene emission was observed for the fruit. But more interestingly, when the chilled fruit was left at room temperature (25°C) for about 4 hours, the respiration rate reverted to the normal rate and the oxygen in the package could be depleted to as low as 5% while the ethylene level could reach a value of about 800 to 1,000 ppm.

The colour of the fruit (flesh) ranged from yellow to orange–red. This correlates with measured surface colour  $b^*$  (the hue on the blue-to-yellow axis) which ranged from 36.74 (dull yellow) to 47.79 (deep yellow) and surface colour  $a^*$  (the hue on the green-to-red axis) which ranged from 0.2 (minimum redness) to 40.19 (moderate redness). Detailed results are given in Table 1.

#### *MP durian*

Fifteen samples of MP durian were tested. Durian samples had the highest pH among the samples we tested. The pH ranged from 6.45 to 7.57. In addition, a high Brix value of >25° (17.5 to 36.88°) and a low total acidity value of about 0.03 to 0.33% were common for the durian samples. This explains the higher pH values observed. The water activity results ranged from 0.94 to 0.98. The oxygen composition ranged from as low as 3.5% to as high as 19.1%. Ethylene gas levels were found to be well above 1,000 ppm for most durian samples. The colour of the fruit (flesh) ranged from light yellow (creamy) to yellow. This correlates with measured surface colour  $b^*$  which ranged from 20.78 (very light yellow) to 48.49 (yellow) and surface colour  $a^*$  which ranged from -4.52 to 2.8 (shades of red). Detailed results are given in Table 2.

### **Pesticide contamination**

Organophosphorus compounds, pyrethroids, dithiocarbamates and N-methylcarbamates were not detected in any of the MP fruits. Only three samples of jackfruit were found to contain 0.01 or 0.02 ppm of gamma-benzene-hexachloride ( $\gamma$ -HCH). Another sample of durian was found to contain 0.01 ppm beta-benzene-hexachloride ( $\beta$ -HCH) and 0.02 ppm quinoxaline. Two samples of durian were also found to

contain either 0.6 or 0.9 ppm of dithiocarbamates (as total CS<sub>2</sub>). All of the pesticides detected were within the Food and Agricultural Organization of the United Nations/World Health Organization (FAO/WHO) Codex Alimentarius Commission's maximum residue limits. The detection of the organochlorine compounds in the fruits suggests that organochlorine compounds (which were banned in the early 1970s in many countries) are still persistently found in the environment.

### **Microbiological contamination**

#### *MP jackfruit*

Ten samples of MP jackfruit were tested. The results of the total plate counts ranged from <5,000 organisms/g to  $4.66 \times 10^6$  organisms/g. 6 out of 10 cases (60%) had counts fractionally above the  $1 \times 10^5$  organism/g limit of Singapore's Food Regulations. Counts for psychrophiles, coliforms, *E. coli* and *Lactobacillus* were acceptable. *E. coli* 0157:H7 was not detected in any of the samples tested. However, 4 of the 10 samples had high counts of *S. aureus* (ranging from 111 to 1,089 organisms/g). These would be probably due to contamination by the fruit handlers, and might cause problems if these strains are enterotoxin-producing. Enterotoxins of *S. aureus* are very stable. Taken together, the results suggest that the jackfruit had been handled in a hygienic manner, although the high counts of *S. aureus* might be cause for concern. Detailed results are given in Table 3.

#### *MP durian*

11 samples of MP durian were tested. The results of the total plate counts ranged from 5,000 to  $2.89 \times 10^7$  organisms/g. The one excessively contaminated sample ( $2.89 \times 10^7$  organisms/g) would either have experienced temperature abuse or have been handled in a very unhygienic manner. Another of the durian samples had an exceptionally high psychophilic count of  $1.49 \times 10^6$  organisms/g. Detailed results are given in Table 4.

### **Reference**

Rolle, R.S. and Chism, G.W. 1987. Physiological consequences of minimally processed fruits and vegetables. *Journal of Food Quality*, 10, 157–177.

**Table 1.** Physical attributes results for 11 samples of minimally processed jackfruit.

Test	Sample number										
	1	2	3	4	5	6	7	8	9	10	11
Colour of flesh	pale yellow	orange–red	orange–red	dull yellow	yellowish orange	orange	orange	yellow	reddish orange	reddish orange	orange–yellow
pH at 25°C	5.48	5.20	5.28	5.38	5.21	5.77	5.50	5.60	5.60	5.09	5.07
°Brix	18.70	15.20	15.00	15.00	20.00	19.80	13.00	16.00	16.20	22.50	18.60
% citric acid	0.14	0.18	0.14	0.15	0.21	0.15	0.09	0.13	0.24	0.29	0.08
Water activity	0.99	0.97	0.99	0.97	0.96	0.99	0.98	0.97	0.98	0.96	0.94
% oxygen	19.80	16.90	6.30	19.30	17.10	6.30	15.60	15.60	14.80	15.60	11.30
Ethylene (ppm)	900	720	>1 000	300	1 000	1 000	650	650	495	>1 000	615
Surface colour $L^*$	72.83	58.79	54.53	51.37	59.74	57.25	57.53	63.52	56.38	55.23	56.49
Surface colour $a^*$	0.20	9.20	6.93	4.31	12.99	1.44	7.08	40.19	12.42	14.67	11.17
Surface colour $b^*$	44.98	43.97	46.86	36.74	40.47	36.62	41.32	47.79	42.74	43.03	43.89
Surface colour $C^*$	44.98	44.92	47.36	31.03	41.58	36.64	41.93	48.03	44.50	45.60	45.29
Hue angle ( $H^\circ$ )	89.70	78.30	81.70	83.50	77.50	87.80	80.33	85.13	13.87	70.70	45.84

Notes on surface colour measurements:  $L^*$  indicates lightness or darkness (0 = black, 100 = white);  $a^*$  indicates the hue on the green-to-red axis (negative value = greenness, positive value = redness);  $b^*$  indicates the hue on the blue-to-yellow axis (negative value = blueness, positive value = yellowness);  $C^*$  is the intensity of the hue [ $C^* = (a^{*2} + b^{*2})^{1/2}$ ]; and hue angle ( $H^\circ$ ) is the angle in the colour wheel of 360° ( $H^\circ = \tan^{-1}b^*/a^*$ ).

**Table 2.** Physical attributes results for 15 samples of minimally processed durian.

Test	Sample number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Colour of flesh <sup>a</sup>	Y	Y	LY	Y	LY	Y	Y	Y	Y	O	Y	Y	Y	Y	Y
pH at 25°C	6.97	7.57	6.85	6.92	6.99	6.55	6.48	6.45	6.53	6.63	6.82	6.63	6.67	6.68	6.69
°Brix	29.40	33.00	30.00	29.80	26.70	36.88	25.25	25.20	17.50	27.50	22.50	28.50	25.80	21.00	22.00
% citric acid	0.03	0.03	0.05	0.06	0.03	0.08	0.08	0.08	0.12	0.21	0.33	0.30	0.05	0.15	0.06
Water activity	0.97	0.94	0.98	0.97	0.98	0.96	0.97	0.94	0.96	0.95	0.97	0.98	0.97	0.97	0.95
% oxygen	11.20	14.20	19.10	4.30	14.50	8.60	13.60	19.10	6.80	5.80	12.50	4.10	12.00	4.90	3.50
Ethylene (ppm)	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	>1 000	770	775
Surface colour <i>L</i> *	72.56	70.76	75.07	73.40	76.42	75.18	74.30	71.40	58.87	51.39	45.85	51.72	64.35	55.69	46.03
Surface colour <i>a</i> *	-1.46	-2.88	-2.54	-2.83	-4.52	-2.71	-0.75	2.40	0.26	2.80	-0.45	0.65	-1.48	0.26	0.60
Surface colour <i>b</i> *	25.66	24.61	20.78	23.90	29.75	27.15	48.49	40.27	40.21	34.91	31.54	41.16	39.78	28.45	22.79
Surface colour <i>C</i> *	25.70	24.77	20.93	24.13	30.09	27.29	48.49	40.34	40.21	35.03	31.56	41.16	39.82	28.46	22.80
Hue angle ( <i>H</i> °)	93.20	96.60	96.90	96.70	98.60	95.67	90.80	93.36	89.70	85.27	90.97	89.20	92.50	89.57	88.47

<sup>a</sup> Flesh colour: Y = yellow, LY = light yellow and O = orange.

Notes on surface colour measurements: *L*\* indicates lightness or darkness (0 = black, 100 = white); *a*\* indicates the hue on the green-to-red axis (negative value = greenness, positive value = redness); *b*\* indicates the hue on the blue-to-yellow axis (negative value = blueness, positive value = yellowness); *C*\* is the intensity of the hue [ $C^* = (a^{*2} + b^{*2})^{1/2}$ ]; and hue angle (*H*°) is the angle in the colour wheel of 360° ( $H^\circ = \tan^{-1}b^*/a^*$ ).



**Table 3.** Microbiological results for 10 samples of minimally processed jackfruit.

Test (count)	Sample number									
	1	2	3	4	5	6	7	8	9	10
Total plate count	$6.2 \times 10^5$	$2.18 \times 10^5$	40 000	$1.11 \times 10^5$	47 600	$1.57 \times 10^5$	<5 000	<5 000	$4.66 \times 10^6$	$9.48 \times 10^5$
Psychrophilic count (PPC)	<5 000	<5 000	<5 000	<5 000	<5 000	<5 000	<5 000	$2.82 \times 10^4$	5 000	$4.96 \times 10^4$
Coliforms	143	238	<3	222	>1 100	40	3	<3	<3	>4
<i>Escherichia coli</i>	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
<i>Staphylococcus aureus</i>	67	1 089	325	<10	<10	111	501	<10	<10	<10
<i>Lactobacillus</i>	<10	<10	<10	<10	<10	<10	<10	ND	<10	<10
<i>E. coli</i> 0157:H7	NT	NT	NT	ND	ND	ND	ND	ND	ND	ND

Note: ND = not detected, NT = not tested.

**Table 4.** Microbiological results for 11 samples of minimally processed durian.

Test (count)	Sample number										
	1	2	3	4	5	6	7	8	9	10	11
Total plate count	$1.22 \times 10^4$	$2.89 \times 10^7$	$2.19 \times 10^4$	<5 000	<5 000	<5 000	$4.86 \times 10^4$	<5 000	$10.5 \times 10^4$	$1.69 \times 10^4$	$5.22 \times 10^4$
Psychrophilic count (PPC)	<5 000	<5 000	$1.89 \times 10^4$	<5 000	7 720	<5 000	<5 000	$1.39 \times 10^4$	$1.49 \times 10^6$	<5 000	$6.03 \times 10^4$
Coliforms	>1 100	1 062	<3	<3	4	<3	3	<3	>1 100	228	3
<i>Escherichia coli</i>	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
<i>Staphylococcus aureus</i>	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
<i>Lactobacillus</i>	<10	<10	NT	NT	NT	NT	NT	NT	NT	NT	NT
<i>E. coli</i> 0157:H7	NT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND = not detected, NT = not tested.

# Maturity Indices and Harvesting Practice of 'Arumanis' Mango Related to the Target Market

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## Abstract

Mango as a climacteric fruit is frequently harvested when less than fully ripe. This is often necessary to obtain optimal eating quality at the time of consumption where markets are a considerable distance from the place of harvest.

In this study the age of fruit was calculated, based on the time of flowering. The orchard selected for the trials was located in northern part of Bali, Indonesia. The laboratory analyses were carried out at Udayana University.

The results showed that optimal maturity of 'Arumanis' mango for best consumption is when the fruit is harvested 13–14 weeks after flowering. Fruit age has a close relationship with total soluble solids (TSS), total acidity and pH content. This study found that 'Arumanis' mango is best for consumption when the TSS content of the fruit is not less than 16.8°Brix, total acidity 0.18%, pH 4.8, flesh colour rating 6–6.5, and taste score 5.

MANGOES CAN be classified into two groups based on their ability to reproduce from seed: monoembryonic and polyembryonic types. The major commercial cultivars in Indonesia, the Philippines and Thailand are of the polyembryonic type, while in Malaysia and Singapore, a mixture of polyembryonic and monoembryonic seeds are extensively grown (Kusumo et al. 1984). 'Arumanis' mango, which is classified as polyembryonic, is considered to have much commercial potential.

The definition of maturity as 'the stage of development giving minimum acceptable quality to the ultimate consumer' implies a need for objective measures of maturity. Indication of maturity is of considerable importance during the marketing chain (Reid 1985). Mango growers harvest fruit using their judgement based on the appearance of the fruit. Consequently, fruit harvested by conventional criteria may exhibit significant variations in both ripening rate and

fruit quality (Kosiyachinda et al. 1984). Therefore, there is a need to find objective measures which can be used to determine fruit maturity in order to determine optimal harvesting time.

Mango fruit traded commercially are commonly harvested green. Various methods for determining maturity in mango have been proposed, namely, softness of cheeks, peel colour, development of shoulder, specific gravity, and starch content. However, these methods have found limited commercial application since they are mainly applicable to fruit that have reached an advanced degree of ripeness. The objective of this trial was to study the maturity indices and harvesting practice of fresh 'Arumanis' mango fruit related to the target market.

## Materials and Methods

Fruit were obtained from local farmers in the northern part of Bali island, and the analyses were carried out at the Analytical Laboratory, Udayana University, Denpasar. Fruit were harvested at six stages of maturity at one-week intervals: P1 = harvested 11 weeks after fruit set; P2 = harvested 12 weeks after fruit set; P3 = harvested 13 weeks after fruit set; P4 = harvested 14 weeks after fruit set; P5 = harvested 15

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weeks after fruit set; and P6 = harvested 16 weeks after fruit set.

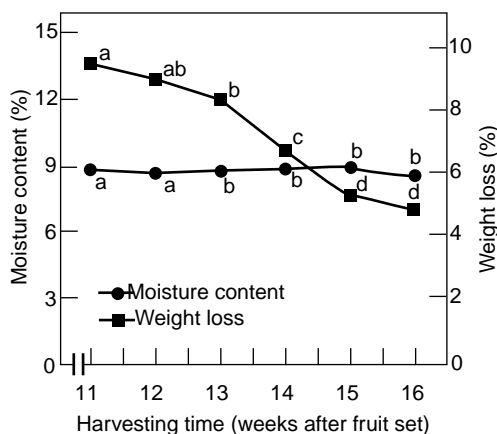
On arrival at the laboratory, the samples of fruit were selected on the basis of good condition and even maturity. Fruit of uniform size were selected. Each fruit was carefully sorted according to visual assessment of its size, freshness and level of damage. After sorting, the fruit were washed, dipped in a fungicide solution, and dried until the skin was dry. The sample units were then randomly allocated to each treatment. A randomised block design was used which consisted of six treatments and four replicates. An analysis of variance of data from the experiment was carried out and where significance was shown, the data were further analysed using Duncan's multiple range test (Gomez and Gomez 1976) to determine the significance between individual treatments.

Observations were made on weight loss, fruit firmness, total soluble solids, total acidity, vitamin C content, pH, and organoleptic evaluation (colour and taste). Observations on fruit freshness were carried out daily to calculate the storage life.

## Results and Discussion

### Weight loss and moisture content

Weight loss decreased with the onset of fruit maturation. The highest weight loss was observed in fruit harvested at 11 weeks after fruit set (9.28%), and sig-



**Figure 1.** Weight loss and moisture content of 'Arumanis' mangoes harvested at one-week intervals after fruit set. Points marked with different letters are significantly different at the 5% level.

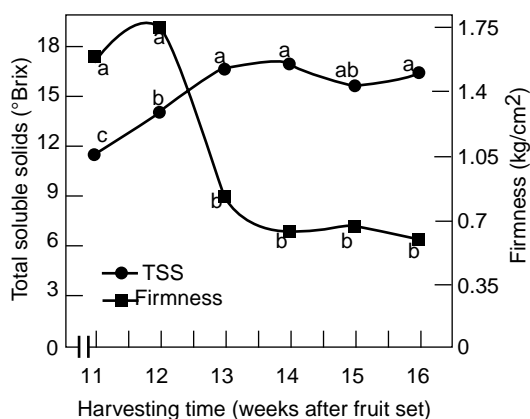
nificantly decreased in fruit harvested at 13, 14, 15, and 16 weeks after full bloom. The lowest value for weight loss was observed in fruit harvested at 16 weeks after fruit set (4.92%), but was not significantly different to fruit harvested at 15 weeks after full bloom (Figure 1).

The moisture content of fruit flesh increased slightly with the increase in fruit maturation. Fruit harvested at 11 weeks after full bloom showed the lowest moisture content (8.74%), and the highest was in fruit harvested at 15 weeks after fruit set (Figure 1).

### Fruit firmness

'Arumanis' mango does not lose its green colour even when fully ripe (Yuniarti 1980). The absence of a quick visual index of ripeness in 'Arumanis' mango makes it difficult to ascertain the degree of fruit ripeness without the use of destructive analytical procedures, although it is possible that firmness could be used as an index.

Fruit firmness was highest in fruit harvested 12 weeks after full bloom (1.73 kg/cm<sup>2</sup>) and deteriorated significantly as time to harvest after fruit set increased. The lowest value was observed in fruit harvested at 16 weeks after fruit set (Figure 2), but was not significantly different to fruit harvested 13, 14 and 15 weeks after full bloom. Fruit harvested at 13 and 14 weeks after fruit set had fruit firmness values of 0.79 and 0.63 kg/cm<sup>2</sup>, respectively.

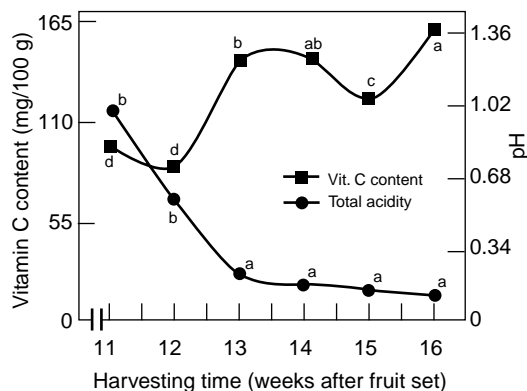


**Figure 2.** Total soluble solids and fruit firmness of 'Arumanis' mangoes harvested at one-week intervals after fruit set. Points marked with different letters are significantly different at the 5% level.

According to Pantastico et al. (1984), comprehensive studies on 'Carabao' mango showed that fruit firmness decreased abruptly early in the ripening period, but continued to decrease with further ripening. Softening changes in ripening mango have been previously attributed to the activity of enzymes that degrade pectic substances. In Malaysian 'Arumanis' mango, the activities of pectin methylesterase and polygalacturonase were low in immature fruit, and increased with increasing physiological age. When harvested fruit were allowed to ripen under ambient conditions, pectic enzyme activity initially decreased but then markedly increased in ripening fruit.

### Total soluble solids

Total soluble solids (TSS) increased with the onset of fruit maturation. However, the highest TSS was observed in fruit harvested at 14 weeks after fruit set (16.96°Brix), and was significantly different to fruit harvested at 11 and 12 weeks after flowering. The lowest value of TSS observed was of fruit harvested at 11 weeks after full bloom (11.72°Brix) (Figure 2). Pantastico et al. (1984) reported that total sugars and soluble solids increased as the 'Carabao' mango fruit ripened, with the most marked increases occurring early in the ripening process. Mendoza et al. (1972) also found that the soluble solids content of mango increased with the onset of maturation, however at 10–15 weeks after fruit set, the change in soluble solids did not show a consistent trend.



**Figure 3.** Vitamin C content and total acidity of 'Arumanis' mangoes harvested at one-week intervals after fruit set. Points marked with different letters are significantly different at the 5% level.

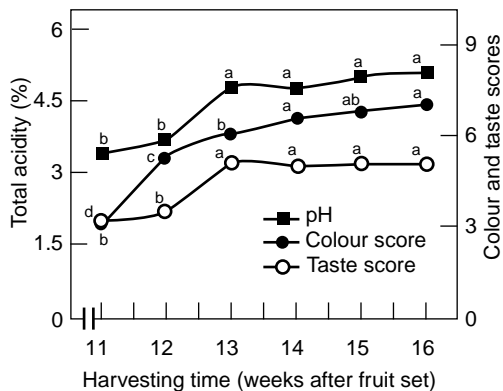
### Total acidity

Total acidity decreased with the onset of fruit maturation. The highest value was in fruit harvested at 11 weeks after fruit set (0.98%), and significantly decreased in fruit harvested at 12, 13, 14, 15 and 16 weeks after fruit set. The lowest value for total acidity was observed in fruit harvested at 16 weeks after full bloom (0.13%), but this value was not significantly different to fruit harvested at 13, 14 and 15 weeks after full bloom (Figure 3). Kosiyachinda et al. (1984) stated that titratable acidity decreases with the onset of maturation, however no common value for the maximum titratable acidity exists that could be used to determine the earliest acceptable picking time.

### Vitamin C content and pH

The highest vitamin C content was observed in fruit harvested at 16 weeks after full bloom (161.7 mg/100 g), and the lowest value was measured in fruit harvested at 12 weeks after full bloom (85.8 mg/100 g). The vitamin C content increased as the time before harvesting increased, except in fruit harvested at 15 weeks after fruit set where the value decreased slightly (123.2 mg/100 g) (Figure 3).

The pH of fruit flesh significantly increased with the onset of fruit maturation. Fruit harvested at 11 weeks after fruit set had the lowest pH (3.40), which was significantly different to fruit harvested at 13, 14, 15 and 16 weeks after fruit set. The highest pH was measured in fruit harvested at 16 weeks after fruit set (5.15) (Figure 4).



**Figure 4.** pH, flesh colour score and taste score of 'Arumanis' mangoes harvested at one-week intervals after fruit set. Points marked with different letters are significantly different at the 5% level.

## Flesh colour and fruit taste

Flesh colour was judged using a rating where: 1 = all white; 2 = white with a slight yellow; 3 = whitest yellow; 4 = yellowish white; 5 = yellow with a slight white; 6 = all yellow; and 7 = yellowish red. The flesh colour score significantly increased with the increase in fruit maturation. The lowest colour score was observed in fruit harvested at the earliest time of harvesting (11 weeks after fruit set, with the score of 3.0 = whitest yellow), and the highest was in fruit harvested at 16 weeks after fruit set (7.0 = yellowish red) (Figure 4).

Fruit taste was judged using a rating where: 1 = dominant sour; 2 = slightly sour; 3 = balance of sweet and sour; 4 = slightly sweet; and 5 = dominant sweet. The taste score significantly increased with the increase in time after fruit set. The lowest taste score was in fruit harvested at 11 weeks after flowering (3.05 = balance of sweet and sour), and the highest was in fruit harvested at 13, 14, 15 and 16 weeks after fruit set (5.0 = dominant sweet) (Figure 4).

## Storage life

Fruit storage life significantly decreased with the increase in fruit maturity. Fruit harvested at 11 weeks after full bloom showed the longest shelf life (9 days) at room temperature ( $29 \pm 1^\circ\text{C}$ ), while the lowest was observed in fruit harvested at 15 and 16 weeks after fruit set (4 days) (Table 1).

**Table 1.** Storage life of 'Arumanis' mangoes harvested at one-week intervals after fruit set.

Treatment	Storage life	
	Days <sup>a</sup>	LSR 5%
P1 (harvested 79 days afs <sup>b</sup> )	9.00 a	
P2 (harvested 86 days afs)	7.00 b	0.36
P3 (harvested 93 days afs)	6.50 c	0.38
P4 (harvested 100 days afs)	5.00 d	0.39
P5 (harvested 107 days afs)	4.00 e	0.40
P6 (harvested 114 days afs)	4.00 e	0.40

<sup>a</sup> Values with different letters are significantly different at the 5% level.  
<sup>b</sup> afs = after fruit set

## Conclusion

The major chemical change in 'Arumanis' mango fruit during growth and maturation was a regular increase of the level of reducing sugars throughout the development period. It was expressed by a gradual increase in total soluble solids up to maturity, a continued decrease in fruit firmness, a decline in total acidity, and an increase in pH and vitamin C content.

The results of the trial showed that the optimal maturity of the fruit for consumption was reached when fruit was harvested at 13–14 weeks after fruit set, characterised by the values of 16.8–17.0°Brix total soluble solids, 0.18–0.22% total acidity, pH 4.8, flesh colour rating of 6–6.5, and a taste score of 5.

In the absence of adequate objective measures of maturity, visual indicators are often employed, such as the shape of the fruit, the appearance of powdery materials or bloom on the fruit surface, or the presence of plant sap at the fruit surface close to maturity.

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## References

- Gomez, A.A. and Gomez, K.A. 1976. Statistical procedures for agricultural research. Los Baños, Philippines, The International Rice Research Institute.
- Kosiyachinda, S., Lee, S.K. and Poernomo, S. 1984. Maturity indices for harvesting of mango. In: Mendoza, D.B. Jr and Wills, R.B.H., ed., Mango: fruit development, postharvest physiology and marketing in ASEAN. Malaysia, Association of South-East Asian Nations (ASEAN) Food Handling Bureau, 33–38.
- Kusumo, S., Lye, T.T., Vangnai, V., Yong, S.K. and Namuco, L.O. 1984. Commercial mango cultivars in ASEAN. In: Mendoza, D.B. Jr and Wills, R.B.H., ed., Mango: fruit development, postharvest physiology and marketing in ASEAN. Malaysia, Association of South-East Asian Nations (ASEAN) Food Handling Bureau, 12–20.
- Mendoza, D.B., Javier, F.B. and Pantastico, E.B. 1972. Physico-chemical studies during growth and maturation of 'Carabao' mango. *Animal Husbandry and Agriculture Journal*, 7, 33–36.
- Pantastico, E.B., Lam, P.F., Ketsa, S., Yuniarti and Kositrakul, M. 1984. Postharvest physiology and storage of mango. In: Mendoza, D.B. Jr and Wills, R.B.H., ed., Mango: fruit development, postharvest physiology and marketing in ASEAN. Malaysia, Association of South-East Asian Nations (ASEAN) Food Handling Bureau, 39–52.
- Reid, M.S. 1985. Product maturation and maturity indices. In: Kader, A.A., Kasmire, R.F., Mitchell, F.G., Reid, M.S., Sommer, N.F. and Thompson, J.F., ed., Postharvest technology of horticultural crops. Cooperative Extension, University of California, Division of Agriculture and Natural Resources, USA, 8–11.
- Yuniarti 1980. Physico-chemical changes of Arumanis mango during storage at ambient temperature. *Bulletin Penelitian Horticultura*, 8, 11–12.

# Quality Assurance Implementation in Practice: Thailand's Experience with Fresh Longan for Export

Sing Ching Tongdee\*

## *Abstract*

Since the introduction of the use of SO<sub>2</sub> fumigation treatment to extend the shelf life of fresh longan fruit in Thailand in 1988, SO<sub>2</sub> residues have been the single most important issue in the trade of fresh longan. A quality control system addressing residue levels of the treated fruit was a part of the SO<sub>2</sub> fumigation technological transfer package recently introduced in Thailand. Intensified efforts to monitor the fumigation process were initiated three years ago as a crisis management strategy to counter restrictions on the export of Thai fresh longan imposed by the Singapore Government because of the SO<sub>2</sub> residue problem. The initial focus for longan quality control was based on Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Points (HACCP). HACCP implementation requires the cooperation of government organisations and the commitment of the private sector. For this, a HACCP implementation model was designed. The action plan included: first, to learn; second, to commit; and thirdly, to do. The quality improvement process continues through ongoing improvement. The model has been tested and applied in Thailand for the fresh fruit export industry. A quality management system with a consumer and integrated business focus is now underway in view of changing market situations. The fresh fruit and vegetable industry is unique in many respects and adoption of quality management systems originally developed for the manufacturing industry presented a big challenge, especially in developing country situations. Some of the factors influencing the speed and success of the implementation of quality assurance systems for fresh produce in Thailand are summarised.

FRESH fruit and vegetable handlers have traditionally regulated their own actions with regard to produce quality, standards, and safety. However, there have been increased incidences and complications of food-borne illnesses and chemical contamination associated with fresh produce. New food hygiene standards have been proposed and enforced to ensure that food is safe to consume. Rules and regulations have been amended to ensure that imported foods are of equal quality to those produced in the consumer countries, especially in matters concerning produce safety.

There has also been a change in consumer attitude over the past three decades resulting in a shift in 'quality' perception toward food. Food must simultaneously meet all safety, quality and legal requirements.

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## **New Regulatory Trends in the Export of Fresh Produce**

In view of increasing liberalisation and reform of international agricultural trade, the latest scientific and regulatory thinking on the control of perishable produce is toward a harmonised and mutually recognised international norm that the industry can follow rather than having to deal with the specific requirements of respective importing countries. The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) was accepted as one of the basic rules for international food trade. The SPS Agreement encourages members to establish their protection measures based on standards/guidelines developed by intergovernmental organisations such as the Food and Agricultural Organization of the United Nations/World Health Organization (FAO/WHO) Codex Alimentarius Commission, the Office Interna-

tional de Epizooties and the FAO International Plant Protection Convention (IPPC). Exporters/importers need to understand the implications of these international standards and requirements.

While the SPS Agreement is a legal text, the standards are not legally binding. Member countries need to develop national standards or codes of practice and to incorporate these practices into operational procedures to suit each specific situation. Countries/industries also need to find feasible implementation mechanisms and this has been one of the major challenges. Many countries, especially developing countries, have found themselves at a crossroad and ill-prepared to face the measures required by the newly established regulations.

## **The Changing Concept and Changing Ways**

Quality was controlled, in the past, by technicians carrying out testing and analysis of the final product. With increasing competitiveness in the global market, the new 'quality' concept is to provide consumer satisfaction or even to exceed consumer expectations. The new multidimensional quality concept also reflects a change away from compliance with grades/standards with emphasis on final product control/inspection to a concept of assessing production processes or system performance.

Quality is no longer just technology but management. Quality assurance (QA) is an analytical, scientific, preventive and systematic assessment involving the participation of all concerned stakeholders. Quality management is a value-adding process and is achieved through three steps: (1) decide upon the appropriate level of quality or value; (2) provide the means to achieve the desired level of quality; and (3) communicate the value of the achieved level of quality. Many—both importing and exporting countries—remain uncertain of the new systematic approach. This is considered one of the major obstacles in implementing quality systems.

## **Quality Management Systems for Fresh Produce and their Implementation in Thailand**

Examples of quality management system options for horticultural crops include Good Agricultural (or Manufacturing) Practice (GAP or GMP), Hazard Analysis and Critical Control Points (HACCP), ISO

9000 series, and ISO 14000. The choice of quality management systems varies with the specific quality level required, the type of produce and possible hazards, the operator's specific business objective (focus) and the quality maturity of the operator and the industry. This requires careful planning in order to have the proper balance and to be achievable, especially in a developing country situation. While there are no regulatory programs as yet, QA measures—especially for the fresh-cut industry—have been in operation in many countries for some time.

The fresh fruit and vegetable industry is unique in many respects. Most operations remain an extension of the domestic market—small scale and family run. From farm to table, the handling chains consist of fragmented and highly individualised sectors, and conflicts of interest are common. The produce is seasonal and perishable, and produce quality is largely influenced by the skill (and even luck) of the operators. The major challenge is how to adapt the quality management systems originally used in the manufacturing industry for use in the fresh produce industry.

Some of the factors influencing the speed and success of QA adoption in Thailand are as follows:

- The influence of policy and role of governments—both of the exporting and importing countries. Lack of understanding or reluctance to agree on international/regional cooperation regarding equivalence and mutual recognition of rules and regulations in a legal context.
- In a QA system, the exporting countries may place emphasis on process performance, while the importing countries have little confidence in the monitoring process carried out by the exporting countries. There is confusion as to whether to assess the process performance carried out in the exporting country, or to assess the final product after it arrives in the importing country.
- Lack of understanding of QA systems for perishable produce results in difficulties in selecting a feasible and suitable quality management system. The need to meet the legal, quality, and safety requirements differs for different produce—greater significance is placed on some particular aspects in some situations, and requirements can be subject to change. Decisions on the type (or combination of types) of QA system to be used are not always clear. For the most part, the operator cannot fully understand the detail and the complexity (or ease) of a specific quality system, the choice of an appropriate system, and priority activities to be undertaken.



- Lack of cooperation between government organisations, government–private sectors, and between private sectors.
- QA is new idea for the fresh produce industry and it takes time for the concept to spread and be adopted by its target users. The most important influencing factors are:
  - the policies, commitment, readiness, business objectives and quality maturity of the operators;
  - the attitude of the operators toward an innovative approach;
  - the nature of the industry, in that it mainly consists of small, family-run operations with the long-held view of exports as an extension of the domestic market;
  - influence of stakeholders' characteristics—given that different stakeholders be highly individualised, may not be closely linked to one another, may have conflicting interests and may lack a common objective. Each participating sector needs to define and develop its own quality indicators and the sum of the parts then form the total system;
  - there is lack of peer pressure to participate in a QA scheme;
  - there are difficulties with the hard agonising complex confusing paperwork (HACCP);
  - there is a lack of training for trainers;
  - there is no competent authorised body to undertake a QA advisory/inspection service;
  - training activities need to be decentralised;
  - the responsibility for training staff on the quality system and procedures lies with the operator; and
  - QA is perceived as financial burden by most.

### **Thailand's Experience with QA of Longan for Export**

Longan is now one of the largest export items, in value terms, of the Thai horticultural industry. Major markets lie mainly in the region. There has been a rapid expansion in export in recent years to supply the vast and newly opened markets in China. Together, China and Hong Kong account for more than 80% of exports. Export of fresh longan to Singapore currently represents less than 10% of total exports.

For export, SO<sub>2</sub> fumigation treatment to extend the shelf life of the longan fruit has become a common practice in Thailand. However, there has been

increasing consumer concern in the importing countries over the SO<sub>2</sub> residues associated with fumigated fruit. In 1996, the Singapore Government imposed a strict limit of zero SO<sub>2</sub> residue tolerance in the aril of the fruit. This has had a dramatic effect on fresh longan exported to Singapore and rippling effects on fresh longan exports in general. Many exporters have voluntarily participated in the Good Fumigation Practice and HACCP schemes.

As a result of this experience with longan, a conceptual QA implementation model was designed. Chronologically, the QA implementation model-testing period included the following activities:

- (1) The level of value required was designed: GMP and HACCP were proposed.
  - Basic requirements were identified. The scope of the objectives/standards was defined to meet legal, safety and quality requirements. A written manual on Good Fumigation Practice was used as the operational standard for SO<sub>2</sub> fumigation for fresh longan. This was a part of the SO<sub>2</sub> fumigation technology transfer package given to the exporters.
  - Data collection phase. Data from 1995 to 1998 were collected from more than 20 exporters in Thailand to set fumigation performance standards and SO<sub>2</sub> residue levels in the fumigated fruit. The Longan Exporters Quality Assurance Club, established in 1993, served as contact point for such activities.
  - A gap analysis was undertaken by assessing the gaps/performance of practices in Thailand against the requirements of the Codex regulations and the importing countries.
  - A 'process control plan' during SO<sub>2</sub> fumigation treatment was developed. Final product quality control for residue testing was only required as a means of monitoring and verification in an overall program.

Verification of the 'process control plan' was conducted, including monitoring of air SO<sub>2</sub> concentrations during the fumigation process and residue levels in the fruit.

- (2) The desired value was provided by: 'to learn', 'to commit', and 'to do or to adopt'.
  - The 'to learn' phase. To teach people what GMP and HACCP are. The Thailand Institute of Scientific and Technological Research (TISTR) organised a series of HACCP training courses for different target groups including project staff, growers, exporters and fumigators-in-charge covering different levels of topics, including

introductory quality management, quality system options for horticultural crops, conceptual design of the QA implementation model, HACCP principles, procedures and documentation, and inspection/certification schemes. Easy-to-understand extension materials were published and distributed.

- The 'to commit' phase. Commitment of the packinghouse operators/exporters to participate in and implement GMP and HACCP. The HACCP plan included only one critical control point addressing the SO<sub>2</sub> residue issue. This phase included working closely with the Longan Exporters Quality Assurance Club. Some 15 exporters voluntarily participated in the scheme.
- The 'to do or to adopt' phase. Exporters participated in the pilot project. Training/service activities were decentralised. Responsibility for fumigation technology and QA management was transferred from TISTR to the Department of Agriculture and the Department of Agricultural Extension in 1999. This enabled the project to carry out advisory and testing services during the model-testing period. Inspectors conducted inspection of packinghouse operations based on GMP checklists, with hands-on verification of process control procedures at the specified critical control points.

(3) The achieved value was communicated.

- Governments of the importing countries—Singapore and Hong Kong—were informed of the GMP and HACCP schemes in operation in Thailand and the implication of SPS Agreement and the standards on SO<sub>2</sub> levels as established in the Codex regulations. Consumer education and market research were undertaken.

(4) Continuous improvement: the model must be practiced to be improved.

- The PDCA (plan, do, check and act) cycle has been put into practice.
- Expansion phase. A quality plan has been developed to add other consumer requirements that are not SO<sub>2</sub> related.
- SWOT (strengths, weaknesses, opportunities and threats) analysis: longan production in China and Vietnam.

Under the model-testing period, the exporters have moved through the phases of awareness, interest, evaluation, to trial, and hopefully to a full adoption of the system in year 2000. In the expansion phase, a more complicated quality management system with a quality and integrated business focus, taking into consideration the competitiveness of the industry, is in progress. There has been a consensus among the exporters that the longan export industry is in need of a strategic plan rather than just a problem solving survival kit in order to meet the challenge of the economic crisis experienced in the region and as a result of recent changes in production practices.

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# Study on a Postharvest Handling System for Lychee

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## Abstract

Lychee is often grown in the northern mountain region of Vietnam. Recently, it has not been possible to export Vietnamese lychee because of the lack of an efficient and adaptable postharvest handling system.

This report presents the technological analysis of the lychee handling system of the Post-Harvest Technology Institute (PHTI). New technology suitable for Vietnamese production conditions was developed in order to maintain quality and prolong the shelf life of 'Thieu' lychee and includes harvesting, transportation, handling, packaging, and storage at normal and low temperatures.

Long postharvest life and good commercial quality can be achieved by using integrated measures, such as SO<sub>2</sub> fumigation, carbendazim (CBZ) dipping and 'ethylene trapping' using a ripening retardant developed by PHTI called 'R3'.

IN VIETNAM, three cultivars of lychee (*Litchi chinensis* Sonn.) are grown as economic fruit crops — 'Thieu', 'Lai' and 'Chua'—with 'Thieu' being the most important. Lychee is mainly grown in three zones—Luc Ngan (Bac Giang Province—see Figure 1), Thanh Ha (Hai Duong Province) and Dong Trieu (Quang Ninh Province). Lychee production is increasing rapidly (20–50%) each year. The production in 1999 was about 20,000 t and is expected to reach 70,000 t in 2003.

A lot of research has been undertaken into prolonging the shelf life of lychee under normal temperatures and under cool conditions, in order to cope with high production during the picking season and to allow distribution of produce to distant areas. However, up to now, the exportation of fresh lychee has been unstable because of the lack of an adaptable and efficient postharvest handling system.

Lychee often deteriorates quickly after harvest, especially through discoloration. However, if stored under cooled conditions, its quality can be maintained

for a week. When the pericarp of lychee has browned, its commercial quality is decreased. Following this, desiccation, black lesions, stem loss, mould etc. occur and finally the fruit is completely spoiled.

We have adopted some of the practices developed through the experiences of Thailand, South Africa, Australia, Madagascar, France, Israel etc., such as SO<sub>2</sub> treatment (Duvenhage 1993; Coates et al. 1994; Paull et al. 1995; Holcroft and Mitcham 1996), fungicide dipping (Sittigul et al. 1994; Coates et al. 1995), and controlled atmosphere storage and modified atmosphere storage (Holcroft and Mitcham 1996).

Since 1997, the Post-Harvest Technology Institute (PHTI) has systematically extended the study on the lychee postharvest handling system and assessment of raw material resources in all three zones (Luc Ngan, Thanh Ha and Dong Trieu) and determination of technical measurements from harvesting to retailing—including storage at ambient temperatures (15–39°C in summer) and at low temperatures (4–6°C). The amounts of fruit used in the study ranged from a bag's weight (1–5 kg) to a truck's quantity (5–10 t).

An important requirement is that the technical system has to be simple and easily applied in rural areas of Vietnam where the level of development is still low.

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## Harvesting

Growers harvest lychee mostly by hand. They depend entirely on their experience which shows that fruit must be harvested in the morning or at the pre-sunset, and not in the rain. Harvest timing contributes to the maintenance of fruit quality. While harvesting, the fruit pickers are often careless and don't use any bags or other equipment. They drop lychee bunches down to the ground regardless of the height of the drop. Fruit are then loaded into bamboo baskets of 40–50 kg, carried to the yards and loaded into piles without any quality distinction. After that, other people (mainly children or women) repick, sort and cut the stems of the fruit (leaving 10–15 cm), tie them into bundles, load the bundles into baskets and take the fruit to market.

This method of harvesting causes severe bruising and damage to 10–30% of the fruit. This physical damage can not be seen right after harvest, but it will appear on the skin of fruit for a long time and contributes to the degree of fruit spoilage during the storage period.

We have persuaded the pickers to bear bags while picking fruit or to hang bags (or baskets) on the trees at the position they are picking the fruit or, better still, to use folding ladders in order to circumvent physical damage to the fruit (Figure 2).

Generally, the amount of lychee harvested daily is about 100 kg to 1 t per family, harvested by 1–2 labourers. We have organised a training course on lychee harvesting and handling for the growers. Apart from improved harvesting procedures, harvested lychee need to be accumulated in places of less sunshine and light wind.

Fresh lychee fruit selected for storage must meet the following criteria:

- maturity of about 90%, nice red skin, sweet and no astringency;
- sound, no physical damage or abrasion; and
- no symptoms caused by pests, such as lesions, pepper spots, silver rot or insect injury.

Of the total harvested lychee in a crop, only 30–60% meet these criteria. Unsound fruit must be removed to prevent disease transmission (Figure 3).

Sorted fruit are packed (Figure 4) and then packages are loaded tightly in trucks side-by-side to avoid displacement during transport. However, the air can flow horizontally through the packages while the trucks are running.

Vietnamese people prefer lychee with stems. When customers buy fruit, first they look at the stem—if the

stem is not there, it is not seen as sound. Thus, whole stem packaging is necessary but it is difficult because of following obstacles:

- stems increase the total weight and occupy more space in containers;
- plastic bags can be easily torn by the stems; and
- stems can thrust into other fruit during packaging and transport, causing serious damage to the skin.

For these reasons, the stem must be limited to less than 12 cm in length and the manner of packing must ensure that these problems are minimised.

## Packinghouse Operation

A standard for packinghouses in Vietnam has not yet been formulated. In order to do this, it is necessary to define the factors necessary for a packinghouse suitable for Vietnamese conditions, including the minimum requirements.

We devised a portable packinghouse which could even be set up at a lychee-producing farm. From our experience, a packinghouse must have the following basic attributes:

- protection from sunlight and rain;
- good ventilation, but no strong wind passing through;
- large enough area for operation—about 50 m<sup>2</sup>/t of fruit;
- easy installation or detachment and easily transported by vehicle; and
- the equipment necessary for the required operations.

At the packinghouse, activities such as sorting, SO<sub>2</sub> fumigation, fungicide dipping, air drying and packing were implemented.

Sulfur fumigation was studied with the dose varying from 0.1 to 5.0 g/m<sup>2</sup> of cabine during 30 to 120 minutes. It was found that the best regime was 1.0 g/m<sup>3</sup> per hour. A survey of sodium methabisulfite replaced by SO<sub>2</sub> was also implemented which showed that SO<sub>2</sub> was more efficient and more convenient (Figure 5).

The fungicides used for dipping were carbendazim (CBZ), thiabendazol (TBZ0, Benlate, Topsin M., and sodium ortho-phenylphenol (SOPP) with doses of 0.1–2.0 g/L (Figure 6). CBZ dipping using 1.0 g/L gave the best result. The use of CBZ is permitted by the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO) Codex Alimentarius committee for fruits, vegetables and some other foods (FAO/WHO 1993).



**Figure 1.** A lychee crop in Luc Ngan (Bac Giang Province), one of Vietnam's three major lychee growing areas.



**Figures 2A (above) and 2B (below).**

Hanging bags (or baskets) on the trees prevents much of the damage that occurs when fruit are otherwise dropped to the ground during harvest.



**Figure 3.** Unsound fruit must be removed to prevent disease transmission.



**Figure 4 (left).**

Packing the sorted lychee for transport to the packinghouse.



Hot dipping was also tried at temperatures of 47, 50, 52 and 55°C. After 20 days storage at 5°C, fruit treated with CBZ at 52°C had the best skin colour and lowest spoilage.

Drying was basically dependent on natural ventilation. In the case of large quantities of fruit and limited area, producers were advised to make shelves to provide more space (Figure 7). Packing took place right after drying (Figure 8). Lychee fruit were lightly loaded (bulk or bunches) into bamboo or wood packages (with the dimensions of 450 × 400 × 250 mm; Figure 9), after packing in thin polyethylene bags (Figure 10). A sachet of R3 ethylene absorbent (1.5 g R3/1 kg fruit) was placed inside the bag on the surface of the fruit before tying up the bags (Figure 10).

### Application of Ripening Retardant

In order to improve fruit quality, utilisation of an ethylene absorbent was tried at the same time as the management of harvest maturity.

A number of ripening retardants of the Chemistry Institute (National Centre for Natural Sciences and Technologies), the Institute of Chemical Industry and the Post-Harvest Technology Institute (PHTI) were tested in the 1999 lychee season. The results obtained were encouraging. At ambient temperatures, the control sample discoloured after 1 day and deteriorated after 3 days. Some treated samples maintained good quality (without discoloration or rotting) for 4 days, with R3 (a preparation devised by PHTI) able to prolong the shelf life of lychee to at least 5 days without any discoloration or rotting, and less than 5% of fruit were mouldy at 30–37°C.

The R3 treatment was very simple—1 × 10 g sachet of R3 was put in every 6–7 kg plastic bag (Figure 10).

The sachet was placed on the surface of the fruit mass. Fruit were protected from direct contamination by R3 through its containment in the paper bag sachets.

### Harvesting System

The harvesting system of lychee was determined and is presented in Figure 11.

If there is no cooling facility, the lychee fruit should be sent to markets after handling and packaging (steps shown on the left of Figure 11). As previously discussed, the storage duration using the R3 procedure could be 5 days. The products can be transported using existing trucks as far as southern Vietnam.

If cooling facilities are available, all the steps in Figure 11 have to be implemented. The cool storage temperature should be controlled between  $5 \pm 1^\circ\text{C}$  with in-room humidity of 70–80% and in-bag humidity of 90%. The possible storage period is 25 days plus 4 days for handling and transport, i.e. a total of 29 days.

The handling–transportation regime described above (at ambient temperature and cool temperature) was applied experimentally on a 10 t capacity scale (Figure 12). The success of these trials has led to economic benefits for lychee handling enterprises.

### Quality of the Produce

The sensory criteria of fresh lychee were evaluated using the Vietnamese Standard TCVN 3216-1994 by an panel of nine trained experts. The results showed that this produce (marked HN1 Table 1) scored 18.33 on the 20-point scale (Table 1).

**Table 1.** Sensory evaluation of cool-stored lychee fruit (according to the Vietnamese Standard TCVN 3216-1994 20-point scale).

Sample	Storage period (days)			
	24	24(+2)	37	37(+2)
BQ <sup>a</sup>	12.99	–	14.08	12.00
V <sup>b</sup>	15.50	14.50	13.96	12.25
HN0 <sup>c</sup>	15.90	14.15	15.87	12.80
HN1 <sup>c</sup>	18.33	15.63	17.77	14.00
Control	10.56	–	8.92	

<sup>a</sup> BQ = treated with benlate and sodium metabisulfite, without R3.

<sup>b</sup> V = treated as BQ, but with R3.

<sup>c</sup> HN0 and HN1 = treated with carbendazim (CBZ), SO<sub>2</sub> and R3, but with a higher dose of CBZ in HN1.

Note: The figure (+2) means the produce was stored for 2 days at the ambient temperature as soon as it was taken out of the cool store.



**Figure 5.** SO<sub>2</sub> fumigation of lychee.



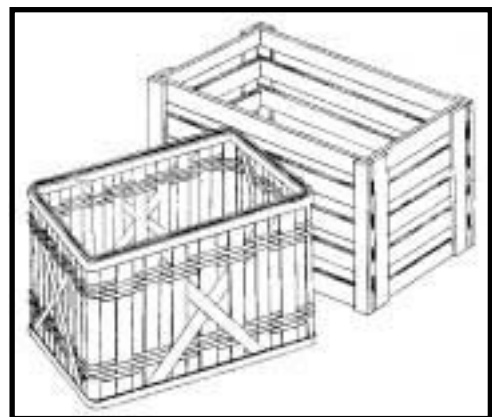
**Figure 6.** Fungicide dipping.



**Figure 7.** Shelves for air-drying lychee.



**Figure 8.** Packing of dried lychee.



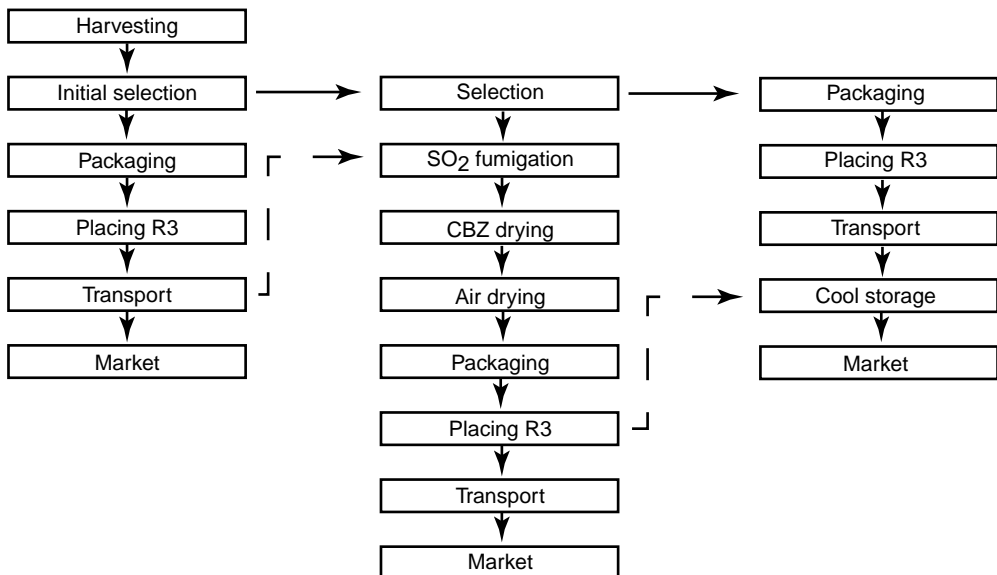
**Figure 9.** Bamboo and wooden packages for lychee.



**Figure 10.** Treated and packed lychee fruit (notice the R3 sachets on the lychee mass).



**Figure 12.** In the cool store with 10 t of experimental lychee.



**Figure 11.** The harvesting system for lychee (R3 = an ethylene absorbent; CBZ = carbendazim).



The hygienic criteria of this produce were tested (microbiological elements and residue of storage chemicals). The results of microbiological analysis showed that the produce was free from microorganisms in amounts which may represent a hazard to health. The fungicide residue in produce was identified as a maximum 0.8 mg per kg of fruit (Table 2).

## Future Research

On the basis of the success in the storage of the 10 t of lychee fruit, maintenance of sensory quality (odour, taste and status) and the shelf life of the fruit, we have a research plan for wider application in the coming years.

**Table 2.** Pesticide residue analysis report.

Commodity:	Stored fresh lychee	
Name of producer:	Post-Harvest Technology Institute	
Date of control:	28 June 1999	
Result:		
Sample	Pesticide name	Residue (mg/kg)
HN1	Carbendazim	0.80
HN0	Carbendazim	0.27
Analysed by The Center of Pesticide Analysis, Department of Plant Protection, Ministry of Agriculture and Rural Development.		

## References

- Coates, L.M., Johnson, G.I., Sardud, U. and Cooke, A.W. 1994. Postharvest diseases of lychee in Australia, and their control. In: Johnson, G.I. and Highley, E., ed., Development of postharvest handling technology for tropical tree fruits: a workshop held in Bangkok, Thailand, 16–18 July 1992. ACIAR Proceedings No. 58. Canberra, Australian Centre for International Agricultural Research, 68–69.
- Coates, L.M., Fitzell, R.D., Bagshaw, J.S. and Underhill, S.J.R. 1995. Postharvest diseases of horticultural produce. Tropical Fruit, Volume 2. Brisbane, Queensland Department of Primary Industries, 41–45.
- Duvenhage, J.A. 1993. Control of postharvest decay and browning of litchi fruit by sodium metabisulfite and low pH dips. Yearbook. South African Litchi Grower's Association, 5, 31–32.
- FAO/WHO (Food and Agriculture Organization of the United Nations/World Health Organization) 1993. Codex Alimentarius, Volume 2. Pesticide Residues in Food. Rome, FAO.
- Holcroft, D.M. and Mitcham, E.J. 1996. Postharvest physiology and handling of litchi. Postharvest Biology and Technology, 9, 265–277.
- Paull, R.E., Reyes, M.E.Q. and Reyes, M.U. 1995. Litchi and rambutan insect desinfestation: treatments to minimize induced pericarp browning. Postharvest Biology and Technology, 6, 139–148.
- Sittigul, C., Sardud, U., Sardud, V. and Chaiwangsri, T. 1994. Effects of fruit maturity at harvest on disease development in lychee during storage. In: Johnson, G.I. and Highley, E., ed., Development of postharvest handling technology for tropical tree fruits: a workshop held in Bangkok, Thailand, 16–18 July 1992. ACIAR Proceedings No. 58. Canberra, Australian Centre for International Agricultural Research, 9–14.

# Twist Test Measurement of Mango Texture

X.H. Nguyen\*, L.U. Opara† and C.J. Studman†

## Abstract

The softening behaviour of mangoes (cultivar 'Buoi' in Vietnam) was investigated during cold storage at 12°C and 85–90% relative humidity using the Massey University Twist Tester. Crushing stress (CS) significantly ( $P < 0.05$ ) declined with increased storage time during the first 20 days, but there was no significant difference between fruit stored for 20 days and longer. During the first 10 days of storage, CS was affected by harvest date. The value of CS for early harvested fruit was significantly higher than for mid- and late-harvested fruit stored for up to 10 days, but subsequently this difference disappeared. Differential softening in the inner and outer mesocarp tissue of 'Buoi' and 'Thom' mangoes was also measured. CS values for the outer part of the mesocarp were significantly higher than for the inner part when fruit were still firm (up to 10 days storage). However, values were significantly lower when fruit become soft (after 15 days storage).

MANGO is an important commercial fruit in Vietnam and the other tropical countries. In practice, firmness of the mesocarp is an indicator of the stage of fruit ripeness and is commonly measured by finger pressure (Brown et al. 1981), the Magness–Taylor penetrometer (Thompson 1971), the McCormick pressure tester (Lazan et al. 1993), or an Instron Universal testing machine (e.g. McLauchlan and Barker 1994). All of these measurement techniques for assessing maturity are based on the principle of compression using a penetrometer. However, there are a number of difficulties with these methods. One of the difficulties is that these methods are unable to assess flesh properties as a function of depth (Studman and Yuwana 1992). This can be important in fruit which ripen unevenly in the pulp, such as mangoes and kiwifruit. The Massey University Twist Tester (MTT) offers a new technique for determining fruit texture which eliminates some of the disadvantages of the penetrometer (Studman and Yuwana 1992). The twist tester is used to measure the moment required to crush fruit cells using a blade which rotates inside the fruit, and this moment is converted to a crushing stress

figure for the fruit tissue by calculation. The principle of this device is showed in Figure 1. For an element of fruit flesh with a radial with  $dx$  and length  $b$ , the flesh crushing stress is obtained through the following formula:

$$\sigma = \frac{M \cdot \sin \epsilon}{a^2 \cdot b} \quad (1)$$

Where:  $\sigma$  = flesh crushing stress (Pa)

$M$  = the maximum moment produced when the arm is horizontal (N.m)

$\epsilon$  = angle of rotation of twist arm at full crushing (m)

$a$  = blade radius (m)

$b$  = blade width (m)

The objective of this study was to investigate maturity assessment and uneven ripening in mango fruit grown in Vietnam using the twist tester.

## Materials and Methods

### Fruit samples

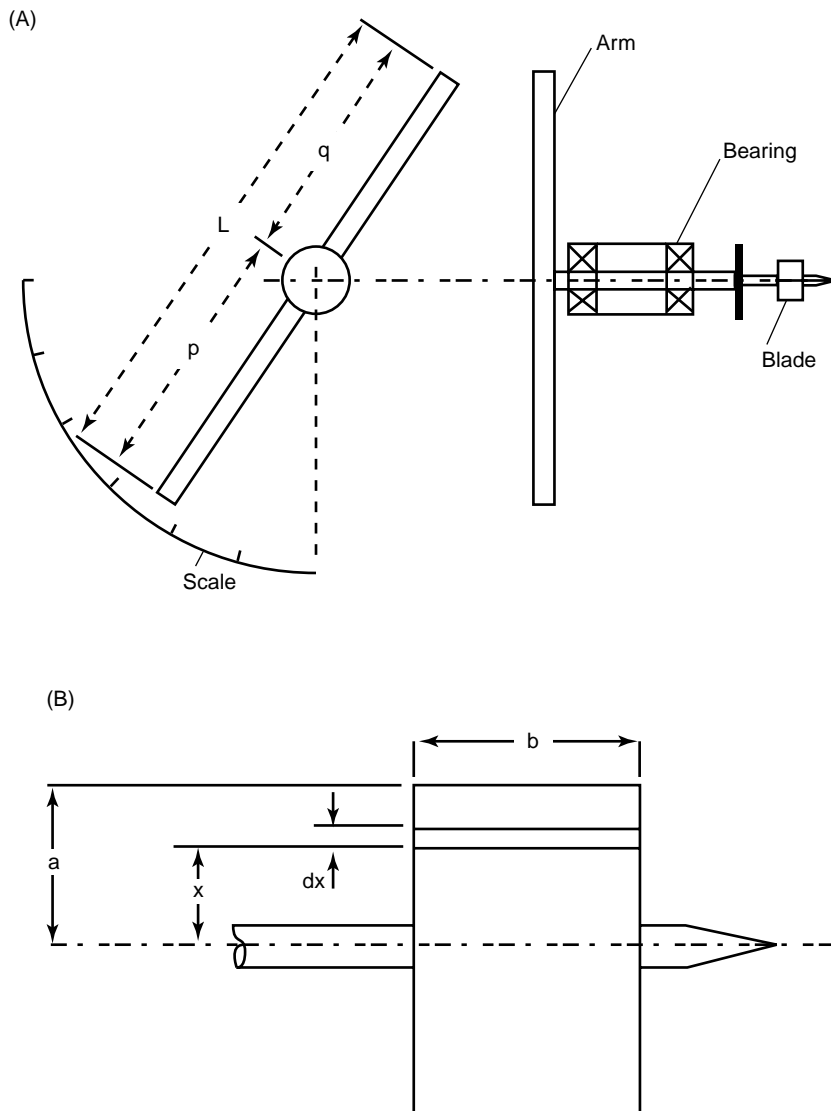
Green mature 'Buoi' and 'Thom' mangoes were harvested during the commercial harvest period from orchards in Hoa Loc area, Cai Be district, in the Tien Giang Province in Vietnam. 'Buoi' mangoes were harvested at three different times (12-day intervals) while 'Thom' mangoes were harvested only once (the

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same time as the second harvest of 'Buoi' mangoes). Fruit were packed in baskets covered by paper and transported to the Post-Harvest Technology Institute (PHTI) in Ho Chi Minh City by car within 12 hours (ambient temperature  $31 \pm 3^\circ\text{C}$ ). At the Institute laboratory, fruit samples were examined for the presence

of mechanical injuries, pests, and diseases, and sorted accordingly. Samples to be used for future experiments were immediately selected and put into a cold store at  $12 \pm 1^\circ\text{C}$ . Tests on the fresh fruit were carried out after sorting.



**Figure 1.** The principal of the Massey University Twist Tester showing (A) the general layout and (B) an enlargement of the blade, where  $L$  = rod length (m),  $p$  and  $q$  = arm lengths (m),  $a$  = blade radius, and  $b$  = blade width.

## Treatments

Three treatments were tested. In treatment 1, a sample of 120 'Buoi' mango fruit from each harvest was stored at  $12 \pm 1^\circ\text{C}$  (85–90% relative humidity; RH) for 25 days. Every 5 days 20 fruit were removed from cold storage and the fruit texture and soluble solids content (SSC) were assessed. Measurements from a sample of fresh fruit were also recorded. In treatment 2, a sample of 30 'Buoi' mango fruit from the second harvest was kept under the same conditions as treatment 1 for 25 days. Every 5 days, 5 fruit were removed from the cold store and the texture of different layers of the mesocarp (inner and outer) was assessed. In treatment 3, a sample of 40 'Thom' fruit was used. 20 fresh fruit were assessed as in treatment 2, and another 20 were stored at  $12 \pm 1^\circ\text{C}$  (RH 85–90%) and assessed after 21 days.

## Assessments

Fruit texture was measured using the twist tester connected to a portable computer. In treatment 1, the blade of the twist tester was inserted in one side of the fruit's cheek to a depth of about 12 mm, and this was then repeated on the other side. The results of these two readings were averaged. In treatments 2 and 3, the blade was inserted in one side of the cheek of the fruit for the test on the outer mesocarp (depth 5 mm), and after all these outer tests were completed, the same measurement was taken but on the other side of the same fruit to measure the properties of the inner mesocarp (depth 8 mm). Thus the results could be recorded in pairs to give readings for the outer and inner mesocarp of the same fruit.

The SSC of expressed fruit juice (% Brix) was measured using a hand-held refractometer (Atago N-20, Brix 0–20%). The tissue used for measuring SSC was taken from the area close to the crushed area used for the texture assessment and at a similar depth.

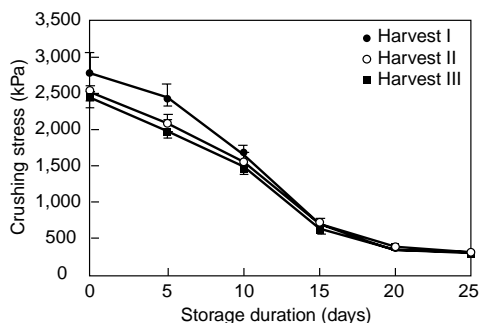
## Statistical analyses

Data from treatments 1, 2 and 3 were subjected to the analysis of variance (ANOVA) and the means were compared using least significant differences.

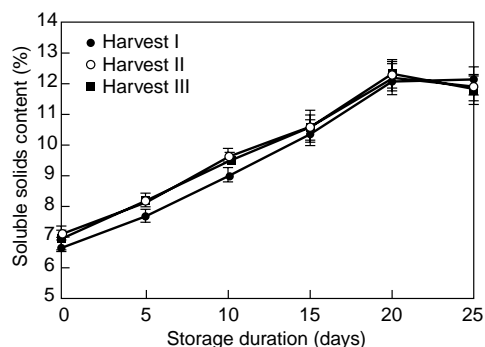
## Results

In treatment 1, the crushing stress (CS) of fruit fresh significantly declined with increased storage time ( $P < 0.05$ ). However, there was no significant dif-

ference between fruit stored for 20 days and for 25 days (Figure 2). For up to 10 days of storage, CS was dependent on the harvest date. The value of CS of early harvested fruit (first harvest) was significantly higher than that in the mid- and late-harvested fruit (second and third harvest) for up to 10 days storage, but after that time this difference disappeared. SSC significantly increased up to 20 days storage, but declined after that (Figure 3). The highest values of SSC were 12.20%, 12.32% and 12.31% for early, mid- and late-harvested fruit, respectively. Up to 10 days storage, early harvested fruit had significantly lower SSC compared to the mid- and late-harvested fruit. However, if fruit were stored longer, there were no differences in SSC for fruit from the three harvests.



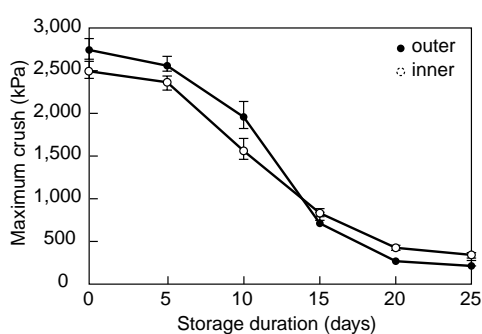
**Figure 2.** Change in texture of 'Buoi' mangoes during 25 days storage at  $12^\circ\text{C}$  from three different harvests.



**Figure 3.** Change in soluble solids content of 'Buoi' mangoes during 25 days storage at  $12^\circ\text{C}$  from three different harvests.

In treatment 2, the storage duration affected the flesh CS of the inner and outer mesocarp of ‘Buoi’ mango fruit (Figure 4). CS of both the inner and outer layers decreased with increasing storage time. Figure 4 shows that for the first 2 weeks of storage at 12°C the CS of the outer mesocarp was significantly higher than that of the inner mesocarp ( $P < 0.05$ ). However, after 2 weeks storage this value changed, so that it was lower than the inner mesocarp value.

In treatment 3, the CS of the outer mesocarp of ‘Thom’ mango at harvest (firm fruit) was significantly higher than the inner mesocarp ( $P < 0.05$ ). However, it was significantly lower after 21 days storage at 12°C (Table 1). By this time the fruit was soft.



**Figure 4.** Change in texture of ‘Buoi’ mangoes in different layers of the mesocarp during 25 days storage at 12°C.

**Table 1.** The effect of differential ripening in ‘Thom’ mango mesocarp during storage at 12°C (85–90% relative humidity). Means with the same letter are not significantly different ( $P < 0.05$ ).

Portion of mesocarp	Crushing stress (kPa) over time	
	0 days storage	21 days storage
Outer	2 971.0 a	277.1 b
Inner	2 636.0 b	377.8 a

## Discussion and Conclusion

The results of both treatments 1 and 2 show that the texture (as measured by CS) of ‘Buoi’ mangoes declined significantly during a period of 25 days storage at 12°C (RH 85–90%). This was similar to the results reported by many other workers, such as Abu-

Sarra and Abu-Goukh (1992) and Aina and Olanjuoye (1993), using other measurement techniques. Most of the decline occurred in the first 2 weeks. This period is believed to coincide with the climacteric maximum (Abu-Sarra and Abu-Goukh 1992). Ripening of mango fruit is characterised by softening of the flesh and is apparently related to a change in the activities of cell wall-degrading enzymes such as pectinesterase (PE) and polygalacturonase (PG). The loss of firmness is associated with an increase in PE activity and a decrease in PG activity (Tucker and Seymour 1991; Abu-Sarra and Abu-Goukh 1992). It has also been reported that this is correlated with an increase in SSC (Chaplin et al. 1990).

In the first 10 days, early harvested fruit were firmer than mid- and late-harvested fruit (Figure 2). This may be explained by early harvested fruit being still immature while mid- and late-harvested fruit were already mature. Figure 3 also shows that during this time, SSC in early harvested fruit was significantly lower than in mid- and late-harvested fruit. Seymour et al. (1990) investigated immature, half-mature and mature mango fruit cultivars ‘Amelie’, ‘Kent’ and ‘Sensation’, and reported similar results. Therefore, it implies that although all the ‘Buoi’ mangoes were harvested by the same method, i.e. based on morphological appearance (Medlicott 1988) and uniform skin colour, the early fruit were still immature.

The results of treatments 2 and 3 for both ‘Buoi’ and ‘Thom’ mangoes showed that in (unripened) firm fruit the CS value in outer mesocarp was significantly higher than in the inner mesocarp. However, in soft (ripe) fruit the result was the opposite; the CS value in outer mesocarp was significantly lower than in inner mesocarp (Figure 4 and Table 1). This result is different to the results reported by both Lazan et al. (1986, 1993) and Chaplin et al. (1990). Their results showed that the inner mesocarp was softer than the outer mesocarp in ripe fruit. There may be differences in terms of the definition of ‘soft fruit’ between the present study and the earlier research. In our study, Figure 4 shows that ‘soft fruit’ had a CS value below about 600 kPa. If, in previous studies, the ‘soft fruit’ measured by the researchers still had a CS value higher than 600 kPa (e.g. about 1,000 kPa), then there would be agreement between these studies. Alternatively, the different results may reflect the use of different measurement techniques based on different principles (i.e. traditional compression tests compared with the new twist test). In ripe mango fruit the density of fibres in the inner mesocarp (nearer to the stone) is normally higher and harder, and therefore the blade of the twist

tester meets more resistance from these fibres, giving a higher CS value. Another possibility is that the results differ because of the use of different mango cultivars. For example, Chaplin et al. (1990) reported that the differences in softness of inner and outer mesocarp sections were greater in 'Arumanis' and 'Mulgoa' than in 'Haden' and 'Kensington'.

Overall, this study has shown that for mango, texture can be used as a maturity index, and it can be assessed by the Massey Twist Tester. To determine harvest date for the early harvest of 'Buoi' mangoes, morphological and uniform skin colour methods are not enough and may lead to picking immature fruit. Therefore, additional methods should be combined with those mentioned above (such as counting the number of days after flowering) to improve maturity assessment. 'Buoi' and 'Thom' are two mango cultivars which display differential ripening throughout their thickness.

## Acknowledgments

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## References

- Abu-Sarra, A.F. and Abu-Goukh, A.A. 1992. Changes in pectinesterase, polygalacturonase and cellulase activity during mango fruit ripening. *Journal of Horticultural Science*, 67, 561–568.
- Aina, J.O. and Oladunjoye, O.O. 1993. Respiration, pectolytic activity and textural changes in ripening African mango (*Irvingia gabonensis*) fruits. *Journal of the Science of Food and Agriculture*, 63, 451–454.
- Brown, B.I., Scott, K.J. and Chaplin, G.R. 1981. Spongy stem-end in mango. *Queensland Fruit and Vegetable News*, 52, 479.
- Chaplin, G.B., Lai, S.C. and Buckley, M.J. 1990. Differential softening and physico-chemical changes in the mesocarp of ripening mango fruit. *Acta Horticulturae*, 269, 233–239.
- McLauchlan, R.L. and Barker, L.R. 1994. Controlled atmospheres for Kensington mango storage: classical atmosphere. In: Johnson, G.I. and Highley, E., ed., *Development of postharvest handling technology for tropical tree fruits: a workshop held in Bangkok, Thailand, 16–18 July 1992*. ACIAR Proceedings No. 58. Canberra, Australian Centre for International Agricultural Research, 41–44.
- Medlicott, A.P., Reynolds, S.B., New, S.W. and Thompson, A.K. 1988. Harvest maturity effects on mango fruit ripening. *Tropical Agriculture (Trinidad)*, 65, 153–157.
- Lazan, H., Ali, Z.M., Lee, K.W., Woon, J. and Chaplin, G.R. 1986. The potential role of polygalacturonase in pectin degradation and softening of mango fruit. *ASEAN (Association of South-East Asian Nations) Food Journal*, 2, 93–95.
- Lazan, H., Ali, Z.M., Soh, J.S. and Talkah, Z. 1993. The biochemical basis of differential ripening in mango. *Acta Horticulturae*, 341, 500–509.
- Seymour, G.B., N'Diaye, M., Wainwright, H. and Tucker, G.A. 1990. Effects of cultivar and harvest maturity on ripening of mangoes during storage. *Journal of Horticultural Science*, 65, 479–483.
- Studman, C.J. and Yuwana 1992. Twist test for measuring fruit firmness. *Journal of Texture Studies*, 23, 215–227.
- Thompson, A.K. 1971. The storage of fruits. *Tropical Agriculture*, 48, 63–70.
- Tucker, G.A. and Seymour, G.B. 1991. Cell wall degradation during mango fruit ripening. *Acta Horticulturae*, 291, 454–460.

# Designing Effective Quality Systems for Horticultural Businesses and Organisations

M.F. Piccone and C.J. Bunt\*

## *Abstract*

An effective quality system in any part of the horticultural supply chain should be designed to meet the needs and requirements of the customer(s), and must also make a valuable contribution to the business or organisation developing and implementing it.

There are several international codes and standards that can be used as guidelines, benchmarks and checklists for applying quality systems. This paper outlines options involving practical and economical methodologies to design and implement an effective, tailored quality system. It also discusses the methodology and uses for 'quality planning'.

THE INTERNATIONAL food industry has to deal with a seeming 'tide' of increasing expectations from governments, the marketplace and the public. In particular, an expectation that food businesses—including horticultural producers and postharvest handlers—must be fully accountable in terms of the integrity of the products they produce and the methods used in producing these products.

Legislation is being introduced in Australia which puts the onus squarely on food producers and handlers in terms of their due diligence and the management of risk in producing safe food—whilst also protecting the environment. This is happening concurrently with ever increasing expectations from retailers, eateries and caterers generally for supplier compliance with product quality specifications and quality system performance standards. To add to this pressure, other issues such as compliance with workplace health and safety legislation and codes of practice are also impacting on food producers and handlers.

## **Quality Management Systems in Australian Horticulture**

A large number of Australian growers perceive quality systems as basically prescriptive, 'you must do it this

way' programs where the primary objective is producing a 'top quality' product aimed at high value markets. Product defects are defined and an 'inspect and reject', 'quality control' style regime is implemented.

These perceptions have developed because many of the industry-based quality assurance programs and training initiatives that have evolved in Australian horticulture in the last 10 years have been designed with their primary focus on product standards and product maintenance, i.e. grading of product to meet product specifications and prevention of spoilage, especially postharvest.

More recently, this focus has been extended to growers, packhouses and wholesalers achieving compliance with 'customer' requirements, such as adherence with retailer-driven food safety codes and also (where applicable) interstate and export quarantine protocols. There has been far less emphasis on horticultural producers and suppliers employing quality management systems as a means to improve their own business performance, i.e. utilising their quality systems to pinpoint internal management strengths and weaknesses, increasing efficiencies 'across the board', quantifying and reducing costs, and further strengthening relationships between themselves and other participants in their respective marketing chains. This is hardly surprising, as retailer-driven codes rightly focus on suppliers consistently

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meeting retailer requirements. It is not the role of retailers to rigorously assess or seek to influence the overall business efficiencies or otherwise of their suppliers.

Recent events in Australia, such as the development and promotion of the SQF 2000 code and the supermarket supplier approval initiatives are reinforcing the perception of quality management as primarily a means of satisfying customer requirements for product quality and safety. These codes place great emphasis on compliance issues such as suppliers exhibiting due diligence and being certified against relevant standards and codes. However, a more positive, commercial approach to quality management from the perspective of suppliers revolves around quality systems being used by growers, packhouses, transporters, wholesalers etc. as an internal business improvement tool, as well as a means of satisfying customer and regulatory requirements.

‘Well rounded’ quality systems are seen as having two main purposes:

- The first is to provide a systematic, objective way of finding out what customers really want in terms of the goods and services created and supplied and ensuring this information is both complete and up-to-date.
- The second purpose follows on from the first in that an effective quality system ensures that the organisation(s) or marketing chain as a whole can deliver exactly what is expected, as cost-effectively and efficiently as possible.

## Business Management Systems

Management systems are the ‘head and heart’ of any organisation. A business or organisation involved in the production, transportation or marketing of horticultural products is likely to (or should!) have effective systems in place to manage a raft of interrelated activities. These would likely include, but may not be limited to:

- Quality systems — i.e. the policies and practices put into place by the organisation to ensure that customer requirements are clearly understood. Once more, that people, processes, products and services are well managed so as to reliably, consistently and cost-effectively meet those needs.
- Food safety systems — i.e. the policies and practices put into place by the organisation to ensure that any food safety hazards that potentially apply to the products being produced, transported or

marketed are clearly understood and are effectively prevented or controlled as required.

- Environmental management systems — i.e. the policies and practices put into place by the organisation to not only consider the actual or potential environmental consequences of their activities, but also the actions then taken to prevent environmental harm and to use environmental resources efficiently.

Other management systems also need to be considered. Australian horticultural producers for example, may manage systems for compliance with quarantine protocols, recruitment and training and workplace health and safety (to say nothing of management of finances).

These systems also need to be understood, integrated and effectively managed if an organisation is to be successful — successful not just financially, but also in terms of meeting the personal expectations of the people active in the organisation whilst also meeting all legal obligations and responsibilities to the greater community.

People genuinely interested in quality, food safety or environmental management systems (or any combination thereof) can greatly increase their understanding of these disciplines by becoming familiar with three ‘core’ sets of documentation:

- the ISO 9000 series of quality management standards;
- the Hazard Analysis and Critical Control Point (HACCP) technique used to identify and control food safety hazards; and
- the ISO 14000 environmental management standards.

The ISO 9000 series is designed to be used in a way that best reflects the organisation(s) concerned and used properly will simplify rather than complicate an organisation’s activities. There is nothing in this standard that isn’t based on absolute common sense.

Elements in the ISO 9000 compliance standards are applied only as appropriate and not at all if an element is not applicable to the organisation(s) concerned.

The emphasis is on simply and clearly documented, market-driven, ever-evolving systems that provide discipline within an organisation yet reflect the pace of change in business. They are also likely to accommodate the need for people to have appropriate flexibility in the way they function wherever this can benefit the organisation and its customers, whilst still ensuring people operate within acceptable parameters.

Another factor horticultural producers and distributors need to consider is this; the best way to produce



and maintain quality assured, 'safe' products is to have all aspects of the business, including the production system, working efficiently. If all your management systems are working well you can't help but achieve good, reliable outputs in a cost-effective manner. Management codes that focus primarily on maintenance of the product rather than management of the system as a whole so as to reliably produce good products and services won't achieve all the principles of good business practice.

## **Integrating Management Systems — Quality Planning**

Many horticultural producers fall into the 'small to medium' business size category. Many are family-run businesses of long standing.

The management systems employed by these businesses are likely to cover a broad spectrum of management policies and on-farm and postharvest activities. These systems may be 'formalised' to some degree or another by way of being documented, or they may operate 'informally', i.e. based on long-standing practices and attitudes instilled on the farm or in the packhouse by way of verbal instruction and management example. In formalising management systems, businesses go through a process of:

- reviewing current policies and practices;
- making adjustments to existing policies and practices where these are seen to be necessary (perhaps due to changing customer/regulatory requirements, perhaps due to management objectives for increasing efficiencies); and
- documenting the management system in the form of company policies, job descriptions, procedures/work instructions, perhaps specifications and also records (where seen as necessary).

This 'quality planning' process repeats itself over time by way of management reviews, customer feedback, performance analyses etc. so that the systems are constantly improved and refined.

## **Summary**

Quality management systems only really work and reach their potential when developed holistically. Given the nature of most horticultural businesses, the most logical way of both structuring and implementing on-farm and packhouse management systems is to integrate quality, food safety, environmental, workplace health and safety, and quarantine management into one, fully-integrated management system. This is a particularly logical approach given a range of factors:

- Workers on the farm or in the packhouse are likely to be dealing with a range of these issues concurrently as part of their everyday work.
- All of these issues tend to overlap to some extent or another.
- The only way to make a management system 'work' is to incorporate it fully into everyday management practices and business operations.
- Integrating documentation and key activities (such as training) so as to cover the range of management issues encountered 'on the job' is more cost-effective and less confusing for people active in the system.

# Preliminary Results on a Fruit Fly Investigation in the South of Vietnam

Nguyen Ngoc Thuy, Huynh Tri Duc and N.H. Vu\*

## Abstract

Southern Vietnam has a wide variety of tropical fruits whose cultivation has been rapidly developing in recent years. As many fruit types—both seasonal and non-seasonal—are overlapping, the conditions are very favourable for sustaining a diversity of pest species. Losses of fruit caused by fruit fly (family Tephritidae) result from deposition of eggs under the skin of fruit and subsequent larval feeding and premature fruit drop. This leads to unacceptable quality of infested fruit which can not be exported due to the quarantine restrictions imposed by most of the importing countries.

Therefore, a research program for fruit fly management at the preharvest stage has been conducted to reduce these losses as well as to contribute to improved postharvest treatments to disinfest the fruit. An investigation into the identification of susceptible species showed that there are about 15 kinds of economically important fruits which are attacked by fruit fly, including guava, wax apple, jujube, mango, citrus, longan, rambutan, sapodilla and papaya. Of these, damage to guava and wax apple was recorded to be as high as 50% of the yield.

Using traps, we have so far identified 11 species of fruit fly in southern Vietnam, occurring with various frequency. The most common were *Bactrocera correcta*, *B. cucurbitae* and *B. dorsalis* complex.

FRUIT FLIES are a global problem, causing damage to a wide range of fruits and vegetables. They comprise a large number of species, whose distribution and severity of impact varies from region to region. Fruit flies are crucial to fruit and vegetable import–export guarantee schemes. During recent years, along with rapid development of fruit production in southern Vietnam, the need for an effective investigation into appropriate control measures has become urgent in order to allow the export of Vietnamese fruit to international markets.

Although there have been fruit fly studies made in different parts of the world, there has been very little work undertaken in Vietnam in this area. However, in order to establish effective control measures, we need clear knowledge about the present status of: fruit fly species diversity; and the relationship between fruit flies and crops and the environment. This study aimed to investigate the diversity and distribution of fruit flies and the range of host crops to provide a basis for further studies.

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## Materials and Methods

### Diversity and distribution of fruit flies

#### Male fruit fly study

To study the male fruit fly, Steiner traps were used with the application of following the chemicals as pheromones:

- methyl eugenol (4-allyl-1,2-dimethoxybenzene);
- Cuelure (2-butanol,4-hydroxyphenyl acetate); and
- Trimedlure (butyl-4,chloro-2-methyl cyclohexane carboxylate).

The traps were permanently installed under various environmental conditions in the provinces of Tien Giang, Vinh Long, and Can Tho in The Mekong Delta, and Binh Duong, Dong Nai, and Binh Thuan in south-eastern area.

Flies were collected from the traps weekly in Mekong Delta and fortnightly in the south-eastern area then classified and counted. To calculate the rate and the frequency of a fruit fly species present in one location, the following formula were applied:

$$\text{Appearance frequency of a species (\%)} = \frac{\text{Number of times of appearance}}{\text{Number of times of observation}} \times 100 \quad (1)$$

$$\text{Rate of appearance (\%)} = \frac{\text{Number of bodies of species trapped}}{\text{Total number of fruit flies trapped}} \times 100 \quad (2)$$

#### Female fruit fly study

For the female fruit fly study, McPhail traps were used at Tien Giang Province with the application of hydrolysed proteins. The chemical was refilled weekly at the time of fruit fly sample collection.

### Host crops survey

Fruits, vegetables, industrial crops, ornamental plants, and wild plants were sampled at various times and places. The samples were brought back to the laboratory and observed until flies emerged, where possible. Fruit flies were coaxed out of the fruits over 10 days using a sugar-protein solution, then identified and classified. The corresponding host plants were also recorded.

The taxonomic keys used for identification and classification were:

- Drew 1989;
- Drew and Hancock 1994;
- Ian M. With and Madelene M. Elson-Harri (Fruit flies of economic significance); and
- some of samples were identified by Dr Dick Drew (Griffith University, Australia ) and Dr Gerard Delvare (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement —CIRAD, France).

### Evaluating the infection level of some host fruit crops

The infection level was preliminarily evaluated using the total number of times each crop was sampled, the number of samples infected, and the number of infected fruit to provide a ranking of the infection level.

## Results and Discussion

### Host fruit crops

646 fruit samples of different plant species were collected, including fruit crops, vegetables, industrial crops, landscaping plants, and wild plants. A complete list of the plants and their severity of infection is given in Table 1.

**Table 1.** Plant hosts of fruit fly and their infection levels in southern Vietnam (Southern Fruit Research Institute 1999).

No.	Common name	Botanical name	Severity <sup>a</sup>	Sample site <sup>b</sup>
<i>Fruit crops</i>				
1	Guava	<i>Pisidium guivava</i>	++++	TG, DT, CT, BT, DN
2	Water apple	<i>Prunus salicina</i> Lind.	++++	TG, CT, BT, DN, BD
3	Jujupee	<i>Zizyphus mauritiana</i> Lamk.	+++	TG, DT, CT
4	Mango	<i>Mangifera indica</i> L.	++	TG, CT, KH, DN, BT
5	Mandarin	<i>Citrus reticulata</i> Blanco	++	VL, CT, DT
6	King mandarin	<i>Citrus nobilis</i>	++	TG, BT
7	Longan	<i>Nephelium longana</i>	+	TG, BT, VL
8	Rambutan	<i>Nephelium lappaceum</i>	++	TG, BT, DN
9	Soursop	<i>Annona muricata</i>	++	TG, ST
10	Papaya	<i>Carica papaya</i> L.	+	TG, BT, DT
11	Carambola	<i>Averrhoa carambola</i> L.	++	TG, CT, DN, BT
12	Sapodilla	<i>Achras sapota</i>	++	TG, CT, DN, BT

<sup>a</sup> Severity of infection: ++++ = serious; +++ = hard; ++ = moderate; + = low.

<sup>b</sup> Sample sites: TG = Tien Giang Province; BT = Ben Tre; CT = Can Tho; DT = Dong Thap; DN = Dong Nai; VL = Vinh Long; BT = Binh Thuan; ST = Soc Trang; DL = Da Lat.

**Table 1.** (Cont'd) Plant hosts of fruit fly and their infection levels in southern Vietnam (Southern Fruit Research Institute 1999).

No.	Common name	Botanical name	Severity <sup>a</sup>	Sample site <sup>b</sup>
<i>Fruit crops</i> (cont'd)				
13	Avocado	<i>Persea americana</i> Mill.	+	DN, DL
14	Dragon fruit	<i>Hylocereus undulatus</i> (Haw.)	+	TG
<i>Vegetables</i>				
1	Bitter gourd	<i>Momordica charantia</i> L.	+++	TG, CT, BT
2	Soft melon	<i>Cucumis melo</i> L.	+	DN, DL
3	Bean	<i>Vigna sesquipedalis</i> L.	+	DN
<i>Industrial crops</i>				
1	Cashew	<i>Anacardium occidentale</i> L.	++	DN, BT
<i>Wild plants</i>				
1	Gymnopetalum	<i>Gymnopetalum ochinchinense</i> (Lour.-)	++++	VL, CT
2	Calophyllylum	<i>Calophyllum inophyllum</i> L.	+	CT, VL, TG
3	Coccinia	<i>Coccinia</i> sp.	++++	TG, CT, BT
4	Terminatia	<i>Terminalia catappa</i> L.	+++	TG, DN

<sup>a</sup> Severity of infection: ++++ = serious; +++ = hard; ++ = moderate; + = low.

<sup>b</sup> Sample sites: TG = Tien Giang Province; BT = Ben Tre; CT = Can Tho; DT = Dong Thap; DN = Dong Nai; VL = Vinh Long; BT = Binh Thuan; ST = Soc Trang; DL = Da Lat.

14 fruit species were infected, with guava and rose apple ranking highest in the infection level in all locations. *B. correcta* and *B. dorsalis* were the predominant fruit fly species in both cases. The number of infected mango samples were relatively low.

While in Malaysia and southern Thailand the fruit fly attack on carambola is by *B. carambolae*, in Bin Thuan the major problem species was *B. correcta*, although *B. carambolae* was also recorded in methyl eugenol traps.

Most of fruits infected were at the mature or ripening stage, however fruit fly also attacked immature sapodilla fruit collected in Ben Tre.

The infection level of other fruits was low (Table 1). However, as harvest seasons of the different fruits occur at different times of the year, the fruit flies have continuous sources of food and several generations of fruit flies can be produced, resulting in a huge population.

On vegetables, the most prominent fruit fly recorded was *B. cucurbitae* and bitter gourd was worst affected at the harvesting stage.

*Coccinia* sp. and *Gymnopetalume ochichinense* were most infected among the wild plants by *B. cucurbitae*, *B. correcta*, and *B. calophyli*, and other

*Bactosera* spp. were also recorded on other wild plant species.

## Diversity and distribution of fruit flies

The diversity and distribution of fruit flies trapped are shown in Tables 2, 3, 4 and 5.

### *Methyl eugenol traps*

Among seven fruit fly species identified, *B. correcta* had the highest frequency and rate of appearance (85–100% and 86.9%, respectively) while *B. dorsalis* complex had an appearance frequency of 9.5%, and other species 3.6%. Some flies were only identified to the *Bactrocera* complex level. *B. carambolae* ranked high in frequency (76.5%), but low in the rate of appearance. These results suggest that is dominant to the *B. dorsalis* complex and other species, and we suggest there is competition between the two species, with some unknown factors affecting this competition.

### *Cuelure traps*

*B. cucurbitae* was the dominant species caught in the Cuelure traps. This finding concurs with the observation that most of the flies emerging from the vegetable fruit samples were from this species. From this, we can say that the main fruit fly attacking plants

**Table 2.** Important fruit fly species and the crops they affect (Southern Fruit Research Institute 1999).

Scientific name	Crop
<i>Bactrocera (Bactrocera) correcta</i> (Bezzi)	Guava Water apple Mango Jujubee Carambola Sapodilla
<i>Bactrocera (Bactrocera) dorsalis</i> (Hendel)	Guava Water apple Mango Jujubee
<i>Bactrocera (Zeugodacus) cucurbitae</i> (Coquillette)	Bitter gourd Soft melon Bean Coccinia Gymnopetalum

**Table 3.** Species of fruit flies and where they were collected (Southern Fruit Research Institute 1999).

No	Species of fruit flies	Collected from
1	<i>Bactrocera (B) correcta</i> (Bezzi)	ME <sup>a</sup>
2	<i>Bactrocera (B) dorsalis</i> (Hendel)	ME
3	<i>Bactrocera (B) carambolae</i> (Drew & Hancock)	ME
4	<i>Bactrocera (B) zonata</i> (Saunders)	ME
5	<i>Bactrocera (B) osbeckia</i>	ME
6	<i>Bactrocera (B) verbascifolia</i>	ME
7	<i>Bactrocera (B) raiensis</i>	ME
8	<i>Bactrocera</i> sp.	ME
1	<i>Bactrocera (Zeugodacus) cucurbitae</i> (Coquillette)	CUE <sup>a</sup>
2	<i>Bactrocera (Zeugodacus) tau</i> (Walker)	CUE
3	<i>Bactrocera rubigina</i>	CUE
4	<i>Bactrocera hochii</i>	CUE
5	<i>Bactrocera longicornis</i>	CUE
6	<i>Bactrocera</i> sp.	CUE
7	<i>Dacus (Callantra)</i> sp.	CUE
1	<i>Batrocera (Gymnodacus) calophylli</i> (Perkin & May)	Fruit
2	<i>Bactrocera (Zeugodacus) cucurbitae</i> (Coquillette)	Fruit
3	<i>Bactrocera (B) correcta</i> (Bezzi)	Fruit
4	<i>Batrocera (B) papayae</i>	Fruit

<sup>a</sup> ME = collected from methyl eugenol traps  
<sup>b</sup> CUE = collected from Cuelure traps

of the Cucurbitaceae is *B. cucurbitae*. Seven other fruit fly species were also found in Cuelure traps, including *Dacus (Callantra)* sp. and *Bactrocera* sp. not yet identified to the species level.

**Table 4.** The occurrence of some fruit fly species in the Mekong Delta (Southern Fruit Research Institute 1999).

Species	Frequency (%)	Rate (%)
Methyl eugenol trap		
<i>Bactrocera correcta</i>	100.0	86.9
<i>Bactrocera dorsalis</i>	86.7	9.5
<i>Bactrocera carambolae</i>	6.5	2.1
Cuelure trap		
<i>Bactrocera cucurbitae</i>	99.5	90.1
<i>Bactrocera</i> sp.	43.3	5.3
<i>Dacus (Callantra)</i> sp.	40	4.4

**Table 5.** The occurrence of some fruit fly species in the south-eastern areas of Vietnam (Southern Fruit Research Institute 1999).

Species	Frequency (%)	Rate (%)
Methyl eugenol trap		
<i>Bactrocera correcta</i>	85	25
<i>Bactrocera dorsalis</i>	98.0	70
<i>Bactrocera</i> sp.	25	5
Cuelure trap		
<i>Bactrocera cucurbitae</i>	100	85
<i>Bactrocera</i> sp.	13	3
<i>Dacus (Callantra)</i> sp.	28	12

*B. calophylli* was found in fruit samples, but not in either the methyl eugenol or Cuelure traps. No fruit flies were recorded in the Trimelure traps during the

study, suggesting that *Ceratitis* spp. are not present in the region.

Using male or female attractants in bait sprays such as methyl eugenol and Cuelure, alone or in combination with hydrolysate protein products such as Buminal (Bayer), protein hydrolysate (Map Pacific), Promar (Malaysia), Autolysat (Australia), showed effective control of fruit fly in the region.

Application of protein baits as spot sprays should be promoted in the orchards of southern Vietnam and this is an expected output of future cooperation with the Australian Centre for International Agricultural Research (ACIAR).

## Conclusions

More than 20 fruit fly species were recorded during the study, with generally the most important followed by *B. dorsalis* complex. However, the latter was sometimes more dominant in some locations.

*B. cucurbitae* is the main fruit fly attacking the Cucurbitaceae plants. Further studies are planned to investigate this species.

14 fruit crops were listed as host plants of fruit flies and guava and rose apple were the most infected. Wild plants were also found to be important source of food for fruit flies throughout the year and this needs to be considered.

As only limited numbers of samples were collected during this investigation, we conclude that further study is needed to complete the list of fruit fly species active in Vietnam.

## References

- Drew, R.A.I. 1989. The tropical fruit flies (Diptera: Tephritidae: Dacinae) of the Australasian and Oceanian regions. *Memoirs of the Queensland Museum*, 26, 1–521.
- Drew, R.A.I. and Hancock, D.L. 1994. The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bulletin of Entomological Research*. Supplement No. 2. Wallingford, CAB International, p68.

# Nondestructive Method for Sorting of Gamboge and Translucent Pulp in Mangosteen by Specific Gravity: Precision and Efficiency

J. Sornsrivichai, R. Podee, K. Saengnil and T. Yantarasri\*

## *Abstract*

Specific gravity of mangosteen fruit at three different maturity stages and at 0, 2, 4 and 6 days after harvest was studied. There were no differences in the specific gravity values of mangosteen fruits at all stages. However, when sorting of the fruit was delayed after harvest, the specific gravity significantly decreased. The specific gravity values of the fruit with gamboge, translucent pulp disorder and the combination of both symptoms were higher than fruit with normal pulp. Separation of fruit with normal and damaged pulps using different specific gravity values of 0.980, 1.000, 1.016, 1.020 revealed that specific gravity at 0.980 was able to separate all degrees of translucent pulp disorder with 95% efficiency and with 89% for fruit with the gamboge disorder. The accuracy in sorting of normal fruit depended on the amount of water accumulated in the rind and the interference of an air cavity created by the drying seed or aril tissue.

TRANSLUCENT AND resin-contaminated (gamboge) pulp disorder of mangosteen is a major cause of reduced fruit quality. This internal disorder cannot be separated from normal fruit by external appearance and causes a significant loss of confidence in this product in the market. The cause of the disorder is migration of excess water to the pulp caused by heavy rain during the harvesting season (Laivisethkul 1994). Pankasemsuk et al. (1996) showed that fruit with translucent pulp disorder had a water content in the rind 65% and pulp 82% higher than fruit with normal pulp (63% and 80% in the rind and pulp, respectively). Lakanathinwong (1996) confirmed that the translucent fruit had a 1.21% higher water content and 15 times smaller air space compared to the normal pulp. This indicated that the specific gravity (SG) of fruit with the translucent disorder may be higher than the normal fruit. This result was confirmed by Pankasemsuk et al. (1996) who found that 90% of fruit with normal pulp floated in water and their SGs were less than one. They

also showed that after being subjected to vacuum water infiltration, normal floating fruit sank, the pulp became translucent and contaminated with yellow resin, and the SG increased to more than one. However, Nantachai et al. (1991) found that the accuracy and efficiency of sorting normal fruit from fruit with the disorder using the floatation method varied from year to year, relating to rainfall conditions during harvest. Several factors might affect the change in SG values of normal and damaged fruit. The objectives of our study were:

1. to investigate the factors affecting the change in SG values of normal and damaged fruit, namely, maturity of the fruit and delay in sorting after harvest;
2. to investigate the SG distribution in mangosteen with various degrees of flesh translucency and types of resin contamination;
3. to determine the accuracy and efficiency of sorting fruit with various types of disorder using differences in SG; and
4. to optimise SG values for sorting, considering rainfall levels during harvest.

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## Materials and Methods

Mangosteen fruit of three different stages of maturity selected by peel colour appearance—pinkish-yellow, pink and brownish purple—were sampled for determination of SG distribution. The SG values were measured on the same day as harvest and then every two days for six days.

The SG values in fruit with various degrees of pulp translucency and types of resin contamination were determined using the buoyancy method (Pomeranz and Meloan 1978). In this method, the SG of the fruit is calculated from the ratio of the weight of fruit in air divided by the difference between the weight of fruit in air and the weight of fruit weighed under water multiplied by the SG value of water. A total of 1,830 fruit were used. After the SG determination, the fruit were cut open and assigned to six categories according to their degree of translucency and severity of resin contamination of the pulp. The data collected in these procedures were used for the following determinations and calculations.

### Determination of SG distribution

The SG distribution of each type of internal disorder was recorded. The SG values for sorting were 0.980, 1.000, 1.016 and 1.020. The percentage of fruit having each level of disorder at each SG level was calculated. The optimal SG values for sorting were selected according to the precision of sorting of the normal fruit and efficiency of sorting out fruit with disorders.

### Calculation of sorting precision

The precision of sorting at each SG level was calculated by the following equation:

$$\text{Precision} = \frac{\text{No. of normal fruit sorted} \times 100}{\text{Total no. of fruit at that SG}} \quad (1)$$

### Calculations of sorting efficiency

The efficiency of sorting at that SG level was calculated of sorting for each symptom (Equation 2) and of sorting for all symptoms (Equation 3):

$$\begin{aligned} &\text{Efficiency of sorting for each symptom} = \\ &\frac{\text{No. of normal fruit sorted correctly for a symptom} \times 100}{\text{No. of fruit with that symptom}} \quad (2) \end{aligned}$$

Efficiency of sorting for all symptoms =

$$\frac{\text{No. of normal fruit sorted correctly for all symptoms} \times 100}{\text{Total no. of fruit}} \quad (3)$$

## Results and Discussion

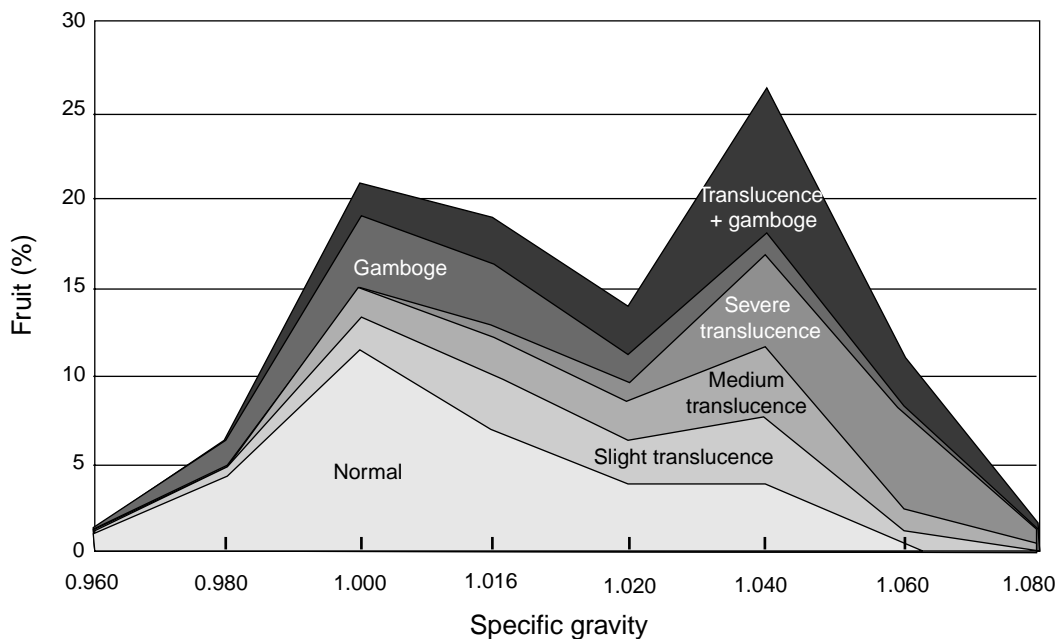
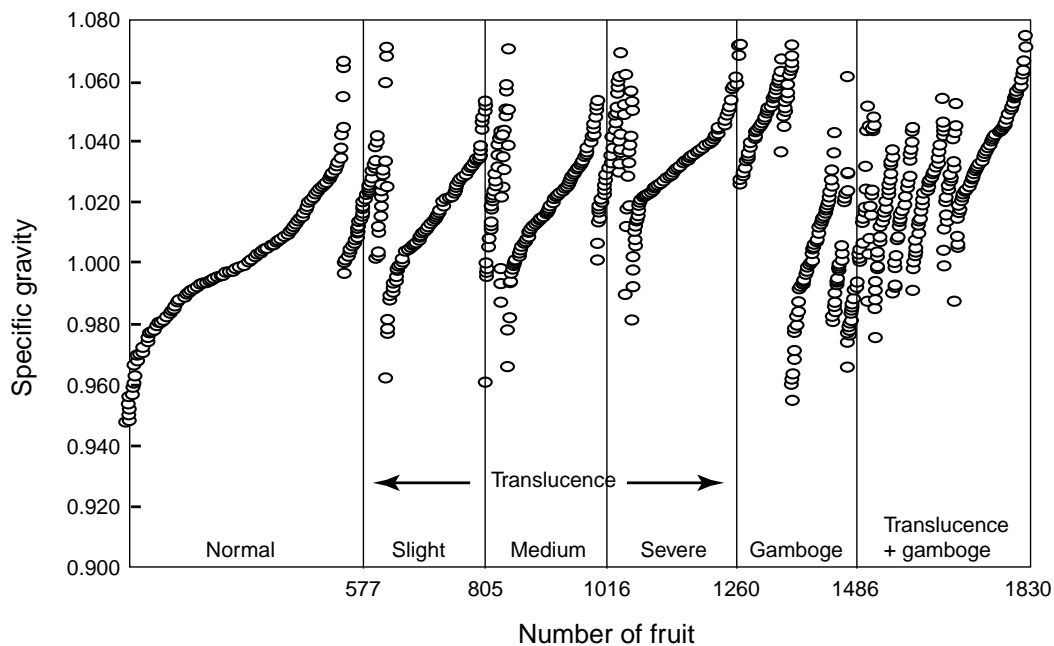
### Effect of fruit maturity on SG value

Mangosteen fruit can be harvested when the peel colour turns pinkish with deep pink dots scattered over the whole peel; this is referred to as stage 2. Harvesting of the fruit can be delayed until stage 4 in which the fruit peel colour turns red–purple. It was found that the SG values of fruit at each maturity stage after harvest were not significantly different, however the SG values decreased significantly in the 2–6 days after harvesting. This suggests that the fruit at different stages of peel colour could be sorted from the same batch, but the fruit should be sorted on the same day as harvesting. This is to avoid damaged, but floating, fruit being mistaken for normal fruit and thus contaminating the normal fruit.

### Distribution of normal fruit and those with various types of internal disorders according to their SG

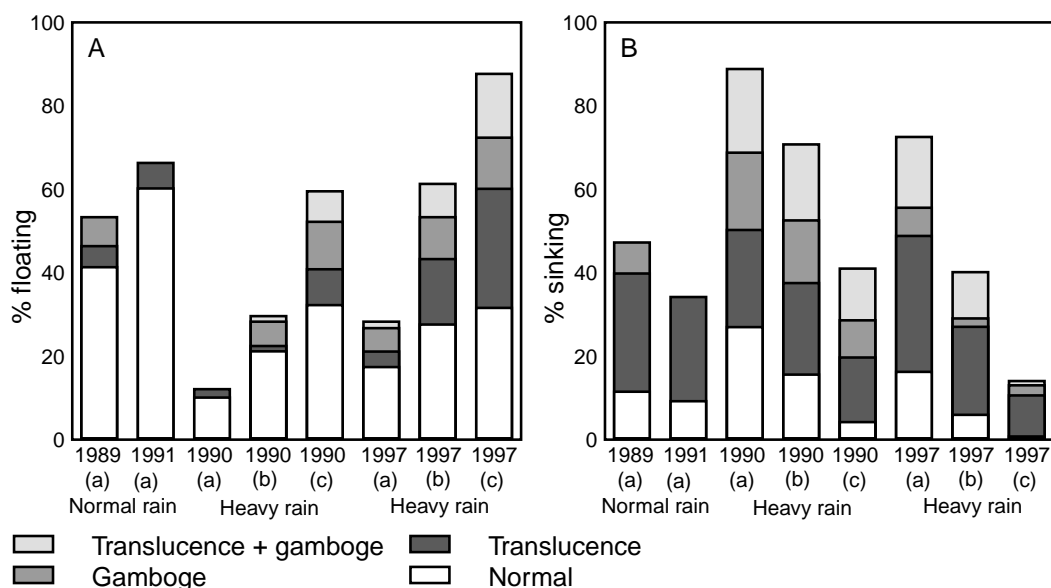
The number and percentage of each type of fruit disorder and their SG distributions are shown in Figures 1 and 2. Calculation of the average SG values for each type of damaged fruit showed that the fruit with gamboge, translucent pulp disorder and the combination of both symptoms had higher SGs than the normal fruit. However, our data revealed that there was a wide range of SG values for normal fruit and fruit with each type of internal disorder fruit, and the SG range overlapped. Our data, which was collected in the 1997 season, is compared to other harvest seasons studied by Nanthachai et al. (1991) and Pankasemsuk (1990) in Figure 3. Both the percentage and SG distribution of normal fruit and fruit with various types of disorder depended on the extent of rainy conditions. Table 1 shows that for the years with light rainfall (1989 and 1991) the percentage of normal fruit was 54% and 68%, respectively, but with the heavy rainfall during harvest in 1990 and 1997) the percentage of normal fruit dropped to 35% and 32%. The excess water from heavy rain may cause more fruit to become translucent and develop the gamboge disorder.





**Figure 1** (above). Specific gravity of mangosteen with various internal disorder characteristics.

**Figure 2** (below). Percentage of fruit with different internal disorder characteristics corresponding to the variation in fruit specific gravity.



**Figure 3.** Percentage of floating (A) and sinking (B) fruit, sorted using the specific gravity values of (a) 1.0, (b) 1.02 and (c) 1.04.

### Determination of precision and efficiency of sorting

The precision and efficiency of using various SGs for sorting the different types of internal disorder in relation to rainy conditions are shown in Table 1. The data indicate that the efficiency of sorting for normal fruit increased with the increase of SG value used for sorting, but the sorting of fruit with disorders was reduced, together with the accuracy of sorting for the normal fruit. The accuracy and efficiency of sorting at each SG value was not consistent but was dependent on the degree of rain during the harvesting season. Sorting using the SG value of 1.000, the efficiency of sorting normal fruit was reduced from 80–88% in a normal rainfall year to only 26% and 53% in the heavy rainfall year. The heavy rainfall during the harvesting season may lead to excess water accumulating in the rind but not yet entering the pulp. This phenomenon would cause the SG value of the normal fruit to increase and the fruit would sink, together with the fruit with internal disorders. These results confirm the previous report of Pankasemsuk et al. (1996) that the water content of normal fruit which sank (65.4%) using a SG value >1.0 was significantly higher than the normal floating fruit (63.0%) using a SG value of <1.0. The X-ray CT (computerised tomography) image of the fruit conducted by Yantarasi et al. (1996)

and Podce (1998) also showed an accumulation of water in the rind of normal fruit which sank.

The variation in accuracy in sorting fruit with disorders was also found to depend on interference by the air cavity created by the drying seed and aril tissue (Podce 1998). This further indicates that the percentages of normal and internally damaged fruit, and their SG distribution, may vary from year to year depending on the amount of rainfall and planting location. Therefore, at the point of implementation, a sample batch of fruit should be taken for the determination of the percentage and SG distribution of normal fruit and fruit with various types of disorder so that SG values can be optimised to obtain a high efficiency for sorting.

### Optimisation of SG values for efficient sorting

Table 2 shows the sorting efficiency and sorting error of different types of internal disorders using four levels of SG. The data are based on 2,000 fruit harvested in 1997, which was a heavy rainfall year. If the SG at 0.980 was chosen for sorting, the sorting efficiency of all symptoms was 83.4%, which is higher than using other SG values, but the sorting efficiency for the normal fruit was only 16.5%. When the SG

value of 1.000 was selected, efficiency for sorting of normal fruit increased to 52.9%, but total efficiency decreased to 77.4% and the sorting error increased from 16.6% to 22.6%.

Therefore, we suggest that the fruit should be sorted at low SG first for premium grade fruit, and then sorted at higher SG for marketable grades. However, the data used here come from the fruit harvested from The Horticultural Research Center at Chantaburi, in south-

eastern Thailand where there is a high incidence of heavy rainfall during the harvest season. High rainfall decreased the percentage of normal fruit to only 31.6% from 2,000 (Table 2). Therefore, for better sorting efficiency of mangosteen, the SG sorting method should be applied to the fruit cultivated in areas which have lower rainfall during harvesting. The problem of translucency and resin contamination is also yet to be solved.

**Table 1.** Precision and efficiency of sorting different types of internal disorder at various specific gravity levels of fruit harvested in years with normal or heavy rainfall during the harvesting season.

Year	Normal fruit (%)	Specific gravity selected	Precision of sorting normal fruit	Efficiency of sorting			
				Normal	Translucent	Gamboge	Translucent + gamboge
Normal rainfall							
1989	54	1.00	77.2	79.6	51.7	30.9	–
1991	68	1.00	90.7	87.9	80.2	–	–
Heavy rainfall							
1990	35	1.00	79.3	26.2	99.2	9.8	100
1990	35	1.02	64.3	59.1	92.9	72.9	92.8
1990	35	1.04	38.1	91.8	65.0	43.5	64.3
1997	31.6	1.00	60.0	52.9	90.5	55.3	90.1
1997	31.6	1.02	44.6	86.5	59.6	13.7	60.8
1997	31.6	1.04	35.5	98.6	22.7	3.1	17.4

**Table 2.** Sorting efficiency of different types of internal disorder using four levels of specific gravity.

Type of disorder	Sorting efficiency (%) at each specific gravity			
	0.980	1.000	1.016	1.020
Normal	16.5 <sup>a</sup> (83.5) <sup>b</sup>	52.9 (47.1)	74.4 (25.6)	86.5 (13.5)
Slight translucence	97.4 (2.6)	81.6 (18.4)	48.7 (51.3)	37.3 (62.7)
Medium translucence	98.6 (1.4)	85.8 (14.2)	68.2 (31.8)	46.9 (53.1)
Severe translucence	100.0 (0.0)	98.8 (1.2)	94.3 (5.7)	87.7 (12.3)
Gamboge	88.9 (11.1)	55.3 (44.7)	25.7 (74.3)	13.7 (86.3)

<sup>a</sup>See Equation 2 for how this was calculated

<sup>b</sup>Error in sorting (%)

<sup>c</sup>See Equation 3 for how these figures were calculated

**Table 2.** (Cont'd) Sorting efficiency of different types of internal disorder using four levels of specific gravity.

Type of disorder	Sorting efficiency (%) at each specific gravity			
	0.980	1.000	1.016	1.020
Translucence + gamboge	99.1 (0.9)	90.1 (9.9)	76.5 (23.5)	60.8 (39.2)
Total efficiency for all symptoms <sup>c</sup>	83.4 (16.6)	77.4 (22.6)	64.6 (35.4)	55.5 (44.5)

<sup>a</sup>See Equation 2 for how this was calculated

<sup>b</sup>Error in sorting (%)

<sup>c</sup>See Equation 3 for how these figures were calculated

## References

- Laivisethkul, S. 1994. Factors affecting pulp translucency symptom of mangosteen. MSc thesis, Department of Horticulture, Kasetsart University, Thailand (in Thai).
- Lakanathinwong, V. 1996. The study on chemical composition, cell viability and influence of water on flesh translucent disorder in mangosteen. MSc thesis, Department of Horticulture, Kasetsart University, Thailand (in Thai).
- Nantachai, S., Ratanachinakarn, B. and Pumhirum, J. 1991. Method for separation of mangosteen fruit with translucent pulp disorder from normal fruit. Annual Report 1991. Horticultural Research Center at Chantaburi, Department of Horticulture, Ministry of Agriculture and Co-operatives, Thailand (in Thai).
- Pankasemsuk, T., Garner, J.O. Jr, Matta, F.B. and Silva, J.L. 1996. Translucent flesh disorder of mangosteen fruit (*Garcinia mangostana* L.). HortScience, 31, 112–113.
- Podde, R. 1998. Nondestructive methods for separation of translucent pulp in mangosteen by specific gravity and X-ray computerised tomography. MSc thesis, Postharvest Technology, Chiang Mai University, Thailand (in Thai).
- Pomeranz, D. and Meloan, C.E. 1978. Food analysis theory and practice. Westport, Connecticut, AVI Publishing.
- Yantarasri, T., Sornsrivichai, J. and Chen, P. 1996. X-ray and NMR for nondestructive internal quality evaluation of durian and mangosteen fruits. Acta Horticulturae, 464, 97–102.



# Future Research and Development in Agricultural Produce Quality

P.J. Hofman\*

## *Abstract*

Consumer preferences and lifestyle will be the main driving forces for the future research and development (R&D) on quality of agricultural produce. These will centre around consistent quality, a wide range of product choices, convenience, and sound environmental practices during production and postharvest handling, and will be achieved at a cost the consumer will tolerate.

On this basis, future R&D will concentrate on:

- Food safety, or negligible risk to health from biological contamination and chemical residues. This will involve research on minimal chemical use through resistant cultivars, reducing non-targeted toxicity, reducing applications, and finding alternative, non-chemical control treatments. Better technologies for minimising and monitoring contaminants will also be developed.
- Waste reduction, to safely prevent deterioration after harvest. Measures such as physical treatments and enhancing host defence mechanisms will be improved. There will be continuing research to control ripening and senescence in perishable commodities through genetic manipulation and other means. Supply chain management will also be pivotal in reducing losses and minimising the time from harvest to consumption.
- Product differentiation will increase through developing different cultivars with specific quality characteristics, and new processed products. Rapid tests to confirm product identity, varietal purity or suitability will become more important.
- Quality differentiation will be achieved by differentiating different quality lines from the same cultivars for specific markets, through better harvesting and sorting techniques. More sophisticated systems will be developed to determine quality.

Underpinning the commercial implementation of these ongoing developments will be quality management systems and effective supply chain management.

POSTHARVEST food losses have been quoted as being 15–50% for horticultural products, and 10–20% for grains and oil seeds (Okezie 1998). However, these estimates generally do not include income losses due to quality deterioration that do not result in total wastage. Thus, losses to grower income are likely to be higher than those given above.

In the past, production research and development (R&D) of agricultural produce has received greater attention than postharvest issues, especially in traditional agricultural development projects (Okezie 1998). This has resulted in improvements to pro-

duction outstripping the capacity to minimise losses after harvest.

There are also continued changes in consumer preferences and demand. For example:

- The consumer is becoming more aware of different products and experiences because of the information age and exposure to different experiences through multi-culturalism and travel. For example, in the mid-1990s, 58% of Australians preferred dishes such as pasta, rice, and stir fries, compared to the old favourites such as chops and mince.
- There is a shift of power to the consumer in relation to product availability and quality. Thus, individual choice is becoming the name of the game.

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- In the past, purchases were based mainly on search attributes (characteristics that can be determined by inspecting the product and its packaging) and experience attributes (those which can be judged after using the product, e.g. taste). Now credence attributes (those that can not be judged even after the product has been used), such as pesticide residues or being organically grown, are becoming more important (Caswell 1999).
- Tolerable food preparation times are decreasing. It is currently about 15 minutes, but will soon be down to several minutes.
- By 2000, fresh cuts will make up 20% of all fresh produce sold in Australian supermarkets.
- There is increasing demand that the products are produced with minimal environmental impact.

Based on these emerging patterns, the following factors will influence postharvest R&D in the future:

- There will be increased customer (consumer) demand for consistent quality in all markets.
- Consumers will demand a wider range of products to suit different lifestyles.
- Perceptions of quality will change with time, e.g. food safety is currently important.
- The demand for value for money will increase.
- Postharvest losses will need to decrease to reduce costs and increase efficiencies.
- The imbalance between production and postharvest research will need re-adjustment.
- In developing countries, the increased growth of the supermarket sector, and the opening of export markets because of trade liberalisation, will require higher and more consistent quality.

Based on these characteristics of agricultural industries and their consumers, R&D on product quality will most likely focus on the following issues.

## Food Safety

### Biological contamination

Biological contamination can occur during the many production and postharvest operations. Many mechanisms of transmission may be involved, including animals and insects, faeces, sewage, water, soil, cross-contamination from other agricultural products, and from contact with packhouse equipment etc. (Beuchat 1995; De Roever 1998).

Bacteria are the main causes of biological contamination. Instances of contamination from non-economic carriers will be difficult to control, since

control measures against these carriers would not normally be implemented. Biological contamination from organic manures and recycled water could increase with the increased demand for organic produce and water conservation. More research is required to minimise health risks from these sources. Treatments such as non-chemical pasteurisation with heat and better application methods may be further investigated.

Biological contamination can also be common during packhouse operations, especially when water is used for offloading fruit from field bins to reduce mechanical damage, and for washing. In most instances this contamination results in quality loss due to disease, but there have been direct health concerns in some instances. More effective chemical and non-chemical means of reducing contamination during these processes will continue to be developed.

Biological contamination during processing, especially minimal processing, poses a far greater risk, and is generally addressed in developed countries through food safety legislation and programs such as Hazard Analysis and Critical Control Points (HACCP). It is a significant issue in developing countries because of the large number of small food businesses, and the rise in demand for prepared foods. Cost-effective and simple means of improving food safety in these establishments will need to be developed.

### Chemical residues

Considerable postharvest pest and disease control research is now focused on developing non-chemical treatments, mainly because of the shorter time from application to consumption resulting in less margin for error with residue levels, and the continued de-registration of existing chemicals.

Several approaches can be used to reduce the risks associated with chemicals use, as discussed below.

#### *Reduce chemical toxicity*

There will be continued effort to develop more effective chemicals with minimal environmental impact. These may often be natural chemicals or their derivatives, obtained from plant sources that show natural resistance. For example, the absence of fungal pathogens in mushrooms is partly due to the strobilurin group of chemicals they contain. Strobilurins have recently been shown to be highly effective in the control of a number of diseases (Miller 1997), and to have very low toxicity to mammals, birds and fish. Investigations on natural host defence mechanisms

(Johnson et al. 1998) may result in identification of effective chemicals with low environmental impact.

#### *Biological control*

Integrated pest management during production will continue to reduce the risk of chemical residues, even though the main driving force may be environmental impact rather than food safety. The principles underlying integrated pest management will be applied to a greater extent to disease control. This will require more research on the interaction between disease organisms and the natural microflora. There will be more effort on understanding the pest and pathogen so that outbreaks can be more accurately predicted, and management of these risks improved.

It is expected that biological control strategies will concentrate on organisms that rely on mechanisms other than antibiotics for efficacy, such as competition for food. Further commercial development of this approach will occur as existing control measures become less acceptable. Preharvest applications are likely to be developed for quiescent infections such as anthracnose and stem end rot in mango and avocado, and postharvest treatments for wound pathogens (Korsten et al. 1994; Holmes et al. 1998). Issues to be addressed will include the high costs of commercial development for lower volume products, and the different handling and application methods requiring change in grower practices etc.

Immunisation—the process of inoculating the host with heat-killed or less virulent strains of the pathogen in order to induce a defence mechanism—has been successfully used to control many human and animal diseases. There is evidence that similar responses can occur in plants (Johnson and Sangchote 1994). There are relatively few commercial adaptations of this concept to control plant diseases, but these may increase with further research. Also, investigation of the plant responses to ‘immunisation’ may result in the identification of host defence mechanisms that can be triggered by more direct means.

#### *Physical treatments*

Physical treatments are aimed at either directly killing the pathogen or pest, or reducing pest or disease symptom development to a greater extent than ripening or senescence of the host, so that the product is consumed or processed before symptoms appear.

Smarter use of ripening temperatures may have potential in climacteric fruit. For example, ripening avocado fruit at 15°C results in less disease in ripe fruit than when ripened at 20°C (Hopkirk et al. 1994). This

concept needs to be investigated in other tropical fruit. However, cold storage generally results in higher disease severity, presumably because the lower storage temperatures slow down product senescence more than disease development.

Cold temperatures are also used for insect disinfection, but the 16 days at 1°C generally required for fruit fly control can cause chilling damage, and is often considered too long when sea freight is required to overseas markets, or when rapid responses to market changes are desired. Hot air and hot water treatments (total treatment times of about 6–12 hours) can overcome these concerns. However, hot water can also cause damage (Jacobi and Wong 1992), and hot air currently requires expensive equipment. Research will continue to develop more economic application systems, and to reduce product damage through pre-conditioning treatments (Woolf and Lay-Yee 1997; Woolf et al. 1998). Other ways of applying heat, such as microwaves, may have commercial potential when ways of reducing the risk of uneven produce heating have been developed. Treatment combinations, such as heat and controlled atmospheres, have shown potential to control some insects (especially surface pests), and further development may see commercial application of this approach.

Heat is also used in grains to reduce the moisture content to levels that minimise disease development. Continued efficiencies in this area will be pursued, which may include more efficient use of solar energy (either direct or captured).

Heat treatments alone (without fungicides) can control postharvest diseases (Suhardjo et al. 1994), but fruit are susceptible to damage, and are more sensitive to preharvest and postharvest conditions (Cooke and Johnson 1994). Controlled atmospheres have shown little potential to directly control disease, with the notable exception of *Botrytis* in strawberries, due to fruit tolerance to high CO<sub>2</sub> concentrations. Further research may increase the use of physical treatments other than cold to control postharvest diseases.

Irradiation is highly effective for disinfection in a range of commodities (Hallman 1999). There is less information on disease control by irradiation, but there are indications that this may also be a useful method. Increased use of irradiation in foods could depend more on consumer acceptance of the technique more than on further R&D. Other physical treatments, such as ultraviolet light, can have direct effects on pathogens or increase host defence mechanisms (el Ghaouth 1998). There will be increasing investigation



into these techniques, especially as treatment combinations.

#### *Physical contamination*

Contamination by wood splinters, glass etc. is an important commercial consideration. Research may continue into better detection systems, but this will require relatively lower resource input.

#### *Measuring contaminants*

Increased globalisation of markets resulting in access to products from a range of countries, greater sensitivity to food safety, and cost pressures will increase the demand for more rapid and cost-effective quantification of chemical and biological contaminants. Quick and reliable techniques such as the enzyme-linked immunosorbent assay (ELISA) are being more widely used in developed and developing countries, and improvements in these systems will continue. We can also expect to see smarter systems such as specific electronic sensors similar to those for selected volatiles ('electronic nose'). More rapid and reliable quantification of biological residues can be expected through simpler DNA-related techniques, which will be facilitated by cheaper equipment for these tests.

## **Quality Loss**

This section will discuss both quality loss and 'waste reduction', since these both occur through similar processes.

Quality loss can occur through pest and disease activity, and control measures relating to these areas have been discussed above. This section will discuss losses due to premature senescence, although there is some interaction between treatments intended mainly to control senescence, and their impact on pests and diseases (e.g. low temperatures).

## **Storage systems**

Low-cost cooling strategies that rely on concepts, such as cooler night air and evaporative cooling, will continue to be developed and applied in developing countries at the village level (Anon. 1998). There will also be continued improvements in more sophisticated environmental control systems. More energy and cost-efficient refrigeration systems will result in wider use of temperature-controlled storage. Controlled atmosphere (CA) applications are becoming more common due to more reliable and cheaper systems. Advances

will be greater in CA transport systems because of expansion in global markets, and lower-cost control systems that are more compact and cheaper.

Further research in modified atmosphere (MA) applications will be based on the ability to develop films with specific permeability, so that MA systems can be tailored to specific requirements. Current developments include improving the chemical composition of films, and using smart patches or 'windows' on bags. Smart MA systems that have the ability to adjust membrane permeability according to changes in product behaviour or storage temperature will increase the robustness of MA systems, and allow wider application in areas with less developed cool chains. Improved cool chains (maintaining the storage temperature at all stages during product distribution) will also allow increased use of MA.

## **Chemical and genetic manipulation of senescence and bruising**

The recent development of chemicals such as 1-methylcyclopropene (1-MCP), which binds to the ethylene binding site to retard ripening and senescence, is a good example of further developments we may see in this area. This chemical is very effective in delaying senescence of cut flowers (Macnish et al. 1999, 2000), and in retarding ripening of bananas (Golding et al. 1998) and several other subtropical and tropical fruit (Hofman, unpublished results). Obviously, these need to be considered in relation to reducing chemical use and toxicity when used with edible commodities.

Genetic control of ripening and senescence is the long-term approach to quality loss and wastage. However, the challenge is to retard the undesirable processes for as long as possible, but then 'switch' them on again when required.

There are several examples of manipulating ripening processes using traditional breeding programs, e.g. the *rin* and *nor* tomato cultivars. However, genetic engineering will provide additional potential in this area. For example, cultivars have been developed where activity of selected enzymes in the ripening process have been reduced, and research is currently under way to regulate ethylene production and action in several subtropical and tropical climacteric fruits by similar means.

Improvements in the ability of a product to withstand other postharvest stresses will continue to reduce quality loss. Increasing firmness to reduce bruising etc. has been achieved by traditional breeding

programs in fruit such as tomato and strawberry, but future programs will need to achieve these objectives without sacrificing other characteristics such as eating quality. The 'anti-browning' technology of manipulating polyphenol oxidase activity has been incorporated into potato and other commodities, and there is currently a program to do this for pineapple. These concepts can be applied to a range of fruits where browning contributes to quality loss (e.g. avocados) but in some instances there may be more appropriate approaches, such as improving membrane stability to the lower temperatures at which damage usually occurs.

### **Predicting product quality and performance**

There will be increased interest in predicting the ability of products to withstand storage and distribution, and in ensuring consistent product quality at the retail level. An important component of this is predicting and controlling the effects of production practices on quality. Many production factors can influence quality (Hofman and Smith 1994; Hofman et al. 1997) and there is growing recognition and interest in the importance of these influences (Ferguson et al. 1999; Kays 1999; Mattheis and Fellman 1999; Sams 1999). As knowledge accumulates, modelling approaches will be used to help alter production practices to achieve the desired product quality.

A current, commercial example of this approach is the use of calcium sprays during fruit growth to reduce physiological disorders in apple during storage. Also, apple physiology is sufficiently well understood to estimate the potential for these disorders to develop during storage by measuring fruit mineral concentrations (especially Ca, Mg and K) just before harvest (Ferguson et al. 1999). Fruit batches that do not have the required minerals ratio are not stored. There are indications that similar relationships exist in other fruit (Hofman et al. 1998), but these will need further investigation.

Currently, these techniques are applied to batches of fruit from orchard blocks etc., even though there would be variation in storage potential and quality between fruit in that batch. Modelling the relationships between more easily measurable characteristics of the fruit at harvest, such as colour in cucumbers and firmness in kiwifruit (Polderdijk et al. 1993; Tijssens and Polderdijk 1996; Johnson and Ridout 1998), can be used to determine the storage potential of individual

fruit, and further improve product consistency after storage.

These approaches are being made possible by technical advances allowing in-line systems in the packhouse. More sophisticated techniques are also seeing commercial application because of these improvements. For example, near infrared (NIR) spectroscopy is now used commercially to non-destructively estimate the sugars content of fruit on the sorting line, so that fruit can be marketed as guaranteed sweet (Guthrie and Walsh 1997). Nuclear magnetic resonance (NMR) may also have packhouse application in the future to identify internal defects, such as jelly seed and stem end cavity in mango (Chen et al. 1996; Clark et al. 1997). There may even be potential to determine disease load at harvest by using genetic markers and dyes etc.

This concept will be further expanded to allow quality characterisation at the retail level so that consumers can determine the stage of ripeness of climacteric fruit. For example, simple firmness testers (Mizrach et al. 1997; Galili et al. 1998; Hung et al. 1999) can be placed in stores to allow consumers to predict the number of days for fruit to reach the eating soft stage, thereby reducing the risk of fruit becoming overripe. This can also be used by retailers to group fruit based on firmness or time to eating ripe, again reducing the risk of damage by consumer handling.

### **The supply chain**

A significant cause of quality loss is excessive time from harvest to consumption, especially with inadequate infrastructure to prevent deterioration. The negative impacts of excessive time can be reduced by temperature and atmosphere control systems, however optimising supply chain operations is another essential component which will have significant impacts in the future. Strong commitment by all members of the supply chain to its mutual development will increase transparency and communication between members. There will be better information exchange from the retailer to the grower in relation to planting and harvesting requirements, and from the grower to the retailer about the need to increase product sales due to more harvests because of climatic conditions etc. This will result in less risk of over-supply at the wholesale or retail levels, and reduced quality loss. There will be a greater move to the concept of 'just in time' product flow common in manufacturing industries, where harvested product is held at the wholesale and retail levels for the shortest possible time. These advances

can only be achieved through commitment and efficient information flow.

## Quality Differentiation

Improved returns can be achieved by separating lines of differing quality and marketing accordingly, rather than marketing the one line with mixed quality. With improved systems for measuring quality, higher quality lines (because of better growing conditions and cultivars) can now be identified and sold at prices that reflect their quality, resulting in improved returns. The potential for this approach will increase as measuring systems improve, and cultivars are developed for specific purposes and growing conditions. Similar concepts have been applied to fruits and vegetables for many years by visually sorting into first and second grade in the packhouse. However, this concept will be expanded as new technology is developed. The potential to estimate internal quality with NIR and NMR (see above) will allow quality separation based on parameters other than visual factors.

These concepts may expand to include selective harvesting etc. For example, mango fruit harvested from the north side of the canopy (in Australia) are generally more mature, and will have better skin colour (Hofman et al. 1997). This is being used commercially—mango fruit destined for the Japanese market are harvested only from the north side of the tree and from the outside of the canopy, which improves the level and consistency of quality. Further application of these principles may come with the development of systems that will harvest fruit based on their internal quality as estimated by NIR or similar means.

## Product Differentiation

Specific cultivars will continue to be developed for targeted uses. Cultivar characteristics will include processing quality (for grains), internal quality and flavour, and appearance (fruits and vegetables). There will also be continued emphasis on storage potential to overcome seasonal supply fluctuations, and more efficient access to distant markets. This will see increased turnover of cultivars to keep pace with changing consumer demand, as well as to continually optimise production costs.

Product differentiation is also achieved through product presentation such as packaging. For example, sale of finger packs of bananas has improved presentation and sales in some sectors. Minimally processed

products will continue to expand as the demand for easy-to-prepare products increases. Research and development will continue to find new and safer ways of presenting these products.

Accurate identification of product constituents will become more important to ensure that these meet consumer requirements. This will become more important as ‘controversial’ techniques such as genetic engineering and irradiation are used. The high cost of genetic engineering to develop new cultivars will also require that these can be identified to protect variety rights and royalties. The rapid development of biotechnology has increased efficiency in this area, and these developments will continue.

## Summary

Underlying most of the future R&D on quality are several important issues. Supply chain management will be increasingly important. This will apply to both developing and developed countries, since supply chains exist as soon as product leaves the farm. The concepts of open information sharing between all partners in the chain to ensure adequate product flow, maintenance of quality, cost reductions and so on, will be essential in these chains. In addition, the growing influence of supermarkets in the developing countries, and the increased potential to access international markets will further increase the need for appropriate supply chains at all levels.

The R&D agencies will do a better job of assisting industry to meet consumer demands. This will be achieved by agencies working with industry to identify the key constraints in existing supply chains that reduce competitive advantage, and then providing appropriate services to facilitate appropriate changes.

Quality management (QM) systems have a significant role to play in maintaining product specifications (safety and quality) within levels required by the consumer. However, QM systems can also contribute to identifying quality constraints and the importance of these constraints through data such as rejects analysis (Baugher et al. 1996). This information will be used by R&D agencies to better identify areas where improvements will have a real industry impact.

The practical results of biotechnology as an alternative to conventional breeding will become more apparent with time. However, consumer concern over the potential risks associated with this approach will require considerable attention if the real benefits of biotechnology are to be realised. Also, there is risk that the emphasis on biotechnology will result in a loss of

more conventional postharvest skills, and that biotechnology is applied to problems when better ways of addressing the challenges exist. Thus, a clear focus needs to be maintained on the problem rather than the techniques.

More integrated approaches to production and marketing will be developed. No longer can the artificial 'separation' of production, postharvest processes and marketing be sustained, and approaches to address issues will need to consider the potential for solutions to exist in other parts of the system. In addition, current results indicate that non-chemical disease control systems are not as effective as the current chemical controls, so that a number of control mechanisms, such as biological control agents and natural host defence techniques, will have to be used in combination. Thus, management of quality in the future will have to be more integrated to achieve the increasing consumer demands for quality.

## References

- Anon. 1998. African experience in the improvement of postharvest techniques. Rome, Food and Agriculture Organisation of the United Nations.
- Baughner, T.A., Hogmire, H.W., Biggs, A.R. and Lightner, G.W. 1996. Packout audits of apples from five orchard management systems. *HortTechnology*, 6, 34–41.
- Beuchat, L.R. 1995. Pathogenic microorganisms associated with fresh produce. *Journal of Food Protection*, 59, 204–216.
- Caswell, J. 1999. Consumer food markets of the future: an overseas (US) perspective. Department of Resource Economics, University of Massachusetts USA.
- Chen, P., McCarthy, M.J., Kim, S.M. and Zion, B. 1996. Development of a high-speed NMR technique for sensing maturity of avocados. *Transactions of the ASAE (American Society for Agricultural Engineers)*, 39, 2205–2209.
- Clark, C.J., Hockings, P.D., Joyce, D.C. and Mazucco, R.A. 1997. Application of magnetic resonance imaging to pre- and post-harvest studies of fruits and vegetables. *Postharvest Biology and Technology*, 11, 1–21.
- Cooke, A.W. and Johnson, G.I. 1994. Mango postharvest disease control: effect of rain at harvest, fungicide treatments and fruit brushing on fruit appearance. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Postharvest handling of tropical fruits*. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 448–449.
- De Roever, C. 1998. Microbial evaluations and recommendations on fresh produce. *Food Control*, 9, 321–347.
- el Ghaouth, A. 1998. Use of elicitors to control postharvest diseases in fruit and vegetables. In: Johnson, G.I., Highley, E. and Joyce, D.C., ed., *Disease resistance in fruit*. ACIAR Proceedings No. 80. Canberra, Australian Centre for International Agricultural Research, 131–135.
- Ferguson, I., Volz, R. and Woolf, A. 1999. Preharvest factors affecting physiological disorders of fruit. *Postharvest Biology and Technology*, 15, 255–262.
- Galili, N., Shmulevich, I. and Benichou, N. 1998. Acoustic testing of avocado for fruit ripeness evaluation. *Transactions of the ASAE (American Society for Agricultural Engineers)*, 41, 399–407.
- Golding, J.B., Shearer, D., Wyllie, S.G. and McGlasson, W.B. 1998. Application of 1-MCP and propylene to identify ethylene-dependent ripening processes in mature banana fruit. *Postharvest Biology and Technology*, 14, 87–98.
- Guthrie, J. and Walsh, K. 1997. Non-invasive assessment of pineapple and mango fruit quality using near infra-red spectroscopy. *Australian Journal of Experimental Agriculture*, 37, 253–263.
- Hallman, G.J. 1999. Ionizing radiation quarantine treatments against tephritid fruit flies [Review]. *Postharvest Biology and Technology*, 16, 93–106.
- Hofman, P.J. and Smith, L.G. 1994. Preharvest effects on postharvest quality of subtropical and tropical fruit. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Postharvest handling of tropical fruits: proceedings of an international conference*, Chiang Mai, Thailand, 19–23 July 1993. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 261–268.
- Hofman, P.J., Smith, L.G., Meiburg, G.F. and Giles, J.E. 1997. Production locality affects mango fruit quality. *Australian Journal of Experimental Agriculture*, 37, 801–808.
- Hofman, P.J., Vuthapanich, S., Klieber, A., Whiley, A.W. and Simons, D.H. 1998. Effect of locality, irrigation and paclobutrazol on quality of 'Hass' avocado. In: Coates, L.M., Hofman, P.J. and Johnson, G.I., ed., *Disease control and storage life extension in fruit: proceedings of an international workshop held at Chiang Mai, Thailand, 22–23 May 1997*. ACIAR Proceedings No. 81. Canberra, Australian Centre for International Agricultural Research, 67–76.
- Holmes, R.J., de Alwis, S., Shanmuganathan, N., Widyastuti, S. and Keane, P.J. 1998. Enhanced biocontrol of postharvest diseases of apples and pears. In: Johnson, G.I., Highley, E. and Joyce, D.C., ed., *Disease resistance in fruit*. ACIAR Proceedings No. 80. Canberra, Australian Centre for International Agricultural Research, 162–166.
- Hopkirk, G., White, A., Beever, D.J. and Forbes, S.K. 1994. Influence of postharvest temperatures and the rate of fruit ripening on internal postharvest rots and disorders of New Zealand 'Hass' avocado fruit. *New Zealand Journal of Crop and Horticultural Science*, 22, 305–311.

- Hung, Y.C., Prussia, S.E. and Ezeike, G.O.I. 1999. Nondestructive firmness sensing using a laser air-puff detector. *Postharvest Biology and Technology*, 16, 15–25.
- Jacobi, K.K. and Wong, L.S. 1992. Quality of 'Kensington' mango (*Mangifera indica* Linn.) following hot water and vapour heat treatments. *Postharvest Biology and Technology*, 1, 349–359.
- Johnson, D.S. and Ridout, M.S. 1998. Prediction of storage quality of 'Cox's Orange Pippin' apples from nutritional and meteorological data using multiple regression models selected by cross validation. *Journal of Horticultural Science and Biotechnology*, 73, 622–630.
- Johnson, G.I., Highley, E. and Joyce, D.C. (ed.) 1998. Disease resistance in fruit. ACIAR Proceedings No. 80. Canberra, Australian Centre for International Agricultural Research.
- Johnson, G.I. and Sangchote, S. 1994. Control of postharvest disease of tropical fruits: challenges for the 21st century. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Postharvest handling of tropical fruits*. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 140–161.
- Kays, S.J. 1999. Preharvest factors affecting appearance. *Postharvest Biology and Technology*, 15, 233–247.
- Korsten, L., De Villiers, E.E., Wehner, F.C. and Kotze, J.M. 1994. A review of biological control of postharvest diseases of subtropical fruits. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Postharvest handling of tropical fruits*. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 172–185.
- Macnish, A.J., Joyce, D.C., Hofman, P.J. and Simons, D.H. 1999. Involvement of ethylene in postharvest senescence of *Boronia heterophylla* flowers. *Australian Journal of Experimental Agriculture*, 39, 911–913.
- Macnish, A.J., Simons, D.H., Joyce, D.C., Faragher, J.D. and Hofman, P.J. 2000. Responses of native Australian cut flowers to treatment with 1-methylcyclopropene and ethylene. *HortScience* (in press).
- Mattheis, J.P. and Fellman, J.K. 1999. Preharvest factors influencing flavor of fresh fruit and vegetables. *Postharvest Biology and Technology*, 15, 227–232.
- Miller, A. 1997. The strobilurin race heats up. *Chemistry and Industry London*, 1, 7.
- Mizrach, A., Flitsanov, U. and Fuchs, Y. 1997. An ultrasonic nondestructive method for measuring maturity of mango fruit. *Transactions of the ASAE (American Society for Agricultural Engineers)*, 40, 1107–1111.
- Okezie, B.O. 1998. World food security: the role of postharvest technology. *Food Technology*, 52, 64–69.
- Polderdijk, J., Tijskens, L., Robbers, J. and Van Der Valk, H. 1993. Predictive model of keeping quality of tomatoes. *Postharvest Biology and Technology*, 2, 179–185.
- Sams, C.E. 1999. Preharvest factors affecting postharvest texture. *Postharvest Biology and Technology*, 15, 249–254.
- Suhardjo, Hermanto, C. and Yuniarti 1994. Hot-water control of anthracnose on mango varieties Arumanis, Golek and Manalagi. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Postharvest handling of tropical fruits*. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 453–454.
- Tijskens, L.M.M. and Polderdijk, J.J. 1996. A generic model for keeping quality of vegetable produce during storage and distribution. *Agricultural Systems*, 51, 431–452.
- Woolf, A.B., Ball, S., White, A., Spooner, K.J., Bowen, J.H., Lay-Yee, M. and Ferguson, I.B. 1998. Hot air and hot water treatments reduce chilling injury of avocados during storage. *World avocado congress III proceedings*, Tel Aviv, October 1995, 348–353.
- Woolf, A.B. and Lay-Yee, M. 1997. Pretreatments at 38°C of 'Hass' avocado confer thermotolerance to 50°C hot water treatments. *HortScience*, 32, 705–708.

# Biotechnological Approaches to Control Postharvest Problems

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## Abstract

Fruits and vegetables exhibit short life spans after harvesting. Senescence in vegetables and ripening in fruits account for large losses in many crops, especially in temperate and tropical countries. Careful handling and development of new technologies are fundamental in minimising postharvest losses. Atmosphere control (carbon dioxide and humidity), refrigeration, irradiation etc. have proven useful in controlling postharvest losses, but the implementation of many of the existing and new technologies is quite difficult in many developing countries due to the lack of infrastructure and specialised personnel in rural areas.

Although still in its infancy, biotechnology is emerging as a useful tool to address many postharvest problems. To date, several approaches have been implemented in model crops to control traits that influence postharvest characteristics such as firmness and delay of ripening and senescence. Control of the cell wall-degrading enzyme polygalacturonase in tomato has resulted in longer life fruit with increased solids content. Transgenic fruit containing very low levels of polygalacturonase enzyme remain firmer for a longer period, decreasing transport losses and increasing effective shelf life. Ethylene is one of the major factors contributing to the spoiling of fruits and vegetables after harvest, therefore considerable effort has been directed toward controlling ethylene production. Two enzymes in the ethylene biosynthetic pathway, 1-aminocyclopropane-1-carboxylic acid (ACC) synthase and ACC oxidase, have proven to have good potential for biotechnological applications. Antisense technology has been used to knockout ACC synthase and ACC oxidase in tomato with outstanding results. Transgenic fruit showed an extensive delay in ripening when compared to control fruit. The recent cloning of the mutant ethylene receptor gene (*etr-1*) from *Arabidopsis thaliana* has opened the door to a new approach—ethylene insensitivity. Copies of the mutant gene have been introduced into tomato and petunia conferring ethylene insensitivity to both species.

ONCE a plant is harvested it starts a process of decay that will result in the inevitable death of the organism and the deterioration of its organic matter. This process is even more accentuated if the harvested tissue is a particular organ (fruit, leaf, seeds etc.) instead of the whole plant. In an ideal world, this fact should not be a problem—we would grow our vegetables and fruits in our backyard and consume them fresh every day. However, in real life, most of the food we consume has been grown hundreds or even

thousands of kilometres away from the shop from which we bought it. An agronomist will tell us that our backyard has the appropriate type of soil for some crops but not for others; in addition, the place where we live is too cold for some plants and too hot for some others. Even in a perfect world where we could create microclimates to suit most of the food crops, many of them are seasonal, i.e. the supply is limited to one particular season of the year. Therefore, we are daily confronted with the fact that food crops, after they are grown, need to be transported to intermediate destinations, stored, transported again and distributed before finally reaching

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the consumer. Aside from the natural/physiological reasons stated above, sociological aspects need to be considered—the backyard, self-sufficient growing strategy will not work nowadays because many of us do not have a backyard. The world is evolving from a predominantly rural population to a new demographic distribution based on high human concentrations in urban areas. Centres of food production are therefore far away from centres of food consumption.

We are consequently fighting a continuous battle to bring the right food to the right place with a minimum of losses. Sadly, although important advances have been made in postharvest technology, we are still losing the battle. Postharvest losses account for losses ranging from 20% to an astounding 100% depending on the crop, the country and the year. Whereas technically advanced countries such as the United States of America (USA) and European countries fit in the lower side of the scale, developing countries are closer to the higher end. In addition, many of the developing regions in the world are situated in the tropics, where high temperatures and humidity exacerbate the problem.

Postharvest technologies such as atmosphere control (carbon dioxide and humidity), refrigeration, irradiation etc. have proven useful in controlling postharvest losses, but the implementation of many of the existing and new technologies is quite difficult in many developing countries due to a lack of infrastructure and specialised personnel in rural areas. In addition, many crops are grown on small farms, meaning that a single grower is not able to afford the economic cost of setting up treatment plants and has no access to specialised packaging requirements. Regional centres, either governmental or private, can alleviate the situation but require a level of organisation commonly non-existent.

Biotechnology is emerging as a powerful tool for plant improvement. Although in its initial stages, the potential for applying biotechnology to enhance the agronomical characteristics of crops is almost limitless. In my view, biotechnology has two major advantages over other classical technologies:

1. Biotechnology can break the species barrier (and even the kingdom barrier), providing genes from very distant species—a limitation of traditional breeding. Today it is not necessary to find a disease resistance gene for wheat in a compatible wild relative and breed it in. We can obtain the gene from rice or pineapple and introduce it into the wheat variety of interest.

2. In many cases, biotechnological products are the end products in themselves. A slow-ripening papaya does not need other technology to support it and achieve its goal. No specialised personnel or equipment are needed, no farmer training, no refrigerated warehouse or transport. It just lasts longer. The same logic applies to a disease-resistant mango.

The Plant Genetic Engineering Laboratory is involved in several biotechnology projects aimed at improving the postharvest characteristics of several tropical and subtropical fruits and this paper will mostly centre on this topic.

## **Biotechnological Control of Fruit Ripening and Postharvest Diseases**

Most fruits ripen, deteriorate in appearance and eating quality, and succumb to postharvest diseases very rapidly after harvest. Poor postharvest characteristics such as poor flavour development, very short shelf life, quick softening, easy spoilage, sensitivity to low temperatures (chilling injury) and sensitivity to pathogen attack (by fungi etc.) are major constraints to profitability for the domestic market, and to the expansion of existing and new export markets. Among all fruits, tropical fruits are notorious for their poorer than average postharvest qualities.

Two major obvious targets to improve the postharvest characteristics of tropical fruits are (i) extension of shelf life and (ii) resistance to pathogen attack.

### **Fruit ripening**

The ripening process involves a large number of biochemical pathways in the fruit that will result in marked changes in texture, taste and colour. At the molecular level there are a large number of genes involved and they are tightly regulated in order to induce the right changes at the right time in a highly coordinated process. In general, fleshy fruits are classified as climacteric or non-climacteric depending upon their patterns of respiration and ethylene synthesis during ripening. Climacteric fruits are characterised by an increased respiration rate at an early stage in the ripening process accompanied by autocatalytic ethylene production, whereas non-climacteric fruits show a different respiration pattern and display a lack of autocatalytic ethylene synthesis. Many of the economically important fruit crops are climacteric, therefore a large amount of research has been devoted

to studying the biochemical and molecular pathways operating during the climacteric ripening of fruits.

## Genetic engineering techniques

To date, most of the genetic engineering approaches aimed at improving the shelf life and general appearance of fruits have centred on the set of genes controlling fruit texture (membrane and cell wall properties) and the ripening rate (ethylene production or perception). These approaches have targeted endogenous genes with vital functions in the ripening process, aiming to down-regulate (reduce) their activity by gene silencing. Gene silencing can be achieved in a variety of ways but the two most common ones used in plants are antisense and co-suppression techniques.

The first method involves making a genetic construct in which the targeted gene has been inverted and is therefore in an opposite or 'antisense' orientation with respect to the endogenous gene. This construct is subsequently transferred to the plant, producing a transgenic plant with the targeted gene in both orientations. While the endogenous (original) gene will continue to produce regular ribonucleic acid (RNA), the newly introduced antisense gene will produce molecules of RNA complementary to the endogenous ones, 'sequestering' them and reducing the availability of the original RNA to produce protein.

The mechanism of action of the co-suppression technique is only beginning to be understood. The technique consists of adding extra copies of the targeted gene into the plant genome (normally under the control of a strong promoter). The plant 'senses' the abnormality of having either too many copies of the gene or too much RNA of the same species and starts mechanisms to correct the situation. These mechanisms can be either transcriptional inactivation or post-transcriptional targeted RNA degradation.

### *Control of fruit texture/softening*

Softening is an important contributor to losses experienced during the handling and transport of fruits. Among the genes involved in texture, the most extensively studied is the one coding for polygalacturonase (PG) (DellaPenna et al. 1986; Grierson et al. 1986), a cell wall enzyme that catalyses the hydrolysis of polygalacturonic acid chains. Partial silencing of the PG gene has been achieved in tomato by sense and antisense techniques. Experiments using either a partial or the full length PG gene successfully reduced the levels of PG mRNA and enzyme activity (Sheehy

et al. 1988; Smith et al. 1988, 1990). It is important to remark that these were the first examples of the successful use of the antisense technique in plants. Different transgenic lines showed different degrees of gene silencing, indicating that the position where the transgene is inserted in the genome plays an important role in the effectiveness of the technique and suggesting that, for a commercial output, it is necessary to produce a relatively large number of lines. In tomato, PG has been extensively associated with softening because of the temporal and spatial coincidence of the increase of PG activity during the softening period of the fruit.

Contrary to all expectations, the antisense PG fruits produced by Smith et al. (1988) did not show any appreciable change in softening when measured by classical methods (such as compression tests). A debate was started on whether PG had any effect on texture changes and internal softening of the fruits, and the widely accepted idea that PG was directly responsible for the softening process was shaken. Nevertheless, a new and more detailed study of transgenic, sense and antisense PG plants revealed a number of important changes in the transgenic fruit (Schuch et al. 1991). Low PG tomatoes are more resistant to cracking and splitting than regular fruit. They also have superior handling and transport characteristics, showing a greatly reduced degree of damage during those processes (Schuh et al. 1991).

How much inhibition of the PG gene is necessary to observe any changes in the fruit phenotype? This question has not yet been fully answered because of the difficulty in regulating the exact amount of gene silencing in transgenic lines. Genetic engineering of plants has not reached the high level of sophistication needed to pre-determine or manually regulate the level of gene silencing. Nevertheless, molecular analysis of the transgenic tomato lines showed that fruit in which PG activity had decreased to less than 1% of normal levels contain longer polygalacturonic acid chains, affecting cell adhesion and making the fruit sturdier.

Agronomically, the effect of low PG translates into fruit that can be left on the vine for a longer time—therefore enhancing the flavour—since the softening process has been slightly delayed. Nevertheless, the main commercial use of the low PG tomato fruit has been in the processing industry. Transgenic low PG tomatoes show enhanced viscosity of the processed products and produce less waste. The new characteristics of these fruit have also allowed simplification of the manufacturing process.



'Flavr Savr', a low PG tomato, marked an important milestone in plant biotechnology by being the first genetically modified plant food to reach the market, commercialised by Calgene in the USA in 1994. Zeneca and associates are currently commercialising a tomato puree based on genetically modified, low PG tomatoes. This product first went on sale in the United Kingdom in 1996 (Sainsbury and Safeway supermarkets).

The results of the genetically modified, low PG tomatoes have shown that, although PG plays a significant role in texture changes during fruit ripening in tomato, it is not the primary factor controlling softening. There are a number of cell wall-modifying enzymes that have been characterised at the biochemical level and shown to be active during fruit softening, including cellulases, pectinesterases, galactanases etc. It is also important to remark that, based on the research data available, it is likely that there is not a single softening pathway common to all fruits. Different species have been shown to have very different cell wall-modifying enzyme activity patterns during ripening. Therefore, it is not possible to devise a single, universal strategy to control softening.

#### *Altering ethylene synthesis/perception*

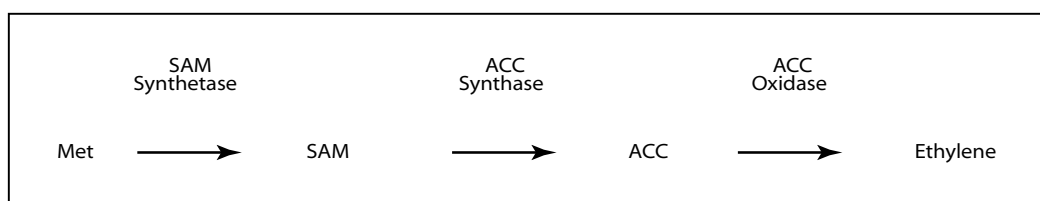
Ethylene is one of the simplest organic molecules with biological activity and is the only gaseous hormone known to date. In climacteric fruits, ethylene controls the rate of ripening and therefore several strategies have been devised to interfere with either the rate of ethylene synthesis or its perception by the fruit. The elucidation of the ethylene biosynthetic pathway by Yang and Hoffman (1984) (Figure 1) opened the door for the isolation of the enzymes involved and the cloning of the corresponding genes.

1-aminocyclopropane-1-carboxylic acid (ACC) synthase and ACC oxidase are the key enzymes in this pathway controlling the last two steps in the production of ethylene. Both of them are encoded by multigene families and, normally, only one member of

the family is active in the fruit during ripening. In tomato, the ACC synthase gene active during ripening (LEACC2) was silenced using antisense techniques, effectively reducing the production of ethylene by the ripening fruit by 99.5% (Oeller et al. 1991). While control fruit began to produce ethylene 48–50 days after pollination and immediately underwent a respiratory burst, genetically modified tomatoes produced minimal levels of ethylene and failed to produce the respiratory burst (at least during the 95-day period analysed in the report). Transgenic fruit started showing symptoms of chlorophyll degradation 10–20 days after the control fruit turned yellow, and eventually developed an orange colour two months later; meanwhile, control tomato fruit needed only ten days for the transition from fully mature green to fully ripe red tomatoes.

The transgenic tomatoes studied by Oeller et al. (1991) never turned red and soft and never developed aroma when kept on the plant or stored in an air atmosphere. Obviously, these characteristics are not desirable for a commercial fruit crop since the consumer wants a ripe product with fully developed attributes of colour, aroma, flavour etc. There is an evident question of whether this phenotype is reversible by treatment with ethylene or whether the genetic change has created fruit completely unable to undergo the ripening process. When mature, green, transgenic fruit (49 days after pollination) were treated with ethylene, they developed a fully ripe phenotype within 7 days (as opposed to 2 days for control fruit). The ethylene-treated, genetically modified, ripe fruit were indistinguishable from naturally ripened control fruit in colour, texture, aroma and compressibility. Although scientifically this work is of foremost importance, such extreme phenotypes may not prove useful in a commercial situation and intermediate phenotypes should be targeted.

It is clear from the above studies that ethylene is the trigger that starts the respiratory burst in climacteric fruits and controls the rate of ripening.



**Figure 1.** The ethylene biosynthetic pathway (Met = methionine, SAM = *S*-adenosylmethionine, ACC = 1-aminocyclopropane-1-carboxylic acid).

The ripening-related ACC oxidase gene has also been cloned in tomato and its expression inhibited by 95% (Hamilton et al. 1990; Picton et al. 1993). This level of inhibition did not block ripening in the transgenic plants and hence allowed normal development of the fruit. However, the onset of senescence, over-ripening, cracking of fruit and other general over-ripening effects were delayed. Nevertheless, when mature green fruit were picked from the plant they never fully ripened. Even when exposed to ethylene, they developed a full red colour but the levels of carotenoids never reached those achieved by fruit fully ripened on the plant (Picton et al. 1993).

Instead of tampering with the enzymes controlling the biosynthesis of ethylene, two commercial companies (Monsanto and Agritope) opted for alternative strategies aimed at depleting the intermediate substrates of the pathway. Monsanto used a bacterial enzyme (ACC deaminase) to drain the cell of the immediate precursor of ethylene (ACC). Overexpression of an ACC deaminase gene in tomato plants led to a marked depletion of the levels of ACC and therefore reduced the availability of this precursor to be converted into ethylene (Klee et al. 1991). The levels of ethylene reduction achieved with this strategy were not as successful as with the ACC synthase antisense strategy, but the transgenic fruit showed symptoms of delayed ripening. Agritope used another bacterial gene encoding *S*-adenosylmethionine (SAM) hydrolase, in conjunction with a ripening-specific promoter, to hydrolyse the first intermediate of the ethylene biosynthetic pathway (SAM) specifically in ripening tomato fruit (Kramer et al. 1997). The transgenic fruit exhibited a delayed ripening phenotype and a reduction of spoilage due to over-ripening.

Is it possible to control ripening in other fruits? All the studies described here have been achieved in tomato. The reason for the choice of this system is clear—tomato is a very important crop with an extensive research history into the biochemistry and genetics of ripening. In addition, tomato transformation is relatively easy when compared to other fruit species and the results of a transformation experiment can be evaluated in a glasshouse in 1 year (as opposed to an entire field and 5–7 years for fruit trees). Nevertheless, there is a clear indication that the approaches described earlier can be applied to other crops, as is the case for melon. Ayub et al. (1996) used antisense techniques to inhibit ACC oxidase levels and concomitant ethylene production during ripening of cantaloupe ‘Chanterais’ melons. This variety has excellent eating

quality but a notoriously poor storage capacity. Genetically modified plants were produced with ethylene synthesis severely impaired (less than 1% of controls). Storage capacity was extended, with transgenic fruit remaining fresh after 10 days at 25°C, at which time the control fruit had spoiled. Exposing the transgenic fruit to external ethylene restored the ripening phenotype.

A final alternative to the control of ethylene production by fruit during ripening is to decrease the sensitivity of the fruit to the hormone. It has been established that during ripening, fruits not only increase the production of ethylene but they also become more sensitive to it (Theologis 1994). The recent cloning of the first ethylene receptor (*etr1*) in *Arabidopsis thaliana* (a species used as a ‘model’ plant for genetic studies) has opened the door to the manipulation of ethylene perception instead of ethylene production. A mutated version of *etr1* in *Arabidopsis* (*etr1-1*) confers ethylene insensitivity as a genetically dominant trait. The same mutated gene has also been introduced into tomato and petunia conferring ethylene insensitivity and producing fruits that fail to ripen or flowers with extremely delayed senescence, respectively (Wilkinson et al. 1997). It is clear that ethylene insensitivity is not a desired trait for a fruit since it would render the fruit unable to ripen even when exposed to ethylene, but decreased levels of ethylene receptors in ripening fruits could prove useful.

## Resistance to pathogens

Resistance to postharvest pathogens is another priority target for genetic engineers but the necessary basic knowledge on the physiology, biochemistry and genetics of the resistance mechanisms is not as advanced as in ripening. In addition, there is no common defence mechanism applicable to all pathogens or all crops (as is the case of ethylene in climacteric fruit ripening)—which suggests that resistance genes need to be found on an individual basis. Nevertheless there is an increasing number of genes being cloned and the mechanisms underlying the resistance process are being rapidly unravelled. Aside from specific resistance genes, an interesting secondary effect of reducing the production of ethylene during ripening have been recently reported by Cooper et al. (1998). An extensive study of the susceptibility of transgenic tomato plants to *Colletotrichum gloeosporioides* was reported using two groups of transgenic tomato plants. The first group

contained genetically modified plants in which the levels of polygalacturonase had been reduced in transgenic fruit. The second group consisted of genetically modified tomato plants in which antisense constructs had been used to partially silence the ACC oxidase gene and therefore the fruit produced reduced levels of ethylene during ripening. The ripening characteristics of these fruit have been previously discussed in this paper and in previous reports (Sheehy et al. 1988; Smith et al. 1988; Hamilton et al. 1990; Picton et al. 1993). Wild type and antisense ACC oxidase fruit were manually inoculated with *C. gloeosporioides* and the extent of the infection scored 5 days after inoculation, showing an average infection score of 44.8% and 15.8%, respectively. Wild type fruit inoculated with *C. gloeosporioides* showed a marked increase in ethylene production in response to the infection whereas in transgenic ACC oxidase fruit this response was reduced by 96%. Transgenic fruits with reduced levels of PG did not show any noticeable change in behaviour in response to infection or any resistance to fungal infection.

As mentioned before there is an increasing number of resistance genes being cloned that have proven useful under laboratory conditions. The main task remains now of proving their efficacy against commercially important pathogens in the field.

## Genetic Engineering of Tropical Fruits

Due to their short life and poor storage qualities, tropical fruits could greatly benefit from the use of biotechnology in order to improve the quality and post-harvest characteristics of the fruits. Nevertheless, tropical fruits are not major crops in many of the developed countries and therefore the amount of research devoted to them has been comparatively scarce. Most of the biotechnological efforts in tropical species have been centred on the development of micropropagation and tissue culture methods but there is a lack of reliable and efficient transformation and regeneration methods.

### Papaya

One notable exception to this rule is papaya where an efficient transformation method has been developed by Fitch et al. (1993). They have not only developed the method but used it to introduce resistance to ringspot virus through genetic manipu-

lation. Ringspot virus-resistant plants have been produced and evaluated under laboratory and field conditions and show a great degree of resistance against the virus. Fruit from genetically modified trees have been tested and approved by the Food and Drug Administration (FDA) in the United States of America and are now under commercial production and being sold in supermarkets throughout America. Other research groups in Taiwan, Thailand, Malaysia, the Philippines, Mexico, Cuba and Australia are also producing transgenic papayas resistant to their own local viral isolates and some of them are already at the field trial stage.

Papaya is a typical climacteric fruit, having a respiratory burst and a concomitant increase in the production of ethylene at the start of ripening. Nevertheless, at the molecular level the ripening process in papaya is quite uncharacteristic since there are two ACC synthase genes involved instead of one (Mason and Botella 1997). One of the genes (*capacs1*) is expressed during fruit development—detectable in mature green fruit and decreasing rapidly during ripening. The second gene (*capacs2*) is undetectable in mature green fruit but as soon as the fruit begin to ripen there is a dramatic increase in the messenger ribonucleic acid (mRNA) levels. The presence of two genes in papaya fruit could indicate that ethylene plays a role during the development of the fruit as well as controlling ripening. According to the expression studies, *capacs1* is the gene implicated in fruit development while *capacs2* exerts its effect during the ripening process.

My laboratory has been studying papaya fruit ripening at the molecular level since 1994. With support from the Australian Centre for International Agricultural Research (ACIAR), we are now involved in an international effort with collaborators in the Philippines and Malaysia to use genetic engineering techniques in order to control ripening in papaya. We have prepared genetic constructs containing *capacs1* and *capacs2* in either the sense or antisense orientation and produced a total of 100 independent transgenic lines containing the constructs. The lines are being now micropropagated in the laboratory and regulatory approval has been requested to start field evaluation of the plants during 2000. If successful, this project will prove that genetic engineering approaches are applicable to the improvement of postharvest characteristics in tropical fruits.

## Mango

Mango is one of the tropical fruits with very high commercial potential if export markets can be developed. Export of mango fruit is notoriously difficult due to the poor handling and transport characteristics of the fruit, the very short postharvest life and the high incidence of postharvest diseases. In addition to these problems, traditional mango improvement by breeding has been hampered by the long generation times, making improvement programs either too long-sighted or plainly impractical. Therefore mango seems an ideal candidate for the use of biotechnological approaches. *Agrobacterium tumefaciens*-mediated transformation of mango with reporter genes has been reported (Mathews et al. 1992), but the whole transformation process was very lengthy. My laboratory is currently researching improved methods for mango transformation using the 'gene gun'. We have also cloned the mango ripening-related ACC synthase genes and will shortly attempt transformation experiments aimed at silencing the gene in fruit during ripening.

## Pineapple

Pineapple is not a tropical fruit but it is widely grown in subtropical regions of many Southeast Asian countries. Pineapple is affected by a number of important postharvest disorders that could be addressed using biotechnology techniques, such as blackheart. Australian and Malaysian research teams are engaged in research aimed at cloning the genes responsible for this disorder and producing transgenic plants with those gene silenced. Although pineapple is not a climacteric fruit we have found that the two genes responsible for ethylene production are up-regulated during ripening (Cazzonelli and Botella 1998). We are now performing field trials of genetically modified pineapples in which we aim to silence the ripening-related ACC synthase gene. These trials will help to elucidate the role of ethylene in pineapple and whether there are any agronomical traits that can be controlled by silencing its expression during ripening. One common practice among pineapple growers is to gas the harvested pineapple fruit with ethylene to enhance chlorophyll degradation and achieve uniform colour development. Therefore it is reasonable to expect that the genetically modified fruit could show inhibition of colour development but due to the lack of data on the role of ethylene during

pineapple ripening it is hard to speculate on the possible phenotypes that will be observed.

Flowering is not an obvious stage affecting the post-harvest period, but it could have a profound effect in the postharvest area if synchronisation of flowering could be achieved. Flowering genes are being cloned in model systems and the mechanisms that control the flowering process are being elucidated. Therefore, biotechnological control of flowering is no longer a far-fetched possibility. Nevertheless, in crops such as pineapple, synchronised flowering is already an achievable task since the mechanisms controlling initiation of flowering are known and the genes responsible have already been cloned. In pineapple, ethylene released on long, cold nights is thought to instigate the flowering process and growers spray the crops with ethylene-releasing compounds in order to induce flowering in the field. Nevertheless there is a percentage of plants that initiate flowering naturally before the spraying takes place. The severity of natural flowering varies from year to year, but its incidence is noticeable as it forces the growers to perform several harvesting passes and has meant that mechanised harvesting machinery has not been developed. We have cloned a set of genes that are putatively involved in the initiation of flowering in pineapple—transgenic plants bearing genetic constructs to inactivate those genes have been produced and are presently being evaluated in field tests.

## Genetic Engineering of Vegetables

Many leafy and flower vegetables exhibit a very short life span after harvest and require very elaborate methods in order to extend their life. Reducing the rate of senescence is not an easy task either by conventional or biotechnological methods and the amount of knowledge available regarding the postharvest manipulation of vegetables is scarce when compared to fruit ripening.

Senescence is the final stage of development and, contrary to its external appearance, it is a highly regulated and organised process that plays an integral part in the plant life cycle. From an agricultural point of view, senescence is a major contributor to post-harvest losses. It is important to emphasise the complexity of the problem and the lack of information about the molecular mechanisms involved in the onset and regulation of senescence. The only attempts to use genetic manipulation to alter senescence have been based on hormone physiology—either enhancing

cytokinin production or blocking ethylene production or perception.

It has been known for some time that cytokinins can delay leaf senescence and that during senescence there is a drop in endogenous cytokinin levels (Gan and Amisino 1996). Overproduction of IPT, a bacterial enzyme that catalyses the rate-limiting reaction in the biosynthesis of cytokinins, resulted in transgenic plants with high levels of cytokinins and delayed leaf senescence. But these plants also showed many developmental abnormalities since cytokinins are not only implied in senescence but in a myriad of other developmental processes. An ingenious solution has been provided by Gan and Amasino (1995). These authors placed the IPT gene under the control of a senescence-specific promoter that activates the production of cytokinins only at the onset of senescence. The over-expression of cytokinins inhibits the senescence process and consequently results in a reduction of the activity of the senescence-specific promoters, avoiding the accumulation of cytokinins.

Ethylene often has an opposite effect to cytokinins, promoting senescence. Therefore blocking the production or the perception of ethylene could have a positive effect in the longevity of green tissues. Transgenic tomato plants with reduced levels of ethylene production have shown retarded leaf senescence (John et al. 1995). Transgenic *Arabidopsis* plants with the *etr1-1* dominant mutation that renders them insensitive to ethylene have also shown delayed leaf senescence (Grbic and Bleeker 1995).

The only example, to my knowledge, of genetic manipulation to extend the postharvest life of vegetables has been done in broccoli. Transgenic broccoli has been produced containing antisense copies of a tomato ACC oxidase gene (Henzi et al. 1999). Several of the transgenic lines have shown a decrease in ethylene production after harvest and the evaluation of the agronomical characteristics is presently being carried out.

## References

- Ayub, R., Guis, M., Amor, M.B., Gillot, L., Roustan, J.P., Latche, A., Bouzayen, M. and Pech, J.C. 1996. Expression of ACC oxidase antisense gene inhibits ripening of cantaloupe melon fruits. *Nature Biotechnology*, 14, 862–866.
- Cazzonelli, C., Cavallaro, A. and Botella, J.R. 1998. Cloning and characterisation of ripening-induced ethylene biosynthetic genes from non-climacteric pineapple (*Ananas comosus*) fruits. *Australian Journal of Plant Physiology*, 25, 513–518.
- Cooper, W., Bouzayen, M., Hamilton, A., Barry, C., Rossall, S. and Grierson, D. 1998. Use of transgenic plants to study the role of ethylene and polygalacturonase during infection of tomato fruit by *Colletotrichum gloesporioides*. *Plant Pathology*, 47, 308–316.
- DellaPenna, D., Alexander, D.C. and Bennett, A.B. 1986. Molecular cloning of tomato fruit polygalacturonase: analysis of polygalacturonase levels during ripening. *Proceedings of the National Academy of Science, USA*, 83, 6420–6424.
- Fitch, M.M.M., Manshardt, R.M., Gonsalves, D. and Slightom, J.L. 1993. Transgenic papaya plants from *Agrobacterium* mediated transformation of somatic embryos. *Plant Cell Reports*, 12, 245–249.
- Gan, S. and Amasino, R.M. 1995. Inhibition of leaf senescence by autoregulated production of cytokinin. *Science*, 270, 1986–1988.
- Gan, S. and Amisino, R.M. 1996. Cytokinins in plant senescence: from spray and pray to clone and play. *Bioessays*, 18, 557–565.
- Grbic, V. and Bleeker, A.B. 1995. Ethylene regulates the timing of leaf senescence in *Arabidopsis*. *Plant Journal*, 8, 595–602.
- Grierson, D., Maunders, M.J., Slater, A., Ray, J., Bird, C.R., Schuch, W., Holdworth, M.J., Tucker, G.A. and Knapp, J.E. 1986. Gene expression during tomato ripening. *Philosophical Transactions of the Royal Society of London*, B314, 399–410.
- Hamilton, A., Lycett, G.W. and Grierson, D. 1990. Antisense gene that inhibits synthesis of the hormone ethylene in transgenic plants. *Nature*, 346, 284–287.
- Henzi, M.X., McNeil, D.L., Christey, M.C. and Lill, R.E. 1999. A tomato antisense 1-aminocyclopropane-1-carboxylic acid oxidase gene causes reduced ethylene production in transgenic broccoli. *Australian Journal of Plant Physiology*, 26, 179–183.
- John, I., Drake, R., Farrell, A., Cooper, W., Lee, P., Horton, P. and Grierson, D. 1995. Delayed leaf senescence in ethylene deficient ACC-oxidase antisense tomato plants: molecular and physiological analysis. *Plant Journal*, 7, 483–490.
- Klee, H.J., Hayford, M.B., Kretzner, K.A., Barry, G.F. and Kishore, G.M. 1991. Control of ethylene synthesis by expression of a bacterial enzyme in transgenic tomato plants. *The Plant Cell*, 3, 1197–1193.
- Kramer, M.G., Kellog, J., Wagoner, W., Matumura, W., Good, X., Peters, S., Clough, G. and Bestwick, R.K. 1997. Reduced ethylene synthesis and ripening control in tomatoes expressing S-adenosyl-methionine hydrolase. In: Kanellis, A.K., Chang, C., Kende, H. and Grierson, D., ed., *Biology and biotechnology of the plant hormone ethylene*. Dordrecht, Kluwer Academic Publishers.
- Mason, M.G. and Botella, J.R. 1997. Identification and characterisation of two 1-aminocyclopropane-1-

- carboxylate (ACC) synthase cDNAs expressed during papaya (*Carica papaya*) fruit ripening. *Australian Journal of Plant Physiology*, 24, 239–244.
- Mathews, E., Litz, R.E., Wilde, H.D., Merkle, S.A. and Wetzstein, H.Y. 1992. Stable integration and expression of  $\beta$ -glucuronidase and NPTII genes in mango somatic embryos. *In Vitro Cellular and Developmental Biology*, 28, 172–178.
- Oeller, P.W., Min Wong, L., Taylor, L.P., Pike, D.A. and Theologis, A. 1991. Reversible inhibition of tomato fruit senescence by antisense RNA. *Science*, 254, 437–439.
- Picton, S., Barton, S.L., Bouzayen, M., Hamilton, A.J. and Grierson, D. 1993. Altered fruit ripening and leaf senescence in tomatoes expressing an antisense ethylene-forming enzyme transgene. *Plant Journal*, 3, 469–481.
- Schuch, W., Kanczler, J., Robertson, D., Hobson, G., Tucker, G., Grierson, D., Bright, S. and Bird, C. 1991. Fruit quality characteristics of transgenic tomato fruit with altered polygalacturonase activity. *HortScience*, 26, 1517–1520.
- Sheehy, R.E., Kramer, M. and Hiatt, W.R. 1988. Reduction of polygalacturonase activity in tomato fruit by antisense RNA. *Proceedings of the National Academy of Sciences, USA*, 85, 8805–8809.
- Smith, C.J.S., Watson, C., Ray, J., Bird, C.R., Morris, P.C., Scuch, W. and Grierson, D. 1988. Antisense RNA inhibition of polygalacturonase gene expression in transgenic tomatoes. *Nature*, 334, 724–726.
- Smith, C.J.S., Watson, C.F., Bird, C.R., Ray, J., Schuch, W. and Grierson, D. 1990. Expression of a truncated tomato polygalacturonase gene inhibits expression of the endogenous gene in transgenic plants. *Molecular General Genetics*, 224, 477–481.
- Theologis, A. 1994. Control of ripening. *Current Opinion in Biotechnology*, 5, 152–157.
- Wilkinson, J.Q., Lanahan, M.B., Clark, D.G., Bleecker, A.B., Chang, C., Meyerowitz, E.M. and Klee, H.J. 1997. A dominant mutant receptor from *Arabidopsis* confers ethylene insensitivity in heterologous plants. *Nature Biotechnology*, 15, 444–447.
- Yang, S.F. and Hoffman, N.E. 1984. Ethylene biosynthesis and its regulation in higher plants. *Annual Review of Plant Physiology*, 35, 155–189.

# Modelling Respiration of Edible-coated, Minimally Processed Mango in Modified Atmosphere Packaging

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## Abstract

The objectives of this study were to assess the respiration parameters and quality changes of edible-coated, minimally processed (ECMP) 'Arumanis' mango stored inside modified atmosphere packaging (MAP), and to develop a computer simulation model to predict the respiration rate and the shelf life of the ECMP 'Arumanis' mango stored inside MAP. ECMP fruit samples at various weights were stored in respiration chambers covered by stretch film at various storage temperatures: 5, 10, 15 and 20°C. The respiration rates were observed and recorded until the oxygen inside the chambers reached a steady state.

The data were calculated to obtain the maximum rate of the oxygen consumption ( $R_{O_2}^{\max}$ ), the oxygen internal partial pressure at the half level of  $R_{O_2}^{\max}$  ( $K_{1/2}$ ), and the respiration quotient (RQ). The empirical models of  $R_{O_2}^{\max}$ ,  $K_{1/2}$ , and RQ as the functions of storage temperatures were found to be  $R_{O_2}^{\max} = 32.593 \exp(0.1093 T)$ ,  $K_{1/2} = 0.122 \exp(0.1291 T)$ , and  $RQ = 0.995 \exp(0.0166 T)$ .

The critical quality parameters of the ECMP 'Arumanis' mango were the fruit hardness and yellowness which limited the shelf life of the products in relation to the minimum acceptable score of 3.5 from the results of organoleptic testing by 12 panelists. A simulation model for the respiration and shelf life of the ECMP mango has been developed and validated to satisfy the experimental data gained from storing the ECMP mango inside MAP made from styrofoam trays and stretch film. The ECMP 'Arumanis' mango stored inside the MAP system using the stretch film at 10°C could maintain an acceptable quality for five days.

IN RECENT years, consumers worldwide have been more health-conscious in their eating habits but at the same time have less time to prepare their meals. As a result, the market demand is increasing for 'ready-to-eat' fresh fruits and 'ready-to-cook' vegetables which have been washed, skinned, cut and sliced into various forms. Produce handled in this way is called minimally processed (MP) or lightly processed food and does not involve any preservation treatments which could change the physical characteristics of the products (Shewfelt 1987). Siriphanich (1993) indicated that characteristics of fruits suitable for minimal processing included: a risk of obtaining poor quality pulp, fruit peeling difficulties, and weight reduction for transportation. In Indonesia, mango is one of the

most popular fruits, with the 'Arumanis' cultivar ranked highest in production. 'Arumanis' mangoes weigh about 300–500 g per fruit and have a green colour which hinders consumers in making a good choice of fruit of appropriate ripeness.

Studies have been carried out to assess various MP fruits such as kiwifruit, papaya, cantaloupe, pineapple, honeydew melon and apples (O'Connor-Shaw et al. 1994; Cameron et al. 1995). The problem with MP fruits is that they deteriorate faster than whole fruits under similar low storage temperatures. One way of reducing the rate of respiration in MP fruits is to cover the exposed surface with an edible-coating film. Edible-coating film is a continuous film made out of edible materials which is applied to the food products by soaking or spraying. Edible coating functions as a barrier to mass transfer (of water vapour, oxygen, lipids and soluble materials). In addition, it can act as a carrier for food additives, facilitates food handling,

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maintains the cell structural integrity, and hinders the losses of volatile compounds (Kester and Fennema 1986; Krochta 1992; Gennadios et al. 1994; Nisperos-Carriedo 1994). Edible coating has been applied to sliced apples (Wong et al. 1994) and tomatoes (Park et al. 1994). Baldwin et al. (1995) found out that edible-coated sliced apples had a shelf life of 3 days under atmospheric conditions.

The application of edible coating onto MP 'Arumanis' mango and its characteristics have been assessed by Purwadaria et al. (1997), Setiasih et al. (1997) and Wuryani et al. (1998). These researchers have also developed the standard operational procedure (SOP) for the minimal processing and the edible coating process of mangoes. Purwadaria and Wuryani (1999) developed the respiration model for the edible-coated, MP (ECMP) 'Arumanis' mango stored under known atmospheric compositions at various temperatures. However, none of the publications to date have described the ECMP mango stored in modified atmosphere packaging (MAP).

Previous studies have been carried out on whole mango fruit stored under modified atmosphere conditions, such as the one carried out by Kader (1992) which recommended a composition of 3–5% O<sub>2</sub> and 5–10% CO<sub>2</sub> at 10–15°C, whilst Ratule (1999) determined the optimal atmospheric composition for the ECMP 'Arumanis' mango to be 4 ± 1% O<sub>2</sub> and 11 ± 2% CO<sub>2</sub> at 10°C, and suggested stretch film for MAP. The study also found out that the critical quality parameters for the ECMP mango were the fruit hardness and yellowness.

The objectives of this study were (1) to assess the respiration parameters and quality changes of the ECMP 'Arumanis' mango stored inside MAP, and (2) to develop a computer simulation model to predict the respiration and the shelf life of the ECMP 'Arumanis' mango stored inside MAP.

## Research Methods

### Edible coating of MP 'Arumanis' mango

'Arumanis' mango fruit, harvested 90 days after peak blooming from the Galasari orchard in Gresik-East Java, were conditioned at room temperature for 3 days prior to minimal processing. The mangoes were then peeled and cut horizontally into six slices per side following the standard operational procedure for MP mango (Purwadaria et al. 1997). The mango slices were then dipped into the edible coating formula

developed by Setiasih et al. (1998) with isolate soybean protein and stearic acid as the main constituents.

### Determination of model inputs

In developing the computer simulation model, the following input parameters were initially determined: (i) the oxygen and carbon dioxide permeabilities of the edible coating and packaging film, (ii) the respiration parameters of the ECMP 'Arumanis' mango, and (iii) the critical quality parameters and the shelf life criteria of the ECMP 'Arumanis' mango.

#### *Measurement of edible coating and packaging film permeability*

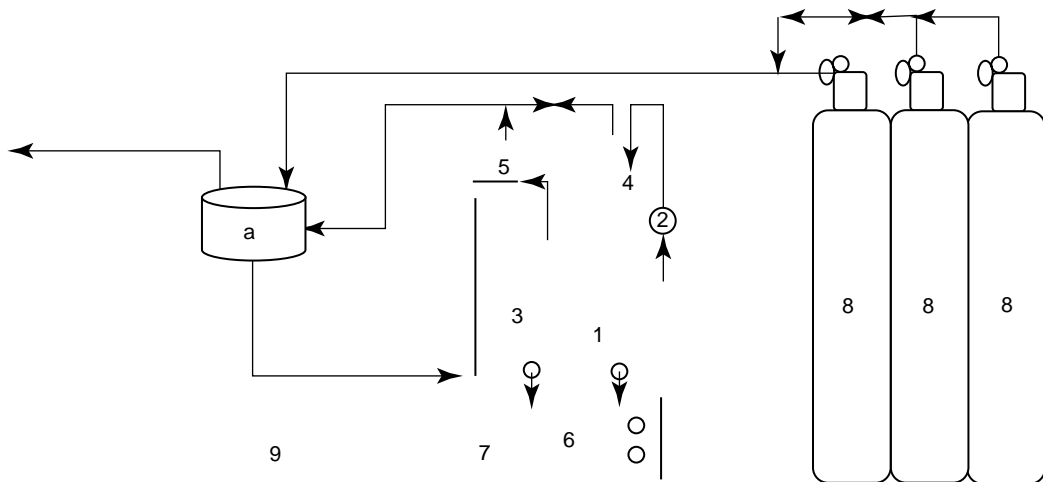
The experimental decay method using a permeability cell according to the ASTM D-3985 was used to determine the O<sub>2</sub> and CO<sub>2</sub> transmission through the edible coating and the stretch film at 5, 10 and 25°C (room temperature) and 80% relative humidity. The experimental set-up is illustrated in Figure 1.

#### *Determination of respiration parameters of ECMP 'Arumanis' mango*

Fruit samples at various weights (30, 56, 82, 107, 129 and 154 g), corresponding to the number of ECMP mango slices (1, 2, 3, 4, 5 and 6 slices, respectively), were put inside a respiration chamber with a volume of 0.002 m<sup>3</sup> and a surface area of 0.015 m<sup>2</sup>, covered with the stretch film and stored at 5, 10, 15 or 20°C. Changes in the atmospheric composition inside the respiration chamber due to fruit respiration were monitored and recorded until a steady state condition was achieved.

The symbols used in this paper are explained in Table 1. O<sub>2</sub> and CO<sub>2</sub> were then analysed by the gas chromatograph model 3700 and the results were called (O<sub>2</sub>)<sub>pkg</sub> and (CO<sub>2</sub>)<sub>pkg</sub>. The data were further processed to determine R<sub>O2</sub>, R<sub>CO2</sub>, (O<sub>2</sub>)<sub>int</sub>, (CO<sub>2</sub>)<sub>int</sub>, R<sub>O2</sub><sup>max</sup>, K<sub>1/2</sub> and RQ as functions of the storage temperature. An ethylene absorbent at a concentration of 2% was used to avoid the effects of ethylene on the respiration rate.





- |                             |  |
|-----------------------------|--|
| 1. O <sub>2</sub> analyser  | 6. Recorder  |
| 2. Manometer                | 7. Power regulator   |
| 3. CO <sub>2</sub> analyser | 8. CO <sub>2</sub> , O <sub>2</sub> and N <sub>2</sub> tanks |
| 4. Humidifier               | 9. Refrigerator containing (a) permeability cell             |
| 5. Dehumidifier             |  |

**Figure 1.** Experimental set-up for the film permeability test.

**Table 1.** List of symbols used in this paper.

Symbol	Explanation
$A^i$	= Surface area of barrier i, m <sup>2</sup>
$K_{1/2}$	= Internal O <sub>2</sub> partial pressure at the half level of R <sub>O<sub>2</sub></sub> <sup>max</sup> , kPa
$P_j^i$	= Standard measure of permeability of given barrier i to gas j, mol.m.m <sup>2</sup> /kPa/s
$R_{O_2}$	= Rate of O <sub>2</sub> uptake, mol/kg/s
$R_{O_2}^{max}$	= Maximum rate of O <sub>2</sub> uptake, mol/kg/s
$R_{CO_2}$	= Rate of CO <sub>2</sub> production, mol/kg/s
RQ	= Respiratory quotient
T	= Storage temperature, °C
V	= Void volume inside the packaging, m <sup>3</sup>
W	= Weight of fruit samples, kg
$\delta^i$	= Thickness of barrier film, m
$(O_2)_{int}$	= Steady state partial pressure of internal O <sub>2</sub> , kPa
$(O_2)_{pkg}$	= Steady state partial pressure of O <sub>2</sub> inside the packaging, kPa
$(O_2)_{ext}$	= Steady state partial pressure of O <sub>2</sub> outside the packaging, kPa
$(CO_2)_{pkg}$	= Steady state partial pressure of CO <sub>2</sub> inside the packaging, kPa
$(CO_2)_{ext}$	= Steady state partial pressure of CO <sub>2</sub> outside the packaging, kPa
$\beta_j^i$	= Total permeability of barrier i to gas j per kilogram of product, mol/kPa/kg/s
sf	= Stretch film
ec	= Edible coating film

O<sub>2</sub> uptake (R<sub>O<sub>2</sub></sub>) and CO<sub>2</sub> production (R<sub>CO<sub>2</sub></sub>) were calculated as follows (Cameron et al. 1989):

$$R_{O_2} = \frac{p_{O_2}^{sf} \cdot A^{sf}}{\delta^{sf} \cdot W} \cdot ([O_2]_{ext} - [O_2]_{pkg}) \quad (1)$$

$$R_{CO_2} = \frac{p_{CO_2}^{sf} \cdot A^{sf}}{\delta^{sf} \cdot W} \cdot ([CO_2]_{pkg} - [O_2]_{ext}) \quad (2)$$

R<sub>O<sub>2</sub></sub><sup>max</sup> and K<sub>1/2</sub> were then determined as the inverse of the slope from the Hanes-Woolf function (Shuller and Kargi 1992):

$$\frac{(O_2)_{int}}{R_{O_2}} = \frac{K_{1/2}}{R_{O_2}^{max}} + \frac{1}{R_{O_2}^{max}} \cdot (O_2)_{int} \quad (3)$$

whilst the (O<sub>2</sub>)<sub>int</sub> was obtained from the following equation (Cameron et al. 1995):

$$(O_2)_{int} = (O_2)_{pkg} + \frac{p_{O_2}^{sf}}{p_{O_2}^{ec}} \cdot (O_2)_{ext} - (O_2)_{pkg} \quad (4)$$

taking the total O<sub>2</sub> permeability as

$$\beta_{O_2}^i = \frac{P_{O_2}^i \cdot A^i}{\delta^i \cdot W} \quad (5)$$

Finally, the RQ was calculated from the mathematical expression developed by Wills et al. (1991):

$$RQ = \frac{R_{CO_2}}{R_{O_2}} \quad (6)$$

### Assessment of critical quality parameters and the shelf life criteria of the ECMP ‘Arumanis’ mango

The fruit samples stored inside MAP under the conditions specified in Table 2 were observed for their critical quality parameters, fruit hardness and yellowness according to Ratule (1999). The observations were conducted on the 0, 2<sup>nd</sup>, 4<sup>th</sup>, 6<sup>th</sup>, 8<sup>th</sup> and 10<sup>th</sup> day with three repetitions. The shelf life of the ECMP fruit was determined based on the acceptance score given by 12 trained panelists in the organoleptic tests performed on each sample at the same time. To establish the relationship between the organoleptic score and the critical quality parameters, an objective test was carried out for the fruit colour using a Chroma Meter CR-200 and the hardness using an Instron 1140 instrument.

### Development and validation of the computer simulation model

The developed computer simulation model is illustrated in the flow chart presented in Figure 2. The model covered two structures, one to predict the respi-

ration rate and the other to predict the shelf life of the ECMP ‘Arumanis’ mango in the MAP system. The model was then validated to the experimental data obtained from the treatments similar to the assessment on critical quality, but instead of putting the fruit samples inside the respiration chamber, they were stored inside the commercial MAP using a styrofoam tray of 21 cm × 14 cm × 1 cm as the packaging base.

## Results and Discussion

### Permeability of edible coating and packaging films

The film permeability of the edible coating at 0.5% ISP (isolate soybean protein) concentration and the stretch film are listed in Table 3. The permeability to CO<sub>2</sub> was higher than that of O<sub>2</sub>. The ratio of CO<sub>2</sub> to O<sub>2</sub> permeability ranged from 6.36 to 7.11 for the edible coating, and 4.77 to 6.10 for the stretch film at 5 to 25°C. Higher temperatures gave an increase in the O<sub>2</sub> and CO<sub>2</sub> permeability of both the edible coating and stretch film. They also increased the ratio of CO<sub>2</sub> over O<sub>2</sub> permeability.

**Table 2.** Specification of treatment conditions for edible-coated, minimally processed (ECMP) ‘Arumanis’ mango.

Samples	Weight (kg)	Surface area of packaging film (m <sup>2</sup> )	Storage temperature (°C)
ECMP ‘Arumanis’ mango	0.7880	0.0336	5
	0.5754	0.0310	10

**Table 3.** Permeabilities of edible coating and packaging films at 80% relative humidity ( $\times 10^{-14}$  mol/mm<sup>2</sup>/kPa/s).

Film permeability	Temperature (°C)	Edible coating film (0.5% ISP <sup>a</sup> )	Stretch film
Oxygen	5	1 910.45	90.01
	10	1 963.49	121.51
	25	2 080.80	216.14
Carbon dioxide	5	12 145.23	529.56
	10	13 175.58	712.88
	25	14 798.11	1 317.39
Ratio of carbon dioxide to oxygen	5	6.36	4.77
	10	6.71	5.87
	25	7.11	6.10

<sup>a</sup> ISP = isolate soybean protein

Decreasing the temperature gave a lower permeability value both for O<sub>2</sub> and CO<sub>2</sub>. The edible coating had much higher permeability than the packaging film, supporting the idea that the MAP is necessary to extend the shelf life of the ECMP fruit.

### Respiration parameters

The obtained respiration parameters R<sub>O<sub>2</sub></sub><sup>max</sup>, K<sub>1/2</sub> and RQ of the ECMP ‘Arumanis’ mango are listed in Table 4. R<sub>O<sub>2</sub></sub><sup>max</sup>, K<sub>1/2</sub>, and RQ decreased along with the lowering of storage temperature since the respiration of the ECMP ‘Arumanis’ mango also slowed down at cooler temperatures. The effect of temperature on the respiration parameters could be expressed as the following Arrhenius equations:

$$R_{O_2}^{\max} = 32.5930 \exp(0.1093T);$$

$$R^2 = 0.9956 \quad (7)$$

$$K_{1/2} = 0.1224 \exp(0.1291T);$$

$$R^2 = 0.9977 \quad (8)$$

$$RQ = 0.9954 \exp(0.0166T);$$

$$R^2 = 0.8913 \quad (9)$$

### Critical quality parameters and shelf life criteria

The critical quality parameters of the ECMP 'Arumanis' mango, the fruit hardness and yellowness were plotted against the organoleptic score obtained from the samples tested periodically during the experiments. The relationship could be expressed in linear regressions as illustrated in Figure 3. Taking the minimum acceptable score from the trained panelists as 3.5 out of a score range of 1–5, the corresponding value of fruit hardness was 1.37 kPa and the yellowness was 24.47.

The shelf life of the ECMP 'Arumanis' mango then was determined by drawing the line of the fruit hardness at 1.37 kPa and the yellowness at 24.47 parallel to the x-axis until it crossed the curve of quality degradation during storage (Figure 4). The result indicated that the shelf life of the ECMP 'Arumanis' mango was 5.2–5.31 days (rounded to 5 days) when stored in the MAP using the stretch film at 10°C.

### Model simulation and validation on the respiration and shelf life of ECMP mango inside MAP

The model simulation has been developed and Table 5 presents the statistical test to validate the predicted average O<sub>2</sub> and CO<sub>2</sub> concentration in the MAP with the experimental data for the ECMP 'Arumanis' mango. Since all the t calculations were lower than t table for both 5 and 1% significance levels, there was no significant differences between the predicted and the experimental data. In other words, the model simulation was validated and able to represent the respiration process.

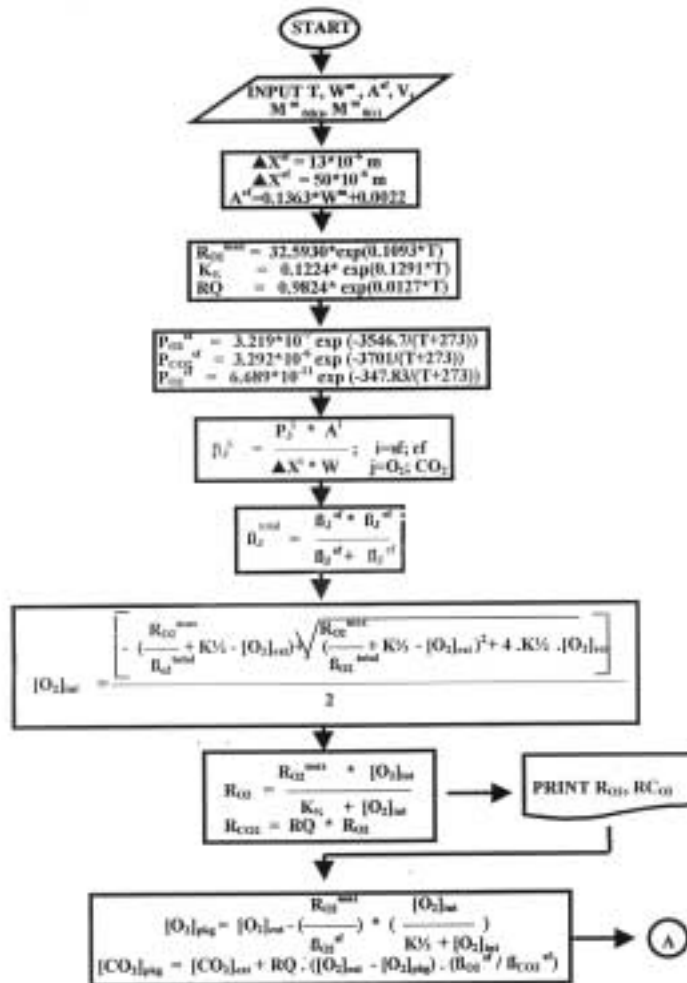
**Table 4.**  $R_{O_2}^{\max}$ ,  $K_{1/2}$  and RQ (see Table 1 for explanation of symbols) of edible-coated, minimally processed (ECMP) 'Arumanis' mango fruit inside the modified atmosphere chamber at various storage temperatures.

Temperature (°C)	$R_{O_2}^{\max}$ (nmol/kg/s)	$K_{1/2}$ (kPa)	RQ
5	58.140	0.220	1.056
10	95.238	0.400	1.112
15	168.730	0.746	1.162
20	303.030	1.545	1.286

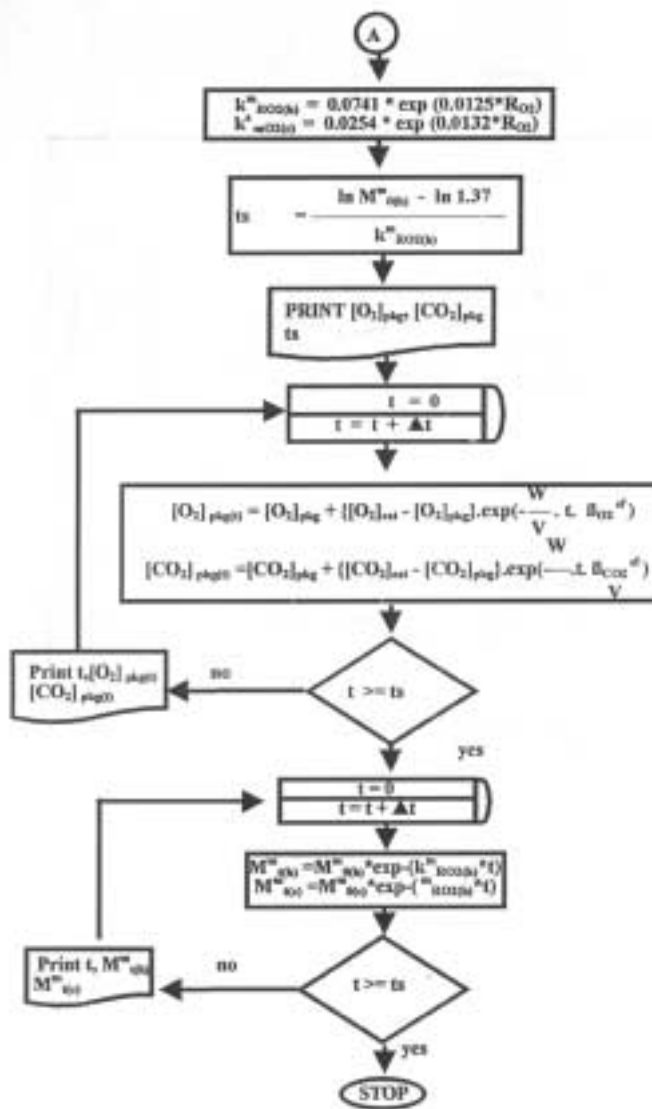
**Table 5.** Statistical test (student t test) to validate predicted oxygen and CO<sub>2</sub> inside modified atmosphere packaging with experimental data.

Sources	Average concentration (kPa)		t calculation	t table	
	Experimental data	Predicted result		0.05	0.01
<i>Storage temperature 5°C</i>					
Oxygen	9.999	10.474	-0.237	2.048	2.763
Carbon dioxide	2.713	2.470	0.857	2.048	2.763
<i>Storage temperature 10°C</i>					
Oxygen	10.059	10.660	-0.267	2.064	2.797
Carbon dioxide	2.931	2.674	0.730	2.064	2.797

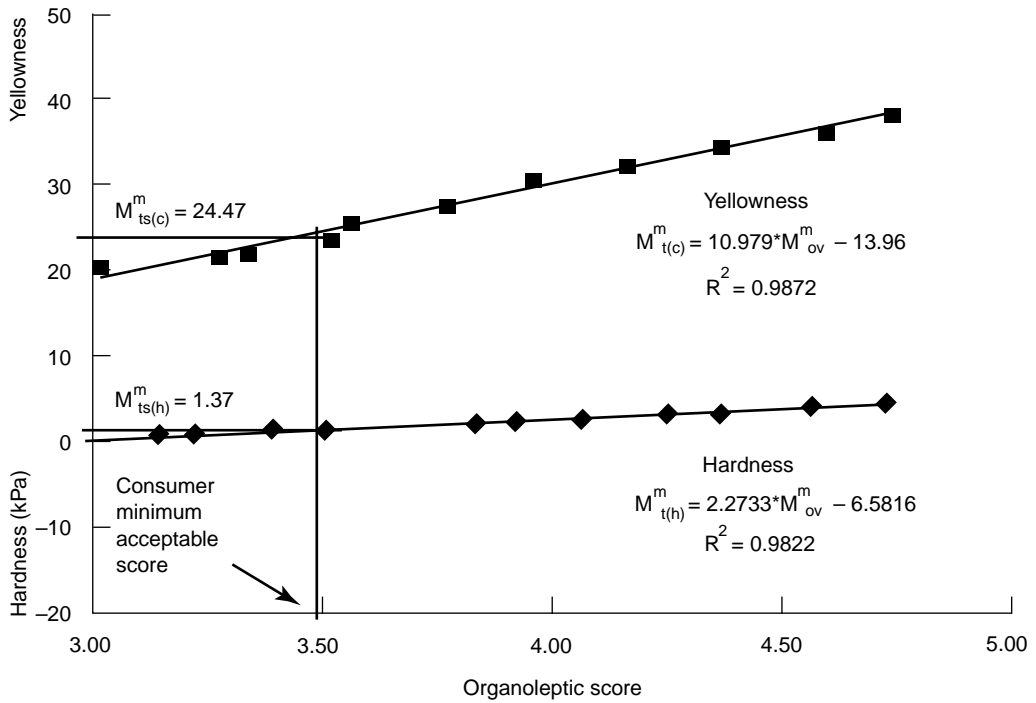
Note: t calculation < t table



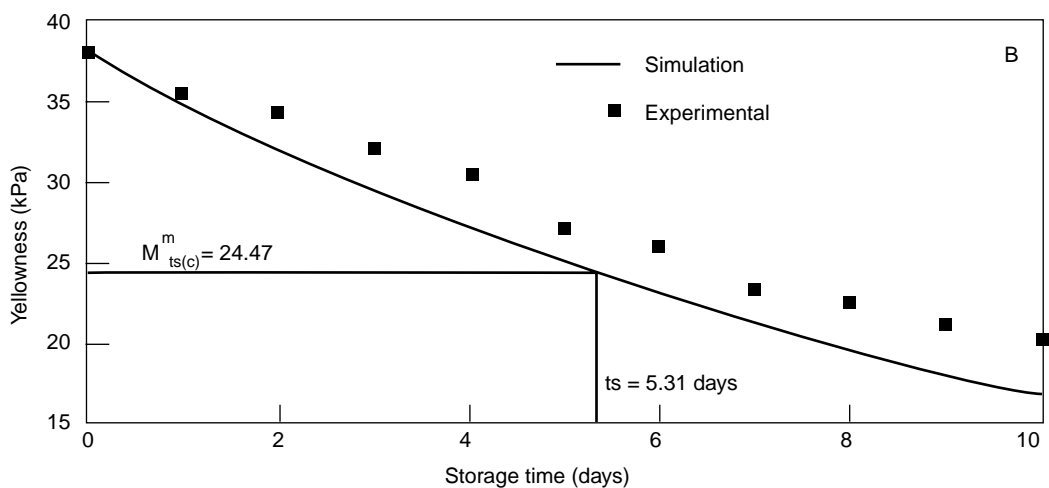
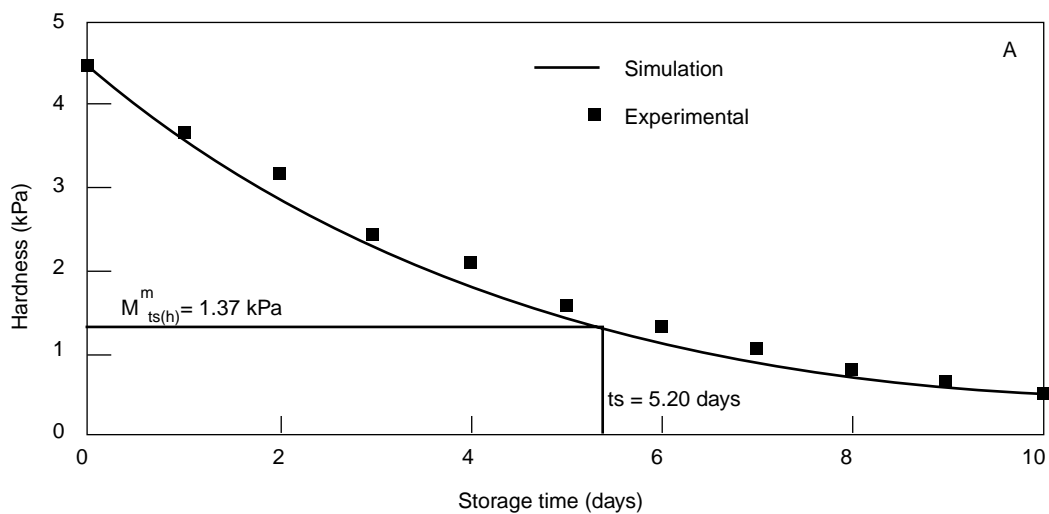
**Figure 2.** Flow chart of the computer simulation model to predict the respiration rate and shelf life of edible-coated, minimally processed 'Arumanis' mango stored inside modified atmosphere packaging.



**Figure 2.** (Cont'd) Flow chart of the computer simulation model to predict the respiration rate and shelf life of edible-coated, minimally processed 'Arumanis' mango stored inside modified atmosphere packaging.



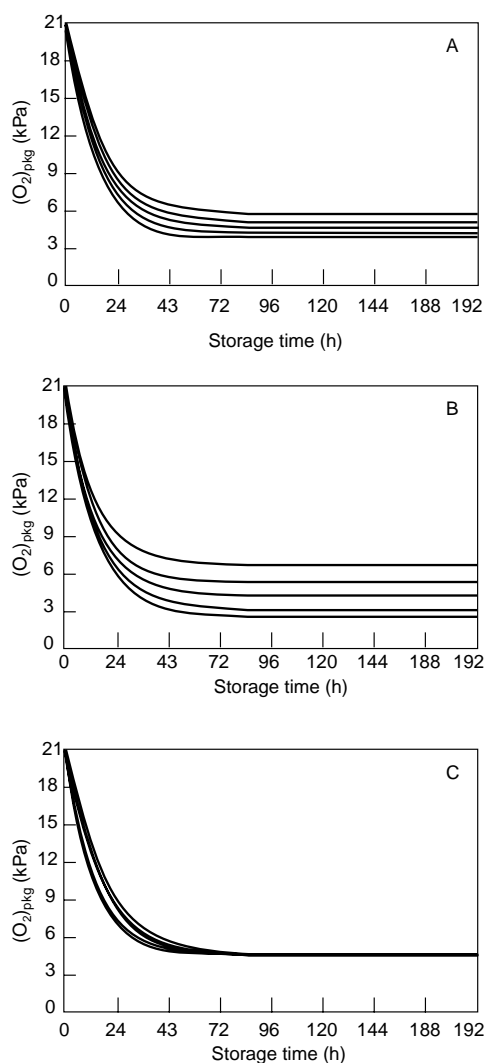
**Figure 3.** Relationship of critical quality parameters and organoleptic score of edible-coated, minimally processed 'Arumanis' mango stored inside modified atmosphere packaging.



**Figure 4.** Determination of the shelf life of edible-coated, minimally processed ‘Arumanis’ mango on the simulation of (A) fruit hardness and (B) yellowness.



The capability of model to predict the  $(O_2)_{pkg}$  during the respiration process at various storage temperatures, fruit weights and void volumes inside the MAP is illustrated in Figure 5. The simulated quality degradation on the fruit hardness and yellowness is presented in comparison with experimental data in Figure 4.



**Figure 5.** Model prediction for  $(O_2)_{pkg}$  of edible-coated, minimally processed 'Arumanis' mango stored inside modified atmosphere packaging at various (A) temperatures, (B) fruit weights and (C) void volumes.

## Conclusions and Recommendations

The empirical models of  $R_{O_2}^{max}$ ,  $K_{1/2}$ , and RQ as the functions of storage temperatures were found to be  $R_{O_2}^{max} = 32.593 \exp(0.1093 T)$ ,  $K_{1/2} = 0.122 \exp(0.1291 T)$ , and  $RQ = 0.995 \exp(0.0166 T)$ .

The critical quality parameters of the ECMP 'Arumanis' mango were the fruit hardness and yellowness which limited the shelf life of the products related to the minimum acceptable score of 3.5 from the results of the organoleptic testing of 12 panelists.

A simulation model for the respiration and shelf life of the ECMP mango has been developed and validated to satisfy the experimental data gained from storing the ECMP mango inside MAP made from styrofoam trays and stretch film.

ECMP mango stored inside the MAP system using the stretch film at 10°C could maintain an acceptable quality for five days.

## References

- Baldwin, E.A., Nisperos-Carriedo, M.O. and Baker, R.A. 1995. Edible coatings for lightly processed fruits and vegetables. *Journal of Horticultural Science*, 30, 35.
- Cameron, A.C., Botlan-Pett, W. and Lee, J. 1989. Design of modified atmosphere packaging system: modelling oxygen concentration within sealed package of tomato fruit. *Journal of Food Science*, 54, 1413–1416.
- Cameron, A.C., Talasia, P.C. and Joles, D.W. 1995. Predicting film permeability needs for modified atmosphere packaging of lightly processed fruits and vegetables. *Journal of Horticultural Science*, 30, 25.
- Gennadios, A., McHugh, T.H., Weller, C.L. and Krochta, J.M. 1994. Edible coatings and films based of proteins. In Krochta, J.M., Baldwin, E.A. and Nisperos-Carriedo, M.O., ed., *Edible coatings and films to improve food quality*. Lancaster, Pennsylvania, USA, Technomic Publishing Company.
- Kader, A.A. 1992. Modified atmosphere during transport and storage. In: *Postharvest technology of horticultural crops*. Davis, California, Division of Agriculture and Natural Resources, University of California.
- Kester, J.J. and Fennema, O.R. 1986. Edible films and coatings: a review. *Food Technology*, 40(12), 47–59.
- Krochta, J.M. 1992. Control of mass transfer in foods within edible coatings and films. In: Singh, R.P. and Wirakartakusumah, M.A., ed., *Advances in food engineering*. Boca Raton, Florida, CRC Press, 517–538.
- Nisperos-Carriedo, M.O. 1994. Edible coatings and films Based on polysaccharides. In: Krochta, J.M., Baldwin E.A. and Nisperos-Carriedo, M.O., ed., *Edible coating and films to improve food quality*. Lancaster, Pennsylvania, USA, Technomic Publishing Company.

- O'Connor-Shaw, R. Roberts, R., Ford, A.L. and Nottingham, S.M. 1994. Shelf life of minimally processed honeydew, kiwifruit, papaya, pineapple and cantaloupe. *Journal of Food Science*, 59, 1202.
- Park, H.J., Chinnan, M.S. and Shewfelt, R.L. 1994. Edible coating effect on storage life and quality of tomatoes. *Journal of Food Science*, 56, 568–570.
- Purwadaria, H.K., Budaraga, I.K., Pujantoro, L. and Budiastira, I.W. 1997. Pengkajian awal respirasi minimally processed buah mangga Arumanis pada kondisi penyimpanan atmosfer normal. [Assessment on the respiration of minimally processed Arumanis mango in the atmospheric condition.] *Proceedings. Seminar PERTETA, Bandung, Indonesia*, 7–8 July 1997.
- Purwadaria, H.K. and Wuryani, S. 1999. Respiration model for edible coated minimally processed mango. Paper presented at the Sixth International Mango Symposium. Pattaya, Thailand, 6–9 April 1999.
- Ratule, M.T. 1999. Penentuan komposisi atmosfer penyimpanan irisan buah mangga segar terlapis film edibel. [Determination of Atmospheric Composition for Storing Edible Coated Minimally Processed Mango.] Thesis, Program Pascasarjana, Institut Pertanian Bogor.
- Setiasih, I.S., Wuryani, S., Rusmono, M. and Fardiaz, D. 1997. Preliminary study on utilization of low methoxy pectins and alginates as edible coatings for minimally processed fruits. Poster paper, Third International Symposium of Horticultural Economics in Developing Countries and 1<sup>st</sup> International Conference of Woman and Horticultural Development, Malang, Indonesia, 13–17 October 1997.
- Shewfelt, R.L. 1987. Quality of minimally processed fruits and vegetables. *Journal of Food Quality*, 10, 143–156.
- Shuller, M.L. and Kargi, F. 1992. *Bioprocess engineering, basic concepts*. New York, Prentice Hall.
- Siriphanich, J. 1993. Minimal processing of tropical fruits. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Postharvest handling of tropical fruits. Proceedings of an international conference held at Chiang Mai, Thailand, 19–23 July 1993*. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 127–137.
- Wills, R.B.H., McGlasson, W.B., Graham, D. and Hall, E.G. 1991. *Postharvest, an introduction to the physiology and handling of fruit and vegetables*. New York, Van Nostrand Reinhold.
- Wong, D.W.S., Camirand, W.M. and Pavlath, A.E. 1994. Development of edible coating for minimally processed fruits and vegetables. In: Krochta, J.M., Baldwin, E.A. and Nisperos-Carriedo, M.O., ed., *Edible coatings and films to improve food quality*. Lancaster, Pennsylvania, USA, Technomic Publishing Company, 65–88.
- Wuryani, S., Zulfebriadi, Purwadaria, H.K. and Syarif, A.M. 1998. Penentuan konstanta laju perubahan mutu mangga terolah minimal berlapis film edibel. [Determination of the rate constants for the quality changes of edible coated minimally processed mango.] *Proceedings Seminar dan Kongres PERTETA, Yogyakarta, Indonesia 27–28 July 1998*.

# Quantitative Descriptive Analysis and Volatile Component Analysis of Minimally Processed 'Arumanis' Mango Coated with Edible Film

D. Fardiaz\*, I.S. Setiasih†, H.K. Purwadaria§ and A. Apriyantono\*

## Abstract

An experiment was conducted to assess the taste and aroma of minimally processed (MP) 'Arumanis' mango coated with low methoxy pectin-based edible film. Quantitative descriptive analysis (QDA) was used in the experiment with twelve trained panelists. In addition, volatile components of the fruit were determined using a gas chromatograph/mass spectrometer. Four types of taste and six types of aroma were detected using QDA in MP 'Arumanis' mango either without or with edible film coating. The four types of taste are 'sour', 'sweet sour', 'sweet honey' and 'sweet sucrose'. The six types of aroma are 'fresh', 'sour', 'sweet mango peel', 'sweet mango', 'sweet ethereal' and 'sweet honey'. There were 53 types of volatile component identified in MP 'Arumanis' mango which consisted of the following groups: aldehyde, alcohol, ester, aliphatic hydrocarbon, carboxylic acid, ketone, furan, lactone, and terpene. Storage at relatively low temperatures affects the magnitude of the taste and aroma as well as the volatile components of MP 'Arumanis' mango.

IN RECENT years, there has been an increasing demand from consumers for more healthy foods and for 'speedy foods' which can be prepared quickly. Consequently, consumers have shifted their demand to foods that are fresh as well as 'ready-to-eat' or 'ready-to-cook'. Ready-to-eat fresh fruits and ready-to-cook vegetables which have been washed, skinned, cut and sliced into various forms are examples of food products that are increasingly sold in the market. The process of preparing such products is called 'minimal processing' or 'light processing' and is done without applying any preservation treatment which may change the characteristics of the product. The advantages of minimally processed (MP) products are very obvious if the process is applied to fruits that are difficult to peel and to fruits that have a bulky skin and seed.

Several studies were previously conducted to assess the shelf life of various MP fruits such as kiwifruit, papaya, cantaloupe, pineapple, honeydew melon and apples (O'Connor-Shaw et al. 1994; Cameron et al. 1995). A major problem of MP fruits is that the shelf life of these products is shorter than that of the whole fruits under similar low storage temperatures. One technique to overcome this problem is to reduce the respiration rate of MP fruits by coating them with an edible, thin film. Edible coating is a continuous film made of edible materials that are applied to food by dipping or spraying. Several functions of the coating are as follows: as a barrier to the mass transfer of water vapour, oxygen, or soluble materials etc.; as a carrier for food additives; to facilitate food handling; to maintain the cell structural integrity; and to hinder the loss of volatile compounds (Krochta et al. 1994). Edible coating has been applied in sliced apples (Wong et al. 1994; Baldwin et al. 1995) and tomatoes (Park et al. 1994).

Mango, especially the 'Arumanis' variety, is one of the favourite fruits in Indonesia. The fruit has a characteristic green colour which makes it difficult for consumers to make a good judgement on the appro-

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prate ripeness of the fruit. Therefore, the application of minimal processing to 'Arumanis' mango may help consumers to make a better choice. Low methoxy pectin-based edible coating was applied in this experiment on MP 'Arumanis' mango and the characteristics of its taste and aroma were assessed by the quantitative descriptive analysis (QDA) method. Furthermore, the volatile components of the products were determined using a gas chromatograph/mass spectrometer.

## Materials and Methods

### Application of edible coating film on MP 'Arumanis' mango

Mangoes of the 'Arumanis' variety were obtained from the orchard of Galasari Co., Gresik, East Java. The fruit were harvested at 97 days after flowering and ripened for 3 days, including the time used for transportation, at room temperature before they were minimally processed.

Edible coating film was made of low methoxy pectin as a gel-based material, mixed with 87% glycerol as a plasticiser, and other components such protein isolate and stearic acid. The pH of the film solution was adjusted with sodium bicarbonate and citric acid. The edible coating film solution was heated to 69.7°C, cooled to room temperature, degassed, and applied onto MP 'Arumanis' mango by dipping the fruit in the film solution for several seconds. A solution of 0.75% calcium chloride was used as a gel hardening agent. Dipping time was adjusted so that the thickness of the coating was around 50 µm. Both MP 'Arumanis' mangoes with and without edible coating film were stored in a refrigerator at 5 and 10°C for certain periods of time and evaluated for their characteristics of taste and aroma.

### Quantitative descriptive analysis (QDA)

As many as 32 candidates were recruited as potential sensory panelists and their sensitivity in the detection of taste and aroma was tested. Twelve of those tested panelists were selected as sensory panelists and were further trained in order to be eligible as QDA panelists. The QDA was applied to describe the taste and aroma of both MP 'Arumanis' mango with and without edible coating during storage at 5 and 10°C. The results of the analysis were plotted in the form of spider web graph.

### Analysis of volatile components

Extraction of volatile components of both MP 'Arumanis' mango with and without edible coating was done through the following steps: maceration of mango fruit to form a pulpy slurry; addition of the internal standard 1,4 dichlorobenzene; mixing of the slurry with pentane and dichloromethane; and storage of the mixture in a freezer for 24 h. Following this, the mixture was evaporated in a 'rotavapor' until its volume was 5 mL, then blown with nitrogen gas until the volume of the mixture was 1 mL. The 1 µL sample was injected into a gas chromatograph/mass spectrometer (Shimadzu 17A-QP-5000). Gas chromatographic separation of volatile components was done in 30 m × 0.32 mm (i.d.) HP-5 capillary column with helium at 40.4 KPa pressure as the carrier gas. The conditions of separation were as follows: injector and interface temperature 230°C; initial temperature 40°C with 5 min holding; rate of temperature increase 4°C/min; final temperature 225°C for 5 min. Mass spectra were interpreted using the mass spectra library of the National Institute for Standards and Technology. Furthermore, the linear retention indices (LRI) of the interpreted component mass spectra were compared with the LRI of the corresponding components which had been published.

### Principal component analysis

To determine the relationship between volatile components and descriptive taste and aroma, principal component analysis (PCA) and partial least square-2 (PLS-2) analysis were made using the computer program The Unscrambler . 6.0 (Camo, AS, Norwegia, 1996).

## Results and Discussion

### Edible-coated, MP 'Arumanis' mango

Low methoxy pectin-based edible coating was successfully applied onto MP 'Arumanis' mango. It has the following characteristics: water vapour transmission rate of 770.76 g/m<sup>2</sup>/24 h; moisture content of 38.66%; and water activity ( $a_w$ ) of 0.61. The edible-coated, MP (ECMP) 'Arumanis' mango had a shelf life of 5 days if stored in a refrigerator at 5°C and 4 days at 10°C. The advantage of applying edible coating onto MP 'Arumanis' mango is an additional 2 days of storage. The results of the experiment showed that the application of edible coating onto MP 'Aru-

manis' mango reduced the loss of moisture and reduced the decrease in total sugar, vitamin C, total weight, and colour.

## Quantitative descriptive analysis (QDA)

The results of the sensory tests for fresh as well as MP and ECMP 'Arumanis' mango were plotted as a QDA graph in Figure 1 for taste and Figure 2 for aroma. The QDA panelists were able to detect four kinds of taste of the MP 'Arumanis' mango: 'sour', 'sweet sucrose', 'sweet honey' and 'sweet sour'. The QDA graph for taste indicates that the taste pattern of ECMP 'Arumanis' mango after 4 days of storage at 10°C under normal atmospheric conditions was similar to that of MP 'Arumanis' mango without edible coating after 3 days of storage at the same temperature (Figure 1B). Both MP and ECMP 'Arumanis' mangoes were significantly sweeter either as 'sweet sucrose' or 'sweet honey' than the fresh mango, while the 'sour' and 'sweet sour' tastes remained the same (Figures 1A and 1B).

There were six kinds of aroma detected by QDA panelists from both MP and ECMP 'Arumanis' mangoes as follows: 'fresh', 'sour', 'sweet mango peel', 'sweet mango', 'sweet ethereal' and 'sweet honey', as shown in Figure 2. Except for the 'sour' aroma, other aromas in MP 'Arumanis' mango without edible coating slightly increased in intensity, as compared to the aromas of fresh mango, during storage in the refrigerator at 10°C. Edible coating seems to delay the changes in aroma as shown in Figure 2B, however the overall appearance of the QDA graph for aroma indicates that the freshness of 'Arumanis' mango is still retained.

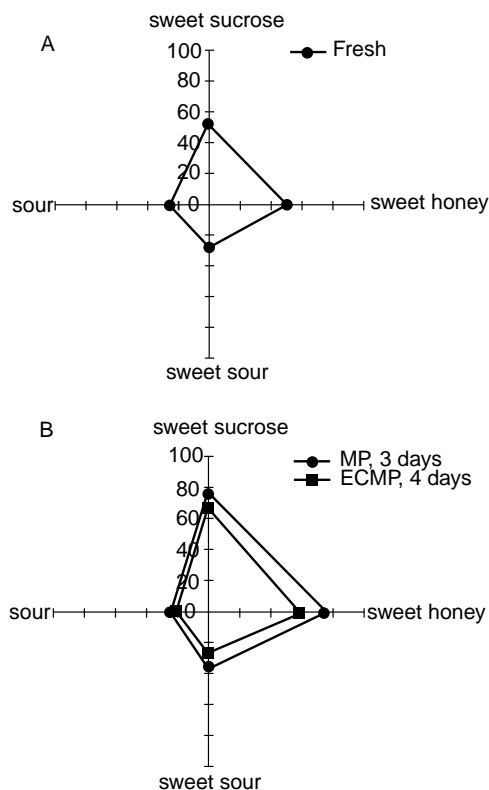
These results show that the application of edible coating onto MP 'Arumanis' mango has successfully retained both the taste and the aroma of the fresh mango to up to four days of storage in the refrigerator at 10°C under normal atmospheric conditions.

## Volatile components and their relationship with QDA

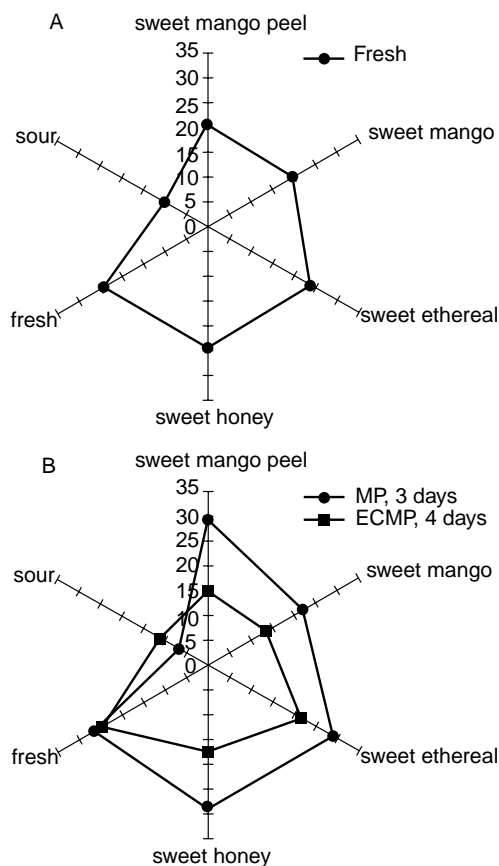
As many as 53 volatile components were identified from fresh, MP and ECMP 'Arumanis' mangoes, as shown in Table 1. The volatile components could be classified into 11 groups, as follows: aldehydes, alcohols, esters, aliphatic hydrocarbons, carboxylic acids, ketones, furans, lactones, pyrans, benzene derivatives, and terpenes. There were two other components which did not belong to the above-mentioned

classes. The esters group—with 12 components identified—seems to be dominant in the aroma of 'Arumanis' mango, followed by the alcohols group which had 9 components identified. Other volatile components identified were: 6 components from the carboxylic acids group; 5 components from each of the lactones and terpenes groups; 4 components from the ketones group; 3 components from each of the aliphatic hydrocarbons and furans groups; 2 components from the pyranone group; and 1 component from each of the aldehyde and benzene-derivative groups.

To examine the relationship between the aroma profile of MP 'Arumanis' mango, both with and without edible coating, as detected by QDA, and volatile components as identified, principal component analysis (PCA) was used for samples which were stored in the refrigerator at 5°C.



**Figure 1.** Quantitative descriptive analysis for taste of (A) fresh 'Arumanis' mango and (B) minimally processed (MP) and edible-coated, MP (ECMP) mangoes stored at 10°C.



**Figure 2.** Quantitative descriptive analysis for aroma of (A) fresh 'Arumanis' mango and (B) minimally processed (MP) and edible-coated, MP (ECMP) mangoes stored at 10°C.

The results indicated that storage time seems to have a significant effect on the profile of the volatile components. The volatile components of both MP and ECMP 'Arumanis' mango stored for 1 day are characterised by the presence of isoocctanol, while after 3 days of storage, this changes to isocaryophilene. However, after 5 days of storage there were differences in the volatile component characteristics between MP and ECMP 'Arumanis' mango: the aroma of MP 'Arumanis' mango without edible coating is characterised by the presence of ocimene, while ECMP 'Arumanis' mango is characterised by the presence of  $\alpha$ -trans-ocimene. Both volatile components are in the same terpenes group.

The relationship between the aroma description as detected by QDA and the identification of volatile components seems to be strong, as indicated by the partial least square for multi  $x$ - $y$  variables (PLS-2) analysis (data not shown). The contribution of volatile components to aroma description can be described as follows: hexadecanoic acid and  $\alpha$ -trans-ocimene have a good relationship with the 'sour' aroma; 2-butanol and  $\gamma$ -caprolactone with the 'sweet ethereal' aroma, ethyl acetate and ethyl butanoate with the 'fresh' aroma, 5-pentyl-dihydro-2(3H)-furanone and isocaryophilene with 'sweet mango peel' aroma, and heptanoic acid, oleic acid, ocymene, and furan derivative seem to correlate with 'sweet mango' aroma.

**Table 1.** Volatile components identified in fresh, minimally processed (MP) and edible coated, MP (ECMP) 'Arumanis' mangoes.

Group	Component
Aldehyde	1. Long chain aldehyde
Alcohols	2. 2-butanol
	3. 2-pentanol
	4. 1-hexadecanol
	5. Long chain alcohol
	6. Isoocctanol
	7. Octadecanol
	8. (E)-isoeugenol
	9. (E)-2-tridecenol
	10. 2,2,4-trimethyl-3-penten-1-ol
Esters	11. Ethyl acetate
	12. Ethyl butanoate
	13. Ethyl ester
	14. Ethyl tridecanoate
	15. Ethyl tetradecanoate
	16. Ethyl pentadecanoate
	17. Ethyl hexadecanoate
	18. Ethyl-9-hexadecanoate
	19. Ethyl octadecanoate
	20. Ethyl octanoate
	21. Butyl acetate
	22. Butyl-3-hydroxy butanoate
Aliphatic hydrocarbons	23. Alkane
	24. Branch alkane
	25. 2,3-nonadiene

**Table 1.** (Cont'd) Volatile components identified in fresh, minimally processed (MP) and edible coated, MP (ECMP) 'Arumanis' mangoes.

Group	Component
Carboxylic acids	26. Pentanoic acid
	27. Heptanoic acid
	28. Oleic acid
	29. Tetradecanoic acid
	30. Hexadecanoic acid
	31. Dodecanoic acid
Ketones	32. 2-pentanone
	33. Branch ketone
	34. 3-hydroxy-2-butanone
	35. 3-methyl-2-butanone
Furans	36. Dihydro-4,5-dimethyl-2(3H)-furanone
	37. 5-pentyl-dihydro-2(3H)-furanone
	38. Furan derivative
Lactones	39. $\delta$ -prolactone
	40. 5-hydroxy nonanoic acid lactone
	41. $\gamma$ -undecalactone
	42. $\delta$ -octalactone
	43. $\epsilon$ -decalactone
Pyranones	44. 6-propyl-tetrahydro-2H-pyran-2-one
	45. 6-heptyl-tetrahydro-2H-pyran-2-one
Benzene derivatives	46. Naphthalene
Terpenes	47. $\alpha$ -trans-ocimene
	48. Ocimene
	49. Terpinolene
	50. Isocaryophylene
	51. $\beta$ -caryophylene
Other	52. Farnesol
	53. Unknown

## Conclusion

Low methoxy pectin-based edible coating can be applied onto MP 'Arumanis' mango to lengthen the shelf life of the product. Application of the coating is able to keep the freshness of MP 'Arumanis' mango up to 5 days if stored in a refrigerator at 5°C or up to 4 days if stored at 10°C under normal atmospheric conditions. QDA detected four types of taste and six types of aroma in fresh, MP, and ECMP 'Arumanis' mangoes. Volatile component analysis identified 53 types of component which contribute to aroma of the fruit. A strong relationship was obtained between the results of QDA and volatile component analysis in MP 'Arumanis' mango coated with edible film.

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## References

- Baldwin, E.A., Nispero-Carriedo, M.O. and Baker, R.A. 1995. Edible coatings for lightly processed fruits and vegetables. *Journal of Horticultural Science*, 30, 35.
- Cameron, A.C., Talasia, P.C. and Joles, D.W. 1995. Predicting film permeability needs for modified atmosphere packaging of lightly processed fruits and vegetables. *Journal of Horticultural Science*, 30, 25.
- Krochta, J.M., Baldwin, E.A. and Nisperos-Carriedo, M.O. (ed.) 1994. *Edible coatings and films to improve food quality*. Lancaster, Pennsylvania, Technomic Publishing Company.
- Kester, J.J. and Fennema, O.R. 1986. Edible films and coatings: a review. *Food Technology*, 40(12), 47–59.
- O'Connor-Shaw, R.E., Roberts, R., Ford, A.L. and Nottingham, S.M. 1994. Shelf life of minimally processed honeydew, kiwifruit, papaya, pineapple and cantaloupe. *Journal of Food Science*, 59, 1202.
- Park, H.J., Chinnan, M.S. and Shewfelt, R.L. 1994. Edible coating effect on storage life and quality of tomatoes. *Journal of Food Science*, 56, 568–570.
- Wong, D.W.S., Tilin, S.J., Hudson, J.S. and Pavlath, A.E. 1994. Gas exchange in cut apples with bilayer coatings. *Journal of Agricultural and Food Chemistry*, 42, 2278–2285.

# Postharvest Quality Changes in Dokong (*Lansium domesticum* Corr.) Harvested at Different Stages of Ripeness

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## Abstract

Dokong harvested at different stages of colour development 4, 7, 10 and 14 days after the fruit yellowing stage were observed for quality changes after being stored for 5 days under ambient conditions. Fruit yellowing (FY) is the stage at which all dokong fruit in a bunch have a yellowish-green pericarp. Results from this experiment suggested that fruit of dokong could be harvested as early as at 4 days after FY (6–8 fruit in a bunch exhibited a shade of green on their skin, while the rest were yellow) if the fruit were to be stored for a longer period of time. The pericarp colour of fruit from all stages of ripeness changed to brownish-yellow after 5 days of storage. Fruit firmness decreased 2-fold after storage. The amount of total soluble solids (TSS) in fruit harvested at 4 and 7 days after FY was found to increase during storage whilst total titratable acidity (TTA) in fruit from all stages of ripeness decreased, which resulted in an increase in the TSS-to-TTA ratio. The fruit harvested at an early stage of ripeness were able to attain acceptable sweetness after 5 days of storage under ambient conditions.

DOKONG is another form of *Lansium domesticum* Corr. (Meliaceae) besides langsung (or lanzones of the Philippines), duku-langsar and duku. In terms of external and internal characteristics of the fruit from this species, dokong is intermediate between langsung and duku-langsar (Norlia 1997) while duku-langsar is intermediate between langsung and duku (Salma and Razali 1987). Dokong is generally regarded as superior to langsung and duku but its taste and flavour are comparable to duku-langsar. Dokong is almost seedless, thin-skinned and free of latex while langsung has 1–2 seeds and thin skin that exudates latex when peeled even when fully ripe (Bamroongrugsua 1992).

Another good characteristic of dokong which is absent in duku-langsar is that all the fruit in a bunch ripen simultaneously which facilitates harvesting.

Dokong, which is known as 'longkong' in Thailand, is a new, important economic crop that is gaining popularity in Malaysia. The demand for this fruit is increasing tremendously compared to other *Lansium* species because the fruit is juicy and has a pleasant taste. However, reports on postharvest characteristics of dokong and other *Lansium* species in general are very limited. Some information on the compositional changes in langsung during growth and development are reported by Del Rosario et al. (1977) and Paull et al. (1987) and Ahmad Tarmizi et al. (1998) recently reported some changes in dokong fruit during maturation. According to Ahmad Tarmizi et al. (1998), the change in fruit colour was the best indicator for determining fruit maturation of

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dokong since the degree of yellowness at different stages is quite easily distinguishable. Dokong fruit start to develop yellow colour on their pericarp about 87 days after fruit set (Norlia 1997) and the fruit can be harvested 11–17 days after that stage (Ahmad Tarmizi et al. 1998). At 11 days, all the fruit in a bunch have attained their maximum size and have developed a fully yellow colour and maximum soluble solids content, whilst at 17 days, fruit colour turns brownish-yellow. However, fruit harvested at this stage have a very short shelf life (about 4 days under ambient conditions). Harvesting the dokong fruit at earlier stages of colour development may help to extend the shelf life of fruit provided that the fruit quality is comparable to the fruit harvested at 11 days or at later stages. Therefore, this study aimed to determine the quality changes during storage at ambient temperature in dokong harvested at different stages of ripeness.

## Materials and Methods

Dokong used in this study were obtained from the Malaysian Agricultural Research and Development Institute (MARDI) Research Station, Jeram Pasu Kelantan, in October 1998. The colour stage called 'fruit yellowing' (FY), at which all fruit in a bunch turned yellowish-green, was used as the basis for harvesting. Fruit bunches were harvested randomly from five trees at 4, 7, 10 and 14 days after FY (DAFY). Ten bunches from each colour stage were individually wrapped with newspaper, packed in corrugated fibre-board cartons and transported on the same day to the laboratory in Serdang, Selangor. Fruit were then stored for 5 days under ambient conditions (24–28°C, 70–80% relative humidity).

Observations on fruit quality such as colour, firmness, soluble solids content, acidity and dry matter content were carried out before and after the fruit were stored for 5 days. The surface colour of individual fruit was measured using a Minolta Chroma meter and the colour was recorded in numerical notation system as  $L^*$ ,  $a^*$  and  $b^*$ , where:  $L^*$  indicates lightness or darkness (0, black; 100, white);  $a^*$  indicates the hue on a green-to-red axis (negative value, greenness; positive value, redness); and  $b^*$  indicates the hue on a blue-to-yellow axis (negative value, blueness; positive value, yellowness). The numerical values of  $a^*$  and  $b^*$  were converted into hue angle ( $H^\circ = \tan^{-1} b^*/a^*$ ) and chroma [ $C^* = (a^{*2} + b^{*2})^{1/2}$ ] (Carreño et al. 1995; Nunes et al. 1995).  $H^\circ$  is an angle in the colour wheel of 360°, with 0, 90, 180 and 270° representing the hue red–purple,

yellow, bluish-green and blue, respectively, while  $C^*$  is the intensity of the hue (vivid or dull).

Fruit firmness was measured with a texture meter Steven's Texture Referencing & Analysis System using a 7 mm diameter Magness Taylor's plunger. The plunger was forced down the fruit surface to the distance of 5 mm from the original position without breaking the pericarp. For chemical analysis, the fruit aril was homogenised in a Waring blender and the homogenate was used to measure total soluble solids, total titratable acidity and dry matter content. Total soluble solids was determined with a hand-held digital refractometer (Model PR-1, Atago Co. Ltd., Tokyo Japan). Results were expressed as degrees Brix. Total titratable acidity was determined by titrating the known volume of homogenate with 0.1 N NaOH to the end point of pH 8.1 and results were expressed as percentage anhydrous citric acid. Dry matter was determined by drying the sample in an oven at 60°C for 36 h and its value was calculated based on percentage of water loss.

## Results and Discussion

The pericarp colour of dokong changed from green to 'trace of yellow' as the fruit were approaching the ripening stage. In this study, the colour stage called 'fruit yellowing' (FY) was used as the basis for harvesting. The colour of each fruit in a bunch harvested at the FY stage varied from yellowish-green to greenish-yellow. The fruit took about 87 days after fruit set to reach this colour stage (Norlia 1997). As the fruit reached advanced stages of ripening, the green colour disappeared and the fruit became yellow. However, there were 6–8 fruit in a bunch harvested at 4 DAFY, and 1–2 fruit in a bunch (located at the bottom of the bunch) harvested at 7 DAFY, which still showed shade of green at the styler end of the fruit. The colour of fruit harvested at different ripeness stages is presented in Table 1.

Data on fruit colour at harvest and after storage recorded using the  $L^*$ ,  $a^*$  and  $b^*$  notation system are presented in Table 2. Higher  $L^*$ ,  $a^*$ ,  $b^*$  and  $C^*$  values respectively indicated lighter, more reddish, more yellowish and brighter (more intense) surface colour of the fruit. Furthermore, fruit with higher  $H^\circ$  or lower  $H^\circ$  were more yellowish or more brownish, respectively. Generally, the colour of dokong at harvest was found to differ significantly with different ripeness stage as indicated by differences in  $a^*$ ,  $b^*$  and  $H^\circ$  values.

**Table 1.** The pericarp colour of dokong fruit harvested at different stages of ripeness.

Days after fruit yellowing	Pericarp colour
4	Pale yellow with 6–8 fruit per bunch having a greenish colour at the stylar end
7	Deep yellow with 1–2 fruit located at the bottom of the bunch exhibiting a shade of green at the stylar end
10	Light to bright yellow
14	Brownish-yellow

Fruit harvested at 4 and 7 DAFY were yellow with a tinge of green as indicated by lower  $a^*$  and higher  $b^*$  values, whereas fruit harvested at 14 DAFY were brownish-yellow (higher  $a^*$ , lower  $b^*$  and lower  $H^\circ$ ). Results showed that the colour of fruit from all stages of ripeness changed to brownish-yellow after 5 days of storage under ambient conditions as indicated by the decrease in  $H^\circ$  and  $b^*$  values and increase in  $a^*$  values. However, all stored fruit, regardless of ripeness stage at harvest, exhibited a similar brownish-yellow colour and there were no significant difference in  $L^*$ ,  $a^*$ ,  $b^*$ ,  $C^*$  and  $H^\circ$  values with stages of ripeness at harvest. Furthermore, the decrease in  $L^*$  values and increase in  $C^*$  values in stored fruit showed that the stored fruit were darker and dull compared to the fruit before

storage. These results indicated that dokong harvested as early as 4 DAFY with 6–8 fruit in a bunch exhibiting a tinge of green were able to turn full yellow after storage. The fruit were considered mature and ready to be harvested at this stage. In lanzones (langsats), another form of *Lansium*, a bunch was considered mature if all the fruit were dull-yellow without any tinge of green (Pantastico et al. 1975).

Fruit softening occurred in dokong during storage. Table 3 shows that fruit firmness was reduced by 50% after 5 days of storage under ambient conditions, regardless of the ripeness stage at harvest. However, there were no significant differences in fruit firmness between fruit of different ripeness stages both after harvest and after storage. The fruit could easily yield to pressure when pressed with fingers.

Dry matter (DM) content in dokong between fruit of different ripeness stages generally did not differ significantly both before or after storage, although their DM content seemed to be lower in fruit harvested at 4 DAFY and higher in fruit harvested at 14 DAFY (Table 3). Also, no changes in DM content occurred in dokong during storage.

Total soluble solids (TSS) and total titratable acidity (TTA) are also presented in Table 3. It is clear that TSS in dokong significantly increased as the stage of ripeness advanced. TTA was significantly higher in fruit harvested at an earlier stage of fruit maturation (4 DAFY). Acidity was reduced thereafter and did not differ in fruit harvested between 7, 10 and 14 DAFY.

**Table 2.** Colour changes of dokong fruit harvested at different stages of ripeness, before and after storage for 5 days under ambient conditions (DAFY = days after fruit yellowing).

Ripeness stage (DAFY)	$L^*$	$a^*$	$b^*$	Chroma ( $C^*$ )	Hue angle ( $H^\circ$ )
After harvest					
4	58.4 ab	-1.4 a	35.2 d	35.2 c	94 d
7	61.6 b	-0.3 ab	34.5 cd	34.5 bc	92 c
10	61.6 b	+0.3 b	34.4 cd	34.4 bc	92 c
14	60.3 ab	+8.2 d	29.9 a	31.0 a	74 a
After storage					
4	56.7 a	+1.7 c	32.0 b	32.1 a	87 b
7	57.7 ab	+1.8 c	32.5 bc	32.6 ab	87 b
10	58.1 ab	+1.7 c	32.7 bc	32.8 ab	87 b
14	56.8 a	+2.3 c	32.0 b	32.0 a	86 b

\*Days after fruit yellowing

Note: Values in each column marked with the same letter of the alphabet are not significantly different at the 5% level using Duncan's multiple range test (DMRT).

This finding was in agreement with that reported by Ahmad Tarmizi et al. (1998). The increase in TSS without an increase in TTA resulted in an increase in the TSS-to-TTA ratio and led to the fruit tasting sweeter. Dokong with a TSS-to-TTA ratio of about 20 was highly acceptable in terms of taste and the fruit became sweeter as the ratio increased (Ahmad Tarmizi et al. 1998).

Some changes in TSS and TTA occurred during storage. Interestingly, TSS in fruit of 4 and 7 DAFY maturation increased from 8 and 13°Brix, respectively, to 15 and 17°Brix, respectively, after 5 days of storage under ambient conditions. The decrease in TTA however, was negligible and acid content in fruit after storage for all ripeness stages did not differ significantly. The TSS-to-TTA ratio in fruit harvested at 4 and 7 DAFY was found to increase significantly to 20 and 24, respectively, after storage. The results show that dokong harvested as early as at 4 DAFY were acceptable in terms of taste after being stored for 5 days under ambient conditions.

In the past, dokong was normally harvested from 11 days onwards after the fruit yellowing stage when all the fruit in a bunch had turned full yellow, although some growers harvested a little earlier. It is now recommended that the fruit can be harvested much earlier, about 4–5 days after the fruit yellowing stage if the fruit is to be transported to distant markets. At this stage, the whole bunch of fruit has turned yellow with 6–8 fruit per bunch still having a greenish tinge at the

stylar end. The fruit harvested at this stage can be kept for at least 5 days under ambient conditions and the fruit bunch is able to turn full yellow. Fruit quality is highly acceptable as the sweetness increases due to an increase in total soluble solids and a decrease in acidity after 5 days after harvest. Fruit may be kept longer when stored at low temperatures. Duku-langsar, another species of *Lansium* can be stored for 2 weeks at 10°C (Mohd Salleh et al. 1985). Therefore, further research needs to be carried out to study the storage behaviour of dokong under low temperature conditions.

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## References

- Ahmad Tarmizi, S., Norlia, Y., Pauziah, M. and Tham, S. L. 1998. Changes in fruit colour and composition of dokong (*Lansium domesticum* Corr.) during maturation. *Journal of Tropical Agriculture and Food Science*, 26, 127–133.
- Bamroongrugsra, N. 1992. Longkong: another plant type of *Lansium domesticum* Corr. In: Salleh, H., Kamariah, M.,

**Table 3.** Firmness and chemical characteristics of dokong harvested a different stages of ripeness, before and after storage for 5 days under ambient conditions (DAFY = days after fruit yellowing, TSS = total soluble solids, TTA = total tritrate acidity).

Ripeness stage (DAFY)	Firmness (kg force)	TSS (°Brix)	TTA	TSS/TTA	Dry matter (%)
After harvest					
4	4.69 d	8.3 a	1.18 c	7.1 a	17.9 ab
7	4.24 bc	13.4 b	0.82 ab	16.5 b	18.7 abc
10	4.08 b	18.3 e	0.84 b	22.0 c	19.8 cd
14	4.58 cd	23.4 f	0.82 ab	29.4 d	22.5 e
After storage					
4	2.68 a	15.2 c	0.76 ab	20.3 bc	17.4 a
7	2.48 a	16.8 d	0.71 ab	23.8 cd	19.3 bcd
10	2.30 a	18.1 e	0.75 ab	24.6 cd	19.9 cd
14	2.35 a	18.5 e	0.68 a	27.5 de	20.5 d

Note: Values in each column marked with the same letter of the alphabet are not significantly different at the 5% level using Duncan's multiple range test (DMRT).

- Norlia, Y., Abd. Jamil, Z., Hashim, A.B. and Tan, H.H., ed., Proceedings of a seminar on cultivation of duku terengganu, dokong and salak (in Bahasa Malaysia) 4 October 1992, Kuala Terengganu, Terengganu. Serdang, Malaysian Agricultural Research and Development Institute (MARDI), 29–33.
- Carreño, J., Almela, L., Martínez, A. and Fernández-López, J.A. 1995. Colour changes associated with maturation of the table grape cv. Don Mariano. *Journal of Horticultural Science*, 70, 841–846.
- Del Rosario, R.P., Abilay, R.M. and Pantastico, E.B. 1977. Fruit set and development of lanzones sprayed with some growth regulators. *Philippines Agriculture*, 60, 330–8.
- Norlia, Y. 1997. Flowering and fruiting of dokong (*Lansium domesticum* Corr.). In: Vejaysegaran, S., Pauziah, M., Mohamed, M.S. and Ahmad Tarmizi, S., ed., Proceedings of an international conference on tropical fruits, 23–26 July 1996, Kuala Lumpur. Serdang, Malaysian Agricultural Research and Development Institute (MARDI), Vol 3, 281–286.
- Mohd Salleh, P., Abdullah, H. and Abd Aziz, I. 1985. Effect of temperature on storage of duku-langsar fruit (*Lansium domesticum*). *Teknologi Buah-buahan*: 1, 5–10 (in Bahasa Malaysia).
- Nunes, M.C.N., Brecht, J.K., Morais, A.M.M.B. and Sargent, S.A. 1995. Physical and chemical quality characteristics of strawberries after storage are reduced by a short delay to cooling. *Postharvest Biology and Technology*, 6, 17–28.
- Pantastico, E.B., Subramanyam, H., Bhatti, M.B., Ali, N. and Akamine, E.K. 1975. Harvest indices. In: Pantastico, E.B. ed., *Postharvest physiology, handling and utilisation of tropical and subtropical fruits and vegetables*. Westport, Connecticut, USA, AVI Publ. Co. Inc., 56–74.
- Paull, R.E., Goo, T. and Chen, N.J. 1987. Growth and compositional changes during development of lanzone fruit. *HortScience*, 22, 1252–1253.
- Salma, I. and Razali, B. 1987. The reproductive biology of duku langsung, *Lansium domesticum* Corr. (Meliaceae), in Peninsular Malaysia. MARDI (Malaysian Agricultural Research and Development Institute) Research Bulletin, 15, 142–151.

# Protection of the Environment and Produce from Contamination with Pesticide Residues

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## *Abstract*

Preventing the contamination of the environment and of agricultural produce with pesticide residues is a complex task. The design of a successful strategy demands:

- accurate information on the physical and chemical properties of agrochemicals;
- reliable research data on their fate and transport;
- simple techniques for ecological risk assessment and risks to human health;
- an economical means to monitor produce and the environment for contamination; and
- means of instituting best management practices, based on traceback of cases of contamination.

In Australia, an extensive program of research for the cotton industry has been undertaken to reduce the level of contamination by chemicals, such as endosulfan, pyrethroids, organophosphates and carbamate and other, newer chemicals, such as the benzoylphenylureas and herbicides. This has required a very comprehensive approach involving the development of new technology for monitoring pesticide residues. In this paper, by examining several case studies, we will demonstrate our approach to developing these techniques over the past 10 years. Specific topics include: the role of quality assurance in analysis; enzyme-linked immunosorbent assays (ELISAs) for specific, sensitive screening for residues; and studies of pesticide sorption and desorption from soil and transport aerially, in water and sediments in run-off. We will also consider the role of traceback to determine the cause of contamination and of fugacity modelling to carry out ecological risk assessment. The possibility that a new theory—the action resonance theory—will soon yield models of ecosystem processes allowing better regulation of the amount of contamination in ecosystems is discussed.

USING modern methods of chemical pest control, achieving an environment and produce free of significant levels of pesticide contamination is a challenging task. In this paper, we will examine some of the key factors producing risk and the measures that can be taken to reduce this risk to a minimum level. However, it must be understood at the outset that a complex strategy is needed for success to be assured.

Unfortunately, it is almost impossible to apply pesticides in such a way that only the target pest is exposed. It is natural that chemicals applied almost anywhere in the environment will tend to be distributed to all of the surrounding environment. The rate and extent of this distribution is a complex interaction between the physical and chemical properties of the pesticide, the methods of application, environmental conditions and management practices. However, for all these factors, the key to successful environmental management always depends on accurate knowledge about these processes. Unwarranted optimism regarding risk and even gross ignorance regarding some essential features is usually the cause of serious problems that may develop.

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## Chemical and Physical Properties of Agrochemicals Affecting Dissipation

The main physico-chemical factors of relevance in the contamination of ecosystems and produce include those discussed below.

### Solubility

Agrochemicals display a wide range of solubilities in different solvents or phases in the environment. Thermodynamically, solutes will dissolve to the greatest extent in phases where they can minimise their chemical potential and free energy. At equilibrium, the chemical potential ( $\mu_i$ , a measure of capacity to do chemical work) reaches the same value in all phases involved in the equilibrium. Thus:

$$\mu_i = \text{constant} \quad (1)$$

This may be achieved at vastly different concentration values in different phases. In effect, this equality involves matching the quantum state transitions for molecules leaving or entering each phase. When the magnitude of the quantum of energy needed for molecular transition to a common phase (e.g. to the atmosphere as vapour) is equal, the chemical substance in each phase is said to have the same chemical potential and they will be at equilibrium with one another.

Reference texts, such as *The Pesticide Manual* (Tomlin 1997), contain information on laboratory studies related to solubility in different phases. These include values for  $K_{ow}$ , the octanol–water coefficient, which measures the ratio of the equilibrium concentrations in octanol and water;  $K_{oc}$ , the equilibrium partition coefficient in organic carbon and an aqueous solution, which will vary depending on the properties of the organic material; and  $K_d$ , which is a measure of the partition coefficient in phases such as soil or water. Thus,  $K_d = K_{aw}$  would be the distribution coefficient between air and water. Practical relationships between these may be expressed as mathematical equations and are of relevance in examining the distribution of pesticides in soil fractions. Isotherms relating the constant temperature distribution of agrochemicals dissolved or suspended in water with soil or clay, such as the Freundlich isotherm (equation 2) are also often of utility in describing their behaviour.

$$S = KCe^n \quad (2)$$

where:  $S$  = concentration sorbed on soil;  $Ce$  = equilibrium concentration on soil; and  $K$  and  $n$  are constants (Baskaran and Kennedy 1999).

The octanol–water coefficient ( $K_{ow}$ ) can be used to predict the likelihood of persistence of chemicals in produce or the environment. Lipophilicity or solubility in fats indicates that a substance is non-polar, with little or no distortion of electron clouds in the molecular structure. Halogenated organic molecules have increased solubility in fats so that substances like DDT (1,1,1-trichloro-2,2-bis(4-chlorophenyl ethane)) and the cyclodienes such as endosulfan and dieldrin tend to be very strongly partitioned into fats. They have a correspondingly high  $K_{ow}$ . This makes them prone to contaminate fatty foods, such as animal products like beef, dairy products and other oils. They also tend to become immobilised in soil organic matter or in sediments in aquatic systems. In general, they are also unavailable for degradation or for transfer to other phases when dissolved in fat. The case study in Australia involving chlorfluzuron (Helix<sup>®</sup>) contamination of beef in the mid-1990s (Kennedy et al. 1998) as a result of feeding cotton trash from ginning mills to livestock was eminently predictable—given that this chemical has one of the highest  $K_{ow}$  values known. Unfortunately, those with the appropriate chemical knowledge were unaware that cotton trash would be fed to stock during a drought period and were not consulted about the wisdom of this action.

### Volatility

Another physical property of significance is the tendency of an agrochemical to volatilise, thus entering the atmosphere. The vapour pressure of a chemical substance in a closed space over a sample of the pure compound is one measure of the tendency of a chemical to become volatile. However, the rate and extent of volatilisation also depends on the solubility of the chemical in solid and liquid phases. Where a chemical has high solubility in soil, water or vegetation, indicating its preference for that particular medium, the chemical potential is very much reduced from that of the pure compound, and the resultant vapour pressure is also reduced. Where the solubility in soil or water is relatively low, the chemical potential, the escaping tendency and the rate of volatilisation are correspondingly increased.

Another important partition coefficient affecting volatilisation is  $K_{AW}$ , the air–water distribution coefficient mentioned above.

$$K_{aw} = \frac{C_a^s}{C_w^s} = \frac{P^s}{RT C_w^s} \quad (3)$$

where:  $C^s$  indicates the saturation concentration;  $P^s$  is the corresponding vapour pressure ( $P^a$ ); and  $C_w^s$  is the solubility in water ( $\text{mol/m}^3$ ).  $P^s/C_w^s$  is known as the Henry's Law Constant ( $H$ ) =  $K_{aw}RT$ . This constant has the physical dimensions of energy per mole and a high value indicates a high propensity to become volatile.

In Table 1, the solubility, vapour pressure and Henry's Law constants for benzene, DDT and 2,4-dichlorophenoxyacetic acid (2,4-D) are given, showing large differences in the volatilising behaviour of these three chemicals. Note that DDT has a very low solubility in water but also a very low vapour pressure. As a result, DDT has high volatility from water despite a low vapour pressure, whereas 2,4-D is mainly distributed to water rather than the atmosphere.

## Chemical degradation

The chemical properties of agrochemicals also affect the rate of their dissipation and the likelihood of contamination of produce or the environment. For example, organophosphate compounds are subject to alkaline hydrolysis, usually yielding non-toxic products. Typically, toxic organophosphates have short degradation times, declining to half the original concentration in days or weeks. However, some are more stable than others. For example, chlorpyrifos is relatively long-lived, with a half-life of several months. Thus, as the pH value of soil or water rises, so does the rate of hydrolysis. Typically, chemicals subject to alkaline hydrolysis will degrade ten times faster for each increase in the pH value of one unit.

**Table 1.** Volatility of organic chemicals from the aqueous phase, showing the solubility, vapour pressure and Henry's Law constants (see text and equation 3 for full explanation).

	Molecular mass	Solubility ( $\text{g/m}^3$ )	Vapour pressure (Pa)	$H$	$K_{AW}$
Benzene	78	1 780	12 700	556	0.22
DDT	355	0.003	0.00002	2.4	$9.5 \times 10^{-4}$
2,4-D	221	890	0.000056	$1.4 \times 10^{-5}$	$5.6 \times 10^{-9}$

Note: for benzene,  $C^s=1780/78=22.8 \text{ mol/m}^3$ ;  $H$  is then  $P^s/C_w^s = 556$ ; etc.

Endosulfan is also subject to alkaline hydrolysis and degrades to non-toxic endosulfan diol as the pH value is raised.

## Biodegradation

Many agrochemicals are subject to biodegradation. Chemicals absorbed by soil microbes may be attacked by a variety of enzymatic processes including hydrolases (e.g. phosphatases, demethylases, sulphatases etc.) and oxidases, including mono-oxygenases and conjugases. In general, oxidative processes make fat-soluble or lipophilic agrochemicals more water soluble, and more prone to further metabolism and breakdown. Some agrochemicals, such as 2,4-D, can provide sources of growth substrates for microbes, with most of the deoxyribonucleic acid (DNA) coding for genes of 2,4-D degrading enzymes being carried on transmissible plasmids. It is therefore possible to genetically engineer microbes by such transfers (Van Zwieten et al. 1995; Feng and Kennedy 1997).

## Research on Fate and Transport

Despite the ability to make predictions from physico-chemical properties, no exact model of the behaviour and fate of agrochemicals in ecosystems is currently available. This is in large measure a result of the fact that their dissipation is a non-equilibrium process in which fluctuations in source strengths are at their maxima when chemicals are periodically applied and in the driving potentials causing their transport occur. Apart from the concentration at the source, a number of factors or processes may be involved in contamination of produce or the environment. These include:

- Drift during application. Depending on environmental conditions, a proportion of the agrochemicals applied either aerially or by ground application may drift onto surrounding areas—directly onto livestock or onto pasture or water. In

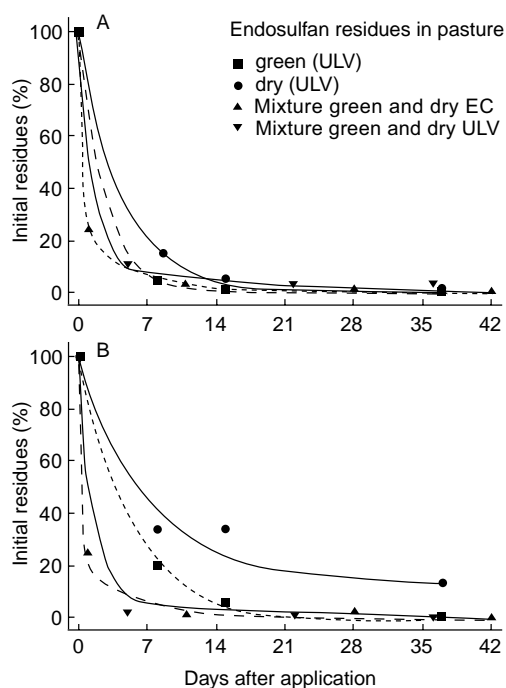
general, the intensity of drift onto pasture falls off with distance (Craig et al. 1998).

- In Figure 1, the rate of degradation of residues in green and dry pasture with time for small drop (ultra low volume—ULV) and large drop size (emulsifiable concentrate—EC) applications is shown. Thus, an interaction between the drift profile with distance and the rate of degradation, including biodegradation, is involved in this case.
- Dissipation rates on crops and in soil. Depending on the physical and chemical properties of agrochemicals, their persistence will depend on environmental factors, as well as biodegradation rates (Kennedy 1998). In the case of edible crops, the dissipation rate is a critical factor in establishing the withholding period before produce is released for marketing, direct consumption or for value-added processing. It is essential that the produce should contain concentrations below the maximum residue limits (MRLs) and it would be prudent to have a means of confirming this. Case studies for endosulfan dissipation rates in cotton production systems were presented earlier (Kennedy et al. 1998).
- Transport in run-off and infiltration. Depending on the rate of dissipation in soil or on crops, run-off water from irrigation or storms will contain different levels of pesticide residues (Kennedy et al. 1998). In general, there is a good correlation between levels on fields and those in run-off water. But the partitioning between suspended sediments and the water fraction will depend on the chemical and distribution properties of each chemical. Agrochemicals with relatively high water solubility, such as the herbicide atrazine, may have a tendency to migrate to groundwater. Obviously, knowledge of residue concentrations in run-off or groundwater is essential if secondary contamination of stock or produce is to be avoided.

## Ecological Risk Assessment

The fugacity or escaping tendency for a chemical from a concentrated zone then dictates that a dispersive process will occur, utilising whatever means of transport or modes of motion that are available. Usually, such processes are explained by statistical mechanics on a stochastic basis, as a result of random fluctuations. But this purely statistical viewpoint has recently been challenged in a new general hypothesis called the ‘action resonance theory’. This theory asserts that valid statistical outcomes require forceful

dispersive interactions based on quantum exchange forces that cause all motion in coherent groups of sub-atomic particles called molecules. The basic dynamic explanation for such real world processes is discussed at length in a new book (Kennedy 2000) that stresses the significance of a physical property called action. Planck’s quantum of action ( $h$ ) is the unit value of action. In the thermodynamic sense, both the action and the entropy of chemicals and all other matter are increased as the process of dispersion occurs. Entropy is a dimensionless capacity factor indicating the amount of energy needed to continuously sustain the action of the system, easily expressed as a logarithmic function of the action (Kennedy 1983).



**Figure 1.** Endosulfan residues from drift onto pasture as a result of (A) direct spray (10 m) and (B) downwind drift (100 m). The decline with time and distance from the swathline of the aerial application for ultra-low volume (ULV) and emulsifiable concentrate (EC) on green and dry pasture is shown. The maximum concentrations for 10 m and 100 m were 50 ppm and 5 ppm, respectively.

The more macroscopic the process involving a particle or an association of particles—in the change



of scale of interactions from nuclear to electromagnetic to gravitational—the less energy is needed to achieve the next highest action state. Consequently, nuclear processes require quanta with the highest frequency ( $>10^{20}/s$ ) or rate of impulses, acting on very brief time scales with high local precision and carrying the greatest momentum and potential to develop force in the short term. Electromagnetic interactions involved in chemical changes employ quanta with intermediate magnitude on this scale ( $<10^{18}/s$  and  $>10^{12}/s$ ). Gravitational processes such as those involved in transport of sediments suspended in runoff water require the coordinated dispersive action of vast numbers of quanta of low to vanishingly low magnitude. The low impulsive force provided by individual quanta is compensated for by the large density of quanta acting together. This analysis suggests that the concept of entropy as a continuous measure of disorder is misleading, since an optimised development of entropy and action is essential for the functioning of ecosystems.

The mechanism for development and evolution of all these processes is similar to that of Brownian motion, by which Einstein (1917) explained results from forces of recoil caused by the interchange of impulsive quanta of energy within molecular systems or larger particles. The impulses from such quanta act along the direction of transmission so that asymmetry of the force fields generated is possible if matter is arranged in an asymmetric fashion. Such recoil to the absorption or emission of quanta amounts to a thermodynamic force capable of inducing motion in molecules. This concept of action state has been generalised for all scales (Kennedy 2000) to provide a common forceful mechanism for a range of physical and chemical work phenomena in ecosystems as part of the action resonance theory. This will allow chemical, electrical and gravitational processes to be considered in the same model, all acting by integration to the appropriate scale of the local action exchange forces. In future, we anticipate that simplified physical action models will be developed, allowing this approach to be easily applied to many microscopic and macroscopic processes occurring in ecosystems.

In the meantime, these action exchange forces are considered as the driving force for the redistribution of agrochemicals in ecological risk assessment, modelled more traditionally using the fugacity model of Connell (1991, 1997). An ecological risk assessment of 32 pesticides which have been used in previous years on a cotton farm adjacent to a nature reserve in the Macquarie Marshes in the Macquarie River valley (see

Figure 2) has been conducted (Sanchez-Bayo et al. 2000). Specifically, the impact of 18 chemicals that would be used in a new development proposed by the grower for extending the area farmed has been examined using the fugacity model—incorporating a new relative risk model (Table 2).

## Calculating risk

Based on a simple quotient model, the new expression to calculate relative risk used here also considers the exposure/toxicity in each compartment. For the entire ecosystem, the relative risk ( $RR$ ) of a chemical is the sum of its risk in each environmental compartment ( $RR_i$ ) as determined by the following equation:

$$\text{Relative Risk } (RR) = \sum RR_i \quad (4)$$

where  $i$  is the environmental compartment considered, and for which the risk is calculated in mathematical terms as

$$RR_i = \frac{\text{exposure}}{\text{toxicity}} = \frac{C_i \left( \sum P_{iv} \times V_{iv} \right) \times t_{1/2i} \times BCF}{LD_{50ij} \sum (S_{ij} + 1)} \quad (5)$$

and  $C_i$  = the concentration of the chemical (ppb) in the compartment  $i$ ;

$P_{iv}$  = the probability of the event  $v$  in the compartment  $i$ ;

$V_{iv}$  = the volume ( $m^3$ ) affected by such event  $v$  in the compartment  $i$ ;

$t_{1/2i}$  = the half-life (days) of the chemical in the compartment  $i$ ;

$BCF$  = the bioconcentration factor for the chemical;

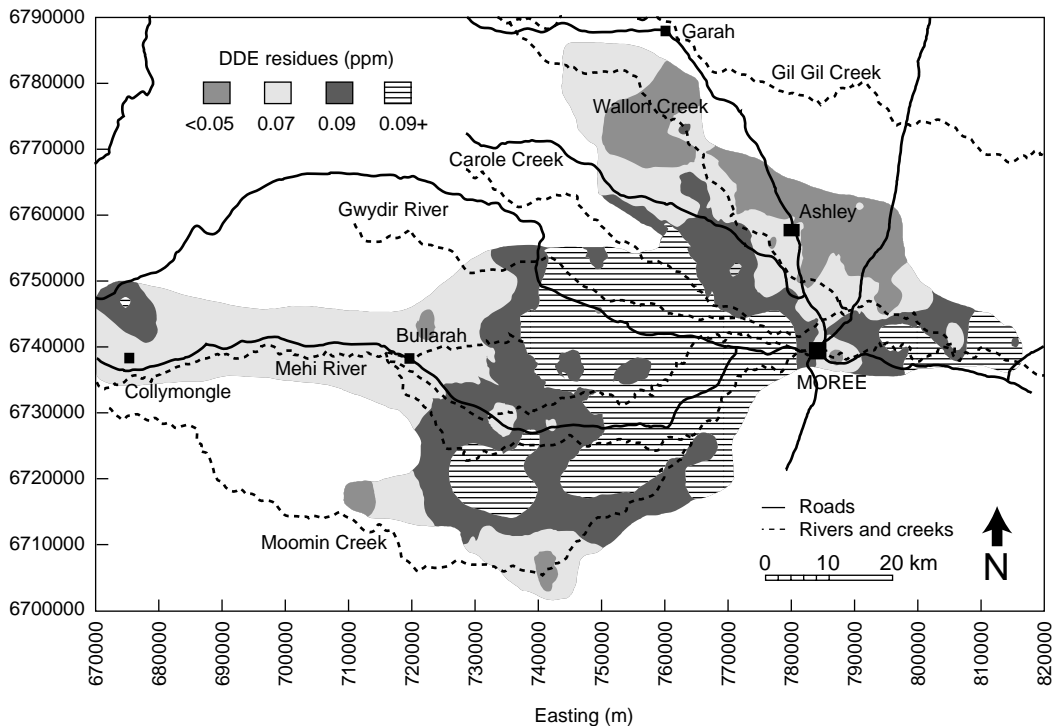
$LD_{50ij}$  = the toxicity (ppb) of the animal class  $j$  affected in the compartment  $i$ ; and

$S_{ij}$  = the number of species of the animal class  $j$  exposed to the compartment  $i$ .

The value of  $LD_{50j}$  is calculated as a weighted average of the estimated  $LD_{50}$ , after taking into account the number of species ( $n$ ) in each group:

$$LD_{50j} = \left( \sum nLD_{50} \right) \quad (6)$$

Then, the  $RR$  values will be specific for a particular ecosystem, since they will be comparing chemicals against all the environmental conditions as well as the probable effect that they will have on the species of that ecosystem. Because of the multiplicity of param-



Note: DDE (1,1-bis(p-chlorophenyl)-2,2-dichloroethylene) is a breakdown product of DDT (1,1,1-trichloro-2,2-bis (4-chlorophenyl ethane)).

**Figure 2.** Monitoring of DDE residues in the Gwydir Valley, New South Wales, by the enzyme-linked immunosorbent assay (ELISA). Geographical information system (GIS) profiling was established using GIS software by Dr I.O.A. Odeh performed when DDT was last sprayed in the area around 1982. Soil samples were taken in 1995–97 and represent average concentrations for 0–10 cm in the soil profile.

eters involved, the *RR* values are dimensionless and can be used as a score to rate the risk under several situations. From these calculations a relative risk rating index can be formulated for each chemical. In this ecological risk assessment, four risk-ranking categories have been established:

High risk	$RR > 100$
Medium risk	$10 < RR < 100$
Low risk	$1 < RR < 10$
Negligible risk	$RR < 1$

In normal farming situations, because of retention of all tail drain run-off, all chemicals would be contained within the farm boundaries, except for small amounts transported off-field by aerial drift. The analysis based on previous research shows that a buffer zone extending 1,400 m all around the cotton fields would capture 99.9% of any drift and volatilisation from aerially-applied chemicals, whereas a 200 m buffer

would suffice to contain an equal proportion of drift from pesticides applied by ground-rig.

As shown in Table 2:

- The pesticide identified as having the highest risk within the buffer zones during the growing season under normal farming conditions is parathion-methyl, which affects mainly the soil and vegetation of the buffer zone.
- Under normal growing conditions, propargite, endosulfan and aldicarb were identified as medium-risk pesticides. Aldicarb has a risk in the farm irrigation system, whereas propargite and endosulfan in the vegetation compartment of the south-western riverine woodland—the risk of propargite involves the pasture of the neighbour’s property, and—if applied aerially—a small portion of the nature reserve.

- During winter time, however, none of the 32 chemicals are of great concern.
- Other than by drift and volatilisation, the major transport route off-farm is by floodwaters. High floods occur once in 3 years and, in this case, pesticide residues would spread over the buffer zone and downslope. Despite the dilution of residues experienced under these situations, some impact would be felt in the marshes ecosystems. Large storms, with a probability of 1/year or less, could wash chemicals from soil and vegetation, but these residues are contained within the farm irrigation system or in the reservoirs established in the buffer zone to contain stormwater run-off. In these situations, the risk of pesticides to waterbirds coming to the farm for feeding/drinking is to be considered. This approach has been generalised (Sanchez-Bayo et al. 2000) for other cases where farms may be established near areas posing risk, such as rivers and other farming enterprises.

## Monitoring of Produce and the Environment

It is essential to have means of ensuring produce or the environment in which it is produced is not contami-

nated. This demands some system of monitoring the concentration of a large range of agrochemicals. Effective monitoring requires considerable infrastructure and a set of validated sampling and analytical protocols to ensure that reliable data are generated. A quality assurance manual for the monitoring of pesticide residues in cotton production systems is available (Kennedy et al. 1998), emphasising the need for highly skilled and experienced personnel and extensive equipment.

The possibility of using simple tests for screening purposes is becoming more feasible. This is a result of the development of testing procedures, based on techniques such as the enzyme-linked immunosorbent assay (ELISA). We describe the feasibility of such approaches separately (Lee et al., this proceedings). We have previously described the application of ELISA to environmental monitoring, pointing out how a much more comprehensive assessment of contamination can be obtained with chemicals such as endosulfan (Lee et al. 1997). The advantages of such tests can be considerable in cost and also the numbers of samples that can be analysed promptly, so that action can be taken immediately. It may also be possible to provide special advantages in such assays.

**Table 2.** Chemicals of high (bold) and medium risk under several scenarios.

Area at risk	Flooding scenarios		Normal scenarios	
	Summer	Winter	Summer	Winter
<i>On farm</i>				
Buffer zone	<b>Parathion-methyl</b> Propargite Endosulfan Chlorpyrifos -cypermethrin Bifenthrin Profenofos	Parathion-methyl Propargite	<b>Parathion-methyl</b> Propargite Endosulfan	None
Buffer zone	Propargite	Propargite	Propargite	None
Irrigation system	Dimethipin	Dimethipin	Aldicarb	None

**Table 2.** (Cont'd) Chemicals of high (bold) and medium risk under several scenarios.

Area at risk	Flooding scenarios		Normal scenarios	
	Summer	Winter	Summer	Winter
<i>Off farm</i>				
Riverine forest and woodland	<b>Parathion-methyl</b> Propargite Endosulfan Chlorpyrifos _cypermethrin Bifenthrin Dimethipin Profenofos	Parathion-methyl Propargite	<b>Parathion-methyl</b> Propargite Endosulfan	None
Nature reserve	Propargite Dimethipin	Propargite Dimethipin	Propargite	None

For example, the ELISA test used in our research program for endosulfan actually measured the sum of the concentrations of the two isomers of endosulfan present in formulations as well as the toxic oxidative product, endosulfan sulphate, but not non-toxic breakdown products. It must be emphasised, however, that these tests cannot completely replace instrumental techniques, but are used for screening or in a complementary fashion. In practice, it is likely that samples producing positive results with ELISA or other simple tests would then be subjected to solvent extraction and analysis by gas-liquid chromatography or high-performance liquid chromatography, to obtain an accurate value or confirmation of the contamination. ELISAs are now available for a very large range of pesticides including herbicides (e.g. diuron, triazines, pyriithiobac sodium etc.) which we are applying in our fieldwork and in determining the association of pesticides with colloidal fractions suspended in irrigation or storm run-off (Crossan and Kennedy, unpublished) from cotton farms.

### Traceback and Best Management Practices

The purpose of monitoring is to provide feedback on contamination. This can reduce the risk to humans and livestock and also to provide safeguards in the case of produce for export with respect to quality assurance. In order to achieve effective results from monitoring, it is essential to provide some means of traceback to the source of contamination. This will generally require a system of labelling of samples, or access to information regarding the source of batches of produce. Traceback studies have also been instituted in the Australian

cotton industry in order to determine sources of contamination of livestock on nearby farms and to take steps to prevent future contamination (Kennedy et al. 1999). Keeping data for a number of years allows monitoring not only of sources of contamination, but also of the effectiveness of programs set in place to mitigate the likelihood of contamination by agrochemicals. Monitoring of riverine environments is also wise and a program has been in place in the case of the northern rivers of New South Wales used for irrigation farming for a number of years now (Cooper and Muschal 1998). Such monitoring programs, funded by both irrigation users and government, have a number of valuable features.

Best management practices on farms designed to reduce the impact of agrochemicals on produce and the environment are becoming de rigeur. The Australian cotton industry has instituted such a program over the past 2-3 years, coordinated by the Cotton Research and Development Corporation (ACGRA et al. 1997), the industry's research coordinator. This provides a practical set of interactive and continually updated measures recommended to prevent environment impacts from chemicals. This includes requirements to recirculate contaminated waters within the farming system without release to riverine systems, to minimise the degree of contamination. In addition, measures to reduce the direct impact of aerial drift by establishing downwind buffer zones of up to 1.5 km and prohibitions on spraying in unstable atmospheric conditions or inversions require compliance by aerial operators and cotton farmers. Similar programs of management are also being instituted by other industries such as rice production, the wine industry and horticultural industries. The wish to produce clean

produce is almost universal, but it will remain necessary to provide means of monitoring the success of these measures. There may also be a small minority of 'renegade' farmers who may deliberately fail to comply with recommendations. In any case, produce which has been shown to be free of contamination should command a premium in the marketplace and the Australian dried fruit industry has set up its own monitoring program to ensure that all batches of fruit are certified as pesticide-free. Similar measures are now being adopted by the wine industry.

## Conclusion

Protection of produce and the environment from pesticide contamination is a multi-faceted process requiring an integrated response involving the full range of factors considered in this paper. Neglect of even one aspect of this response can have disastrous consequences and cooperative action by personnel with the full range of expertise is essential. More research is needed to improve the current capability.

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## References

- ACGRA (Australian Cotton Growers Research Association), CRDC (Cotton Research and Development Corporation) and Cotton Australia 1997. Australian cotton best practices management manual. Narrabri, CRDC.
- Baskaran, S. and Kennedy, I.R. 1999. Sorption and desorption kinetics of diuron, fluometuron, prometryn and pyriproxyfen sodium in soils. *Journal of Environmental Science and Health*, B34, 943–963.
- Connell, D.W. 1991. Fugacity modelling and the fate of chemicals in the environment. *Proceedings of the Workshop on Modelling Fate Chemicals in the Environment*. Canberra, Centre for Resource and Environmental Studies, Australian National University.
- Connell, D.W. 1997. Basic concepts of environmental chemistry. Boca Raton, Florida, Lewis Publishers.
- Cooper, B. and Muschal, M. 1998. Monitoring the fate of pesticides in the riverine environment—a case study. In: Kennedy, I.R., Baskaran, S. and Sanchez-Bayo, F., ed., *Pesticides in soil, water and produce: analysis, environmental monitoring and remediation*. Sydney, Cooperative Research Centre (CRC) for Sustainable Cotton Production, University of Sydney, 11–19 (copies available on request).
- Craig, I., Woods, N. and Dorr, G. 1998. A simple guide to predicting aircraft spray drift. *Crop Protection*, 17, 475–482.
- Einstein, A. 1917. Zur Quantentheorie der Strahlung. *Physikalische Zeitschrift*, 18, 121.
- Feng, L. and Kennedy, I.R. 1997. Biodegradation and plant protection from the herbicide 2,4-D by plant-microbial associations in cotton production systems. *Biotechnology and Bioengineering*, 54, 513–519.
- Kennedy, I.R. 1983. Action and entropy in a neurological disorder. In: Jeffrey, P.L. and Austin, L., ed., *Molecular aspects of neurological disorders*. Sydney, Academic Press, 147–150.
- Kennedy, I.R. 1998. Pesticides in perspective: balancing their benefits with the need for environmental protection and remediation of their residues. In: Kennedy, I.R., Skerritt, J.H., Johnson, G.I. and Highley, E., ed., *Seeking agricultural produce free of pesticide residues*. ACIAR Proceedings No. 85. Canberra, Australian Centre for International Agricultural Research, 23–30.
- Kennedy, I.R., Hugo, L. and Sanchez-Bayo, F. 1999. Endosulfan residues in cattle: traceback project. Cotton Research and Development Corporation (CRDC) report, September 1999. Narrabri, New South Wales, CRDC.
- Kennedy, I.R., Sanchez-Bayo, F., Kimber, S.W.L., Ahmad, N., Beasley, H., Lee, N. and Southan, S. 1998. Integrated monitoring and dissipation studies for the development of best practice management of chemicals used in cotton farming. In: Kennedy, I.R., Skerritt, J.H., Johnson, G.I. and Highley, E., ed., *Seeking agricultural produce free of pesticide residues*. ACIAR Proceedings No. 85. Canberra, Australian Centre for International Agricultural Research, 88–99.
- Kennedy, I.R. 2000. Action in ecosystems: biothermodynamics for sustainability. Baldock, United Kingdom, Research Studies Press/John Wiley and Sons Distributor, 220 p.
- Lee, N., Beasley, H.L., Kimber, S.W.L., Silburn, M., Woods, N., Skerritt, J.H. and Kennedy, I.R. 1997. Application of immunoassays to studies of the

- environmental fate of endosulfan. *Journal of Agricultural Food Chemistry*, 45, 4147–4155.
- Sanchez-Bayo, F., Kennedy, I.R. and Baskaran, S. 2000. Ecological risk assessment and risk management for new cotton developments. Final project report. Narrabri, New South Wales, Australia, Cotton Research and Development Corporation, 116 p.
- Tomlin, C.D.S. 1997. *The pesticide manual*. United Kingdom, BCPC Publications.
- Van Zwieten, L., Feng, L. and Kennedy, I.R. 1995. Colonisation of seedling roots by 2,4-D degrading bacteria: a plant–microbial model. *Acta Biotechnologica*, 15, 27–39.

# Efficacy of Electrolysed Water as a Disinfectant for Fresh-cut Spinach

H. Izumi, T. Kiba and S. Hashimoto\*

## *Abstract*

The effect of electrolysed water on bacterial count was evaluated on freshly prepared and stored fresh-cut spinach leaves. Electrolysed water (pH 6.8), containing 15 to 50 ppm available chlorine, was generated by electrolysis of a 2.5% NaCl solution using an electrolysed neutral water generator. Trimmed spinach leaves were treated with electrolysed water containing 20 ppm available chlorine by dipping, rinsing or dipping/blowing. These treatments reduced the total microbial count (mesophilic aerobic bacteria) by 1.0 to 1.6 log<sub>10</sub> colony forming units (CFU)/g when compared with untreated samples. Electrolysed water containing 50 ppm available chlorine had a stronger bactericidal effect than water containing 15 or 30 ppm chlorine, and was as effective as sodium hypochlorite solution containing 100 to 200 ppm chlorine. When the trimmed leaves were rinsed with electrolysed water containing 50 ppm chlorine and stored in normal air or 4% O<sub>2</sub> at 10 and 20°C, the increasing count of mesophilic aerobic bacteria was restricted when compared with the water-rinsed control. Electrolysed water did not affect the respiration rate nor surface colour of fresh-cut spinach during storage. Microbial populations increased on intact leaves stored at 0°C for 7, 14, 21 or 28 days. The electrolysed water was more effective in reducing the counts of mesophilic aerobic bacteria, psychrotrophic aerobic bacteria and coliform bacteria when the treatment was made using leaves stored for a brief period than for leaves stored for a long period.

FRESH-CUT vegetables are more perishable than intact vegetables mainly due to microbial contamination during and after processing (Brackett 1987; Watada et al. 1996; Zagory 1999). Microbial safety is of major concern in the production and distribution of fresh-cut vegetables in conjunction with the Hazard Analysis and Critical Control Points (HACCP) system (IFPA 1996). HACCP is a system of hazard prevention implemented by the food industry to produce safe food. It involves the systematic assessment of all steps involved in food manufacturing operations and the identification of those steps which are critical with respect to food safety (Wilcox et al. 1994). To reduce microbiological

hazards of fresh-cut vegetables, washing during processing is the only step taken to actively reduce microbial populations. A 50 to 150 parts per million (ppm) chlorine solution prepared from sodium hypochlorite has been widely used in the food industry as a disinfectant, but a high concentration of sodium hypochlorite for increased effectiveness may cause product tainting (Adams et al. 1989) as well as result in sodium residues on the product and the equipment (Ritenour and Crisosto 1996).

Alternatives to sodium hypochlorite, such as chlorine dioxide (Zhang and Farber 1996), sodium bisulfite (Krahn 1997), organic acid (Adams et al. 1989; Zhang and Farber 1996) and ozone (Nagashima and Kamoi 1997), have been studied to control microbial populations on fresh-cut vegetables. We previously reported the effect of electrolysed water on the microflora on several

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fresh-cut vegetables (Izumi 1999). Electrolysed water contains hypochlorous acid generated from the reaction of  $H_2O$  and  $Cl_2$  produced by electrolysis of a NaCl solution of less than 10% using an electrolysed water generator. Our earlier study indicated that electrolysed water containing 15 to 50 ppm available chlorine was effective as a disinfectant for several fresh-cut vegetables, and the potential problems experienced using sodium hypochlorite—high concentration of available chlorine and sodium residue—were not of concern when using electrolysed water.

In this study, we initially determined the effect of electrolysed water on microbial populations on freshly prepared and stored fresh-cut spinach leaves in comparison to that of sodium hypochlorite. Treated, fresh-cut spinach was stored in normal air or 4%  $O_2$ , as virtually all fresh-cuts are packaged in modified atmosphere packaging (MAP). Subsequently, our research was expanded to determine the effect of electrolysed water on the microflora on cut spinach prepared from intact leaves at 0°C, because raw vegetables for fresh-cuts are sometimes several days old by the time they are processed.

## Materials and Methods

### Generation of electrolysed water

Electrolysed water (pH 6.8) containing 15, 20, 30 or 50 ppm available chlorine was generated by electrolysis of a 2.5% NaCl solution using an electrolysed neutral water generator, Ameni Clean (Model FJ-W25M1; Matsushita Seiko, Osaka). The generator was connected to a water faucet and the electrolysed water of each chlorine concentration was automatically provided at a rate of 4 L/min. The concentration of available chlorine was confirmed by the sodium thiosulfate titration method (Asada et al. 1981).

### Sample preparation and electrolysed water treatments

Spinach (*Spinach oleracea* L. 'Sunbest' or 'Joker') leaves were freshly harvested at a farm in Wakayama City, Japan. Sub-samples of the leaves were cut to have 0.5 cm petioles using scissors. Each 50 g sample was treated with tap water as a control or electrolysed water (20 ppm available chlorine) at room temperature. The treatments included: (a) control = rinsed in running tap water at 2 L/min for 4 min; (b) rinsing =

rinsed in running, electrolysed water at 2 L/min for 3 min followed by rinsing in running tap water for 1 min; (c) dipping = dipped in 500 mL electrolysed water for 3 min followed by rinsing in running tap water for 1 min; and (d) dipping/blowing = dipped in 500 mL electrolysed water while simultaneously blowing air at 25 L/min for 3 min, followed by rinsing in running tap water for 1 min. The water rinse after treatments was added because hypochlorous acid had not been approved for use as a food additive by the Japanese Ministry of Health and Welfare. The constraints on the use of electrolysed water had been waived as a special case. All samples were then centrifuged for 3 min to remove surface water.

50 g samples from a different lot were rinsed in running tap water or running electrolysed water containing 15, 30, or 50 ppm available chlorine for 4 min and centrifuged for 3 min to determine the effect of different concentrations of chlorine. A rinsing treatment using sodium hypochlorite solution containing 50, 100, 150 or 200 ppm available chlorine was also included to compare with the effect of electrolysed water containing 50 ppm available chlorine. All of the above treatments were replicated three times.

Total microbial counts (mesophilic aerobic bacteria) were made from the surface of a 10 g sample and of 10 g of macerated sample and the results expressed as  $\log_{10}$  colony forming units (CFU)/g sample as previously described (Izumi and Watada 1994; Izumi 1999).

### Storage of trimmed spinach leaves

Nine trimmed spinach leaves ( $\approx 30$  g) were rinsed with tap water or electrolysed water containing 50 ppm available chlorine for 4 min and centrifuged for 3 min and then placed in a 1.5 L plastic container containing 20 mL of distilled water in a beaker to maintain high relative humidity. Three replicated samples were stored at 10 or 20°C under a continuous stream of normal air or 4%  $O_2$  at 10 or 15 mL/min, respectively. The balance of the gas mixture for the 4%  $O_2$  atmosphere was  $N_2$ . The carbon dioxide content of the inlet and outlet streams of each container was monitored with a  $CO_2$  analyser (Model CD-3A; Ametek, PA) during storage. Three replicated samples of each treatment were taken periodically to measure counts of mesophilic aerobic bacteria and lactic acid bacteria in 10 g samples and surface colour (hue angle =  $\tan^{-1}b^*/a^*$ ) with a chroma meter (Model NR-300; Nippon Denshoku, Tokyo), as previously described (Izumi et al. 1997).



## Storage of intact spinach leaves

Intact spinach leaves were packaged in 30 µm low-density polyethylene film bags and stored at 0°C for 28 days. Sub-samples were periodically removed from the bag, and leaves were cut into sections, dipped in tap water or electrolysed water containing 50 ppm available chlorine for 3 min, and then centrifuged for 3 min. After treatment, counts of mesophilic aerobic bacteria, psychrotrophic aerobic bacteria and coliform bacteria were determined from the surface of a 10 g sample and of 10 g sample homogenate. Culture media and culture conditions for determination of microbial counts were standard method agar incubated at 37°C for 48 h for aerobic mesophiles, or incubated at 7°C for 10 days for aerobic psychrophiles, and desoxycholate agar incubated at 37°C for 24 h for coliforms.

## Results and Discussion

Total counts of mesophilic aerobic bacteria of untreated fresh-cut spinach were similar between the surface and macerate of the sample (Table 1), which may be due to the style and anatomy of leafy vegetables. Rinsing with tap water (control) reduced the microbial load by 1.2 log<sub>10</sub> CFU/g on the leaf surface but not in the macerate, relative to untreated samples, while electrolysed water (20 ppm available chlorine) reduced the microbial load by about 1.6 log<sub>10</sub> CFU/g on the surface and 1.0 to 1.4 log<sub>10</sub> CFU/g in the macerate of samples. There was no difference in the bactericidal effect among the various treatments.

The concentration of available chlorine in electrolysed water had an effect on the microbial populations only on the surface of trimmed spinach leaves (Table 1). The microbial count on the surface was below the detection level (<2.4 log<sub>10</sub> CFU/g) when rinsed with electrolysed water containing 15 or 30 ppm available chlorine and not detectable when rinsed with 50 ppm available chlorine.

The number of mesophilic aerobic bacteria on the surface of trimmed spinach leaves which had been rinsed with sodium hypochlorite solution (available chlorine from 50 to 200 ppm) decreased as the chlorine concentration increased (Table 1). This decrease in microorganism numbers with increased chlorine concentration has been reported with raw apples and tomatoes (Beuchat et al. 1998) and within the sodium hypochlorite solution itself (El-Kest and Marth 1988). The effectiveness of electrolysed water containing 50 ppm chlorine corresponded to that of sodium hypochlorite solution containing 100–150 ppm

chlorine, which was comparable to or more effective than other chemical disinfectants (Adams et al. 1989; Zhang and Farber 1996).

The mesophilic aerobic bacterial count on cut spinach leaves treated with water or electrolysed water (50 ppm available chlorine) and stored at 10 or 20°C increased during storage at both temperatures regardless of the storage atmosphere, and was higher at 20°C than at 10°C (Table 2). The count was lower with electrolysed water-treated samples than water-treated controls during storage at 10 and 20°C except for samples stored in a 4% O<sub>2</sub> atmosphere at 10°C for 15 days. These results agree with those of Bolin et al. (1977) who reported that the initial microbial load of shredded lettuce influenced the storage stability of the product. Park and Lee (1995) reported that cut watercress and onion treated with sodium hypochlorite solution containing 50–1,000 ppm and 10–100 ppm, respectively, maintained lower microbial populations than the control samples for only the first 5 days of storage at 5°C. This indicated that the effectiveness of sodium hypochlorite treatment was limited to short-term storage. Thus the residual effect of electrolysed water on fresh-cuts during storage seems to be greater than that of sodium hypochlorite. Lactic acid bacterial counts on all samples were not detectable on day 0 and were below the detection level (2.5 log<sub>10</sub> CFU/g) during storage at 10 or 20°C.

Electrolysed water did not affect the respiration rate or the surface colour of trimmed spinach leaves held in normal air or 4% O<sub>2</sub> at 10 or 20°C (data not shown).

The mesophilic and psychrotrophic aerobic bacteria on the leaf surface and coliform bacteria in the macerate of fresh-cut spinach prepared from the stored, intact leaves increased by 1.4, 1.5, and 2.5 log<sub>10</sub> CFU/g, respectively, during the 28 days of storage at 0°C (Figure 1). Electrolysed water treatment (50 ppm available chlorine) of cut spinach leaves reduced the population of all microorganisms during storage, and the reduction was greater with leaves stored for a brief period than for a long period. Perhaps the population of microorganisms on spinach stored for a long time became too great for 50 ppm chlorine to remain effective.

**Table 1.** Total microbial count (mesophilic aerobic bacteria) of fresh-cut spinach treated with tap water (control), electrolysed water (EW) or sodium hypochlorite solution.

Treatment	Log <sub>10</sub> colony forming units (CFU)/g	
	Surface <sup>e</sup>	Macerate <sup>f</sup>
<b>Method<sup>g</sup></b>		
Untreated	4.2 a	4.3 a
Control	3.0 b	4.0 a
Rinsing	2.7 b	3.0 b
Dipping	2.6 b	2.9 b
Dipping/Blowing	2.6 b	3.3 b
<b>Concentration<sup>h</sup></b>		
Control	2.9 a	4.3 a
15 ppm	<2.4 b	2.5 b
30 ppm	<2.4 b	2.7 b
50 ppm	ND	2.7 b
<b>Sodium hypochlorite<sup>i</sup></b>		
Untreated	4.4 a	Not measured
EW(50 ppm)	2.8 cd	
50 ppm	3.6 b	
100 ppm	3.2 bc	
150 ppm	3.0 bcd	
200 ppm	<2.4 d	

a–d Means with different letters within each treatment in the same column are significantly different ( $p < 0.05$ ).

<sup>e</sup> Mesophilic aerobic bacterial CFU on tissue surface.

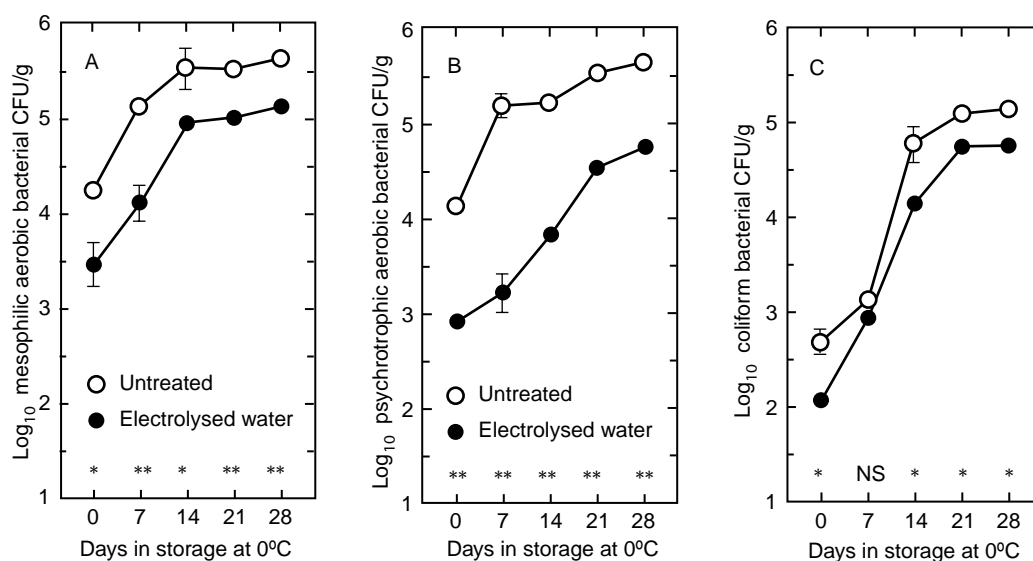
<sup>f</sup> Mesophilic aerobic bacterial CFU in tissue macerate.

<sup>g</sup> Control = rinsing with tap water for 4 min; Rinsing = rinsing with electrolysed water for 3 min followed by rinsing with tap water for 1 min; Dipping = dipping in electrolysed water for 3 min followed by rinsing with tap water for 1 min; Dipping/Blowing = dipping and blowing air at 25 L/min in electrolysed water for 3 min followed by rinsing with tap water for 1 min.

<sup>h</sup> Control = rinsing with tap water for 4 min; 15 ppm, 30 ppm, and 50 ppm = rinsing with electrolysed water containing 15 ppm, 30 ppm, and 50 ppm available chlorine, respectively, for 4 min.

<sup>i</sup> EW(50 ppm) = rinsing with electrolysed water containing 50 ppm available chlorine for 4 min; 50 ppm, 100 ppm, 150 ppm, and 200 ppm = rinsed with sodium hypochlorite solution containing 50 ppm, 100 ppm, 150 ppm, and 200 ppm available chlorine, respectively, for 4 min.

ND = Not detectable.



**Figure 1.** Counts of mesophilic aerobic bacteria (A), psychrotrophic aerobic bacteria (B) and coliform bacteria (C) of fresh-cut spinach prepared from intact leaves stored at 0°C, then dipped in electrolysed water containing 50 ppm available chlorine for 3 min. Vertical lines represent the standard error (SE). SE bars are not shown when masked by the graph symbol (CFU = colony forming units, NS = not significant, \* = significant at  $p < 0.05$ , and \*\* = significant at  $p < 0.01$ ).

**Table 2.** Counts of mesophilic aerobic bacteria (MAB) and lactic acid bacteria (LAB) of fresh-cut spinach treated with tap water (Water) or electrolysed water containing 50 ppm available chlorine (EW) for 4 min and stored at 10 or 20°C under normal air or 4% O<sub>2</sub> conditions.

Days	Treatment	Log <sub>10</sub> colony forming units (CFU)/g	
		MAB <sup>d</sup>	LAB <sup>e</sup>
10°C storage			
0	Water	2.9 a	ND
	EW	<2.5 b	ND
8	Water-air	3.9 a	<2.5 a
	EW-air	3.7 b	<2.5 a
	Water-4% O <sub>2</sub>	3.9 a	<2.5 a
	EW-4% O <sub>2</sub>	3.5 c	<2.5 a
15	Water-air	4.4 a	<2.5 a
	EW-air	3.9 b	<2.5 a
	Water-4% O <sub>2</sub>	4.5 a	<2.5 a
	EW-4% O <sub>2</sub>	4.2 a	<2.5 a

abc Means with different letters within each day in the same column are significantly different ( $p < 0.05$ ).

<sup>d</sup> Mesophilic aerobic bacterial CFU in tissue macerate.

<sup>e</sup> Lactic acid bacterial CFU in tissue macerate.

ND = Not detectable.

**Table 2.** (Cont'd) Counts of mesophilic aerobic bacteria (MAB) and lactic acid bacteria (LAB) of fresh-cut spinach treated with tap water (Water) or electrolysed water containing 50 ppm available chlorine (EW) for 4 min and stored at 10 or 20°C under normal air or 4% O<sub>2</sub> conditions.

Days	Treatment	Log <sub>10</sub> colony forming units (CFU)/g	
		MAB <sup>d</sup>	LAB <sup>e</sup>
20°C storage			
0	Water	3.9 a	ND
	EW	<2.5 b	ND
3	Water-air	5.4 a	<2.5 a
	EW-air	3.6 c	<2.5 a
	Water-4% O <sub>2</sub>	4.9 b	<2.5 a
	EW-4% O <sub>2</sub>	3.8 c	<2.5 a
5	Water-air	6.6 a	<2.5 a
	EW-air	6.1 b	<2.5 a
	Water-4% O <sub>2</sub>	6.5 a	<2.5 a
	EW-4%O <sub>2</sub>	5.7 b	<2.5 a

abc Means with different letters within each day in the same column are significantly different ( $p < 0.05$ ).

<sup>d</sup> Mesophilic aerobic bacterial CFU in tissue macerate.

<sup>e</sup> Lactic acid bacterial CFU in tissue macerate.

ND = Not detectable.

## References

- Adams, M.R., Hartley, A.D. and Cox, L.J. 1989. Factors affecting the efficacy of washing procedures used in the production of prepared salads. *Food Microbiology*, 6, 69–77.
- Asada, S., Uchide, S. and Kobayashi, M. 1981. Analysis of available chlorine in bleaching powder. In: Quantitative analysis. Tokyo, Japan, Gihodo, 95–97.
- Beuchat, L.R., Nail, B.V., Adler, B.B. and Clavero, M.R.S. 1998. Efficacy of spray application of chlorinated water in killing pathogenic bacteria on raw apples, tomatoes, and lettuce. *Journal of Food Protection*, 61, 1305–1311.
- Bolin, H.R., Stafford, A.E., King, A.D.Jr and Huxsoll C.C. 1977. Factors affecting the storage stability of shredded lettuce. *Journal of Food Science*, 42, 1319–1321.
- Brackett, R.E. 1987. Microbiological consequences of minimally processed fruits and vegetables. *Journal of Food Quality*, 10, 195–206
- El-Kest, S.E. and Marth, E.H. 1988. Inactivation of *Listeria monocytogenes* by chlorine. *Journal of Food Protection*, 51, 520–524.
- IFPA (International Fresh-cut Produce Association) 1996. HACCP for the fresh-cut produce industry. In: Food safety guidelines for the fresh-cut produce industry, 3rd edition. Alexandria, Virginia, IFPA, 27–36.
- Izumi, H. 1999. Electrolyzed water as a disinfectant for fresh-cut vegetables. *Journal of Food Science*, 64, 536–539.
- Izumi, H., Nonaka, T. and Muraoka, T. 1997. Physiology and quality of fresh-cut spinach stored in low O<sub>2</sub> controlled atmospheres at various temperatures. In: Gorny, J.R., ed., Proceedings of the 7<sup>th</sup> International Controlled Atmosphere Research Conference, Volume 5. Davis, University of California, 130–132.
- Izumi, H. and Watada, A.E. 1994. Calcium treatments affect storage quality of shredded carrots. *Journal of Food Science*, 59, 106–109.
- Krahn, T.R. 1977. Improving the keeping quality of cut head lettuce. *Acta Horticulturae*, 62, 79–92.
- Nagashima, T. and Kamoi, K. 1997. Sterilization and preservation of vegetables by ozonated water treatment. *Food Preservation Science*, 23, 127–131.
- Park, W.P. and Lee, D.S. 1995. Effect of chlorine treatment on cut watercress and onion. *Journal of Food Quality*, 18, 415–424.
- Ritenour, M.A. and Crisosto, C.H. 1996. Hydrocooler water sanitation in the San Joaquin Valley stone fruit industry. *Central Valley Postharvest Newsletter*, 5, 15–17.
- Watada, A.E., Ko, N.P. and Minott, D.A. 1996. Factors affecting quality of fresh-cut horticultural products. *Postharvest Biology and Technology*, 9, 115–125.
- Willcox, F., Tobback, P. and Hendrickx, M. 1994. Microbial safety assurance of minimally processed vegetables by implementation of the hazard analysis critical control point (HACCP) system. *Acta Alimentaria*, 23, 221–238.
- Zagory, D. 1999. Effects of post-processing handling and packaging on microbial populations. *Postharvest Biology and Technology*, 15, 313–321.
- Zhang S. and Farber, J.M. 1996. The effects of various disinfectants against *Listeria monocytogenes* on fresh-cut vegetables. *Food Microbiology*, 13, 311–321.

# Rapid Analytical Techniques for Pesticide Residues in Food

A. Pasha\*

## Abstract

Pesticide residues encountered in agricultural produce are often above permissible limits, posing health hazards. They are also one of the major problems in international trade. Pesticide residues are analysed by conventional methods like gas chromatography and high performance liquid chromatography (HPLC) which are time-consuming and need trained personnel and expensive equipment. Elaborate sample preparation, clean-up and a low throughput of 4–5 samples/day are the main disadvantages of these methods. Hence there is need to develop simple and rapid alternatives to these classical methods. Enzyme-linked immunosorbent assay (ELISA) is suggested as an alternative technique, but it can give false positive and negative results due to matrix interference and responds to structurally similar compounds.

This paper describes simple and rapid chemical-based methods for analysis of various pesticide residues. Sensitive reagents like N,N-diphenylbenzidine, 4-amino-N,N-dimethylaniline, and o-tolidine were developed earlier for organochlorine, organophosphate and pyrethroid insecticide residues. Highly sensitive reagents were also developed by the author for the analysis of benzimidazole fungicides like carbendazim and benomyl and also thiram residues.

N-bromosuccinimide, N-bromo-1,2-benzisothiazol-3-(2H)-one-1,1-dioxide and copper (I) thiocyanate were used to determine these fungicide residues using a colorimetric method. Fungicide residues as low as 20 ng could be detected on paper strips prepared from some of these reagents using a densitometer. A new reagent, 1,3-dibromo-5,5-diphenyl-(3H,5H)-imidazol-2,4-dione, is now developed to analyse residues of benzimidazole fungicides on fruits and vegetables. 2-aminobenzimidazole (2-AB) obtained from these fungicides under different conditions reacts with the reagent to give a product having  $\lambda_{\text{max}}$  at 450 nm. 2-AD forms brick-red and purple coloured zones instantaneously on paper strips containing N-bromo-1,2-benzisothiazol-3-(2H)-one-1,1-dioxide and 1,3-dibromo-5,5-diphenyl (3H,5H)-imidazol-2,4-dione with a minimum detectable limit of 20 ng.

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# Effects on the Organoleptic Quality of Arabica Coffee Beans Processed for Export when Pulping is Delayed in Papua New Guinea

A.J. Kuri\*

## Abstract

Green bean coffee produced from cherries pulped on the same day of harvest and parchment which was soaked was rated the best in terms of the final raw bean, roasted bean and cup taste qualities. The quality of the green beans progressively deteriorated each day the cherries were not pulped from the day of harvest.

Cherries pulped on the fourth day after harvest produced green beans that were rated low and their quality differed significantly ( $p < 0.05$ ) from those produced from cherries pulped on the day of harvest.

Soaking the cherries prior to pulping had an adverse effect on the final quality of the green beans produced for export, caused by the aqueous environment, and differed significantly ( $p < 0.005$ ) in their total scores for the raw bean, roasted bean and cup taste quality.

Soaked parchment produced superior quality coffee compared to unsoaked parchment and differed significantly ( $p < 0.001$ ) in the total scores for the raw bean, roasted bean and cup taste. The results confirmed that two-stage fermentation of arabica coffee when 'wet processed' produces a superior quality coffee.

PAPUA NEW GUINEA has faced quality problems with their arabica coffee with overseas buyers over the years, which have been caused, in part, by delays in pulping the cherries. Hence, it has been recommended to farmers that they pulp on the same day as harvesting to maintain the final quality. However, pulping on the day of harvest can be delayed for the following reasons:

- limitations in transport due to bad road conditions or no vehicles;
- limited availability or capacity of processing facilities, pulpers and fermentation vats;
- involvement of farmers in other communal activities that may prevent them from pulping the cherries on the day of harvest; or
- unexpected breakdown of processing equipment and transport vehicles.

Each day that pulping is delayed, the quality of the coffee beans is adversely affected. This study was undertaken to evaluate the effects on the organoleptic quality of arabica coffee beans processed for export when pulping is delayed in Papua New Guinea.

Further to that, the effects on the total quality of the green beans when cherries and parchment were soaked in water as compared to those not soaked for the tested coffee were evaluated. The soaking tests were carried out to see if the final bean quality could be improved by soaking in cherry form prior to pulping or in parchment form prior to drying.

Thus the objective was to evaluate the organoleptic quality of 'raw beans', 'roasted beans' and 'cup taste' when:

- pulping was delayed for up to 6 days after harvest;
- the cherries were soaked in water, compared to those not soaked, before pulping; and
- washed parchment was soaked in water and compared to parchment which was not soaked.

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## Materials and Methods

### Materials and equipment

- a) 240 kg of fully ripe and hand-sorted cherries of *Coffea arabica* 'Arusha' were harvested from the seed plots at the Coffee Research Institute in Aiyura, Papua New Guinea.
- b) 1 × coffee pulper (motorised Bentell Novo Drum Pulper)
- c) 1 × Agritech Sinar 6060 moisture analyser
- d) 1 × Probat-Worick sample coffee roasting machine
- e) coffee tasting cups, table, spoons, and sample trays
- f) 1 × Probat sample grinder
- g) 24 × plastic trays with holes made in them for use as fermentation vats

### Methods

Cherries were sorted by hand to remove overripe, under-ripe, dead, and insect damaged beans, then weighed into 24 × 10 kg units. Each day, 4 × 10 kg of cherries were pulped. For those to be pulped after day 1, half of the sample (2 × 10 kg) was soaked in water while the other half (2 × 10 kg) was left in the open. When the samples were pulped, parchment samples from each of the four sets of 10 kg samples were fermented separately in their own vats. An overview of the process is shown in Figure 1.

The fully fermented parchment for each day's pulping was washed clean after an average of 34 h. From the two sets of 10 kg of cherries soaked, one set of clean parchment was soaked in clean water while the other set was sun-dried. Again, from the two sets of 10 kg of unsoaked cherries, one set of clean parchment

was soaked while the other was sun-dried. This process was repeated for all of the six days' pulping.

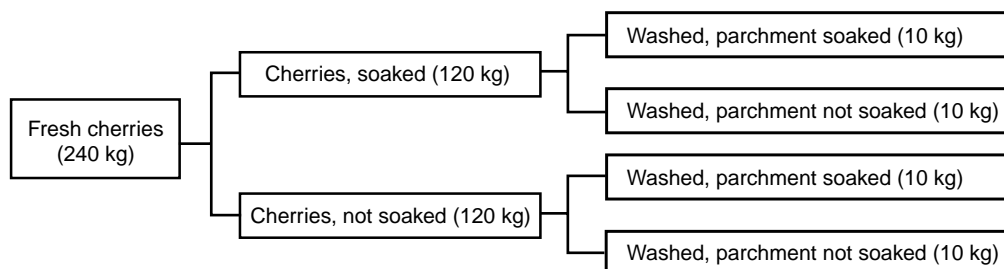
During sun-drying, the moisture content was reduced to 10.5% and the fruit hulled to obtain the green bean as the final product. Green beans were roasted at 180–200°C for a medium roast using a Probat-Werke sample-roasting machine. In order to minimise the effects of the degrees of the roast and brewing formula (ICO 1991), all the samples were carefully roasted to medium roast.

The roasted and cooled samples were finely ground with a sample grinder and prepared for cup tasting in the usual commercial manner. For one coffee sample, three cups were prepared using standard coffee-tasting cups. Ground coffee was measured using the standard scooping spoons (10 g) and tasting cup (30 mL). That is, cups were prepared at a ratio of 1:3 coffee to water.

A score was given on a standardised form, designed for the trial using the same vocabulary as used to describe coffee in Papua New Guinea as well as internationally (see Appendix 1). The score given by the taster for each quality parameter was an average of the three cups tasted. The total quality for the 'raw beans', 'roasted beans' and 'cup taste' was evaluated on a number of parameters assessed for each of the samples. The score given by the taster as a measure of the quality was based on the understanding that the lower the score, the better the quality.

### Statistical package for the analysis

The statistical analysis for the measured parameters was carried out using the Genstat 5 Release 3.2 (PC/Windows 95), Copyright 1995, Lawes Agricultural Trust (Rothamstead Experimental Station). Analysis of the variance for each parameter was tabulated as shown in Appendix 2.



**Figure 1.** Method of sample preparation—process flow for treatment of the 240 kg batch of cherries. 40 kg of cherries were pulped each day for the four treatments as shown.

## Results and Discussion

### Effects of delayed pulping on the raw bean quality

The raw bean quality declined from its original state from the day of harvest as pulping was delayed (Figure 2A). The mean score of cherries pulped on day 4 (5.06), day 5 (4.86) and day 6 (4.81) were significantly higher ( $p = 0.05$ ) than the mean score (3.97) of cherries pulped on the same day of harvest (Tables 1A and 1B).

The cherries which were not soaked produced better raw bean quality compared to the soaked cherries (Figure 2B). For the unsoaked cherries there was a gradual decline in the raw quality from day 1 to day 3 and then a significant decline ( $p < 0.05$ ) from day 3 to day 4. The scores for the soaked cherry indicated that there was a significant decline in the quality from day 1 to day 2 which improved on day 3 but declined on day 4.

The scores for soaked parchment were comparatively lower than those for parchment which was not soaked, indicating that soaking parchment has a positive effect on the raw quality (Figure 2C). The difference between the soaked and unsoaked parchment

was not significant for the cherries pulped on days 2 and 3 but differed significantly ( $p = 0.05$ ) for all the other days.

### Effects of delayed pulping on the roasted bean quality

There was notable negative trend from its intrinsic quality from day 1 to day 2 and from day 3 to day 4, indicating a progressive decline in quality (Figure 3A). Mean scores for the cherries pulped on day 4 (6.78) and day 6 (6.64) were significantly ( $p = 0.05$ ) higher than the mean score (5.75) of cherries pulped on the day of harvest (Tables 2A and 2B).

Soaking harvested cherries had an adverse effect on the roasted bean quality, especially those pulped on days 2, 4 and 5 as compared to the quality of cherries which were not soaked (Figure 3B).

The mean score of the soaked cherries pulped on day 3 (6.00) was significantly lower ( $p < 0.05$ ) than that of day 2 (6.67), while that of day 6 (6.39) was also significantly lower ( $p = 0.05$ ) than the score of day 4 (7.17), indicating possible osmotic behaviour of soluble solids in the beans. There was a progressive decline in quality for unsoaked cherries from day 1 to

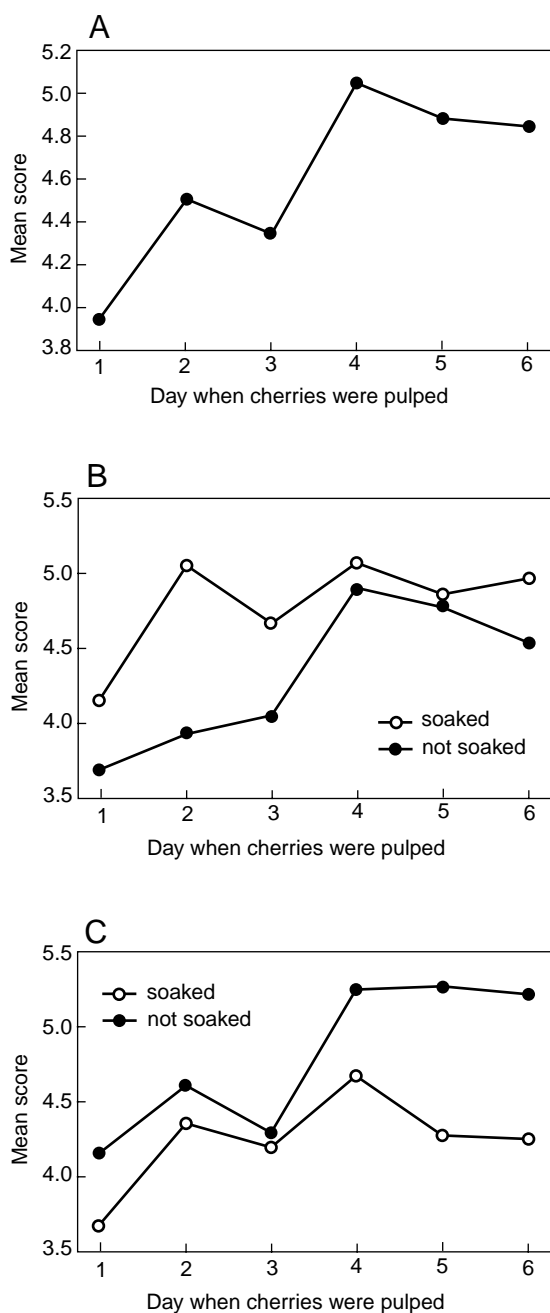
**Table 1A.** Mean scores for raw bean quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	3.97	4.22	3.72	3.72	4.22
Day 2	4.53	5.11	3.94	4.44	4.61
Day 3	4.36	4.67	4.06	4.33	4.39
Day 4	5.06	5.17	4.94	4.83	4.28
Day 5	4.86	4.89	4.83	4.39	5.33
Day 6	4.81	5.11	4.50	4.33	5.28
Overall means	4.60	4.86	4.33	4.34	4.85

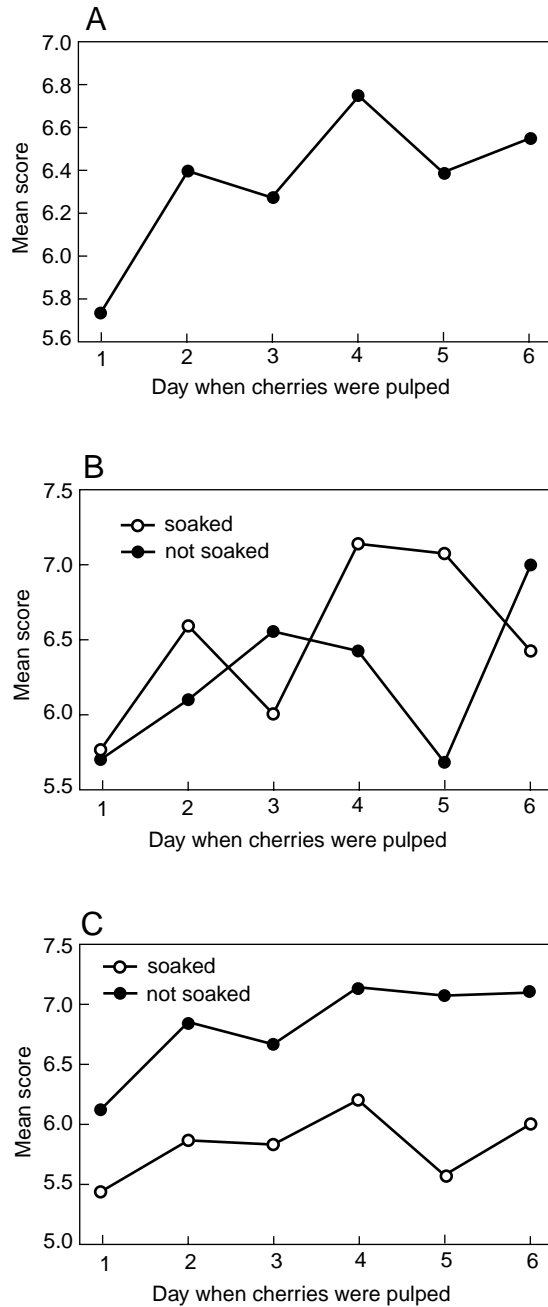
**Table 1B.** Statistics for raw bean quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference f means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.250	0.353	0.697	36	190
Cherry soaking test	0.144	0.204	0.403	108	190
Parchment soaking test	0.144	0.204	0.403	108	190





**Figure 2.** Effects on raw bean quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.



**Figure 3.** Effects on roasted bean quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.

day 3. Those pulped on day 5 scored the lowest, indicating a much improved roast quality which differed significantly ( $p < 0.05$ ) from day 4 and 6.

Soaking washed parchment improved the roasted bean quality and there was a notable difference between the soaked and unsoaked parchment (Figure 3C). Mean scores for the soaked parchment were significantly lower ( $p = 0.001$ ) than for parchment which had not been soaked, indicating an improvement in roast quality. There was a significant ( $p < 0.05$ ) decline in quality from day 1 to day 2 and from day 3 to day 4 but also a significant improvement ( $p < 0.05$ ) from day 4 to day 5.

### Effects of delayed pulping on cup taste quality

The cup taste quality declined progressively each day that cherry pulping was delayed from the day of harvest (Figure 4A). The mean scores of the cherries

pulped on day 3 (7.31) and later were significantly higher than the mean score (6.19) for the cherries pulped on the day of harvest (Tables 3A and 3B). The decline in quality was notable from day 1 to day 2 and was significant ( $p = 0.05$ ) from day 3 onwards. The cup taste quality for the cherries pulped on day 5 and 6 did not vary significantly.

The soaked cherries had higher mean scores compared to the cherries which were not soaked (Figure 4B) and the cup taste quality differed significantly ( $p < 0.001$ ) for the cherries pulped on days 2 and 4. The decline in cup taste quality for the soaked cherries per day was significant ( $p = 0.05$ ) from days 1 to 4, but those pulped on days 5 and 6 improved slightly. There was a significant ( $p = 0.05$ ) progressive decline in the cup taste quality per day up to day 6 when pulping was delayed for the unsoaked cherries.

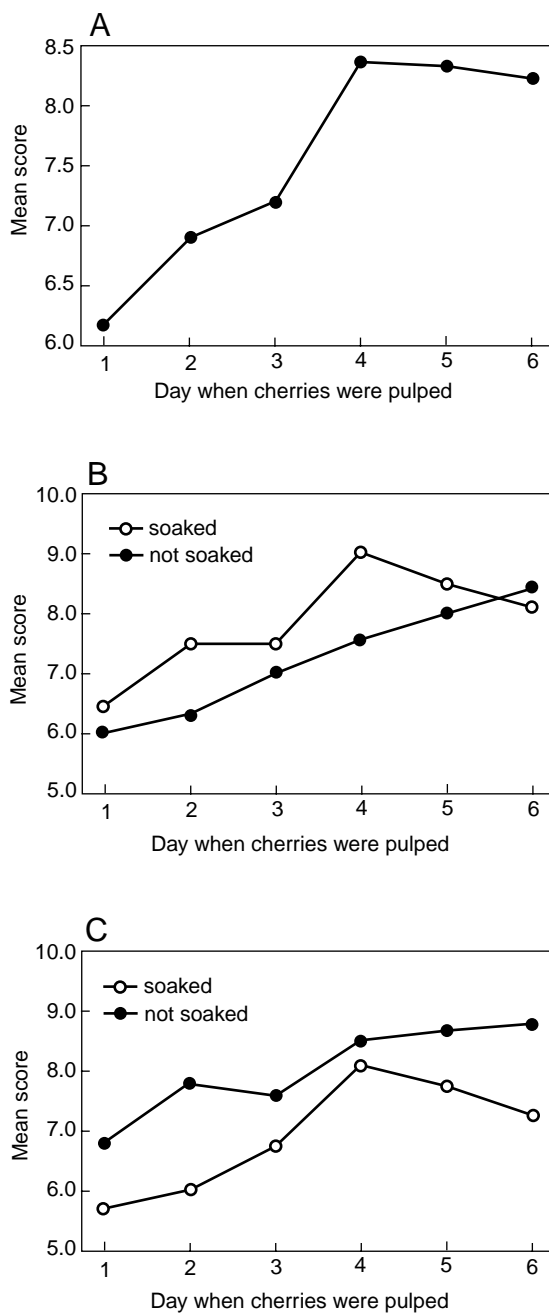
The soaked parchment produced a better cup taste quality compared to the unsoaked parchment with significantly ( $p = 0.005$ ) lower mean scores (Figure 4C).

**Table 2A.** Mean scores for roasted bean quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	5.750	5.779	5.722	5.389	6.111
Day 2	6.389	6.669	6.111	5.889	6.889
Day 3	6.250	6	6.500	5.833	6.667
Day 4	6.778	7.167	6.389	6.333	7.222
Day 5	6.389	7.111	5.667	5.667	7.111
Day 6	6.639	6.389	6.889	6.111	7.167
Overall means	6.366	6.519	6.213	5.870	6.861

**Table 2B.** Statistics for roasted bean quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference f means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.2420	0.3422	0.6750	36	190
Cherry soaking test	0.1397	0.1976	0.3897	108	190
Parchment soaking test	0.1397	0.1976	0.3897	108	190



**Figure 4.** Effects on cup taste quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.

The cup taste quality declined from day 1 to day 2, and significantly ( $p = 0.05$ ) from day 3 to 4 for the soaked parchment. The changes in the cup taste quality of the unsoaked parchment were significant from day 1 to day 2 and from day 3 to day 6.

### Effects of delayed pulping on total quality

The total quality declined progressively each day that pulping of the cherries was delayed from the day of harvest (Figure 5A). According to the scores, the difference in quality between the days was significant ( $p = 0.05$ ) from day 1 to day 6 (Tables 4A and 4B). There was an increased decline in the quality between days 1 and 2 and days 3 and 4.

The soaked cherries had higher scores than those not soaked from days 1 to 5, indicating that soaking the cherries when pulping was delayed had an adverse effect on quality (Figure 5B). The soaked cherry quality declined from day 1 to day 2, improved from day 2 to day 3, declined from day 3 to day 4, and then improved on day 5 and day 6, indicating osmotic behaviour induced by the fluid environment. There was a gradual loss in quality from days 1 to 6 for cherries that were not soaked.

**Table 3A.** Mean scores for cup taste quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	6.19	6.39	6	5.72	6.67
Day 2	6.94	7.50	6.39	6.06	7.83
Day 3	7.31	7.56	7.06	6.89	7.72
Day 4	8.33	9.11	7.56	8.17	8.50
Day 5	8.28	8.67	7.89	7.78	8.78
Day 6	8.14	8.00	8.28	7.33	8.94
Overall means	7.53	7.87	7.19	6.99	8.07

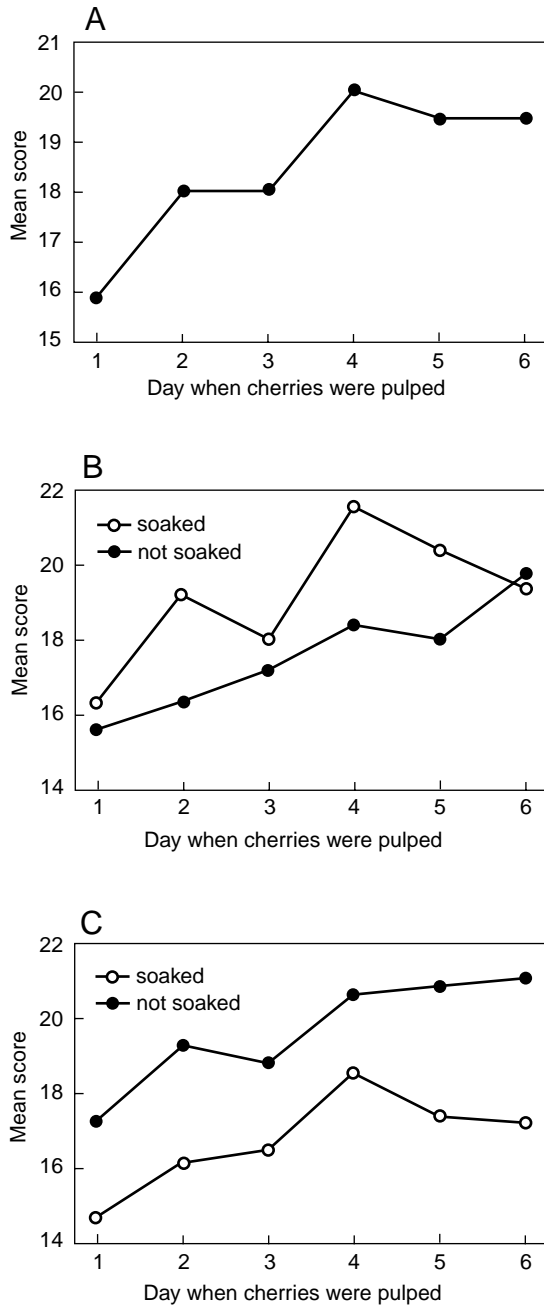
**Table 3B.** Statistics for cup taste quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference of means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.297	0.420	0.820	36	190
Cherry soaking test	0.171	0.243	0.478	108	190
Parchment soaking test	0.171	0.243	0.478	108	190

The soaked parchment scores were significantly ( $p < 0.001$ ) lower than those of the unsoaked parchment, indicating better quality of the former (Figure 5C). Soaking parchment after being washed clean improved the quality of the raw beans, roasted beans, cup taste, and the overall total quality of the product very markedly.

### Conclusions

1. The intrinsic organoleptic quality of the green bean product declined after the day of harvest and to an increasing degree after the third day of delayed pulping.
2. The raw bean and roasted bean quality declined between day 1 and day 2, and more dramatically from day 3 to day 4, when cherry pulping was delayed.
3. The cup taste quality declined each day that pulping was delayed and very significantly after day 3. These results are generally in agreement with Devonshire (1956) and Robinson (1964) who reported that foxy beans, which give colour to the parchment and produce a fruity or sour cup taste, are from coffee beans fermented in cherry form.



**Figure 5.** Effects on overall total coffee quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.

4. There were noticeable differences in quality between the soaked and unsoaked cherries, with the soaked cherries producing poorer raw bean, roasted bean and cup taste quality.
5. The soaked parchment produced a better quality coffee which was favourably scored by the tasters and differed significantly ( $p < 0.001$ ) from the unsoaked parchment. Brownbridge and Wootton (1965) reported that arabica coffee produced from soaking of washed parchment was superior in quality compared to that which had not been soaked. These results show that under Papua New Guinea conditions, arabica coffee produced as such can also be of superior quality.

### Acknowledgments

Many thanks to Mr Kilson Walawia and Mrs Josephine Wamp for their kind assistance in sorting out the data and compiling the report. I also thank Mr Anton Buro, Mr David Nema and Mr David Rumburumba for being part of the tasting panel. Mr Pamenda Talopa's input into statistical analysis of the data is also appreciated.

### References

- Brownbridge, J.M. and Wootton, A.E. 1965. Recent development in coffee processing. Kenya Coffee Journal, May, 187.
- Devonshire, R.O. 1956. Explanation of coffee report form. Kenya Coffee Journal, July, 3.
- ICO (International Coffee Organisation) 1991. Sensory study of the effect of degree of roast and brewing formula on the final cup characteristics. Promotion Fund, Technical Unit Quality Series, Report No. 7.
- Robinson, J.B.D. 1964. A hand book on arabica coffee in Tanganyika, revised and enlarged edition. Tanganyika Coffee Board.

**Table 4A.** Mean scores for total quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	15.92	16.39	15.44	14.83	17.00
Day 2	17.86	19.28	16.44	16.39	19.33
Day 3	17.92	18.22	17.61	17.08	18.78
Day 4	20.17	21.44	18.89	19.33	21.00
Day 5	19.53	20.67	18.39	17.83	21.22
Day 6	19.58	19.50	19.67	17.78	21.39
Overall means	18.50	19.25	17.74	17.20	19.79

**Table 4B.** Statistics for total quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference of means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.539	0.763	1.508	36	190
Cherry soaking test	0.311	0.440	0.869	108	190
Parchment soaking test	0.311	0.440	0.869	108	190

**Appendix 1.** Assessment form used by quality tasters (faq = fair average quality).

Raw			Roast			Liquor			
	Size	Colour	Quality	Type	C/cut <sup>a</sup>	Quality	Body	Acidity	Flavour
Score	a	b	c	d	e	f	g	h	i
1	large	bluish green	v/good	bright	white	v/good	full	sharp	v/good
2	medium	greyish green	good	ordinary	brownish	good	medium	medium	good
3	mixed	green	faq	dull	mixed	faq	light	light	faq
4	small	discoloured	poor		dull	poor	lacking	lacking	poor
5			v/poor			v/poor			v/poor

Classification											Range	Class	Quality		
Attribute	a	b	c	d	e	f	g	h	i	Total	Class	phn <sup>b</sup>	9–11	1	excellent
Score													12–14	2	very good
													15–17	3	good
													18–21	4	faq
													22–26	5	faq to poor
													27–32	6	poor
													33–39	7	very poor

<sup>a</sup> C/cut = centre-cut (describes the split in the middle of a coffee bean. The cleanliness of the centre-cut of a roasted coffee bean is used to assess the manner by which the beans were processed)

<sup>b</sup> phn = phenolic (a flavour character)



**Appendix 2A.** Analysis of variance—raw bean quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	27.440	13.722	6.10	
Day pulped	5	27.875	5.575	2.48	0.033
Soaked cherries	1	15.042	15.042	6.69	0.010
Soaked parchment	1	14.005	14.005	6.23	0.013
Day pulped*Soaked cherries	5	6.356	1.331	0.59	0.706
Day pulped*Soaked parchment	5	6.356	1.271	0.57	0.726
Soaked cherries*Soaked parchment	1	4.449	4.449	1.98	0.161
Day pulped*Soaked cherries*Soaked parchment	5	8.912	1.782	0.79	0.556
Residual	190	427.22	2.249		
Total	215	537.958			

**Appendix 2B.** Analysis of variance—roasted bean quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	7.065	3.532	1.68	
Day pulped	5	22.968	4.594	2.18	0.058
Soaked cherries	1	5.042	5.042	2.39	0.124
Soaked parchment	1	53.005	53.005	25.15	<0.001
Day pulped*Soaked cherries	5	26.486	5.297	2.51	0.031
Day pulped*Soaked parchment	5	2.856	0.571	0.27	0.929
Soaked cherries*Soaked parchment	1	16.116	16.116	7.65	0.006
Day pulped*Soaked cherries*Soaked parchment	5	8.079	1.616	0.77	0.575
Residual	190	400.491	2.108		
Total	215	542.106			

**Appendix 2C.** Analysis of variance—cup taste quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	9.954	4.977	1.57	
Day pulped	5	135.079	27.016	8.51	<0.001
Soaked cherries	1	24.671	24.671	7.77	0.006
Soaked parchment	1	63.375	63.375	19.96	<0.001
Day pulped*Soaked cherries	5	17.968	3.594	1.13	0.345
Day pulped*Soaked parchment	5	12.708	2.542	0.80	0.551
Soaked cherries*Soaked parchment	1	2.042	2.042	0.64	0.424
Day pulped*Soaked cherries*Soaked parchment	5	24.597	4.919	1.55	0.177
Residual	190	603.380	3.176		
Total	215	893.773			

**Appendix 2D.** Analysis of variance—total quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	45.06	22.53	2.15	
Day pulped	5	447.47	89.49	8.55	<0.001
Soaked cherries	1	123.00	123.00	11.75	<0.001
Soaked parchment	1	360.67	360.37	34.42	<0.001
Day pulped*Soaked cherries	5	66.36	13.27	1.27	0.280
Day pulped*Soaked parchment	5	32.32	6.46	0.62	0.687
Soaked cherries*Soaked parchment	1	11.12	11.12	1.06	0.304
Day pulped*Soaked cherries*Soaked parchment	5	96.91	19.47		
Residual	190	1989.38	10.47		
Total	215	3172.00			

# Improvement of Quality of Apples in Shanxi Province, China

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## Abstract

In the past six years in Shanxi Province there have been extensive plantings of fruit trees (particularly apples), but the postharvest system is largely undeveloped. This report describes the results of a project on postharvest systems development, intended to develop and deliver an educational training program on the development of fruit quality assurance systems, and to develop a framework for fruit total quality management systems for one fruit crop in China. After visits by the two collaborating postharvest research groups in China and New Zealand it was agreed to hold a workshop in Shanxi, and the objectives were carefully defined.

The New Zealand team presented a five-day workshop to 37 selected representatives of local growers and support industries. A workshop manual was prepared in English and Chinese.

Before, during and after the workshop, discussions took place between the New Zealand team and the local agricultural development bureau representatives. At the conclusion of the workshop, a summary of the findings and recommendations from the workshop were completed and signed by all involved. Pre and post workshop questionnaires and other evaluation techniques were used in order to evaluate the effectiveness of the workshop. These showed that we had brought about a clear change in attitude of delegates towards recognising the value of postharvest factors, and as a result it was decided to proceed immediately with the formation of a growers' association to focus on developing a quality management system for apples. Establishment of a marketing effort was identified as a key task of the association.

There was a need for research, testing, and advisory systems to be established to enable growers to make continuous improvements to their pre and postharvest systems. A major improvement in infrastructure and in facilities for postharvest systems and quality management of apples should be achieved.

IN CHINA, fruit production has increased dramatically over the past ten years, and in the southern part of Shanxi Province fruit has become a major income source for farmers. However quality control, and postharvest handling and storage techniques are still at a very early stage of development. There is cool-storage capacity for less than one-third of the current apple production, resulting in the need to sell fruit at harvest-time. Considerable gains in quality and profitability could be achieved if modern postharvest technology was used by the industry.

In New Zealand, on the other hand, postharvest technology is already at a very sophisticated state of development, with major export markets being supplied with high quality product. Improvements in

product quality through quality management systems are known to be effective in adding market value to fresh product, and hence to increase the financial return to growers. In addition, quality improvement reduces environmental impact through a reduction in the amount of poor quality product which is shipped and ultimately requires disposal in the marketplace when it cannot be sold.

Shanxi Province lies 1,000 km south-west of Beijing. It is one of the poorest provinces in China. During the project formulation stages, the Shanxi government officials stressed that their production was market driven and that they sought a high yield of high quality fruit. Furthermore they recognised the need for substantial training in postharvest systems in order to meet international standards.

One of the main apple production areas is in Yun Cheng District. This district covers the south-western

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corner of Shanxi. Apples have been grown in the district on a very small scale since 1932. However, with the reformation of agricultural policies there has been a significant increase in the area occupied by fruit trees (Tables 1 and 2). The main city of the district (Yun Cheng City) has a population of 530,000; those directly involved in agriculture and agricultural processing number 440,000. The officials estimated that 50% of those involved in agriculture and agricultural processing are engaged in fruit production and processing. The labour force associated with the fruit production and processing includes 130,000 women.

### Project Initiation

The study arose as a result of an ongoing interaction between the China Agricultural University and Massey University. The project was conducted in four phases. First, linkages were established between two postharvest research groups in China and New Zealand with complimentary skills, together with contacts with agricultural development managers in Shanxi Province. This team completed the initial proposal and established funding for the project, and

remained active in project management throughout the study.

From the beginning of the work, three issues became immediately obvious:

- (1) there were substantial new plantings of fruit which are now coming into peak production—once full production was achieved there would be a substantial increase in the volume of fruit to be moved to market;
- (2) in Shanxi, there was a dearth of knowledge concerning quality assurance in the postharvest system; and
- (3) in order to realise the economic potential of the volume of fruit which would be produced in the future, a framework for fruit quality assurance was essential for the Shanxi producers.

At this stage the objectives were defined by the team as follows:

- to develop and deliver an educational training program on the development of fruit quality assurance systems; and
- to develop a framework for fruit total quality management systems for apples.

**Table 1.** Details of Shanxi Province and Yun Cheng District.

Parameters	Shanxi Province	Yun Cheng District
Area ('000 ha)	15 000	1 400
Population ('000)	33 000	4 510
Rural population ('000)	3 930	
Arable land ('000 ha)	4 000	610
Fruit production area ('000 ha)	175	
Apple production area ('000 ha)	142	
Fruit production 1999 ('000 t)	1 500 <sup>a</sup>	300 <sup>a</sup>
Annual rainfall (mm)	400 (West) 600 (East)	
Temperatures	-18° to +40°C	Average: 11.5°C

<sup>a</sup> Estimated

**Table 2.** Fruit tree plantings in Yun Cheng City, 1995.

Fruit type	Variety	Area planted (ha)
Apples	'Fuji'	24 000
	'New Red Star'	4 300
	'Qin Guan'	4 000
Pears		540
Peach		660
Apricot		530
Grapes		660

These objectives were subsequently affirmed in the intermediate stages of the study.

A proposal was presented to the New Zealand Asia Development Aid Foundation, a government organisation within the New Zealand Ministry of External Relations and Trade. After appropriate modifications the project was approved in 1997.

## Methodology

Following funding approval, the New Zealand team visited Shanxi Province and completed an assessment of the current state of the quality systems used for fruit handling. This visit involved inspection of postharvest handling facilities and orchards in four counties in southern Shanxi Province. Discussions took place between the New Zealand team and representatives of the Shanxi Agricultural Development Bureau. As a result of discussions during this visit, specific requests for information, and the objectives of the proposed workshop (phase 4), were established in consultation with the Chinese team (Studman 1997).

In the next phase of the project three representatives of the Chinese counterparts visited New Zealand, and discussed postharvest handling systems with growers, cool-store operators, industry representatives, Crown Research Institutes, and researchers at Massey University. During this period, further discussion took place to define more clearly the nature of the workshop, details of participants, and identification of target groups for the development of the project after the workshop.

In the final phase of the project, the New Zealand team visited Yun Cheng City and presented a five-day workshop to selected representatives of local growers and support industries.

## Project Implementation

### Preliminary visits

The initial visit of the New Zealand team took place in October 1997, and was designed to coincide with the harvesting period. Four counties in the Yun Cheng District were visited (Studman 1997).

During the visits, we spoke to several growers, cool-store operators, and government officials from the Fruit Enterprises Bureau on the problems they are currently experiencing and which they would like further information about during the workshop in 1998. Problems identified included aspects of fruit

production and postharvest handling, quality assurance, export marketing, and finance.

Discussions were also held with Provincial government officials and staff from Yun Cheng District Fruit Enterprises Bureau to assist in formulating the topics to be covered during the workshop in 1998. The topics identified included the following:

- new types of agro-chemicals, application methods and regulatory standards;
- quality standards—what are they?
- equipment and measurement techniques for fruit quality;
- implementation of a quality assurance system—the people involved and their tasks (i.e. organisation framework required);
- the role of research and development (R&D);
- new production and postharvest techniques to assist in meeting export standards;
- pre-cooling and extending storage and shelf life;
- food safety—criteria and measurement; and
- overview of the New Zealand fruit industry—production, postharvest handling, and marketing.

Next the Chinese team visited New Zealand, where delegates were able to meet with a range of people involved in postharvest operations, and to study postharvest facilities and equipment. Due to unavoidable delays, this took place in October 1998, after the results from the previous season in China had been completed. These data indicated that, while production was increasing as expected, returns to growers were falling as a result of oversupply to the market at the peak harvest times. This highlighted the challenges faced by growers, and the need for better domestic and international marketing options. Extensive discussions took place about the nature of the workshop. It was agreed that the workshop would be run with the purpose of introducing the concept of total quality management to growers and support personnel who would be involved in the development of a pilot program based on the Yun Cheng City region.

### Workshop in China

In the final phase of the project, the New Zealand team visited Yun Cheng City and presented a five-day workshop to selected representatives of local growers and support industries. Names of delegates were advised to the New Zealand team approximately three weeks before the workshop. In this way the New Zealand team was able to ensure that a reasonable representation of women, growers, and support personnel were included in the list of delegates. In the end, a total

of 37 people attended the workshop, although most of the time there were 28 persons present including 10 women. The majority of those attending the conference full-time were growers. Support personnel attended various sessions, particularly the sessions at the later stage of the workshop where the critical issues of management, structure and policy were discussed. A variety of training techniques was employed, recognising the nature of the participants. Most of the delegates attended every session for the entire workshop.

In preparation for the workshop, the New Zealand team prepared a workshop manual (Studman and Opara 1999). The key parts of this manual were translated into Chinese. Information received from companies was compiled into an appendix. The manual was given to all delegates at the workshop. As part of the workshop manual, a draft outline of a code of practice was prepared.

At the start of the workshop, growers indicated some concern about the nature of the workshop. It was evident that they required as much technical information from us as possible about ways to improve what they were doing in the orchard. It became evident that if this view predominated, then the growers amongst the delegates would be unlikely to shift their attitudes towards a more market and customer-orientated view of quality. For the first day and a half of the conference the prevailing attitude was that there was too much information being given about postharvest technology, whereas the majority of people present were growers who were really only interested in improving what they did in the orchard. The critical phase of the workshop was reached when we used the 'leaky barrel' model to describe a total quality management system. During this phase, we asked the growers, using a show of hands (5 = excellent to 1 = poor) to indicate their views on the state of various parts of the system for growing, handling, storage and marketing of their fruit. When we asked them to say how good each system was, growers indicated that, on the whole, what they were doing in the orchard was of a reasonably high quality. However, they realised immediately that the postharvest components were lacking. When this was presented to them in the form of the 'leaky barrel' (Figure 1), the message appeared to go home. Subsequently, we were advised by two or three observers that this model had been highly effective in convincing the growers of the need to improve the postharvest component of the system. The leaky barrel was subsequently left displayed in a prominent position for the remainder of the workshop.

It became evident that an important aspect of the workshop was to bring growers on board with the concepts of a total quality management system, incorporating some form of marketing organisation which could handle the development of quality standards for the industry.

Before, during, and after the workshop, discussions took place between the New Zealand team and Shanxi Agricultural Development Bureau representatives. These discussions focused on the continuation of the program and the development of the initiatives started by the project. At the conclusion of the workshop, a summary of the findings and recommendations of the workshop was completed.

## **Evaluation of the Effectiveness of the Training and Technology Transfer**

In order to evaluate the effectiveness of the workshop, delegates were asked to fill in a questionnaire at the beginning of the workshop. This questionnaire attempted to identify the delegates' understanding of quality and quality management systems. At the end of the workshop, the delegates were asked to fill in the same questionnaire again.

In addition, on the first day, delegates were asked to vote on the best definition of the term 'quality'. At the end of the workshop, delegates were asked to vote again. Each delegate was given 10 yellow stickers and invited to place them against a series of suggested definitions of 'quality' which had been provided by suggestions from the delegates and by the workshop organisers. Finally, at the end of the workshop, delegates were asked to indicate how successfully they believed the workshop had met the objectives specified. This was achieved by asking delegates to raise one hand with the number of digits indicating their views. Thus the scale used was 5 = excellent; 4 = good; 3 = reasonable; 2 = not so good; 1 = poor.

Delegates were clearly satisfied at the end of the workshop that the objectives had been achieved (Table 3). For all objectives we obtained a score of around 4 (indicating that we had met the objective well). In addition, in the written survey, almost all delegates indicated that they had learned more about the subjects listed, or now understood the subject well.

From the assessment, it was clear that growers had moved from a view that value for money would be an acceptable definition of quality to a more customer-orientated view. This was the clear aim of the workshop, indicating that we had achieved our

objective in increasing the delegates' understanding of total quality management systems.

### Pre-workshop and post-workshop questionnaires

The results of the pre- and post-workshop questionnaires showed that we achieved a significant shift of opinion about quality and about the key terms involved in the development of quality marketing systems. In all, 26 pre-workshop questionnaires were received. These were coded with stickers so that we could pair the initial survey with the final survey for each person.

Initially, over half the delegates felt that they understood the terms 'maturity', 'ripeness' and 'spray diary' very well. Areas where they felt a need to improve their understanding were with regard to 'quality standards', 'code of practice' and 'quality control'. To a lesser extent, 'total quality management', 'quality assessment methods' and 'food safety' were also areas

of interest, although delegates had some awareness in these areas. At the end of the course almost all delegates responded that they now understood these topics very well, or that they understood them better.

Before the workshop, when asked "Our apples will be best if..." (followed by a list of options), growers identified production features (producing fruit well, using best varieties and using better technology). Twice as many growers indicated that using more chemicals would result in better apples than using fewer. At the end of the workshop delegates ticked many more boxes, indicating that they felt that a multiple answer was more appropriate. The numbers of respondents indicating 'more' and 'less' chemicals was about equal. The highest rated factor was the need for a better quality control system. Almost all delegates marked this choice compared to under half at the beginning of the workshop. Similarly the number of individuals who responded that "the people buying the apples think they are better" was a key factor also doubled.

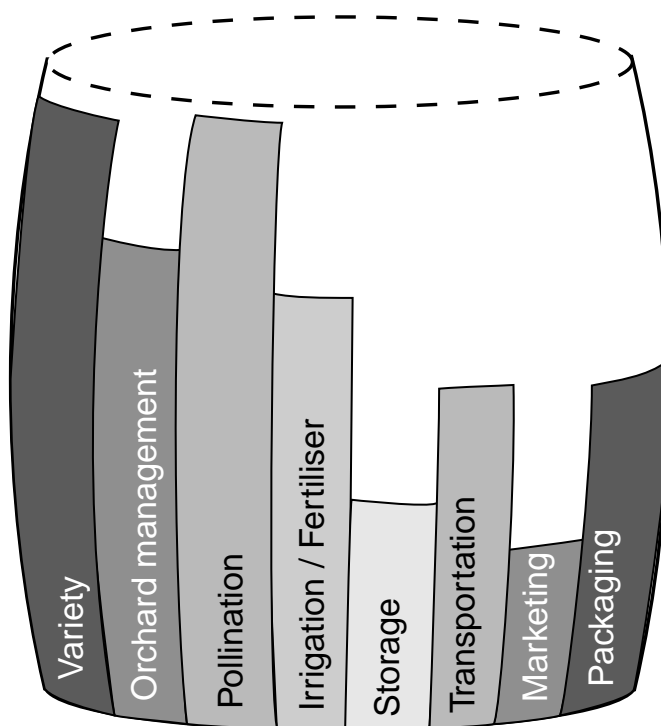


Figure 1. The quality barrel: how much quality will the barrel hold?

**Table 3.** Assessment of how well workshop aims were met, where: 5 = excellent, 4 = good, 3 = reasonable, 2 = not so good, 1 = poor (average estimated by two observers).

Objective	Score
To provide information about pre and postharvest equipment and systems used in New Zealand.	4
To provide a basis for a plan for the development of the project	3.75
To develop the outline for a code of practice for a quality assurance system	4
To improve delegates understanding of quality, and total quality management (TQM)	4.75
To identify steps required to set up a TQM system in the County	4.25
To answer the following requests for information:	
New types of agro-chemicals, application methods and regulatory standards	4
Quality standards—what are they?	4.25
Equipment and measurement techniques for fruit quality	4
Implementation of a quality assurance system—people involved and their tasks (i.e. organisational framework required)	4
The role of research and development (R&D)	4
New production and postharvest techniques to assist in meeting export standards	4
Pre-cooling and extending storage and shelf life	4.25
Food safety—criteria and measurement	4.25
Overview of the New Zealand fruit industry—marketing	3.75

When asked “Where is the best place to start improving the *quality* of our apples?”, a similar response occurred. Initially delegates identified orchard characteristics and activities as being the area in which to improve quality. After the workshop they identified quality control systems, teaching and training, better cool-stores, and a quality research laboratory, higher than the in-orchard features. Again, many more choices were ticked after the workshop than before.

In response to the question “Where is the best place to start to improve the *income* from apples?”, delegates before and after the workshop identified the quality control system as the best place to start. However, afterwards teaching and training were also highly rated. Other aspects of a quality system were also identified by more delegates.

In response to questions on specific subjects, it appeared that more delegates were aware after the workshop that marketing was used. However the shift appears to have been from those who felt that it was already working well to those who felt it could be done better. In response to the questions on quality control, cool chain management, spray diary, controlled atmosphere storage, and food safety, there was a shift to the view that these were in use but could be done better. The change came from delegates who previ-

ously had indicated that they did not know what these terms were.

#### Summary

These questionnaire responses showed that, after the workshop, the attitude of many of the delegates had shifted to the view that it would be possible to do key postharvest operations better. Delegates also indicated that they were better informed, and were concerned that the current system was not working effectively.

### Implementation of a Total Quality Management System

On the last full day of the workshop, a considerable amount of time was devoted to discussion groups among the delegates to identify what would be needed for the introduction of a quality management system for apples in Yun Cheng. Delegates were put into groups of five or six and asked to discuss the question “Could we develop a total quality management (TQM) system in Yun Cheng?” They were also asked to consider how close they were to a system and what would be needed to implement a TQM system. Each group was asked to look at one aspect of the TQM system.

The responses indicated that the delegates had taken on board the ideas and concepts developed in the



workshop. Given the predominance of growers rather than administrative and support personnel, this represented a clear shift of opinion and also indicated an interest and a willingness to adopt the ideas which the Shanxi Agricultural Development Bureau were anxious to achieve. We subsequently learned that the growers had decided to initiate the formation of the Growers' Association, and had arranged the first meeting to take place just 10 days after the workshop. Given that this initiative came from the growers, rather than the Development Bureau, this indicated the extent to which we had achieved a shift in attitude of growers.

At the completion of the workshop, the Chinese team asked us to give our recommendations and views on the implementation of the decisions made at the workshop to establish a cool-store facility and a growers' association in Yun Cheng. These recommendations were conveyed verbally to the Chinese team, and presented in the final report (Studman 1999).

The issues covered were: who will be involved in the grower' association, decisions on the cool-storage system, the quality management system, publicity, marketing, grower association structure, the development of the quality assurance manual, development of appropriate infrastructure facilities, further technical inputs and funding for additional projects, and the future involvement of consultants.

## Gender Issues

In accordance with the sponsor's requirements, our insistence on a minimum of 10 female delegates at the workshop ensured the issue of gender balance was addressed by the Chinese farmers. Although women were in a minority in all areas, nevertheless there were women filling a number of key roles in the infrastructure. In particular, at the district level, one of the key coordinators was involved in the strategic discussions with the Shanxi Agricultural Development Bureau was female. Amongst the growers' representatives, three or four of the women exercised significant leadership roles in the groups. Since delegates attending the workshop will now have a significant role in the formation of the Yun Cheng Growers' Association, we believe the workshop has facilitated and empowered women in leadership roles. It was noted that the initiative for establishing the first meeting of the Growers' Association came from one of the women delegates.

## Discussion

The introduction of total quality management systems to any industry or organisation carries with it some implied basics. One of the key features is the commitment to participation of everyone involved in the organisation. This appears to be particularly fitting for the Chinese system where collective decision-making is a possibility. A further key feature is that quality improvement arises by identifying the current position and attempting an improvement from that position. Therefore the workshop has been effective in committing the delegates to identify improvements which are appropriate to the level of technology which they have already reached.

The initial visit made by the New Zealand team convinced us that implementation of technology from overseas was achievable in the environment within certain limitations. The major difficulty we identified was a narrow focus on quality, largely based on the idea that fruit produced to the top quality in the orchard will therefore be top quality fruit to the customer. Unfortunately this is not the case, since postharvest factors can completely alter the situation. By identifying the need for a systems approach to the problem, the workshop achieved the aim of identifying weaknesses with the current system and seeking to identify ways to move forward from this. The decision to proceed with the program to develop a pilot plant focused around the development of postharvest handling and storage facilities by the Chinese indicates the success of our training.

Inherent in the total quality management approach to the postharvest system for fruit is the recognition that the introduction of technology carries with it the need for equipment maintenance and support. Since the cool-store facility is likely to be developed using Chinese funds and resources, it is evident that ongoing costs are more likely to be funded from local resources.

In our view this project has indeed been an outstanding success. Taken as a whole, our initiative in providing technical input to run the workshop and provide external assistance to the fruit growers in Shanxi Province has resulted directly in the decision to apply for a two million yuan grant to enable the development of cool-store facilities. This in itself will bring about a significant improvement in the quality of postharvest systems in the county. The pilot program will also act as a project capable of wider application when demonstrated to be successful.

Our workshop has also been instrumental in convincing growers of the need for a growers' association in Yun Cheng. This organisation has the potential to be a marketing body for the growers, thereby ensuring a united front in marketing their produce. The importance of apples and other fruits as a developmental tool in the region is readily apparent from discussions and observations in the area. Significant redevelopment is taking place, and extensive rebuilding and prosperity has come to the region. The return from apples has been extremely good, giving growers a three or four-fold increase in profits per unit area of land. While the fall in price for fresh fruit in October/November 1998 has dampened the enthusiasm somewhat, our workshop and the suggestions for ways of increasing the return through good postharvest handling systems has given the delegates some refreshed enthusiasm for fruit growing.

It was evident from the emphasis on a final signing ceremony, and the importance attributed to written findings from the workshop which indicated the potential for external technical assistance, that the value of our input could not be underestimated. It is evident that the Chinese side is extremely dependent on continued inputs of technological assistance from outside China. Our willingness to be involved in the long-term in this project was paramount to the success of the program.

## Conclusions and Recommendations

- The project met and exceeded its aims.
- The workshop and our involvement with the Shanxi Agricultural Development Bureau have resulted in the Chinese counterparts wishing to commit significant in-country funds to the project's development base.
- We have provided a framework for the introduction of a total quality management system amongst growers in Yun Cheng City. This system has given leads and guidelines for the introduction of technical, institutional and developmental improvements.
- Gender issues have been addressed successfully in this project.
- The involvement of the Shanxi Agricultural Development Bureau, the China Agricultural University, and Massey University has resulted in an increased understanding between these three groups. We believe we have laid the foundation for a continued interaction and collaboration for a long-term program of technical assistance in the

development of postharvest systems in Shanxi Province.

The main recommendations were as follows:

- Formation of a growers' association to focus on developing a quality management system for apples (already actioned). Establishment of a marketing effort was identified as a key task of the association.
- Development of additional cool-storage facilities (Chinese proposal supported and submitted).
- Further proposal to extend the project, with the continued involvement of the New Zealand team in assisting with the development of facilities, postharvest systems and the quality management program.
- There is a need for research, testing, and advisory systems to be established to enable growers to make continuous improvements to their pre and postharvest systems.
- Further international technical assistance is still required, both in the short and long term.
- The workshop was most successful and could be repeated with other groups in China and elsewhere.

## Acknowledgments

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## References

- Studman, C.J. 1997. Postharvest systems in Shanxi Province, China. Report to the Ministry of Foreign Affairs and Trade, New Zealand. Palmerston North, Massey University, Centre for Postharvest and Refrigeration Research.
- Studman, C.J. 1999. Fruit quality improvement in Shanxi Province, China. Report to the Ministry of Foreign Affairs and Trade, New Zealand.
- Studman, C.J. and Opara L.U. 1999. Fruit quality management workshop manual, volume 1, English version. Palmerston North, New Zealand, Massey University, 108p.

# New Market-pull Factors Influencing Perceptions of Quality in Agribusiness Marketing (or Quality Assurance for Whom?)

L.U. Opara\*

## *Abstract*

The term 'quality' is elusive and connotes different meanings to different people. Quality is also dynamic and reflects both time and position in the entire food supply chain. The producer, handler/marketer, consumer, and other stakeholders have both influences and perceptions on product quality. There is also a product-oriented definition of quality. In many developing countries, it is a commonly held view that importers from developed countries usually wanted it all their own way by defining both the quality required and the price to be paid. In this paper, we will review the different orientations of quality, including the emerging influences of sustainability of production systems and genetic modification, and the implications on export marketing of agricultural produce from developing countries.

INTERNATIONAL TRADE in fresh agricultural (and horticultural) food products has expanded tremendously during the past decade. This trend has been spurred on by changes in food consumption patterns, particularly in the developed economies in Europe and the United States of America (USA). Consumers are increasingly eating to express their personal values, concerns and aspirations. Consumers also want assurances on freshness, taste, safety/traceability, health/nutrition, animal welfare, sustainability/environment impacts, zero waste, and fair trade. These factors contribute to the overall perception of 'quality'. More than before, the quality of fresh agricultural produce has come under considerable scrutiny by consumers and the general public. Both producers and marketers face the challenge of balancing profitability with increasing customer demand for high quality products backed by a consistently reliable support service.

The increasing global demand for fresh fruits and vegetables creates opportunities for many developing countries, which produce a range of tropical and sub-tropical products. However, to participate com-

petitively in the growing and marketing of fresh food products, appropriate quality assurance (QA) must be developed and implemented to meet customer expectations. This requires a good understanding of (a) the international trends and challenges in agribusiness marketing; (b) the various perceptions of 'quality' throughout the entire chain; and (c) the market-pull (demand/consumer) factors influencing these perceptions. The objective of this paper is to discuss these global trends and perceptions of quality in relation to the development of QA systems.

## **Globalisation and Current Trends in Fresh Food Consumption**

Global trade in fresh fruits and vegetables has increased steadily during the past decade. Changing market trends and innovative industry management have characterised this era, and will continue to influence the way fresh commodities are supplied. Greater labour mobility and demographic shifts in major metropolitan areas have resulted in the introduction of new fresh food products and changing food patterns, particularly where new immigrants are higher consumers of fresh fruits and vegetables. This opens up further opportunities for international trade

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in both tropical, subtropical and temperate fruits and vegetables.

Several global trends in business will continue to impact on current and future global agribusiness marketing, including:

- increasing competition;
- legislative and regulatory demands;
- speed of economic change;
- rapidly changing information and communications technology; and
- global sourcing and strategic alliances.

Rapid growth in information and communications technology, and the unrelenting surge in the use of the Worldwide Web, have led a single, highly networked world, affecting the way we access data and technical information for production, handling and marketing of products. The General Agreement on Trade and Tariffs (GATT), formation of regional trading blocs, and increasing influence of the World Trade Organization (WTO) have facilitated the expansion of international trade in horticultural and agricultural products. The increase in global fresh commodity trading during the past decade is exemplified by the steady increase in the export and import of horticultural products in the USA, a trend that is forecast to

continue (Tables 1 and 2). This trend is also matched by an increase in fresh fruit and vegetable consumption for the past three decades, rising from 257 kg per person in 1970 to 307 kg per person in 1993 (Anon. 1996).

The rise in fresh fruit and vegetable consumption (ranked #7) is one of the top 10 'mega-trends' in food consumption patterns (Sloan 1996). Particularly critical also is the popularity of 'fresh' as the most desirable food label (ranked #5). The quality and variety of (i) fresh fruits and vegetables and (ii) fresh meat ranked second and third, respectively, right behind a clean store, as the reasons consumers elect to shop in a grocery store. This study further noted that the emerging trend for organic foods was yet to reach its full potential (Sloan 1996). Increasingly, consumers are eating to express their personal values, concerns and aspirations. Consumers also want assurances on freshness, taste, safety/traceability, health/nutrition, animal welfare, sustainability/environment, zero waste, and fair trade. These trends in food consumption patterns, coupled with the overwhelming desire for convenience, provide a powerful driving force behind food production and international agribusiness marketing.

**Table 1.** Exports of fruits and vegetables from the United States of America (US\$1,000). (Source: Brown 1996.)

Year	Fresh fruits	Fresh vegetables	Processed fruits and vegetables
1989	356 015	1 134 657	1 000 616
1990	728 648	1 486 489	1 246 753
1991	832 935	1 561 053	1 394 490
1992	899 624	1 683 344	1 558 121
1993	985 953	1 707 147	1 639 583
1994	1 046 789	1 953 767	1 720 891
1995	1 068 572	1 972 864	1 906 561

**Table 2.** Imports of fresh and processed fruits and vegetables into the United States of America (US\$ million). (Source: Brown 1996.)

Year	Fresh and processed fruit	Fresh and processed vegetables
1989	1 820	2 047
1990	2 219	2 266
1991	2 131	2 214
1992	2 216	2 184
1993	2 037	2 450

## Strategic Trends in Agribusiness Marketing and Impacts on Quality Management

Agriculture (and horticulture) is a dynamic industry. Over the past century, we have witnessed the evolution from production-focused agriculture (basic family food supply) to market-oriented agribusiness. Agriculture (including farming) is radically changing to fewer, larger, more sophisticated firms with growing global influence. Competition is shifting to exclusive, shorter, higher technology, higher integrity supply chains, with increasing power of supermarket chains. For instance, global corporations such as Dole, Del Monte, and Chiquita dealing with fresh foods, as well as highly successful marketing cooperatives (such as ENZAFRUIT and ZESPRI in New Zealand), are increasingly expanding their global network so as to increase their market share and provide year-round supply of commodities.

These firms are increasingly applying the concept of 'supply chain management' to the production and delivery of products and services worldwide (Lummus and Vokurda 1999). Global interest in supply chain management has increased steadily since the 1980s as a result of the realisation that collaborative relationships within companies and beyond their own organisations was beneficial. This concept involves managing supply and demand, sourcing raw materials and/or products, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer, and the information systems necessary to monitor all these activities. Supply chain management coordinates and integrates all these activities into a seamless process to ensure that the following conditions are met in the production and handling of agricultural produce:

- use of uncontaminated raw materials;
- clean growing and harvesting conditions;
- specification of product attributes;
- cool-chain control and maintenance;
- commitment to regulatory protocols;
- evidence of an agreed quality assurance (QA) system; and
- use of Good Agricultural Practice (GAP) and application of internationally recognised quality food safety programs such as Hazard Analysis and Critical Control Points (HACCP).

## What is Quality?

The use of superior product quality as a competitive weapon is widely recognised and documented (Garvin 1984). Although the quality of both product and service is widely recognised as important for successful agribusiness, there is often a lack of understanding or agreement on the meaning. This has resulted in a plethora of definitions of quality, often reflecting the type of product, stage in the postharvest handling chain, or the intended use (Botta 1995; Abbott 1999; Shewfelt 1999; Bremner 2000).

Quality is a concept and is dynamic; and thus there is no single, brief, consistent, and universally accepted definition. Shewfelt (1999) argued that the primary dividing line between differing concepts of quality is orientation. Producers, researchers and handlers are mostly product-oriented, in that quality is described by specific attributes of the produce (such as firmness or colour), while consumers, marketers and economists are more likely to be consumer-oriented in that quality is described by consumer wants and needs. Plausible as these viewpoints may sound, particularly in relation to commercial needs, Abbott (1999) argued that it is difficult to divorce the two viewpoints and viewed quality in terms of instrumental or sensory measurements of product attributes that combine to provide an estimate of customer acceptability.

With respect to agricultural and horticultural products, quality involves all of the attributes, characteristics, and features of a product that the buyer, purchaser, consumer, or user expects. A product with excellent quality clearly meets the buyer's or user's highest expectations. Kruihof and Ryall (1994) provide a succinct and definition of quality applicable to agribusiness: "Quality is consistently meeting the *continuously* negotiated expectations of the customer and other stakeholders in a way that represents value for all involved". In practical terms, the customer wants the right product, at the right time, at the right price, and with the right support! The quality of an agricultural/horticultural product is assessed from the relative values of several characteristics which, considered together, will determine the acceptability of the product to the buyer and ultimately the consumer

Developing a good understanding of quality concepts is necessary before strategic marketing issues can be adequately addressed. The orientation of quality adopted will undoubtedly influence the quality standards (product specifications) and techniques used to assess quality. It could also create barriers to quality improvement (Shewfelt 1999). In this respect, the

dynamic nature and non-specificity of quality must be kept in mind.

## Dimensions of Quality

Recognition of the fact that quality is not a single, recognisable characteristic poses a considerable challenge for organisations. Garvin (1984) argues that what is needed is a synthesis of the various definitions and approaches to quality, based upon a careful separation of the various elements of quality. The author suggested the eight dimensions of quality defined in Table 3, stressing that each dimension is self-contained and distinct, for a product can be ranked high in one dimension while being low in another.

Each dimension of quality imposes different demands on the business, and the implication is that the companies should carefully define the dimensions of quality in which they hope to compete, and should then focus their human and capital resources on these elements. Using examples from the automobile and other manufacturing industries, Garvin (1984) showed that a firm is likely to be more successful in pursuing a strategy of high product quality if it selects a small number of dimensions in which to compete, and then tailor them closely to the needs of its chosen market. These principles are equally applicable to agribusiness marketing.

O'Mahony et al. (1994) outlined other general points about 'quality' based on the literature which may be readily applicable to the agricultural and horticultural industry:

- consumers respond to differences in product quality and service; and
- producing higher quality product reduces rather than increases production costs in that labour is able

to concentrate more consistently on higher standards.

With respect to profits, Farris and Reibstein (1979) showed that marketers who inform consumers about quality differences in their product attract higher prices than those who depend on high quality to communicate itself to consumers.

## What is Quality Assurance?

Modern agricultural/horticultural producers and exporters recognise that quality is the most important factor for success in the international free trade, and the main difference between very demanding consumers and others is their insistence on quality product and service (Patnaik 1996). As consumers demand and expect higher and consistent quality/safe fresh food products, growers, handlers and others in the marketing chain must respond to maintain their market share. This requires the development and implementation of quality management systems to reduce variability and maintain quality at all steps in the postharvest chain. These management systems enable to grower to respond to the ever-changing and often conflicting demands of consumers, who are increasingly demanding greater consistency in supply and quality, as well as safety and traceability.

Traditional quality management practices involving product inspection (for finding and removing defects) and quality control systems (for reducing defects) are no longer sufficient to meet the consumer requirements. A fundamental principle underpinning modern approaches to quality management is the need to manage the process, not the output. Consumers paying a premium for quality need the assurance that the product specifications and other criteria have been met. Many global suppliers of fresh produce

**Table 3.** Dimensions of product quality. (Adapted from Garvin 1984.)

Dimension	Explanation	Possible application to fresh fruits and vegetables
Performance	Primary product characteristics	Firmness, colour, sugar
Features	'Bells and whistles'	Packaging, labelling
Reliability	Frequency of failure	Both in supply and product characteristics
Conformance	Match with specifications	Variability
Durability	Product life	Storage and shelf life
Serviceability	Speed of repair	Speed of recall or replacement
Aesthetics	'Fits and finishes'	Presentation, display
Perceived quality	Reputation and intangibles	Quality assurance system

acknowledge food safety guarantees as the single biggest issue for consumers (Marks 1999). As a result, retailers want not only documentation of every aspect of growing and delivery regimes, but also want demonstrated and audited efficacy of labour practices, energy conservation or community contributions (Marks 1999). In addition to the consumer, there are other influential stakeholders who have shown interest in the way we grow and market agricultural products. In a recent article on securing market access, Chandler (1999) argues that it is no longer the customer that needs to be sold, but rather the government, consumer groups and public perception itself.

Quality assurance (QA), therefore, involves those planned activities designed to consistently satisfy customer expectations by defining objectives, planning activities, and controlling variability. Leamon (1989) defined QA as all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy stated or implied needs. Obviously, this requires the systematic interaction of products, services, processes and people. An effective QA system ensures that the quality of the inputs (resources, staff, aims and intended outcomes) and the quality of the process (grading, handling and marketing) are well planned and managed. The intended output quality (product specifications) must be agreed upon from the outset and not imposed or manipulated at the end of the chain. Ultimately, the success of any QA scheme is dependent on the integrity of the auditors who conduct the QA assessment or verification (Lewis-Jones 1998).

Several factors have been identified as important in the development process for QA in horticulture (Leamon 1989):

- definition of quality specifications for the product;
- development of quality control procedures and recording system;
- documentation of the first two points with photographic interpretation in a product quality manual and training material;
- documentation of 'typical' process flow charts and hazard analysis—these are incorporated in a 'model QA manual' which can be used as an example for people unfamiliar with QA; and
- development of training programs for people involved in controlling quality, e.g. pickers, packers and quality controllers.

Legge (1998) discussed four preconditions for successful QA, namely:

- clearly set objectives which are part of the corporate philosophy, ensuring that QA staff cannot agree to short-term expedients which may damage long-term growth;
- a strategic plan incorporated into commercial objectives;
- use of all available tools; and
- an adequate number of suitably trained staff.

It was considered that the most important factor of all these is that QA staff must be an integral part of a buying/selling team.

Implementing a QA program brings several obvious benefits to the grower, marketer, consumer, and other stakeholders including (LRQA 1999):

- better management control;
- improved producer – supplier – consumer relationships;
- less waste and lower costs;
- greater staff motivation and reduced staff turnover; and
- improved customer satisfaction.

QA plays an important role in the maintenance of quality at all levels and tolerances acceptable to the consumer. With respect to international agribusiness marketing, QA and quality standards play a crucial role in creating confidence and ensuring the delivery of consistent quality and safe products. It must therefore be considered as a science and not an art. It is not based on individual personal judgement, but on statistically treated physical, chemical, microbiological and sensory measurements (Askar and Treptow 1993). QA considerations and procedures must be applied at all stages in agricultural production, including procurement of planting materials and extending to all steps in the postharvest chain, with the main emphasis on creating the conditions that lead to the satisfaction of consumer needs and want. QA acknowledges that fixing a quality defect after it has occurred is either very difficult or very costly (Andrews 1999).

## Quality Assurance for Whom?

The production and handling of fresh fruits and vegetables is an integral part of the global food manufacturing industry. Unlike other manufacturing industries, such as automobile and electronics, the agricultural and horticultural industry is characterised by huge variations in growing conditions, which also contribute to considerable variation in product quality. Improper control of the numerous postharvest conditions (such environmental temperature, relative

humidity and packaging) and differences in staff performance at each stage in the chain create additional variations which exacerbate the quality variability problem. Therefore, the importance of QA covering all aspects of the production and distribution chain cannot be overemphasised. However, given the various orientations and dimensions of quality discussed above, and the considerable influence of many stakeholders (Chandler 1999), one could ask the question: QA for whom?

Earlier in this paper, I highlighted some trends affecting agribusiness and consumption patterns. Globalisation, changing technology and the increasing impact on the production and marketing of products, increased international competition, international trade agreements, and the increasing consumer demand for consistent high quality products are some of factors forcing growers to re-examine the way they do business. Put together, these factors create push-pull factors that influence the perception of quality as well as the strategy for agribusiness marketing. To meet the challenges posed by these global trends and remain profitable, we are now witnessing a paradigm shift from technology-push (oriented towards the product, output/yield, producer, supply-driven) to market-pull (consumer, attitudes, demand-driven) in agribusiness.

### **Market-pull Factors Influencing Perceptions of Quality**

The successful fresh food supply chain will become an increasingly complex web, resulting in mutual relationships between the producer, marketer and consumer to meet new consumer demands. The new market-pull factors (new demands) include (Hughes 1994; Hofstede et al. 1998):

- high quality and safe products;
- environmental and ecological sustainability considerations in production and distribution;
- animal welfare considerations;
- products in broad assortments available year-round;
- short lead times (fresh products!); and
- competitive prices.

These factors have resulted in increasing product differentiation and customisation to satisfy consumer demands for health/nutrition, safety, organics/naturalness, labelling, ecological/environmental responsibility, social responsibility, and a peace of mind! Let me comment briefly further on safety and

organics, two factors which have become increasingly influential quality factors in fresh food marketing.

### **Food safety**

Unfortunately, fresh food products such as eggs, beef, chicken, milk, pork, fruit and vegetables have one thing in common: pathogens. This is exacerbated by some agricultural practices (such as spreading animal slurries and human faeces as manure) and poor sanitation and inappropriate postharvest handling practices. Recent fresh food poisoning incidents around the world have resulted in crises of confidence in the food supply chain. Food safety has come under the spotlight and is now the single biggest issue for consumers. Fresh fruits and vegetables, meat, eggs and chicken have been implicated with pathogens, which pose health risks to humans. *Campylobacter* in chickens, *Mycobacterium paratuberculosis* in milk, *Salmonella* in poultry and eggs, and the link between bovine spongiform encephalopathy (BSE) in cattle and new variants of Cruetzfeldt Jacob disease (CJD) in humans are some of the potential safety hazards in our food chain.

Although the incidence of food-related illnesses from direct consumption of raw fruits and vegetables is low, the risks are real. The potential for high pesticide residue levels on produce and the discovery of newly emerging pathogens present further problems for the fresh food industries (Andrews 1999). Many countries have passed new, stringent food safety laws, and set up new food safety agencies to develop policy and implement strategies to ensure public confidence in the food chain. In addition to reducing the incidence of food-related illnesses and death, these actions will also reduce the costs to the public health system and increase labour productivity.

Despite the above actions of some governments around the world, many consumers have generally lost confidence in the ability of governments to protect public health and of science to understand the nature of some of the food problems (McKechnie 1997). This focuses attention on producers, the fresh food industry and retailers. As consumers demand action and answers, there is no indication that this pressure will reduce in the near future especially as the debate over genetically modified foods continues (Halford 1999). Increasing transparency, traceability and assurance have become the norm in modern agribusiness enterprises.



## Organics—a new quality attribute

Increasing public interest in environmental sustainability and our changing lifestyles have raised concern about current farming practices and raw material inputs. These interests have been championed by very powerful political and social interest groups such as the Green Party in New Zealand, Greenpeace, and the Society for the Prevention of Cruelty to Animals (SPCA). The increasing awareness and support of these environmental and animal welfare philosophies has created a new demand for 'organic' food products. For some consumers, 'organic' equates with 'farm fresh', and represents a critical quality attribute. The increasing demand for organic products and the premium prices they command in the marketplace are very significant trends that cannot be ignored by growers and marketers of fresh foods.

To illustrate this growing influence of organic fresh foods in the global agribusiness, let us consider the data from the USA showing dramatic sales increases in recent times. Currently, organic foods account for less than 1% of all food sales, with over 20% annual growth over the past 6 years. It is projected that organic sales will double from \$3.7b in 1997 to \$7.2b in 2000 (Stauffer 1999). A recent survey showed that 60% of all Americans are either consumers of organic foods or interested in these products (Sloan 1998). Increasing concerns about food safety, wholesomeness and genetic modification are converting erstwhile cynics into believers in organic fruits, vegetables and meat products.

The 'organic wave' has also been noticeable in many other parts of the world, including New Zealand. Newspaper headlines such as "Farmers urged to ride Europe's organic meat wave", "Organic apples growers' hope", and "Organic apples sweet" are typical. Over the past three years, organic apples represented 1.5% of the 15.5 million apple cartons exported through ENZAFRUIT International, with 30 of New Zealand's 1,600 export apple growers making the switch to organic. Premium returns up to 30% over conventional fruit were recorded over the same period (Sheeran 1999). One Hawke's Bay organic apple grower earned a gross return of NZ\$109,231.00 per ha, earning NZ\$39.88 per carton compared with growing conventional apples which would have earned him NZ\$39,000.00 per ha, at NZ\$14.10 per carton. Organic meat could demand a premium of 20-40% (lamb), 100% (beef), 200% (pork) and 300% (chicken), reflecting the difficulties in producing these animals organically (Anon. 1999). The three years of

transition from conventional farming to gain organic certification represents loss in production over that time, and growers need to be aware of this.

## Implications of QA for Least Developed Countries

Many developing countries cannot participate in the growing international and regional trade in fresh produce due to a lack of appropriate postharvest techniques, and inadequate infrastructure and marketing systems. Numerous smallholder farms, often less than 2-3 ha and scattered in many locations, pose special problems in forecasting product supply and managing variability. Agriculture in these countries is still at subsistence level, with limited scope for market-oriented production. With stringent quality and phytosanitary requirements in an international market dominated by a few large companies and marketing cooperatives, small-scale farmers in developing countries face huge difficulties to compete favourably.

Most developing countries suffer trade deficits on fruits and vegetables (Hutabarat 1989). However, there is a large number of crops in these countries which bear edible fleshy parts or nuts of acceptable quality and which have considerable economic potential as international commodities (Menini 1991; Wood and Payne 1991). As the production and marketing of the traditional tropical and subtropical fruit crops come under pressure due to increasing supply and over-supply and declining profits in some regions or seasons, there is a need to develop suitable postharvest technologies and quality management systems for the production and marketing of these lesser known crops which have food potential. Improving quality control and implementing QA systems will enable these developing countries to derive benefits from these crops by trading competitively in the lucrative global trade in fresh commodities. The domestic market could also benefit from the improvements to quality standards and development of QA systems.

Certain socio-cultural factors must be considered in developing quality management systems in these developing countries. For instance, horticultural production and marketing follow a clearly-defined gender line in many places, with women predominantly engaged in vegetable production and marketing, while the men are active in fruit production. Religious beliefs and cultural taboos cannot be ignored as these may impact on the adoption and continued use of

appropriate postharvest technology and the successful implementation of QA techniques.

Where export marketing is pursued, growers must participate in setting the quality standards, and receive financial incentives (higher price) to raise quality. Personal experience of the author in the development of horticultural export marketing in Mali under a World Bank Project, showed that many small-scale farmers feel powerless and believe that importers want it all their way by setting quality standards as well as the product price. Efforts to assist these countries must equip them with the tools of QA and the marketing skills to derive the benefits of improvements in product quality.

## Conclusions

Globalisation, competition in international trade in fresh food commodities, changing food consumption patterns, and increasing consumer-orientation of quality are challenging the traditional perceptions of quality. These create strong market-pull influences such as food safety, organics and personal attitudes as important new quality factors in agribusiness marketing. QA systems are necessary to demonstrate transparency, traceability and assure quality of the product and other consumer expectations. These new market-pull factors pose considerable challenges for developing countries which have limited postharvest infrastructure and inadequate QA systems. In order to meet existing international quality standards so as to participate favourably in the competitive international trade in fresh commodities, postharvest technology transfer to developing countries must include the skills to develop and implement appropriate QA systems.

## References

- Abbott, J.A. 1999. Quality measurement of fruits and vegetables. *Postharvest Biology and Technology*, 15, 207–225.
- Andrews, G. 1999. Research priorities in food quality and safety. *Food Science and Technology Today*, 13(3), 156–158.
- Anon. 1996. *Agriculture facts book 1996*. Washington, D.C., United States Department of Agriculture, Office of Communications.
- Anon. 1999. Farmers urged to ride Europe's organic meat wave. *Evening Standard*, 26 May, p11.
- Askar, A. and Treptow, H. 1993. *Quality assurance in tropical fruit processing*. Berlin, Springer-Verlag.
- Botta, J.R. 1995. *Evaluation of seafood freshness quality*. New York, VCH Publishers.
- Bremner, H.A. 2000. Toward practical definitions of quality for food science. *Critical Reviews in Food Science and Nutrition*, 40, 83–90.
- Brown, M.W. 1996. Postharvest—essential for successful export marketing of horticultural products. Paper presented at the South Pacific Regional Workshop on Postharvest Handling and Export Marketing of Fresh Commodities in the South Pacific, Nuku'alofa, The Kingdom of Tonga.
- Chandler, N. 1999. Securing market access. *The Fifth Quarter. Meat and Livestock Australia Co-Products Newsletter*, October, 2–3.
- Farris, P.W. and Reibstein, D.J. 1979. Low prices, and expenditure and profits are linked. *Harvard Business Review*, Nov–Dec, 173–184.
- Garvin, D.A. 1984. Product quality: an important strategic weapon. *Business Horizons*, 27(3), 40–43.
- Halford, N.G. 1999. Dr Frankenstein I presume? *Food Science and Technology Today*, 13(2), 66–67.
- Hofstede, G.J., Trienekens, J.W. and Ziggers, G.W. 1998. The strawberry chain. In: Ziggers, G.W., Trienekens, J.H. and Zuurbier, P.J., ed., *Proceedings of the 3<sup>rd</sup> international conference on chain management in agribusiness and the food industry*. Wageningen, The Netherlands, Management Studies Group, Wageningen Agricultural University, 76–85.
- Hughes, D. 1994. *Breaking with tradition: building partnerships and alliances in the European food industry*. Wye, Wye College Press.
- Hutabarat, B. 1989. Issues and strategies for developing Indonesian horticultural subsector. *Indonesian Agricultural Research and Development (IARD) Journal*, 11, 5–15.
- Kruihof, J. and Ryall, J. 1994. *The quality standards handbook: how to understand and implement quality systems and ISO 9000 standards in a context of total quality and continuous improvement*. Melbourne, The Business Library.
- Leamon, K.C. 1989. Introducing quality assurance into Victorian horticulture. In: Beattie, B.B., ed., *Proceedings of the Australian conference on postharvest horticulture*, Gosford, New South Wales Agriculture and Fisheries. The Australian Institute of Agricultural Science, 335–338.
- Legge, A. 1998. Quality assurance—the driving force. In: Stenning, B., ed., *Quality assessment for the fresh produce market. Conference proceedings, Postharvest Convention, Silsoe College, Cranfield University, Bedford, United Kingdom*, 2–3.
- Lewis-Jones, C.A. 1998. Quality assurance assessment. *The Pig Journal—Proceedings Section*, 41, 99–104.

- LRQA (Lloyd's Register Quality Assurance) 1999. Global change. *Quality Progress*, 32(10), 25.
- Lummus, R.R. and Vodurka, R.J. 1999. Defining supply chain management: a historical perspective and practical guidelines. *Industrial Management and Data Systems*, 99, 11–17.
- Marks, T. 1999. Innovation lifeblood for kiwifruit growers, but food safety critical too. *Zespri News*, 30 (June 21), 2–3.
- McKechnie, S. 1997. Biotechnology—meeting consumer concerns. In Davies, W.P. and Harrison, S., ed., *Advancing biotechnology—prospects for agriculture and the food industry*. United Kingdom, Eye Press, 69–81.
- Menini, U.G. 1991. Potential and issues for collaborative action on tropical fruit research and development. *Chronica Horticulturae*, 31(3): 38–89.
- O'Mahony, R., Lucey, D.I.F. and Cowan, C. 1994. Aspects of quality management in the pigmeat chain. In: Hagelaar, G., ed., *Management studies and the agri-business: management of agri-chains*. Wageningen, The Netherlands, Department of Management Studies, Wageningen Agricultural University, 307–319.
- Patnaik, G. 1996. Quality is the key to success. In: *International fruit world*. Switzerland, AgroPress Inc., 59.
- Sheeran, G. 1999. Organic apples growers's hope. *Sunday Star-Times*, 22 May, pE1.
- Shewfelt, R.L. 1999. What is quality? *Postharvest Biology and Technology*, 15, 197–200.
- Sloan, A.E. 1996. The top 10 trends to watch and work on. *Food Technology*, 50(7), 55–71.
- Sloan, A.E. 1998. Organics: grown by the book. *Food Technology*, 52(3), 32.
- Stauffer, J.E. 1999. Organic foods. *Cereal Foods World*, 44, 677–680.
- Wood, B.W. and Payne, J.A. 1991. Pecan—an emerging crop. *Chronica Horticulturae*, 31(2), 21–23.

# Rice Quality Management— Principles and Some Lessons

M.A. Bell, R.R. Bakker, D.B. de Padua and J. Rickman

## *Abstract*

As economies in the region grow, the demand for higher quality rice increases. In many countries, however, the quality of milled rice is low due to inappropriate management techniques in all aspects of grain handling, including harvesting, threshing, drying and milling. So far there has been little emphasis on quality management in the postproduction sector, and many key players are not aware of the general principles for maintaining grain quality. These principles are simple in essence as they largely relate to management of grain moisture content throughout the postproduction system. For example, grain quality can be improved by mechanical threshing at 20–24% moisture content (MC) to prevent grain damage, by timely drying down to 14% MC to minimise grain spoilage, and by avoiding reabsorption of moisture during storage to prevent fissuring. If these principles were applied on a broader scale, large improvements in grain quality could be accomplished irrespective of the technology involved. While quality management programs can increase awareness and bridge knowledge gaps, there is often a lack of incentives among key players in the postproduction system to consider quality. In this paper, four examples are given of the types of knowledge and incentive gaps that often restrict grain quality improvement in the postproduction system. These examples are taken from Thailand (threshing), Cambodia (milling), and the Philippines (drying and grading), and are helpful in identifying the critical intervention points for a grain quality management program.

AS economies grow throughout the Asian region—albeit with the downturn of 1998—consumer markets are increasingly demanding higher quality rice. Throughout Asia, national laboratories have been established that evaluate the quality of produced grain. These laboratories, however, do not reveal where opportunities for quality improvement lie: at most they provide an indication of the cumulative errors that are made through the entire postproduction system (PPS). The emphasis on quality evaluation rather than management is perhaps related to the fact that so far, research on PPS has focused largely on evaluation of quality characteristics (including studies relating to separate system component effects on quality), while management of grain quality throughout the entire postproduction system has received little attention. This can be illustrated by a recent literature search performed by the authors. Starting with over 110,000 articles on rice, a sequential use of keywords narrowed

the selection down to 1,097 articles on rice grain quality (Table 1). This search revealed that only 10 of these papers dealt with grain quality management (i.e. 0.26% of the literature on rice quality), and that 5 of these papers were available in Japanese, 3 in English, 1 in Spanish, and 1 in Chinese. In addition, a literature search on specific keywords such as water, fertility, nutrition, pests etc. in relation to quality resulted in little additional information on management aspects that affect rice quality. In comparison, a search for specific PPS technologies found several hundred references for each technology. With so little emphasis on quality management, many players in the postproduction sector are not fully aware of the key principles that affect grain quality.

## **Key Principles of Grain Quality— Moisture Management**

Although there is a general dearth of literature on quality management, the key principles of grain

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quality management can be gleaned from some of the individual component technology work. These principles are relatively simple as they largely relate to the management of grain moisture content (MC) during harvesting, handling and processing (Table 2). For example, rice grain quality can be maintained by reducing the variability of MC at harvest time (e.g. uniform crop stand and timely harvest), by mechanical threshing in the 20–24% MC range, and by timely drying down to 14% to minimise grain spoilage and to ensure safe storage and milling. Quality can be further maintained by using appropriate drying rates and temperatures, and by limiting reabsorption of moisture during drying and storage. While these principles are generally recognised by those involved in PPS research, the appropriate question is how they can be applied to the entire PPS. As mentioned by De Datta (1981) almost two decades ago, attempts that have been made to improve rice processing have often not focused on the total system, but have taken a piecemeal approach resulting in little impact on rice quality. It is important to consider the entire postproduction operation and its various players as a system—an approach taken in most temperate climate rice-growing countries.

### Quality Management Applied to the Postproduction System

In the traditional sense, a quality management program refers to a set of guidelines or procedures that one decision-maker (e.g. the manager of a processing facility) can follow in order to improve or maintain quality. Utilisation of a quality management program also assumes that the decision-maker has ample motivation to maintain quality in order to maximise his profits, and sufficient knowledge of, or access to, management techniques that will improve quality should there be a problem. If quality management is to be applied to the rice PPS in Asia, however, then it is important to consider:

1. the large number of decision-makers typically involved in postproduction, their respective roles and relative incentives to consider quality; and
2. the level of knowledge or access to appropriate management practices of each decision-maker in the postproduction chain to maintain quality.

**Table 1.** Results of a literature search on rice grain quality.

Topic/keywords	Number of relevant records
<b>Rice quality management</b>	
Rice	111 309
Rice + Quality	3 920
Rice + Quality + Grain	1 097
Rice + Quality + Grain + Management	10
<b>Rice quality management and individual components</b>	
Rice + Quality + Grain + Nutrition or Fertility	6
Rice + Quality + Grain + Water	6
Rice + Quality + Grain + Pests	0
Rice + Quality + Grain + Insects	1
Rice + Quality + Grain + Diseases	1
<b>Individual components and moisture content (MC)</b>	
Harvest	878
Harvest + MC	31
Threshing	231
Threshing + MC	0
Drying	1375
Drying + MC	55
Storage	1 988
Storage + MC	47
Milling	815
Milling + MC	26

Source: Rice Bibliography, International Rice Research Institute (IRRI), accessible on the Internet at <http://ricelib.irri.cgiar.org/>

### Postproduction Chain—a Series of Opportunities for Quality Loss

Starting with a certain grain quality level at harvest time, subsequent practices in postproduction can only lead to losses in quality, or at best maintenance of quality (with the exception of some parboiled varieties). Thus, the objective of a grain quality management program or campaign should be to minimise quality and quantity losses at each and every point in the PPS. Although the number of decision-makers that handle grain and affect grain quality varies throughout the region, multiple parties are involved in grain handling from producer to consumer. For instance, in

the Philippines, up to eight different groups can be distinguished that each have their own role in grain handling, from harvesting by the farmer to the purchase and preparation by the consumer (Table 3). The postproduction system in Asia is further complicated by the highly fragmented nature of rice production. For example, in one village in Laguna Province, the Philippines, 45 rice farmers with an average farm size of 1.9 ha produced a total of 157 t of rough rice in one crop season (Hayami et al. 1999). These 157 t were procured by 37 different middlemen, who supplied rice to a variety of smaller and larger rice

mills. Therefore, a total of 82 individual decision-makers, each with their own knowledge and incentive to consider quality, handled the grain even before it was passed to a processing point. While different operations could be combined and the number of people that handle grain could be reduced, a more relevant question is—what incentive does each decision-maker have to consider grain quality? And if there is sufficient incentive, what is the level of knowledge on appropriate grain management practices that could reduce grain quality and quantity loss?

**Table 2.** Rice grain quality and moisture management (MC = moisture content).

Activity	Key principle	Primary loss
Harvest	Harvest at 20–24% MC	Spoilage and discoloration if left too long in the field Shattering if too dry
Threshing	Thresh within 24 hr Thresh at 20–24% MC	Spoilage and discoloration if delayed Grain damage and/or fissuring if too dry If too wet, grain retained in unthreshed panicle
Drying	Drying to 14% MC <sup>a</sup>	Spoilage if drying is delayed for several days Drying rate too low: reabsorption of moisture Drying rate too high: fissuring of grain Temperature too high: fissuring of grain
Storage	18% MC for temporary storage 14% MC for long-term storage of rough rice 10% MC for long-term storage of seed	Spoilage and discoloration if grain is too wet
Milling	14% MC	Declining milling recovery and head rice if too dry

<sup>a</sup>For temporary storage (~3 weeks), grain can be dried to 18% MC.

**Table 3.** The production-to-consumption chain of rice grain in the Philippines (adapted from De Padua et al. 1999).

Who?	Farmer	Contractor	Agent	Trader	Processor/ cooperative	Wholesaler	Retailer	Consumer
What do they do?	grow harvest thresh dry	harvest haul thresh	buy and haul on commiss- ion basis for the traders	buy haul dry	procure dry clean handle mill store market	store haul	store haul	buy prepare
What do they handle?	paddy straw hull bran rice	paddy straw	paddy	paddy bran flour rice	paddy hull bran flour rice	paddy flour rice	paddy rice bran flour	milled rice bran flour
	Production .....				Consumption			

## Knowledge and Incentive Gaps in the Postproduction Sector

We hypothesise that in many cases there exists a knowledge gap (i.e. disparity between what is known or acknowledged by researchers and what is known among those that actually handle the grain) or a lack of incentive to implement the key principles of grain quality management. If these key principles could be applied on a broader scale, large improvements in grain quality could be accomplished regardless of what specific PPS technology is involved. The following four examples illustrate the types of knowledge gaps and lack of incentives found in Asia among decision-makers in the postproduction sector. These examples were taken from recent research activities by the International Rice Research Institute (IRRI) in addition to previously reported research papers, and may be helpful in identifying the critical intervention points for a grain quality management campaign.

### Example 1—harvesting in north-eastern Thailand

Rice farmers in north-eastern Thailand indicated that they were losing income due to unacceptably high levels of broken grain as a result of inappropriate threshing. The threshers in their fields were operated by contractors who were paid on a time basis. The farmers contended that the threshers were operated at inappropriately high speeds in order for contractors to maximise their profits (Bell 1999).

Common knowledge indicates that thresher speeds (peripheral drum velocity) should be in the 12–16 m/s range, depending on the diameter of the threshing drum or cylinder. Speeds above this range increase the amount of grain damage, while lower speeds increase the amount of non-threshed grain and thereby result in a declining thresher efficiency and grain loss. During a

field visit, thresher speeds in the area were checked by two of the authors using an rpm meter. They concluded that, contrary to the farmers' conviction, all tested threshers had drum speeds within the acceptable range.

What emerged as more fields were visited, however, was a very low MC of grain in the fields—typically 15% or less, with a number of samples even below 12%. To test farmers' perceptions of appropriate harvest and threshing MC, grain samples were prepared—one in the acceptable range for threshing (20–24%) and others that were too dry (12–15%). Farmers were then asked to identify which of the samples were at the appropriate MC for threshing. Without exception, all farmers identified the over-dried samples as appropriate, saying the higher moisture sample was too wet. This perception may stem from the days of manual threshing when lower MCs were indeed more suitable for threshing.

This example illustrates how a knowledge gap among one group in the PPS, the farmers, affects the grain quality further down the chain. In this particular case, farmers' awareness on correct grain MC could to be raised, and existing harvesting practices—i.e. cutting the crop and leaving it in the field to dry for several days until a thresher is available—could be modified. 'Field drying' prior to threshing can lead to a rapid reduction in MC to 15–19% or lower (i.e. too dry for mechanical harvest), which leads to high shattering losses. Leaving grain in the field can also affect grain quality negatively: individual kernels with low moisture will reabsorb moisture and develop fissures, whereas very wet grain can exhibit rapid discoloration and spoilage. For example, Table 4 shows the equilibrium grain moisture for different combinations of relative humidity and temperature. Knowledge of the effects of these conditions can help save money for drying (using suitable ambient air) and avoid quality problems.

**Table 4.** Equilibrium moisture content of paddy at different temperatures (from Teter 1987). Values in bold are most common in the humid tropics.

Relative humidity (%)	Temperature (°C)						
	22	24	28	32	36	40	44
50	11.2	10.9	10.7	10.5	10.2	10.0	9.9
55	11.7	11.5	11.2	11.0	10.8	10.6	10.4
60	12.3	12.0	11.8	11.6	11.4	11.1	11.0
65	<b>12.7</b>	<b>12.6</b>	<b>12.4</b>	12.2	12.0	11.8	11.6

**Table 4.** (Cont'd) Equilibrium moisture content of paddy at different temperatures (from Teter 1987). Values in bold are most common in the humid tropics.

Relative humidity (%)	Temperature (°C)						
	22	24	28	32	36	40	44
70	<b>13.5</b>	<b>13.3</b>	<b>13.1</b>	<b>12.8</b>	<b>12.6</b>	<b>12.5</b>	12.3
75	14.3	<b>14.0</b>	<b>13.8</b>	<b>13.6</b>	<b>13.4</b>	<b>13.2</b>	<b>13.0</b>
77	14.6	14.3	14.1	<b>13.9</b>	<b>13.7</b>	<b>13.5</b>	<b>13.4</b>
79	14.9	14.7	14.5	14.3	14.1	<b>13.9</b>	<b>13.7</b>
81	15.3	15.1	14.9	14.6	14.5	14.3	14.1
83	15.7	15.7	15.3	15.1	14.9	14.7	14.5
85	16.1	15.9	15.7	15.5	15.3	15.1	15.0
87	16.6	16.4	16.2	16.0	15.8	15.6	15.5
89	17.2	17.0	16.8	16.6	16.4	16.2	16.1
91	17.9	17.7	17.5	17.3	17.1	16.9	16.7

## Example 2—drying in the Philippines

Even though grain drying remains one of the most talked about topics in Asia, the lack of mechanical drying capacity continues to be the greatest reported constraint in achieving better quality rice and reducing grain loss. While new methods for threshing wet grain have been developed and widely adopted (e.g. IRRI's axial flow thresher), difficulties in handling and processing grain are experienced every year due to the continuing reliance on sun-drying. Besides quantitative loss of grain (e.g. animals, spillage), sun-drying can lead to extensive losses in grain quality due to re-wetting by rain, extended drying times, contamination, and road traffic (i.e. where public roadways are used). In addition, sun-drying is labour-intensive and often difficult to realise in the wet season. In the Philippines, the adoption of mechanical dryers for rice has not kept pace with increased rice production and growing demands for higher quality rice among urban consumers. For many years, government programs have aimed at introducing mechanical dryers at the farm level or developing farm cooperatives to provide post-production services. These programs have typically been inefficient, as mechanical dryers have been under-utilised and currently still 90% of paddy in the country is dried by solar pavement drying.

Based on a National Post-Harvest Institute for Research and Extension (NAPHIRE) survey of users and non-users of mechanical dryers in the Philippines, Picar and Cardino (1987) identified six major constraints that hindered a wider adoption of mechanical dryers among farmers and cooperatives (Table 5).

Although this study was done in the mid 1980s, the constraints are still relevant today. At the heart of the matter is a lack of incentive to produce higher quality rice—there is generally no price difference between mechanically dried and sun-dried paddy. This leads to the perception among users that mechanical drying is uneconomical, as increased grain quality is not accounted for in the comparison of different drying methods. Only in emergency situations (inclement weather that makes sun-drying unfeasible) are mechanical dryers used, however not at a rate that would make mechanical dryers profitable. Adding to the lack of incentive is the fact that there is a market for wet grain in the Philippines: many farmers sell their wet grain directly to commission agents or millers. A lack of knowledge among users on proper operation of drying technologies can also add to the preference for sun-drying over mechanical drying. In some cases, operators were observed to increase drying temperatures to speed up the drying process, resulting in uneven drying rates and partly over-dried grain. Finally, dryer introduction programs in the past have been unsuccessful as they were too narrowly focused on farmers and farmer cooperatives. This can be attributed to a lack of understanding of who the players are (e.g. Table 3) and on what the appropriate scale and location is of grain drying within the PPS.

Recently, a number of small recirculating grain dryers have been imported from Taiwan and Korea, primarily for use by traders and millers. These dryers are aggressively promoted by suppliers who offer lenient payment schedules to prospective owners. A recent user survey found that the primary reason for



**Table 5.** Constraints to adoption of mechanical dryers, and related issues (adapted from Picar and Cardino 1987).

Constraint	Knowledge or incentive-related issue	Potential solution
1. High fuel and maintenance costs	Mechanical drying is perceived as unprofitable compared to sun-drying as better grain quality is not accounted for Improper technology operation	Development of grades/standards, and know-how for implementation Extensive user training
2. Incompatibility between capacity of dryer and requirement of end user	Research and development programs are carried out in isolation of end users	Needs assessment training for researchers Systems approach
3. High investment cost/insufficient capital		Public investment in drying facilities Produce dryers locally
4. Poor product quality and inconvenience of operation	Improper operation of dryer	Extensive user training 'Foolproof' technologies
5. Lack of strongly organised farmer groups	Narrow focus of government programs	Increase awareness among policy-makers on issues in the postproduction sector
6. Inadequate extension programs	Potential end users are not aware of the availability of technologies	Effective promotion of technologies

adoption of this dryer was largely related to the reliability and the lack of labour for sun-drying (Douthwaite 1999). While in sun-drying, continuous mixing of grain is necessary to prevent over-drying of grain (with related loss in quality), the mechanical dryers offer lower attendance costs as they automatically shut off when grain reaches 14% MC. Furthermore, the dryers are easy to operate and 'fool-proof', meaning that no extensive understanding of drying fundamentals is necessary to operate the technology. Major agencies involved in PPS research in the Philippines are now responding to these recent developments by including traders and millers as potential beneficiaries of their programs (see related paper by de Padua 1999). In addition, research strategies are evolving towards better needs assessment of the key players in the postproduction sector, and finding new ways to package and deliver information to them. Major improvements in grain quality can only be expected, however, if the market develops the demand and is prepared to pay higher premiums for higher quality rice (see example 4).

### Example 3—milling in Cambodia

Rice milling in Cambodia is done at the village level or at commercial mills. A recent survey found that milling recovery and head rice yield are low and highly variable (Table 6). The survey also indicated

opportunities to increase quality and quantity of milled rice at both scales of production (Rickman et al. 1999).

At the village level, milling is done by either an Engleberg-type steel huller, or a rubber roll dehusker with whitener/polisher. Each village mill services roughly 45–60 families, and milling recovery from village mills is very low (53% recovery on average, with the remaining 47% produced as meal, bran, or husk), with milled rice having a high degree of broken grains. The by-products of milling are used in pig, fish, and poultry production and, depending on the locality, payment is made through the retention of the by-products by the miller. Therefore, there is actually a negative incentive for the miller to improve milling recovery, as it would reduce his revenue. Furthermore, the amount of whole kernels in milled rice is of little importance to rural families that are serviced by the mill.

Commercial mills in Cambodia process rice for larger urban or export markets, and these mills use a rubber roll system for dehusking and friction-type whiteners to remove the bran. Much of the equipment is of Chinese origin and is antiquated, while newer equipment is being imported from Vietnam. Both quantity and quality of milled rice of the commercial mills was higher compared to the village mills, however improvements in performance of existing machinery could be made. In many facilities, rubber rolls were used well beyond their design life, and

**Table 6.** Mill performance of Cambodian rice mills (adapted from Rickman et al. 1999).

	Units	Village mill	Commercial mill
Yearly throughput	t	150–560	500–5 000
Capacity	t paddy/hr (range)	0.20 (0.14–0.32)	1.35 (0.56–2.45)
Head rice	% (range)	not determined	40 (30–48)
Large brokens	% (range)	not determined	22 (1–35)
Small brokens	% (range)	not determined	3 (1–5)
Total white rice	% (range)	53 (50–55)	65
Bran/meal	% (range)	16 (15–23)	11 (8–14)
Husk	% (range)	31 (23–36)	24 (21–27)

milling stones were not refaced on a regular basis. In some instances, millers refaced the stones only once or twice per year irrespective of throughputs. Furthermore, millers did not monitor grain moisture during storage and milling (only one miller owned a moisture meter but he did not use it) and some millers seemed unaware of the effect of moisture on head rice recovery. Others overestimated their head rice yields by 5 to 10%.

In the Cambodian example, there appears to be little incentive to increase grain quality at the village level, although the loss of milled rice in milling is significant and could be reduced. At commercial mills, regular maintenance of equipment and monitoring of grain moisture could increase head rice and improve milling recovery. Efforts to increase mill performance and rice quality therefore should concentrate on raising the awareness among commercial millers on the role of equipment and grain MC in grain quality.

#### **Example 4—quality standards and grades in the Philippines**

As noted earlier, changes in management practices throughout the postproduction chain will only occur if there is sufficient economic incentive to improve grain quality. While technical feasibility can repeatedly be shown, economics will rule the adoption of improved practices that maintain quality. In this respect, determining adequate standards and grades with respect to consumer needs is required. As stipulated by Baird

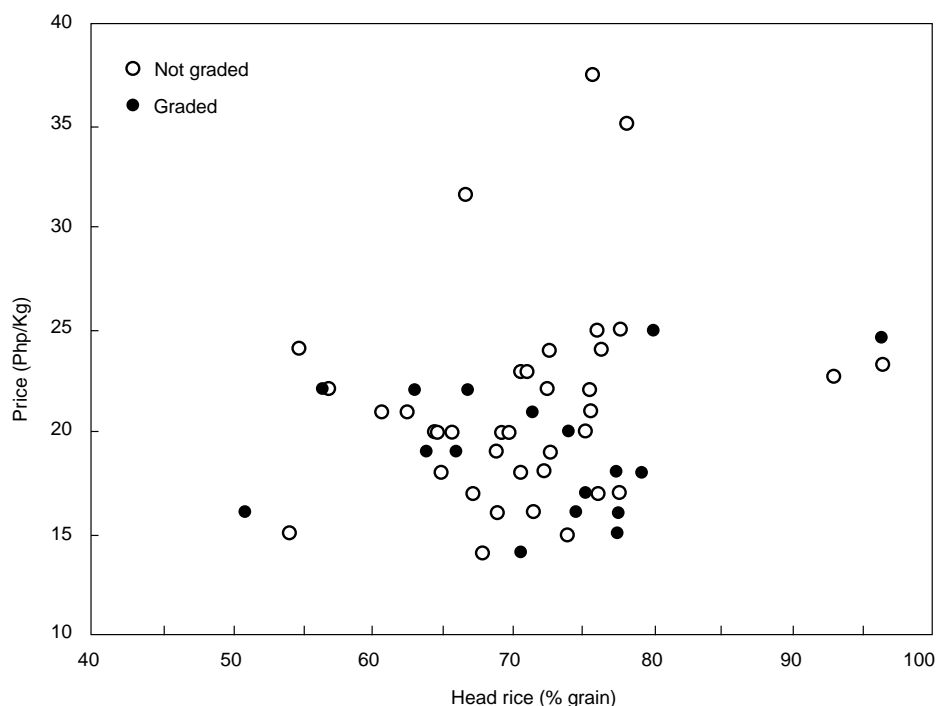
(1987), a standard is a quantitative way of measuring and comparing quality characteristics. Based on this standard, rice is graded. Grading is accomplished to (1) ensure only edible rice reaches the consumer, (2) improve postproduction practices so as to eliminate or reduce losses, (3) improve processing practices for better milling recoveries and for market expansion and, ultimately, (4) protect consumers from price or quality manipulation. These objectives clearly show that a rice grading system, if designed and executed properly, can benefit all the players in the postproduction chain.

In the Philippines, the official system of standard and grades of milled rice is modelled after the United States system for export rice, which consists of a set of well-known quality standards such as percent head rice, brokens, brewer's rice, discoloured grains, chalky or immature grains, and non-grain impurities. An exploratory study of milled rice from retail markets in Laguna Province and Manila showed that the quality of milled rice was poor, regardless of whether rice was graded or not (Billate et al. 1999). More importantly, the study indicated a poor relationship between a quality standard such as head rice, and price (Figure 1). Nevertheless, in the domestic market there are mechanisms that differentiate rice varieties with regard to consumer taste and preference. For instance, rice varieties are commonly characterised as 'fancy', 'special' or 'ordinary', which refers to the appearance of the grain that consumers prefer (e.g. 'fancy' = flinty uniform appearance, glossy, shiny and translucent or

creamy white in colour; Toquero 1987). Furthermore, names of traditional varieties that have established a reputation for ‘good quality’ but are no longer actually grown by farmers, continue to appear on labels. These are usually modern varieties with dimensions similar to the original variety and sold at higher prices, to the point that mislabelling is practiced. One trader acknowledged that he sold IR64 (a long grain variety that is soft and moist when freshly cooked and is preferred by many in the Philippine market) under the name ‘Sinandomeng’, in order to make the grain more marketable. This indicates a lack of objective standards in the domestic market that can be readily identified by farmers, traders and consumers. In the Philippines, changes in current grain standards are now being considered.

## Conclusions and Recommendations

Before embarking on a quality management program it is important to identify who is involved along the postproduction chain and what are the incentives of each to maintain quality. If incentives exist to maintain quality, then awareness of the general principles of grain quality management should be raised, regardless of the PPS technology that is used. There are many knowledge gaps among key players in postproduction with respect to maintaining grain quality, and therefore the challenging issue is how information can be appropriately packaged and distributed to bridge these knowledge gaps.



**Figure 1.** Head rice and retail price of milled rice samples in the Philippines (n = 56) (adapted from Billate et al. 1999).

## References

- Baird, J.H. 1987. Grading, and maintaining grain quality in storage. In: Champ, B.R., Highley, E. and Remenyi, J.V., ed., Technological change in postharvest handling and transportation of grains in the humid tropics: proceedings of an international seminar held at Bangkok, Thailand, 10–12 September 1986. ACIAR Proceedings No. 19. Canberra, Australian Centre for International Agricultural Research, 35–41.
- Bell, M.A. 1999. Thailand trip report. Internal IRRI document. Philippines, International Rice Research Institute.
- Billate, R.D., Barredo, I.R., De Padua, D.B. and Bell, M.A. 1999. Assessment of milled rice quality from selected

- markets. Paper presented at the National Food Authority Grain Standardization Workshop, Manila, October 1999.
- De Datta, S.K. 1981. Principles and practices of rice production. New York, John Wiley and Sons.
- de Padua, D.P., Bell, M.A., Razote, E. and Billate, R. (ed.) 1999. Moving to a brighter future. Proceedings of workshops and discussions, International Rice Research Institute—Australian Centre for International Agricultural Research (IRRI–ACIAR).
- Douthwaite, B.D. 1999. Equipment evolution: case studies of changes in postharvest technology in the Philippines. PhD dissertation, University of Reading.
- Hayami, Y., Kikuchi, M. and Marciano, E. 1999. Middlemen and peasants in rice marketing in the Philippines, *Agricultural Economics*, 20(2), 79–93.
- Picar, G.D. and Cardino, A.G. 1987. Application of grain dryers at farm level. In: Champ, B.R., Highley, E. and Remenyi, J.V., ed., *Technological change in postharvest handling and transportation of grains in the humid tropics: proceedings of an international seminar held at Bangkok, Thailand, 10–12 September 1986*. ACIAR Proceedings No. 19. Canberra, Australian Centre for International Agricultural Research, 176–182.
- Rickman, J.F., Som Bunna and Poa Sinath 1999. Rice milling in Cambodia. Phnom Penh, Cambodia—International Rice Research Institute (IRRI)—Australia Project.
- Teter, N. 1987. Paddy drying manual. Food and Agriculture Organization of the United Nations (FAO) Agricultural Services Bulletin No. 70, 123p.
- Toquero, Z.F. 1987. Issues determining the capitalisation of the rice processing industry in the Philippines. In: Champ, B.R., Highley, E. and Remenyi, J.V., ed., *Technological change in postharvest handling and transportation of grains in the humid tropics: proceedings of an international seminar held at Bangkok, Thailand, 10–12 September 1986*. ACIAR Proceedings No. 19. Canberra, Australian Centre for International Agricultural Research, 77–91.

# A Systematic Approach to Promote the Dryer as a Major Measure of Quality Assurance for Rice Grain

Phan Hieu Hien\*

## Abstract

Mechanical drying has been viewed universally as a major measure to preserve grain quality and reduce rice postharvest losses. However, to promote dryers in a developing country has been, in most cases, a wish rather than actuality. For the first time in Vietnam, within the scope of the 'Post-harvest and Rice Processing Development Project', a massive and systematic campaign has been implemented with the objective of installing 1,200 'normalised' (that is, converted to the equivalent of 4 t/batch unit) flat-bed dryers in Can-Tho and Soc-Trang Provinces of southern Vietnam during 1998–2002. Up to September 1999, 500 of the dryers had been installed. Three factors are identified as contributing to this success story: technology, extension, and credit. The role of each factor is analysed in depth. This systematic approach will be extended to the whole Mekong Delta of Vietnam, to assure rice quality, especially during wet-season harvests.

RAINY-SEASON postharvest losses are a recurrent problem in the Mekong Delta of Vietnam. Every year, rice harvested during a typhoon or 'tropical depression' suffers considerable damage. Piles of harvested paddy germinate and deteriorate on the road or in the farmer's yard, with anxious faces of the farmer's family waiting for the next day's sunshine without certainty. Newspapers report that the selling price of paddy has dropped by 10–15% because of flooding and rain.

The figure of 10–15% coincides with estimates of postharvest losses drawn from various sources. In monetary terms, these losses are huge: each 1% loss corresponds to about US\$7 million (or 100 billion VN dong).

In spite of this, a strategy and procedure to solve the problem was, until recently, still unclear. Many officials from agricultural agencies still considered sun-drying as a matter of fact, appropriate for poor farmers. The use of mechanical means to eradicate, within 10–15 years, these postharvest losses caused by rain, seemed unbelievable to them.

Research and application studies on grain drying have been carried out by several agencies. Among the most successful of the dryers to emerge from these studies are the SHG-4 and SHG-8 dryers (4 and 8 t per batch; see Figures 1–4) designed by the University of Agriculture and Forestry (UAF), Ho Chi Minh City. Up to 1997, about 60 units of these dryers were delivered to several northern and southern provinces of Vietnam; their operations confirmed the relevance of research to the production sector. Compared with the total requirement for drying, however, they were just a small number in a small project. Surveys and/or estimates in the provinces indicate that there were about 1,500 flat-bed dryers in the Mekong Delta in 1997 (Table 1). Only about 9% of the harvested grain is mechanically dried. Thus, to dry 90% of its harvest, the Delta needs some 15,000 dryers, ten times the 1997 number.

Nevertheless, within the scope of the "Rice Post-harvest and Processing Development Project", during the wet-seasons of 1998 and 1999 a dramatic improvement was made in Can-Tho and Soc-Trang Provinces. Building on the research results of UAF, the project has systematically promoted dryers. In two years, 500 flat-bed dryers have been installed in these two provinces, with a total value of 21 billion VND (ca US\$1.5 million). At Can-Tho, a recent survey

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**Figure 1.** SHG-8 dryer (8 t per 8 hour batch), with side air chamber.



**Figure 2.** Fan for SHG-4 dryer, with an airflow of 4 m<sup>3</sup>/s at 300 pascal.

**Table 1.** Numbers of flat-bed dryers in the Mekong Delta, 1997.

Province	Number of existing dryers	Estimate of percentage of grain dried mechanically	Required number of dryers
Soc-Trang	550	35–40	1 400
Kien Giang	360	15–20	1 800
Can-Tho	250	8–10	2 400
An Giang	≈100	3–4	2 400
Others	≈250	1–3	7 000
Total	≈1 500	≈9	15 000

reported that, up to the end of 1997, this province had 255 dryers (with a typical capacity of 4 t/batch). In 1998–1999, the project has installed 250 new dryers, most of which are the 8 t/batch units. In other words, the drying capacity in Can-Tho is now three times what it was in 1997. It has dried some 25–30% of the wet-season harvest, compared with about 9% in 1997. Similarly, Soc-Trang Province had, in 1997, 550 dryers, the largest group in the Mekong Delta, which took care of about 30% of wet-season paddy. In 1998–1999, 250 new dryers were installed (mostly the 8 t/batch units), increasing the share of mechanical drying to 45–50%.

More important than the quantity of installed dryers (the ‘hardware’) is the attitude change of farmers (the ‘software’). We can verify their recognition that *mechanical drying yields quality and effectiveness* following interviews of hundreds of dryer owners and farmers who use contract drying services.

It is too early to call the cases of Can-Tho and Soc-Trang a complete success. That will be possible when all 500 loans for dryers have been repaid to the bank, and the money has become a revolving fund. But from what we saw during monitoring of these dryers in the 1998 and 1999 rainy seasons, we can be optimistic enough to call it an ‘ongoing success’. A solution to the drying problem in the Mekong Delta has become clear and within our reach, so we have the capacity to rapidly reduce postharvest losses and the worries of farmers in this region.

The success in implementing flat-bed dryers in Can-Tho can be traced back to three factors:

- technology;
- extension; and
- credit.

## Analysis of Contributing Factors

### Technology

The drying equipment and technology must meet requirements of capacity, quality, and cost-effectiveness—whether the grain is to be used for milling or for seed, and whether the season is wet or dry. After one batch, farmers should be tempted to use the dryer again, in the next season. On the other hand, just one batch in which paddy was broken, or blackened with ashes, or lost germination, will scare them for several seasons, unless a prolonged typhoon gives them no other choice.

Drying should be effective, meaning that the investment should generate benefits for all. In other words, the drying cost should be lower than a level

acceptable to farmers, while the dryer investor (owner) still makes a profit. Specifically in Can-Tho and Soc-Trang, farmers found it acceptable to pay 80–100 VN dong/kg (US\$6–7.5/t)<sup>1</sup>, at which fee the owner can still achieve pay-back on their investment within 2–3 years.

Technologies which meet the above requirements are now available: they are the SHG-4 and SHG-8 dryers (Appendix 1 gives technical and economic specifications). The designs are simple and suitable for local fabrication. Especially important is the inspection of the *fan* for airflow and static pressure. The success or failure of the whole system depends on the fan.

The Faculty of Agricultural Engineering of UAF has transferred the fan fabrication technology to the Can-Tho and Soc-Trang Projects, which later provide support to only those farmers who bought the approved fan from one or other of seven accredited manufacturers.

The flat-bed dryer is nothing new; it has existed since 1950s in Europe, Japan, and the USA. But a refined design that features both good quality and low cost is not readily available as an ‘off-the-shelf’ item.

In terms of drying capacity, which is related to cost-effectiveness, the SHG-8 dryer (8 t/batch) is preferred than the 4 t unit by investors in the Mekong Delta because it can handle a much larger quantity of paddy in the hectic harvest period. Small dryers, such as the SRR-1, which can dry a 1 t batch in 40 hours, are suitable only for locations with very small-scale production. Although some hundreds of units of the SRR-1 have been promoted independently in the past three years in Long-An and An-Giang, it is now clearly realised that these dryers, because of their low capacity, are not a major solution for the Mekong Delta, but they can be used to supplement larger dryers.

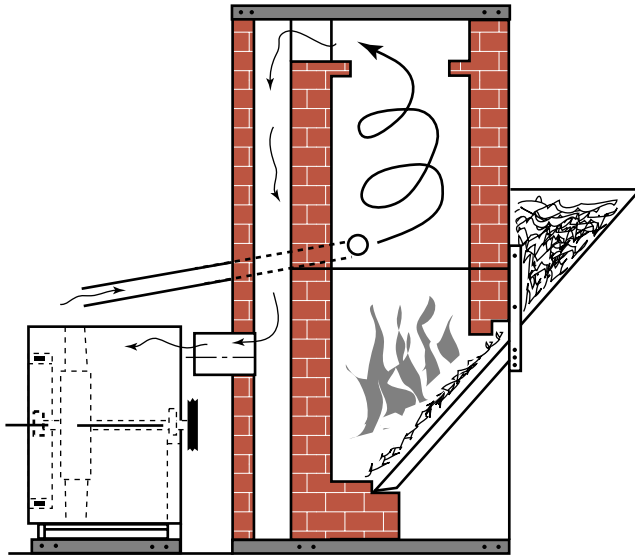
### Extension

This is the most important factor. While mechanical fabrication and investment capital are essential, they are not by themselves sufficient. For drying activities, extension workers are needed to:

- promote dryers to farmers *before* installation;
- advise on technical matters to farmers *during* installation; and
- provide guidance on dryer operation and maintenance *after* installation.

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1. The exchange rate used is the average for 1998:  
US\$1 = 13,333 VN dong.



**Figure 3.** Furnace for the SHG-8 dryer (model 97), with a rice husk consumption of 50 kg/hour.



**Figure 4.** Fan test duct, for ensuring the required airflow and pressure.



The role of the extensionist is similar to the agent for marketing + installation + after-sales service for industrial goods in the city. Similarly, the income of these staff is proportional to the number of dryers installed.

Our experience with staffing in Can-Tho and Soc-Trang is worth some remarks. At the start, there were no mechanical or agricultural engineers at the extension centres—they were at the city factories or somewhere else. The only personnel available were science graduates or technicians in agronomy and plant protection whose normal work involved some dozens of kilograms of seeds or bags of fertilisers valued at less than US\$100. They were not familiar with higher-value, larger-scale mechanical equipment. Their strong point, however, was their closeness to farmers. So, to use these staff for assembling a dryer of value \$2,000–3,500 required appropriate retraining.

Extensionists in Can-Tho and Soc-Trang participated in various training activities to reorientate their skills. First, they took part in a 3-day seminar on drying. Next they participated in a survey on dryers and drying in their province. Following that, they underwent 2 weeks of intensive training on basic mechanical skills (welding, sheetmetal work, adjustment of diesel engines, wiring a 3-phase motor, reading a simple drawing etc.) hosted by Can-Tho University's Faculty of Technology. The aim was to familiarise them with dryer components, and to overcome any fear of machinery; they were not trained to become mechanics.

Next in the training, the trainees (first by group, later individually) were guided by UAF staff in the installation of six dryers. This was a risky business, because UAF was contracted to supply these dryers to farmers. Any errors made by the trainee were thus the responsibility of UAF. Eventually, 15 trainees 'graduated' from the course.

The success of the training was reflected in the fact that farmers allowed extensionists to install more than 90% of the 500 dryers delivered.

Besides the quantity of dryers installed, the extension workers made a substantial commitment to the success of the exercise. They responded when farmers called them, which was at all times and whether the problem was big or small. No manufacturer could have done that. The result was the good operation of all dryers, delivering quality products throughout the harvest period (about one month in each area) without major problems.

Persuading farmers to invest in dryers has not been easy. Previously, among dryers installed by farmer/

mechanics, many did not perform well (causing grain breakage, blackened grain, and other problems). In these cases, farmers subsequently brought their paddy to the dryer only as a last resort, and usually when the grain was about to germinate, in which case drying was too late to preserve quality. The result was a vicious circle involving the dryer owner and the paddy owner. The machine was used for only about 2 weeks per year, representing the time involved in attempts to 'rescue' paddy, and yielding none of the quality advantages of well-managed mechanical drying. The short utilisation time made the payback on investment difficult. Among the questions often raised by farmers was:

"Assume we can dry 4–5 weeks per year, then the dryer is still idle for almost 11 months; how could we make a profit?"

To answer this question to the satisfaction and assurance of farmers requires an extensionist with an understanding of the drying process, with experience in installing dryers, and with confidence in the practical operation of dryers.

In short, the role of dryer extension is not unlike extension in agronomy. The aim of both is to ensure that *farmers understand, farmers believe, and farmers act*. The main difference lies in the US\$2,000–3,000 purchase price of a dryer, much higher than the costs of, say, seeds or insecticides. We therefore come to the third essential factor—credit.

## Credit

The dryer promotion in Can-Tho and Soc-Trang has been favoured with a large credit scheme. Through a government-to-government agreement, the Danish International Development Assistance Agency (DANIDA) provided US\$1.2 million for establishing 600 (4 t) dryers in each province. The Provincial Bank for Agriculture managed the money as a revolving fund. Up to the end of September 1999, the Banks had issued total loans of 21 billion VND (about US\$1.5 million) for dryers. Features of the soft loan arrangement are:

- reduction of collateral (for example, a loan of US\$3,000 for the 8 t dryer needs 1 ha of collateral, instead of the 5 ha normally applied);
- lower interest rate, which was 0.8%/month in 1998, or equal to the rate for the poor, and lower than the commercial interest rate; and
- longer repayment period of 2–3 years, instead of 6 months or 1 year as otherwise applied.

In short, it was farmers' voluntary applications for loans that explicitly indicated the success of the credit program.

However, the question remains: If programs of post-harvest reduction such as those of Can-Tho and Soc-Trang are expanded to all other provinces of the Mekong Delta, where will the capital come from?

- Possibly from additional foreign aid. But this would take time for study, evaluation, and negotiation, and might still be limited to only some provinces.
- It is therefore likely that capital from internal sources would have to be the main source. One million US\$ for one province is not a big budget at the central or provincial level, if the financial agency is sure about the effectiveness of the invested money.
- Furthermore, since a typical province with a production of 500,000 t of wet paddy would lose US\$5 million, assuming 10% postharvest losses, waiting one year for foreign aid means losing US\$5 million in that year!

Vietnam is exporting about 4 million tonnes of rice valued at about US\$1,000 million every year. Less than 1% of this sum of money would be enough to solve the age-old, wet-season grain drying problem for the entire Mekong Delta.

## Policy and management

Policy and management are all-embracing factors. Technology, extension, and credit can be fully effective only under an integrated policy and good management. Unanimous determination by central, provincial, and all related institutions of agriculture,

by science, and by finance and banking to solve the postharvest losses is needed, backed up by a concrete plan with resolutions, orders, guidelines, and an organisational set-up. The Can-Tho and Soc-Trang Projects have been successful because of harmony between all levels of government administration on matters of planning, support, and organisation.

## Who Benefits?

Promotion of rice dryers in the Mekong Delta of Vietnam, as has been done in the pilot projects at Can-Tho and Soc-Trang, would benefit many people. For example, if a SHG-8 dryer (8 t/batch, or 20 t/day) is built for US\$3,000, then the benefits in *one year* are distributed as shown in Table 2.

## Conclusions

Systematic approaches and procedures have been practised to promote flat-bed dryers in the two pilot projects in Can-Tho and Soc-Trang Provinces as a major measure to reduce postharvest losses and to assure grain quality. Three factors are identified as contributing to this success of the approach: technology, extension, and credit.

Postharvest losses in the Mekong Delta are estimated to amount to hundreds of billions of Vietnamese dong or tens of millions of US dollars every year. So large a sum is hard to visualise. Let us scale it down by a small example from a recent rapid interview in a village of this area (with about 1,500 ha of wet-season rice) right after the passage of a tropical depression in October 1998.

**Table 2.** The beneficiaries of grain drying.

Beneficiaries	Estimated benefit	Comments
Farmers	Benefit: US\$6 000–12 000	100–200 farmers, with a calculated loss of 5–10%
Dryer owners	Benefit: US\$ 1400 (range US\$700–2 100)	From drying fee of 5% of 500 tonne of dried paddy (1/2 of which is net profit)
Rice millers	Benefit: US\$200–400 + Benefit due to stable supply for the mill	Increase of 1–2% of head rice recovery
Extension workers	Fee from installation and advice $\approx$ US\$80	
Bankers	Interest: US\$160	
Government and society	Benefit = sum of above	Expenses (minimum) <ul style="list-style-type: none"> <li>• Campaign initiation</li> <li>• Management</li> </ul>

A conservative figure was that 50% of the paddy deteriorated in quality (in terms of blackening, germination, overheating etc.); as a consequence, farmers had to sell paddy for 300 VND/kg less than normal (for example, 1,600 VND/kg instead of 1,900 VND/kg, or US\$120 instead of US\$143/t). Thus, in total, the farmers of that village lost 1 billion VND (US\$75,000). This money would have been enough to consolidate the infrastructure of the village. Say to build some more bridges to facilitate the transport of produce. Or to build a good primary school, with a decent salary for its 10 teachers, in order to increase the educational level of the people. It can be said without exaggeration that the introduction and proper use of paddy dryers helps to break the vicious circle of 'the farmer is poor because he is poor; he is ignorant because he is ignorant'; which is the biggest worry of those concerned about the agriculture and farmers of the Mekong Delta.

## Acknowledgments

Active contributions of the following in the dryer promotion are gratefully acknowledged:

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- the training on mechanical skills by the Faculty of Technology, Can-Tho University;
- the extension and promotion by the technical staff, Can-Tho and Soc-Trang Post-harvest Project;
- the administrative coordination at various levels of Can-Tho and Soc-Trang Provinces; and
- the credit scheme from the Danish International Development Assistance Agency (DANIDA).

**Appendix 1.** Specifications of SHG-4 and SHG-8 dryers.

	SHG-4	SHG-8
	(4 t/batch)	(8 t/batch)
Fan: axial-flow, ( 750 mm.	single fan	twin fan
Airflow 8.0 m <sup>3</sup> /s @ 30 mm WG static pressure, 30 mm H <sub>2</sub> O	4.0 m <sup>3</sup> /s	8.0 m <sup>3</sup> /s
Engine: diesel (fuel consumption)	12–15 hp (1.0–1.5 L/h)	22–24 hp (1.8–2.2 L/h)
(or) Electric motor	7.5 kW	14 kW
<b>Rice husk furnace: with cylindrical chamber</b>		
Rice husk consumption (kg/h)	25	50
Drying chamber: Flat-bed type with a side air-duct, brick construction, perforated floor		
Floor area, m <sup>2</sup>	24–28	50
<b>Paddy</b>		
Drying capacity per batch kg of dried paddy, with 10% moisture reduction	3 600	7 200
Drying time, hours per batch		
For seed	9–11	9–11
For milling	7–8	7–8
Total investment (+ engine and shed), US\$	1 800–2 000	3 000–3 500
Drying cost, US\$/t		
For seed	5.3	4.4
For milling	3.8	3.3
Payback period on investment: depending on the number of days of use per year. For example: with a SHG-8 dryer, 40 drying days per year, 5% of paddy value as drying fee (equivalent to 80 VND/kg or US\$6/t), the payback period is 1.5 years, or a total of 69 drying days. If drying for seed, the payback period is 2 years.		

**Other grains**

(From actual results of SHG-4 dryers which were installed in An-Giang, Dong-Nai, Binh-Duong, Binh-Thuan, Dak-Lak and Ha-Tay)

	Grain			
	Maize	Maize-on-cob	Peanut	Coffee (pulped)
Quantity (t)	5	15	4	4
Drying time (h)	10	48	12	15
Moisture content				
Initial and final (%)	30–15	30–20	25–10	45–15

# Drying Practices and Evaluation of a Low-cost, Low-temperature, In-store Dryer in Bangladesh, India and Myanmar

V. Balasubramanian and A. Morales\*

## *Abstract*

Drying of fresh rough rice (paddy) is a problem in the coastal districts of several Asian countries, due to excess moisture of harvested grains, and rains during the harvesting period of certain crops. A simple, low-cost dryer (named the 'SRR-1' dryer), developed by the University of Agriculture and Forestry (UAF) in Vietnam, would be highly useful to farmers in such areas. In addition, the Vietnamese dryer could be built with local materials in small metal workshops. However, the operation of this dryer requires electricity. In a collaborative project of International Rice Research Institute, UAF, and the National Agricultural Research System, we surveyed the paddy drying practices in selected areas of Bangladesh, India and Myanmar. With the help of UAF engineers, we organised the training of local engineers and technicians, built and commissioned a prototype dryer in each location, and collected users' feedback for follow-up action. Essentially, the farmers and small rice millers in Bangladesh were highly interested in the SRR-1 dryer and 10 demonstration dryers were built throughout the country. Farmers in Myanmar preferred large, village-level dryers rather than small, individually-owned dryers. In India, the farmers' reactions were mixed. They felt that the SRR-1 dryer was most suited to seed producers for drying harvested seed paddy at low temperature to maintain high percentage germination.

DRYING of harvested rough rice (paddy), especially during rainy season, has been a major constraint to rice production in many Asian countries. At present, more than 80% of farmers still use the sun-drying method that can result in high losses in grain quantity and quality. Owing to inadequate drying floors in rural areas, many farmers use the public roads to dry their paddy. Hence, there is a need for a simple, low-cost dryer that could dry paddy economically and efficiently, reduce grain losses, maintain high grain quality and head rice recovery, and reduce labour use in drying.

In 1994-95, the University of Agriculture and Forestry (UAF), Vietnam, participated in a technical cooperation project with the International Rice Research Institute, Philippines, and the donor agency

GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit—German Agency for Technical Cooperation), and developed a low-cost, low-temperature, in-store dryer (called the 'SRR-1' dryer). It can dry 1 t of rough rice (paddy) in 2-4 days and the same unit can be used for storage. Its design was based on the principle of one-stage, low-temperature, in-store drying, and it has application in areas where sun-drying is not feasible. Targeted users are resource-poor farmers with less than 0.5 ha of rice land, having a surplus of 1-2 t of paddy for storage in each season, and living in areas with an electricity supply.

The dryer has three components: a 373 watt, two-stage axial fan; a 1,000 watt electric heater; and a drying bin of bamboo mat or other material. The drying bin consists of two concentric bamboo-mat cylinders of 0.4 m and 1.5 m diameter, with a height of 1.1 m. The inner cylinder is supported by a frame made of 6 mm steel wire. A 373 watt, single-phase, 2,800

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rpm electric motor drives the fan. Two 350 mm diameter, 7-blade plastic rotors are mounted on both ends of the motor shaft and enclosed in a steel-wire casing. The fan is positioned on top of the inner bamboo-mat cylinder. At 40 Pa static pressure, the airflow is 0.3 m<sup>3</sup>/s. The heater is a 1,000 watt resistor from the electric stove which is mounted beneath the lower motor. Supplemental heat from the resistor is used only during certain nights (e.g. cool nights or during continuous rains) (Hien et al 1997).

Tests in Vietnam showed that 1 t of high moisture (26–30% moisture content—MC) paddy could be dried to 14–15% MC in 2–4 days (Ban et al. 1995; Hien et al. 1997). The calculated drying cost was US\$6.00/t. In Vietnam, this dryer costs only US\$55/unit.

## Objectives

This study was conducted to (a) assess the drying practices and problems of small-scale rice farmers in selected target areas of Bangladesh, India and Myanmar; (b) construct, commission, and pilot-test the dryer in each location; (c) train local engineers and technicians; and (d) gather feedback from the farmer-collaborators on the performance and usefulness of the dryer.

## Methodology

Prior to the pilot-testing of the dryer, a rapid rural appraisal was conducted on the drying practices and problems of small-scale rice farmers in selected areas in the three countries in collaboration with National Agricultural Research System staff. A uniform questionnaire for the survey was developed, pre-tested, and circulated to the partners. The survey was conducted by the Bangladesh Rice Research Institute, Bangladesh, in June–July 1996; the Agricultural Mechanization Department, Myanmar, in October–November 1996; and the M.S. Swaminathan Research Foundation, India, in March–April 1997.

A 2-week seminar/training workshop was organised in each country to train the local engineers and technicians on the design, construction, and operation of the dryer. Two Vietnamese engineers from UAF visited each country for 2 weeks to commission and pilot-test the pre-fabricated dryer and work with the National Agricultural Research System collaborators on the design, fabrication and testing of a locally-fabricated dryer. Training and pilot-testing were conducted during 1–14 September 1996 in Bangladesh, 12–22

November 1996 in Myanmar, and 21 April–4 May 1997 in India.

## Results and Discussion

### Survey on paddy drying practices

#### *Bangladesh*

The survey on the drying practices and problems of small-scale rice farmers was conducted in selected villages of the Sylhet and Chittagong Districts. These districts encounter their most acute drying problems during rice harvests in rainy weather. The survey revealed that about 54% of the sample farmers were educated above secondary school level, and 83% had a medium level of income. Only 27% of their total income came from agricultural sources. Almost all the farmers had a landholding of less than 2 ha each. On average, 73% of the respondents cultivated modern rice varieties, and 82% transplanted their rice crops. About 58% of them obtained an average yield of 2–4 t/ha. All farmers used the traditional methods of rice harvesting with sickles, manual threshing, and sun-drying. 98% of the farmers spent a maximum of US\$12–35/ha (Taka—Tk. 500–1,500) for sun-drying in Chittagong District. The drying cost was less in Sylhet District (US\$1.20–2.40/t or Tk. 50–100). About 65% of the farmers reported a drying loss of 1–3%, and 95% felt the need for a dryer. They expressed that a simple, portable, and variable volume/capacity dryer such as SRR-1, that could be built and repaired in village workshops, would be suitable for them.

Almost 94% of the respondents stored their rough rice for 1–7 months for use during the next season, and all of them experienced serious problems in storage. Most farmers (82%) sold their paddy in different lots 1–4 months after harvesting. The dry paddy had a higher market value of US\$130–150/t (Tk. 5,500–6,500/t) than wet paddy sold at US\$117–140/t (Tk. 5,000–6,000/t) at the time of harvesting. Farmers could obtain still higher prices for stored, dry paddy when sold 3–4 months after harvesting. In 1996, about 58% of the farmers sold a portion of their excess paddy 1 month after harvesting at US\$140–150/t (Tk. 6,000–6,500/t), 42% sold 2 months later at US\$150–164/t (Tk. 6,500–7,000/t), 55% sold 3 months later at US\$150–175/t (Tk. 6,500–7,500/t), and 60% sold 4 months later at US\$175–200/t (Tk. 7,500–8,500/t).

Harvesting (99%) and threshing (57%) were carried out by male workers, while drying (57%) and cleaning (77%) by female workers. The wages were US\$0.94–

1.87 (Tk. 40–80) per male worker and US\$ 0.94–1.40 (Tk. 40–60) per female worker. Labour scarcity and wages were higher in Chittagong than in Sylhet District. Farmers in Chittagong District faced labour shortages during harvest (94%), threshing (63%), and drying (75%). Some farmers complained that appropriate machines were not available for threshing (16%), drying (70%), and milling (12%).

### *India*

The survey was conducted by M.S. Swaminathan Research Foundation staff on the drying practices in three biovillages of Pondichery State. The results showed that farmers faced difficulties in drying the dry season ('Kuruvai') rice harvested in moist weather in September/October. Many farmers sold their excess wet paddy immediately after harvest to middlemen or government procurement agents. Procurement agents or millers dry the wet paddy as such, or after parboiling. Most of the farmers dried their paddy for home consumption in open sun on a hard, mud-plastered surface near their homestead or sometimes on public roads. Drying on roads poses a serious traffic hazard. Grain loss due to sun-drying is highly variable depending on the condition of the drying surface and the invasion by birds, ants etc. Parboiling of rough rice, a common practice in Pondichery, repairs cracks and improves head rice recovery during milling. Farmers felt that seed growers would greatly benefit from a small, inexpensive, low-temperature dryer such as the SRR-1.

### *Myanmar*

The survey covered six villages from five townships—Hlegu, Hnawbi, Tikkyi, Gyobingauk, and Zegone—in Yangon and Bogo Divisions (Myint Wai et al. 1996). In the study area, farmers' landholding ranged from 2.4–5.8 ha with a mean of 4.1 ha. Farm income constituted 87–100% of the total income. Harvesting time is April for the summer rice and October for the monsoon rice. Harvested paddy is kept on the threshing floor for 5–10 days before threshing that could adversely affect the grain quality and head rice recovery. According to Myint Wai et al. (1996), about 70% of the farmers used mechanical threshers hired from local Agricultural Mechanization Department Tractor Stations. The machine threshing took about 4 h/ha and the cost was US\$10/ha (kyat—K 1,750/ha) at the official rate of exchange (1 US\$ = K 175). All the farmers used the traditional method of sun-drying. About 13–15 workers/ha were employed for sun-drying at a cost of US\$6.85–7.17/ha (K 1,200–1,255/

ha). The estimated drying loss was 3.0–4.3%. The dried paddy was stored in bamboo bins for 3–5 months. The price of paddy was US\$70/t (K 12,000/t) at harvesting time and US\$83/t (K 14,500/t) 2 months later. Selling milled rice is the most profitable for Myanmar farmers. Most farmers surveyed preferred village-level, high-capacity dryers rather than individually-owned, low-cost, low-capacity dryers such as SRR-1.

## **Pilot-testing of the SRR-1 dryer**

### *Bangladesh*

The pilot-testing of the dryer was conducted at the Bangladesh Rice Research Institute (BRRI) Research Station, Gazipur. Mr Truong Vinh and Mr Vuong Thanh Tien of UAF built a unit of SRR-1 dryer locally, and trained the engineers and technicians of the Farm Machinery and Postharvest Technology Division of BRRI. Two test-runs of the dryer were conducted with two samples of wet raw rice of 23% and 27% MC. The MC was reduced to 14.4% and 13.3%, respectively, for the two samples in 60 hours with a total energy consumption of 59.5 kilowatt-hours (kwh). In addition, 500 kg of parboiled rough rice of 28.8% MC was dried to 11.6% MC within 42 hours and the energy consumption was 30.9 kwh. The head rice recovery was higher when rough rice was dried in the dryer than in open sun. The milling out-turn of both raw and parboiled rough rice was 72%, of which 93% was head rice for raw and 98% for parboiled samples. The cost of the locally manufactured dryer was US\$117 (about Tk. 4,800) and the drying cost was US\$ 6.57/t (Tk. 280/t) of paddy.

The dryer was thus successfully tested in the presence of farmers, extension workers, farm machinery manufacturers, and rice millers. All the participants were impressed by the low cost and good performance of this dryer for drying raw and parboiled paddy. They requested the widespread demonstration of the dryer to farmers and other clients in potential areas, before manufacturing it locally. Ten more dryers were produced in November 1997 to field-test and demonstrate them to farmers in various parts of Bangladesh in 1998 and 1999. Baqui et al. (1996) reported that the initial responses were highly encouraging and that Bangladeshi farmers in coastal areas would benefit immensely from this dryer. It would save the paddy harvested during the wet season and improve the quality of milled rice. It is vital that credit be organised for poor farmers to buy and use the dryers.

## India

Drs P.H. Hien and P.D. Dung of UAF worked with Dr R.S.S. Hopper and staff of the M.S. Swaminathan Research Foundation (MSSRF) Biovillages Project in Pondichery, India. They pilot-tested the SRR-1 dryer and trained the local engineers on the design, construction, and commissioning of the dryer. The prefabricated dryer was installed on a farm in Sivaranthakam village and the drying of wet rough rice (paddy) was demonstrated to about 100 farmers assembled from nearby villages. It took 40 h to dry 1 t of rough rice from 16.0% to 13.2% MC. Another dryer prototype was built from local materials to train the counterpart engineers. Further testing was conducted in other villages in June and September 1997. The MSSRF staff tried using the dryer for drying mushrooms and other produce to see if it could be used as a multi-purpose dryer.

Farmers felt that the dryer was useful for certified seed producers to dry seed at low temperature. Dr Hien explained that germination was 85% for seed dried in the dryer, compared with 70% for sun-dried rice seed. Large-scale farmers could install 3–4 SRR-1 dryers to handle large volumes of paddy.

One SRR-1 unit was given to Dr B.V. Prasad, Agricultural Engineer from the LAM Research Institute, Andhra Pradesh, for field-testing and demonstrating to farmers in the coastal districts of Andhra Pradesh where drying is a serious problem for rice harvested in wet season.

## Myanmar

Two Vietnamese engineers, Mr Nguyen Hay and Mr Thi Hong Xuan, worked with Agricultural Mechanization Department (AMD) engineers to pilot-test the Vietnamese-built dryer prototype, and built another prototype locally to demonstrate the design, construction, and commissioning of the dryer to engineers and technicians from AMD and the Agricultural Machine Manufacturers Cooperative. The farmers' feedback was that they preferred a high-capacity, village-level dryer. Moreover, the SRR-1 dryer requires electricity for operation which is not available in some villages in Myanmar.

## Summary and Recommendations

After the survey on paddy drying practices, pilot-testing of a Vietnamese low-cost, low-temperature SRR-1 dryer was organised at the farm level in Bangladesh, India, and Myanmar during 1996–97. Post-harvest engineers from UAF visited the three

countries, pilot-tested the dryer, and trained of local engineers and technicians on its design, fabrication and operation. In Bangladesh, farmers in coastal districts expressed that a simple, portable, and variable volume/capacity dryer like the SRR-1 could be highly suitable for them. Farmers and rice millers requested the widespread demonstration of the SRR-1 dryer in various parts of the country, before manufacturing it locally. In Myanmar, farmers preferred large, village-level dryers to the SRR-1 model. They pointed out that the need for electricity to run the dryer would be a big constraint in several villages, hence an alternative source of heat for the dryer must be explored, although electricity is still needed to run the fan to circulate air. In India, farmers showed a mixed reaction to the SRR-1 dryer. Some farmers felt that the dryer could be useful to seed producers who have to dry their seeds at low temperature, while others said it might be suitable for drying other produce such as mushrooms, ground nuts, cashew nuts, chillies etc.

## Acknowledgments

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## References

- Ban, L.V., Hung, B.N and Hien, P.H. 1995. A low-cost in-store dryer for small farmers. Paper presented at the International Conference on Grain Drying in Asia, Bangkok, Thailand, 17–20 October 1995, p5.
- Baqui, M.A., Miah, M. and Huda, M.D. 1996. The potential of the Vietnamese low-cost, low-temperature in-bin dryer (SRR-1) for drying rough rice (raw and parboiled) in Bangladesh. Paper presented at the International Seminar on Recent Developments on Agricultural Machinery for Post-harvest Handling of Rice, Surabaya, Indonesia, 9–11 December 1996, p17.



Hien, P.H., Van, L.V. and Hung, B.N. 1997. The “SRR-1” dryer: an application of low-temperature in-bin drying and storage systems in Vietnam. Paper presented at the 18<sup>th</sup> Association of South-East Asian Nations (ASEAN) Technical Seminar on Grain Postharvest Technology, Manila, Philippines, 11–13 March 1997.

Myint Wai, Soe Hlaing and Garcia, A.G. 1996. Rice postharvest drying in Myanmar. Paper presented at the International Seminar on Recent Developments on Agricultural Machinery for Post-harvest Handling of Rice, Surabaya, Indonesia, 9–11 December 1996, p18.

# Prototype of the Cyclonic Rice Husk Furnace

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## Abstract

The objectives of this research were to design, construct and test a rice husk furnace for a commercial fluidised bed paddy dryer with capacity of 10 t/h. The furnace was cylindrical in shape with an inner diameter of 1.37 m and height of 2.75 m. Rice husk was fed into the furnace at a feed rate of 110–136 kg/h. Air and rice husk entered the combustion chamber in a tangential direction with vortex rotation. Experiments were carried out with: ash heights on the grate, 30, 45, 50 and 60 cm; rice husk feed rates, 110–136 kg/h; excess air, 265–350%; and combustion gas temperature, 523–710°C. The thermal efficiency of the furnace system, increasing with excess air, was approximately 57–73%, while the carbon conversion efficiency was approximately 89–97%. The height of ash on the grate had no effect on the system performance. More than 20 units of the furnace have been commercially produced since the beginning of 1999.

SINGH ET AL. (1980) designed and tested a cyclonic rice husk furnace for drying one tonne of paddy from 35% moisture content (MC) down to 14% dry basis (d.b.). Efficiencies of the furnace were different at various rice husk feed rates and airflow rates. The highest efficiency was 80% with a rice husk feed rate of 20 kg/h and airflow rate of 168 m<sup>3</sup>/h. Tumambing (1984) investigated the cyclonic rice husk furnace of Padicor for paddy drying and found that combustion efficiency was 98%. Xuan et al. (1995) investigated two types of husk furnace. The first one was a furnace with an inclined grate and cylindrical combustion chamber. The upper part of the furnace was a heat exchanger. Inlet air entered at the lower part of inclined grate on which rice husk with a feed rate of 20–25 kg/h was burnt. The efficiency of the furnace was 70%. The second one was a pneumatic-fed cyclonic furnace. It consisted of combustion chamber and rice husk feed system. Rice husk was fed into the combustion chamber with primary air and was burnt. Then it fell down to the lower part of the chamber. The secondary air entered at the upper part of the com-

bustion chamber in tangential direction in order to eliminate dust from the flue gas. Rice husk consumption and furnace efficiency were 10–12 kg/h and 75%, respectively.

The past research showed that there were several designs of rice husk furnace, i.e. vortex or inclined grate types, and direct use of flue gas or indirect use of thermal energy from combustion via a heat exchanger. Acceptance of the furnace was still limited in the experimental sites. Therefore, the objectives of this research were to design, construct and test a commercial-scale prototype of cyclonic rice husk furnace for a commercial fluidised bed paddy dryer with a capacity of 10 t/h. The dryer has been sold in several countries for more than 3 years (Soponronnarit et al. 1996).

## Materials and Methods

Design details of the rice husk furnace prototype are available in Shujinda (1997). It consisted of a combustion chamber, rice husk feeding system, air feeding system, controller system and air suction blower. The combustion chamber was made of steel in a cylindrical shape with inner and outer diameters of 1.37 and 1.76 m, respectively, and height of 2.75 m. Materials inside the combustion chamber at the lower part from

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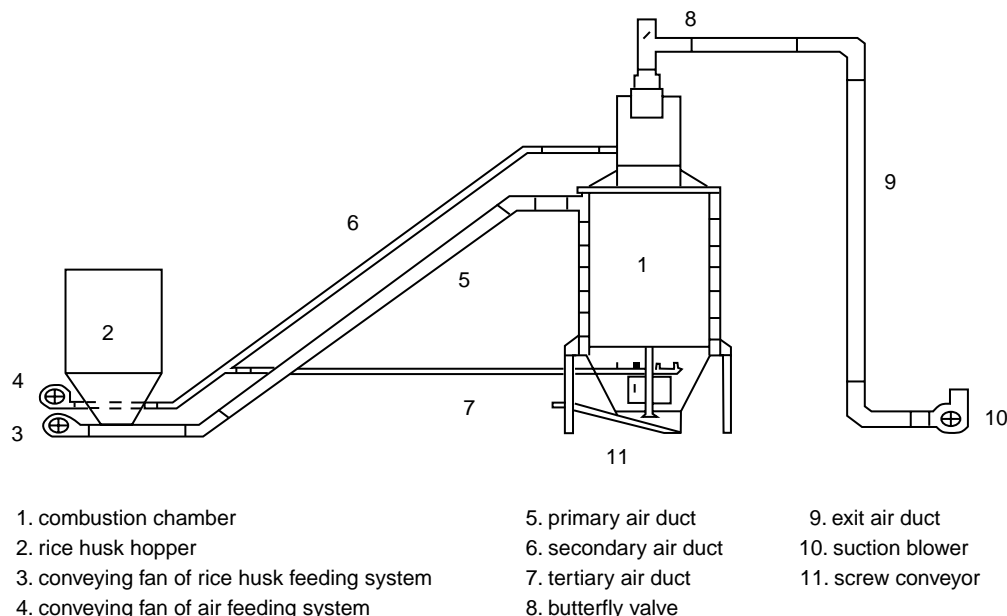
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inner layer to outer layer were the following: fire brick; steel; glass fibre; and covering steel. The combustion chamber was installed on I-Beam steel. The prototype had a grate with a diameter of 1.37 m, thickness of 9.5 m (583 holes/m<sup>2</sup>, hole diameter 0.0127 m) and ash paddle of 50 x 50 mm, and length of 1.1 m at the lower part of combustion chamber. The primary air duct was connected to the upper part of the combustion chamber in a tangential direction. At the upper part of the combustion chamber, a steel cylinder was installed with an inner diameter of 0.8 m and height of 1.6 m. It was insulated with 0.06 m thick cement. The secondary air duct was connected to the cylinder in a tangential direction in order to clean up the flue gas. Rice husk ash was removed from the combustion chamber by the ash paddle followed by a screw conveyor installed under the combustion chamber. The tertiary air duct was connected to the bottom part of the combustion chamber in order to support complete combustion. The rice husk feeding system consisted of a rectangular rice husk hopper with a screw installed at the bottom and driven by a 0.37 kW motor, 0.152 m primary air duct for pneumatic feed of rice husk and conveying fan. The secondary air duct was 0.102 m in diameter. The tertiary air duct with a diameter of 0.076 m separated

from the secondary air duct and then was divided into four ducts with a distributor at the bottom of the combustion chamber under the grate. The air suction system consisted of a 15 kW blower, duct with a diameter of 0.254 m and a valve for regulating inlet fresh air into the combustion chamber.

The measuring instruments used in this experiment were as follows: data logger connected to a type K thermocouple (accuracy  $\pm 1^\circ\text{C}$ ), clamp-on meter, manometer of 0–200 mmH<sub>2</sub>O (accuracy  $\pm 0.1$  mm H<sub>2</sub>O), hygrometer of 0–100% (accuracy  $\pm 1\%$ ), balance machine of 0–50 kg (accuracy  $\pm 200$  g), gas combustion analyser of O<sub>2</sub>, CO, NO<sub>2</sub> and SO<sub>2</sub> with a range of 0–600°C (accuracy  $\pm 3^\circ\text{C}$  for temperature,  $\pm 20$  parts per million (ppm) for CO,  $\pm 0.3\%$  for O<sub>2</sub>).

Figure 1 shows the schematic diagram of the cyclone rice husk furnace. To start the experiment, airflow rates in the primary, secondary and tertiary air ducts were set. A sample of rice husk was taken for component analysis. The rice husk was weighed and fed into the furnace until it reached the height required. Then it was ignited by burning oil and paper. Two fans (labelled 4 and 10 in Figure 1) were switched on to support the combustion. After 10–15 minutes, the third fan (3 in Figure 1) and the controller system of the rice husk feeding and ash paddle were switched on.



**Figure 1.** Schematic diagram of the rice husk furnace.

The control temperature was set at 325°C. The temperature was measured every 3 min and flue gas was analysed every 10 min. Relative humidity was measured by hygrometer. Dry bulb and wet bulb temperatures of ambient air were also measured. When the experiment finished, the rice husk feeding system and two fans (3 and 4 in Figure 1) were switched off, while the third fan (10 in Figure 1) was left on in order to suck hot air from the furnace. Finally, this fan was also switched off and samples of ash were taken for component analysis.

The efficiency of the furnace was determined by using the following equation:

$$\Omega_T = \frac{m_a \times c_p (T_2 - \Phi T_1)}{m_f \times \text{HHV}} \times 100 \quad (1)$$

where:

$\Omega_T$  = efficiency of the furnace (%)

$m_a$  = flow rate of mixed air between fresh air and flue gas (kg/h)

$c_p$  = specific heat of air (kJ/kg, K)

$T_1$  = ambient air temperature (K)

$T_2$  = temperature of mixed air between fresh air and flue gas (K)

$m_f$  = rice husk feed rate (kg/h)

HHV = high heating value of rice husk (kJ/kg)

The carbon conversion efficiency was calculated using the following equation:

$$\Omega_c = \frac{c_h \Phi c_a}{c_h} \times 100 \quad (2)$$

where:

$\Omega_c$  = carbon conversion efficiency (%)

$c_a$  = percentage of carbon in ash  $\times$  ash weight (kg)

$c_h$  = percentage of carbon in rice husk  $\times$  husk weight (kg).

## Results and Discussion

### Air distribution in the tertiary air duct

Tables 1 and 2 show the efficiencies of the furnace and carbon conversion efficiencies at various heights of ash with four air distributors under the grate. The results of experiments 1/97, 2/97, 3/97 and 4/97 with ash heights of 30, 45, 50 and 60 cm were as follows: the carbon conversion efficiencies were 93, 95, 96 and 97%, respectively, and the efficiencies of the furnace were 57–59%. Tables 3 and 4 show the carbon conversion efficiencies at ash heights of 30, 45, 50 and 60

cm with only one air distributor. The results of experiments 1/96, 2/96, 3/96 and 4/96 show that the carbon conversion efficiencies were 88, 93, 85 and 90%, respectively, while the efficiencies of the furnace were 58–63%. It can be concluded that the method of air distribution in the tertiary duct did not significantly affect the carbon conversion efficiency and efficiency of the furnace.

### Airflow rate in the tertiary duct

Combustion was not complete when the airflow rate used in the tertiary duct was too high. This was because increased air made some of the ash fall from the grate. Consequently, the carbon component after combustion was high which resulted in low carbon conversion efficiency, as shown in Tables 1 and 2 (comparison between experiment numbers 6/97 and 11/97).

### Excess air

The results in Table 1 show that when excess air in combustion was 260–280% (experiment numbers 1/97–4/97), the efficiencies of the furnace were 58–59% and the carbon conversion efficiencies were 93–97%. When the excess air increased to 342–350% (experiment numbers 5/97–7/97), the efficiency of the furnace increased to 70–73% and the carbon conversion efficiency increased to be 95–97%. The increase of excess air was derived from decreasing the rice husk feed rate. The best conditions as shown by several experiments were as follows: height of ash on grate, 50 cm; rice husk feed rate, 110 kg/h; excess air in combustion, 350%; and average furnace temperature, 628°C. Carbon in ash after combustion was 5.5%. The carbon conversion efficiency was 96% and the efficiency of the furnace was 73%. Temperature distribution in the furnace with ash height of 50 cm is shown in Figure 2.

### Height of ash on the grate during combustion

The height of ash on the grate during combustion did not affect the efficiency of the furnace, as shown in Table 3.

### Component analysis of rice husk and ash

The composition of substances in the rice husk before combustion was as follows: carbon, 39%;

**Table 1.** Efficiency of the rice husk furnace using four air distributors (experiments conducted in 1997).

Experiment number	Height of ash (cm)	Feed rate of rice husk (kg/h)	Airflow rate for combustion (kg/s)	Airflow rate in primary duct (... = 0.152 m) (kg/s)	Airflow rate in secondary duct (... = 0.102 m) (kg/s)	Airflow rate in tertiary duct (... = 0.076 m) (kg/s)	Excess air (%)	Ambient temperature (°C)	Furnace temperature (°C)	Exit <sup>a</sup> temperature (°C)	Efficiency of furnace (%)
1/97	30	135	0.627	0.400	0.178	0.048	265	34	531	304	58
2/97	45	133	0.627	0.400	0.178	0.048	270	34	530	302	58
3/97	50	136	0.625	0.398	0.178	0.048	260	35	523	304	57
4/97	60	130	0.628	0.401	0.179	0.048	280	33	554	301	59
5/97	30	110	0.628	0.401	0.179	0.048	350	33	571	299	70
6/97	45	112	0.628	0.401	0.179	0.048	342	33	568	306	70
7/97	50	110	0.626	0.400	0.178	0.048	350	34	628	310	73
8/97	50	111	0.621	0.400	0.161	0.060 <sup>b</sup>	342	34	710	311	72
9/97	50	125	0.619	0.400	0.149	0.070 <sup>b</sup>	294	34	598	301	62
10/97	30	133	0.676	0.398	0.178	0.099 <sup>b</sup>	299	35	502	297	57
11/97	45	125	0.674	0.397	0.177	0.099 <sup>b</sup>	323	36	566	297	60
12/97	50	136	0.674	0.397	0.177	0.099 <sup>b</sup>	289	36	527	295	54

<sup>a</sup> Mixed air between combustion air and ambient air

<sup>b</sup> Increased airflow rate in tertiary duct

**Table 2.** Carbon conversion efficiency of the rice husk furnace using four air distributors (experiments conducted in 1997).

Experiment number	Carbon in rice husk (%)	Carbon in ash (%)	Rice husk consumption (kg)	Ash (kg)	CO value (ppm)	O <sub>2</sub> value (%)	Carbon conversion efficiency obtained from carbon balance (%)	Carbon conversion efficiency measured (%)
1/97	39	9.9	318	84	1 025–1 869	17.4–18.6	93	93
2/97	39	7.5	288	70	1 129–1 999	17.2–18.7	93	95
3/97	39	5.9	320	75	142–1 732	17.4–18.4	94	96
4/97	39	4.4	254	60	1 083–1 982	17.0–19.1	95	97
5/97	39	7.0	259	62	1 253–1 946	17.9–18.9	96	95
6/97	39	4.9	253	60	1 204–1 832	17.4–18.4	98	97
7/97	39	5.5	237	53	200–1 803	17.4–18.4	96	96
8/97	39	13.4	250	58	1 200–1 993	17.4–18.4	90	92
9/97	39	14.8	262	74	1 232–1 879	17.5–18.6	87	89
10/97	39	28.7	320	83	1 230–1 896	17.4–18.4	81	81
11/97	39	26.3	289	74	1 235–1 999	17.4–19.0	83	82
12/97	39	22.8	320	79	1 260–1 988	17.2–18.7	85	85

Note: low values of NO<sub>2</sub> and SO<sub>2</sub> (NO<sub>2</sub> = 1–12 ppm, SO<sub>2</sub> = 1–20 ppm).

**Table 3.** Efficiency of the rice husk furnace at various heights of ash using one air distributor (experiments conducted in 1996).

Experiment number	Height of ash (cm)	Feed rate of rice husk (kg/h)	Airflow rate for combustion (kg/s)	Airflow rate in primary duct (... = 0.152 m) (kg/s)	Airflow rate in secondary duct (... = 0.102 m) (kg/s)	Airflow rate in tertiary duct (... = 0.051 m) (kg/s)	Excess air (%)	Ambient temperature (°C)	Exit temperature (°C)	Efficiency of furnace (%)
1/96	30	127	0.626	0.400	0.178	0.048	287	34	294	62
2/96	45	133	0.626	0.400	0.178	0.048	269	34	296	59
3/96	50	126	0.628	0.401	0.179	0.048	290	33	296	63
4/96	60	143	0.631	0.402	0.180	0.049	245	32	297	58

**Table 4.** Carbon conversion efficiency of the rice husk furnace at various heights of ash using one air distributor (experiments conducted in 1996).

Experiment number	Height of ash (cm)	Carbon in rice husk (%)	Carbon in ash (%)	Rice husk consumption (kg)	Ash (kg)	CO value (ppm)	O <sub>2</sub> value (%)	Carbon conversion efficiency obtained from carbon balance (%)	Carbon conversion efficiency measured (%)
1/96	30	36.8	19.3	381	101.0	1 300–1 600	18	87	88
2/96	45	36.8	12.6	399	93.0	1 700–1 800	18	95	93
3/96	50	36.8	24.8	378	102.5	1 600–1 900	18	83	85
4/96	60	36.8	14.9	429	108.0	1 000–1 800	18	94	90

Note: low values of NO<sub>2</sub> and SO<sub>2</sub> (NO<sub>2</sub> = 30–60 ppm, SO<sub>2</sub> = 3–20 ppm).

hydrogen, 5.4%; oxygen, 40.3%; nitrogen, 0.19%; sulfur, 0.04%; moisture, 8.10%; ash, 15.1%; and calorific value, 3,566 cal/g (14.93 MJ/kg).

Ash of each experiment was analysed at the Department of Science Service, Ministry of Science, Technology and Environment. The quantities of carbon after combustion of 12 samples were as follows: 9.9, 7.5, 5.9, 4.4, 7.0, 4.9, 5.5, 13.4, 14.8, 28.7, 26.3 and 22.8%, respectively. Carbon after combustion was high when the air flow rate for supporting combustion in tertiary duct increased, as shown in Table 1. The grate hole became larger and combustible rice husk on grate fell down to the bottom of the combustion chamber when the air flow rate increased.

### Power consumption of the rice husk furnace

Power consumption of the rice husk furnace was as follows: conveying fan of primary air, 1.25 kW; conveying fan of secondary air and tertiary air, 1.18 kW; suction blower, 8.36 kW; motor of ash paddle, 1.79 kW; motor of rice husk feeding system, 0.66 kW; and screw conveyor for ash unloading, 0.72 kW. The total power consumption was 13.96 kW.

Electricity consumption in these experiments was compared to the thermal energy production of the furnace. The results showed that electricity con-

sumption in terms of primary energy (multiplying factor 2.6) was approximately 7% of thermal energy production of the rice husk furnace, as shown in Table 5.

### Financial analysis and commercialisation

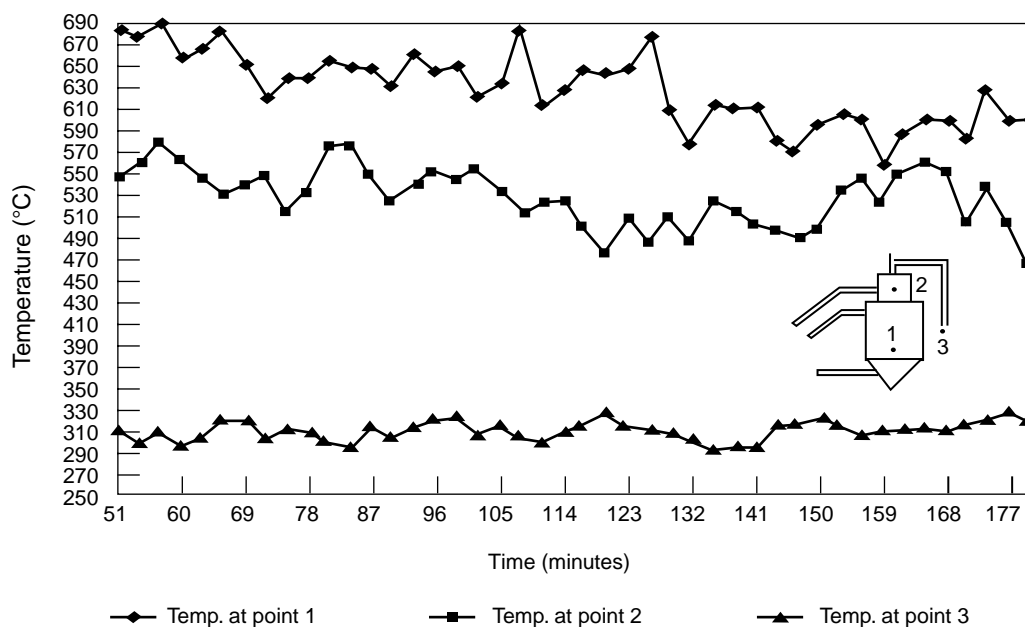
For financial analysis, the rice husk furnace was compared to a diesel oil burner when it was used in a fluidised bed paddy dryer of 10t/h capacity (Soponronnarit et al. 1996). The conditions were as follows: cost of dryer and rice husk furnace, 950,000 baht; dryer capacity, 10,260 t/year; initial moisture content, 28.1% dry basis (d.b.); final moisture content, 22.6% d.b.; power consumption, 37.9 kW; cost of rice husk, 100 baht/t; service life, 5 years; interest rate, 15%; and salvage value, 10% of initial cost. The results showed that the total cost of the system was 400,274 baht/year. When the dryer was used with a diesel oil burner, the cost of the dryer and burner was 850,000 baht. Diesel oil consumption was 31.34 L/h (7.50 baht/L) and power consumption was 32.3 kW. The other conditions were the same as those of the dryer operating with the rice husk furnace. The total cost of the dryer and burner was 596,618 baht/year: 196,344 baht/year higher compared to the former case.

**Table 5.** Electricity consumption (experiments conducted in 1997).

Experiment number	Feed rate of rice husk (kg/h)	Electricity consumption rate (kW)	Electricity consumption rate in terms of primary energy <sup>a</sup> (kW)	Heat production rate of rice husk furnace (kW)
1/97	135	13.96	36.30	559.68
2/97	133	13.96	36.30	551.40
3/97	136	13.96	36.30	563.83
4/97	130	13.96	36.30	538.95
5/97	110	13.96	36.30	456.04
6/97	112	13.96	36.30	464.33
7/97	110	13.96	36.30	456.04
8/97	111	13.96	36.30	460.20
9/97	125	13.96	36.30	518.23
10/97	133	13.96	36.30	551.40
11/97	125	13.96	36.30	518.23
12/97	136	13.96	36.30	563.83

<sup>a</sup>Multiplied by a factor of 2.6





**Figure 2.** Relationship between temperature and time in the rice husk furnace with an ash height on the grate of 50 cm (experiment no. 7/97).

More than 20 units of the cyclonic rice husk furnace have been produced commercially since the beginning of 1999. All of them were installed in private rice mills.

## Conclusion

1. Excess air during combustion affected the efficiency of the furnace. When excess air increased from 260 to 350%, the efficiency of the furnace increased from 57 to 73%.
2. Air distribution in the tertiary duct did not significantly affect the carbon conversion efficiency and efficiency of the furnace.
3. The height of ash on the grate had no effect on the efficiency of rice husk furnace.
4. An airflow rate in the tertiary duct which was too high did not support combustion as it caused a proportion of combustible rice husk to fall from the grate, resulting in incomplete combustion.
5. The total cost of the fluidised bed dryer with a capacity of 10 t operating with a rice husk

furnace was lower than that operating the same dryer with a diesel oil burner.

## Acknowledgments

The authors would like to thank the Thailand Research Fund and Australian Centre for International Agricultural Research for supporting this project. Thanks are also due to Rice Engineering Supply Co. Ltd for supporting fabrication of the prototype rice husk furnace and the Storage and Processing Section, Department of Agriculture for providing the experimental site and technical support.

## References

- Shujinda, A. 1997. Rice husk furnace for fluidized bed paddy drying. Masters thesis, King Mongkut's University of Technology Thonburi, Bangkok, 13–27 (in Thai).
- Singh, R., Maheshwari, R.C. and Ojha, T.P. 1980. Development of husk fired furnace. India, The British Society for Research in Agricultural Engineering, 109–120.
- Soponronnarit, S., Prachayawarakorn, S. and Wangi, W. 1996. Commercial fluidized bed paddy dryer. In:

- Proceedings of the 10<sup>th</sup> International Drying Symposium (IDS'96), Krakow, Poland, 30 July–2 August 1996, volume A, 638–644.
- Tumaming, J.A. 1984. Testing and evaluation of rice hull-fed furnaces for grain drying. In: Semple, R.L. and Frio, A.S., ed., Proceedings of the 7<sup>th</sup> ASEAN Technical Seminar on Grain Post-harvest Technology—Health and Ecology in Grain Post-harvest Technology, Kuala Lumpur, Malaysia, 21–24 August 1984, 197–214.
- Xuan, N.V., Vinh, T., Anh, P.T. and Hien, P. 1995. Development of rice husk furnaces for grain drying. Proceedings of the International Conference on Grain Drying in Asia, Bangkok, Thailand, 17–20 October 1995, 109–120.

# Evaluation of Drying System Performance in Rice Mills

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## Abstract

The suitability of paddy drying systems in three rice mills with different product capacity and drying system installations was examined. The study included drying technique, paddy quality, energy consumption and problems arising during operation. Finally, the most suitable paddy drying system was decided upon. This provides a guide for improving the efficiency of paddy drying systems and minimising the cost of drying. Important other results can be summarised as follows:

1. Use of a fluidised bed dryer with tempering during each drying stage reduced the moisture content (MC) of paddy from 24% to 14% dry basis with acceptable paddy quality.
2. Partial air recirculation reduced energy consumption in the fluidised bed dryer.
3. Energy consumption of each drying system depended on the initial and final MC of paddy, i.e. higher MC, lower energy consumption.

AT PRESENT, mechanical dryers—i.e. the Louisiana State University (LSU) dryer, cross flow dryer, recirculation batch dryer and fluidised bed dryer—are widely used in Thai rice mills. In-store drying is becoming more widely adopted. Soponronnarit (1995) studied the damage to moist paddy after harvest—analysing the causes and using a systematic approach to solving these problems. The solution included aeration of ambient air through the moist paddy bulk using a low flow rate of  $0.35 \text{ m}^3/\text{min}/\text{m}^3$  of paddy to exhaust the heat liberated through respiration during the waiting period before drying. Two-stage drying was necessary in order to reduce the moisture content (MC) of paddy rapidly to 23% dry basis (d.b.) in the first stage using a fluidised bed dryer or other type of dryer, for quality reasons. This was followed by a second stage of slow drying to reduce the MC from 23 to 16% d.b. This stage was carried out in a shed using aeration of ambient air with a flow rate of  $0.5\text{--}1.0 \text{ m}^3/\text{min}/\text{m}^3$  of paddy during the daytime. In the case of storing paddy for several months, intermittent aeration of ambient air through the paddy bulk for 1–3 h/week was necessary to exhaust heat liberated from the paddy.

Mongkonthad (1994) reported that paddy drying using the LSU grain dryer gave a lower head rice yield (maximum 5%) than ambient air drying and reduced the MC of paddy from 27 to 18% d.b., with an output of 30 t of paddy/day. Using rice husk as fuel costs approximately 20 baht/t of paddy. Soponronnarit et al. (1995) designed and tested a prototype, 0.82 t/h capacity, fluidised bed paddy dryer for high MC paddy. Exhaust air was partially recirculated. Experimental results showed that it could reduce the MC of paddy from 45 to 24% d.b. using a drying air temperature of 100–150°C, with the fraction of recirculated air 0.66, a specific air flow rate of 0.05 kg/s/kg of dry matter, superficial air velocity of 3.2 m/s, bed depth of 0.1 m, and total primary energy consumption of 2.32 MJ/kg of water evaporated. Reference data of the energy consumption of many rice mills showed that primary energy consumption ranged between 3–6 MJ/kg of water evaporated, based on the moisture level of paddy.

Soponronnarit et al. (1999) investigated a strategy for reducing moisture in paddy using a combination of the fluidisation technique, tempering, and ambient air ventilation, and examined the results with respect to total operation time and milling quality. The results showed that after the three processes, the MC of paddy was reduced from 33 to 16.5% d.b. within approxi-

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mately 53 min. During the first process, a fluidised bed dryer was used to reduce the MC of paddy to 19.5% d.b. within 3 min. Then the paddy was tempered for at least 30 minutes, but for not more than 1 h. Finally, it was cooled using ambient air with a velocity of 0.15 m/s for 20 min. The quality of paddy in terms of head rice yield and whiteness was acceptable. Taweerattanapanish et al. (1999) studied the yield of paddy dried using the fluidisation technique with paddy of varying initial and final MC using a high inlet air temperature (140 and 150°C). After tempering, head rice yield increased compared to ambient air drying. The initial and final MC of paddy—ranging between 30–45% d.b. and 23–28% d.b., respectively—affected the increase in head rice yield. The head rice yield of tempered paddy was higher than that of untempered paddy, while there was no difference in eating quality scores between the samples.

Each rice mill has a different drying system. Some of these may damage the paddy (i.e. produce low quality paddy), or be expensive to run. This study involved a comparison of drying system performance at three rice mills. The study included paddy drying method, paddy quality, energy consumption and problems arising during operation. The results will be useful for improving the efficiency of paddy drying systems and minimising the cost of drying.

## Materials and Methods

The paddy drying systems were studied in three different rice mills—Nithithanyakit, Kungleechan and Poonsinthalai. Each rice mill uses a different paddy drying system, consisting of some components as follows: fluidised bed dryer, LSU dryer, cross flow dryer, cleaner, cooling bin and tempering bin. Schematic diagrams of the three drying systems are shown in Figures 1–4. In all cases, the MC of paddy was reduced from at least 23 to 14% d.b.

The drying air temperature used depended on the type of dryer and the MC of paddy as follows: 100–150°C for a 10 t/h capacity fluidised bed dryer with a bed depth of 15 cm; and 80–100°C for a 6–40 t capacity LSU dryer.

## Results and Discussion

### Moisture and paddy quality

#### *Nithithanyakit rice mill*

Two-stage drying system, 20 t/h capacity (Figures 1 and 2).

#### *First stage*

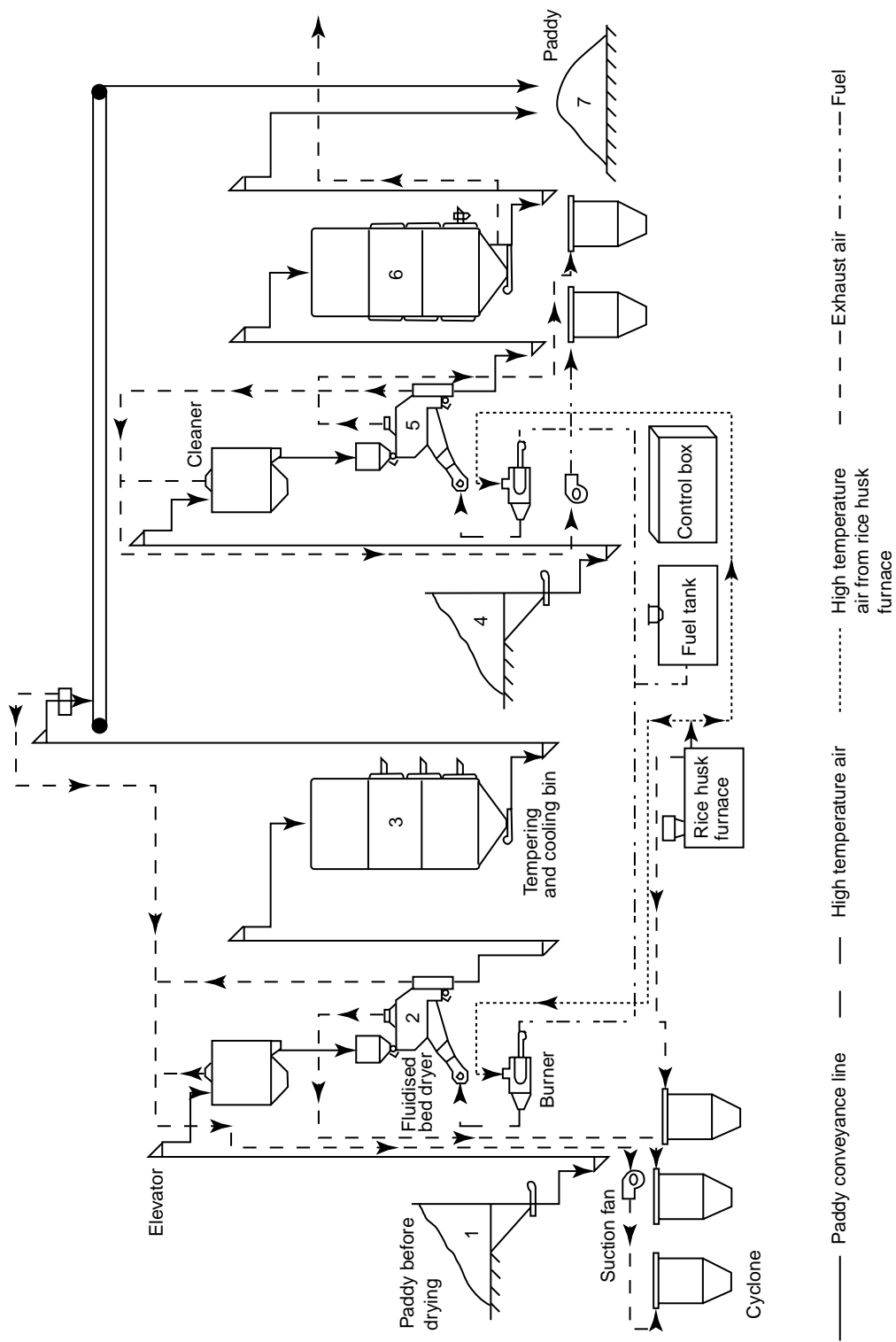
The first stage included two parallel system installations (Figure 1). In the first half of the system, the average MC, head rice yield and whiteness of paddy in a paddy pit (position 1 in Figure 1) were 23.3% d.b., 39.2% and 46.8, respectively. After passing through a fluidised bed dryer (2) at a feed rate of 9.30 t/h and an average drying air temperature of 145°C, the MC, paddy temperature, head rice yield and whiteness of paddy were 18.5% d.b., 62°C, 44.2% and 45, respectively. Then the paddy passed through a 9 t capacity tempering and cooling bin (3). The average MC, paddy temperature, head rice yield and whiteness were 17.3% d.b., 34°C, 47.7% and 44.7, respectively.

In the second half of the system, the average MC, head rice yield and whiteness of paddy in the paddy pit (position 4 in Figure 1) were 20.6% d.b., 36.6% and 47.8, respectively. After passing through a fluidised bed dryer (5) at a feed rate of 10.5 t/h and an average drying air temperature of 149°C, the MC, paddy temperature, head rice yield and whiteness were 18.4% d.b., 65°C, 38.8% and 47.7, respectively. Then the paddy passed through a 9 t capacity tempering and cooling bin (6). The average MC, paddy temperature and head rice yield of paddy were 17.0% d.b., 39°C, and 41.8%, respectively, and there was no change in the average rice whiteness.

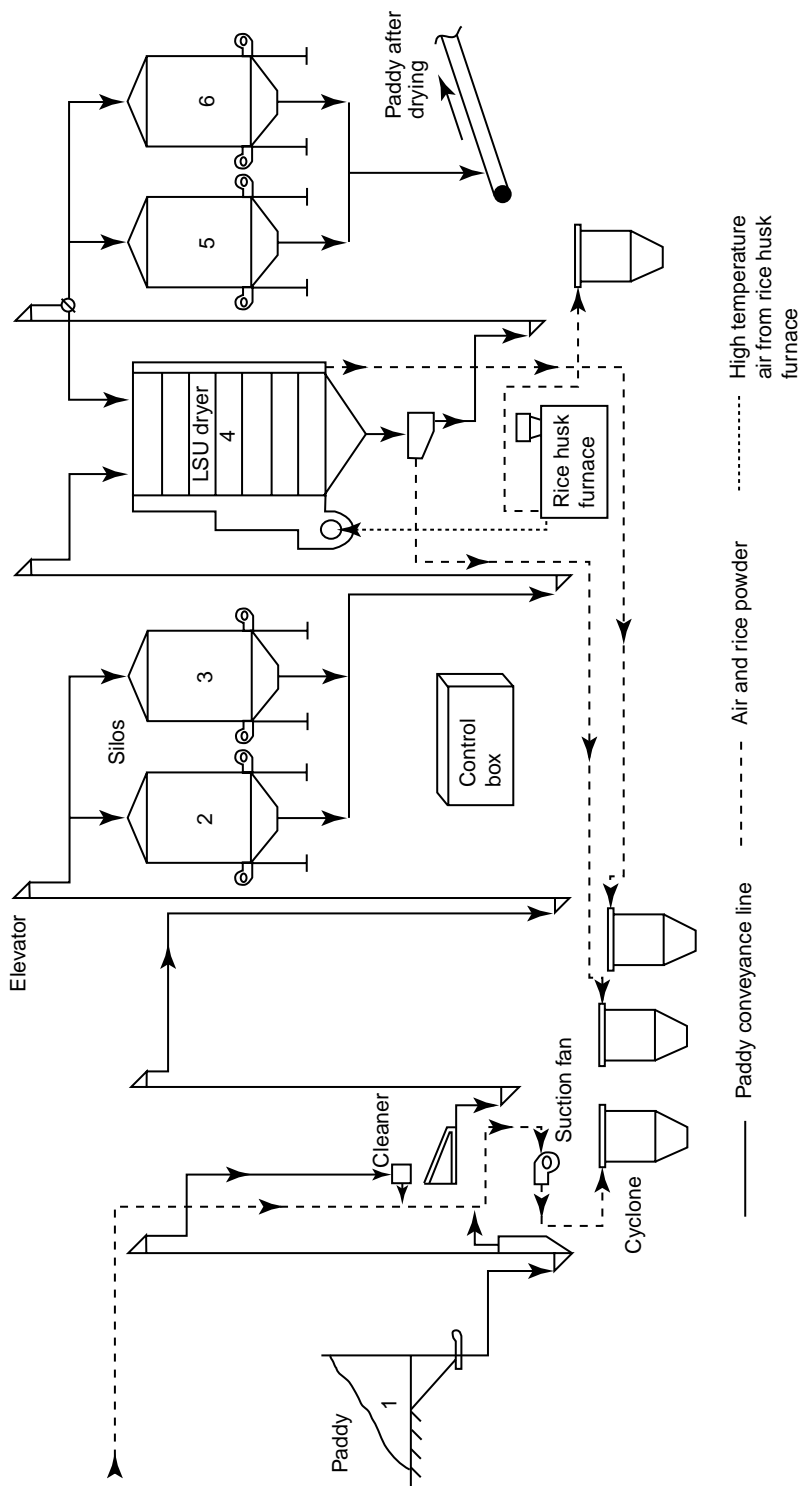
#### *Second stage*

In the second stage (Figure 2), paddy from the tempering and cooling bins (positions 3 and 6 in Figure 1) was conveyed to a paddy bulk (7 in Figure 1; 1 in Figure 2)—which had an average head rice yield of 46.3% and rice whiteness of 45.3, then passed through silos (2 and 3 in Figure 2) to reduce the temperature of paddy to 34°C using ambient air. The average head rice yield and whiteness were 47.4% and 45.8, respectively. Then the paddy passed through a 40 t capacity LSU dryer (4 in Figure 2), with an average drying air temperature of 79°C. The LSU dryer reduced the MC of paddy to 14.0% d.b., with an average paddy temperature of 46°C, head rice yield of 36.4% and whiteness of 46.3. Then the paddy passed through silos (5 and 6 in Figure 2) in order to reduce its temperature using ambient air ventilation. The average head rice yield was 38.7% with no change in rice whiteness.

From these experimental results, the average initial MC of paddy was 20.6–23.3% d.b. After the first stage of drying, the average MC of paddy was 17.0–17.3% d.b. Head rice yield and whiteness were in good ranges compared to the initial condition.



**Figure 1.** The first stage of the drying system of the Nithithayakit rice mill, Khanuworalukburi, Kamphaengphet. Numbers shown on the diagram refer to stages discussed in the text.



**Figure 2.** The second stage of the drying system of the Nithithanyakit rice mill, Khanuwalukburi, Kamphaengphet. Numbers shown on the diagram refer to stages discussed in the text.

After the second stage, the average MC of paddy was 14% d.b. Head rice yield was not very high while the average rice whiteness was good at 46.3, based on the initial whiteness.

#### *Kungleechan rice mill*

Two-stage drying system, 6.06 t/h capacity (Figure 3).

##### *First stage*

The average MC of paddy in the paddy pit (position 1 in Figure 3) was 24.4% d.b. After passing through a cleaner, the average MC was reduced to 23.9% d.b., and average head rice yield and whiteness were 46.0% and 40.9, respectively. Then the paddy passed through a fluidised bed dryer (2) with a feed rate of 9.54 t/h, average drying air temperature of 142°C, bed depth of 15 cm and residence time of 1.4 min. The dryer reduced the MC of paddy to 20.5% d.b. with average paddy temperature of 67°C, head rice yield of 45.9% and whiteness of 41.8. After passing through a 18 t capacity tempering and cooling bin (3), the MC of paddy was reduced to 18.4% d.b., with average paddy temperature, head rice yield and whiteness of 43°C, 44.4% and 40.7, respectively.

##### *Second stage*

Paddy was further dried using a fluidised bed dryer (4) with a feed rate of 9.06 t/h, average drying air temperature of 141°C, bed depth of 12 cm and residence time of 1.2 min. The dryer reduced the MC of paddy to 15.6% d.b. with an average paddy temperature of 75°C, head rice yield of 43.7% and whiteness of 41.2. Then the paddy passed through a 17 t capacity LSU dryer, which operated as a tempering and cooling bin (5) instead of drying. It reduced the MC of paddy to 14.2% d.b. with an average paddy temperature of 42°C, head rice yield of 44.5% and whiteness of 40.2. The paddy was then conveyed to the dust extraction bin (6) where its temperature was reduced to 41°C.

At the Kungleechan rice mill, the average initial MC of paddy was about 24.4% d.b. After two-stage drying using fluidised bed dryers, the MC of paddy was reduced to 14.2% d.b. Head rice yield and rice whiteness were in good ranges.

#### *Poonsinthalai rice mill*

Two-stage drying system, 0.893 t/h capacity (Figure 4).

##### *First stage*

The average MC of paddy in the paddy pit (position 1 in Figure 4) was 28.6% d.b. After passing through a cleaner (2), the MC of paddy was reduced to 28.2% d.b. with an average head rice yield and whiteness of 41.0% and 44.6, respectively. Then the paddy passed through a fluidised bed dryer (3) with a feed rate of 9.32 t/h, average drying air temperature of 103°C, bed depth of 10 cm and residence time of 0.96 min. The dryer reduced the MC of the paddy to 21.7% d.b., with an average paddy temperature of 65°C, head rice yield of 39.6% and whiteness of 45.9.

##### *Second stage*

The paddy was conveyed to a paddy pit (position 4 in Figure 4) for 1 h which reduced the paddy temperature to 49°C. Then the paddy was ventilated with ambient air in a 7 t capacity cross flow dryer (5) for 1.5 h, reducing the MC to 21.0% d.b. with an average paddy temperature of 33°C, head rice yield of 44.1% and whiteness of 44.0. The paddy was then passed back through the same cross flow dryer, with an average drying air temperature of 71°C. Circulated paddy was in this dryer for 10 rounds (47 min/round), resulting in the reduction of MC to 17.0% d.b. with an average paddy temperature of 36°C, head rice yield of 42.0 and whiteness of 44.8. Then it was conveyed to a dust extraction bin (6).

At the Poonsinthalai mill, the average initial MC of paddy was 28.6% d.b. The paddy was dried to 17% d.b. with head rice yield and rice whiteness in good ranges. It should be noted that a bottleneck in the drying capacity was due to the limited capacity of the cross flow dryer.

## **Energy consumption**

Energy consumption for the paddy drying systems was thermal energy for air heating and electricity for running motors. Tables 1 and 2 show that energy consumption increased as the MC of paddy decreased. Air recirculation reduced energy requirements, i.e. first-stage drying in the Nithithanyakit mill, which did not have air recirculation, used more energy than that of the Kungleechan mill which did have air recirculation. A too low drying air temperature also caused higher energy consumption, as shown in the second-stage drying at the Poonsinthalai mill.

**Table 1.** Energy consumption of the first-stage drying at the three rice mills.

Rice mill (Fuel source)	T <sub>a</sub> (°C)	MC <sub>in</sub> <sup>b</sup> (% d.b.)	MC <sub>out</sub> <sup>c</sup> (% d.b.)	Drying rate (kg of dry matter/h)	Heat (MJ/h)	Primary energy from electricity (conversion factor = 2.6) (MJ/h)	Rate of water evaporation (kg/h)	Specific heat consumption (MJ/kg of water evaporated)	Electricity consumption in terms of specific primary energy (MJ/kg of water evaporated)
Nithithanyakit (Rice husk)—first half of the system	145	23.3	17.3	7 928	2 596.29	461.50	476	5.45	0.97
Nithithanyakit (Rice husk)—second half of the system	149	20.6	17.0	8 974	2 596.29	468.89	323	8.03	1.45
Kungleechan (Diesel)	142	24.4	18.4	8 057	1 239.01	402.39	483	2.56	0.83
Poonsinthal (Crude oil)	103	28.6	21.7	7 657	1 053.75	388.44	528	2.00	0.73

<sup>a</sup>T = average drying air temperature during the drying period.

<sup>b</sup>MC<sub>in</sub> = average inlet moisture content of paddy.

<sup>c</sup>MC<sub>out</sub> = average outlet moisture content of paddy

**Table 2.** Energy consumption of the second-stage drying at the three rice mills.

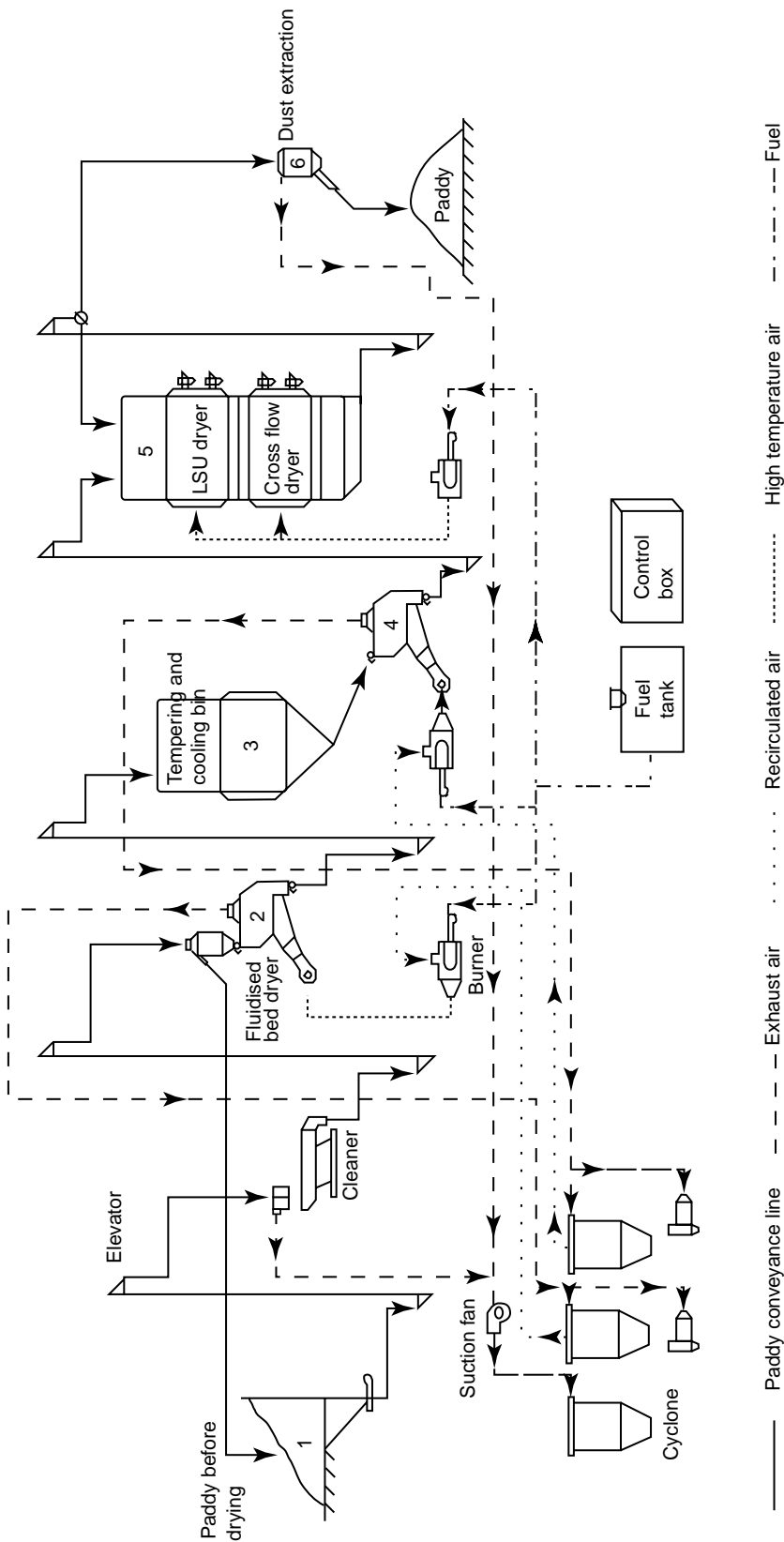
Rice mill (Fuel source)	T <sub>a</sub> (°C)	MC <sub>in</sub> <sup>b</sup> (% d.b.)	MC <sub>out</sub> <sup>c</sup> (% d.b.)	Drying rate (kg of dry matter/h)	Heat (MJ/h)	Primary energy from electricity (conversion factor = 2.6) (MJ/h)	Rate of water evaporation (kg/h)	Specific heat consumption (MJ/kg of water evaporated)	Electricity consumption in terms of specific primary energy (MJ/kg of water evaporated)
Nithithanyakit (Rice husk)	79	17.2	14.0	17 543	3 671.95	590.25	561	6.54	1.05
Kungleechan (Diesel)	141	18.4	14.3	5 302	1 266.94	495.92	217	5.82	2.28
Poonsinthal (Crude oil)	71	21.8	17.0	764	735.64	88.12	37	20.06	2.40

<sup>a</sup>T = average drying air temperature during the drying period.

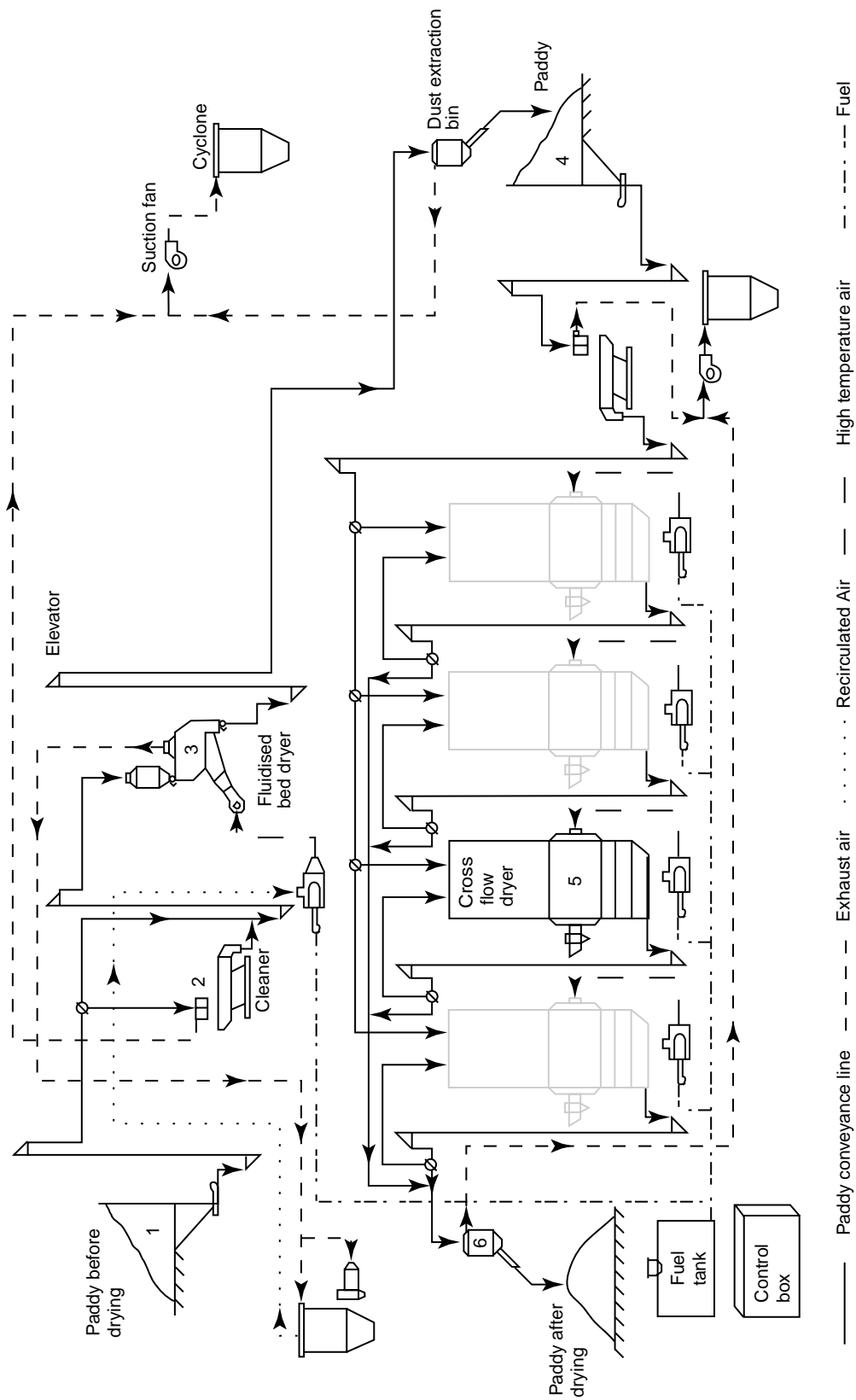
<sup>b</sup>MC<sub>in</sub> = average inlet moisture content of paddy.

<sup>c</sup>MC<sub>out</sub> = average outlet moisture content of paddy

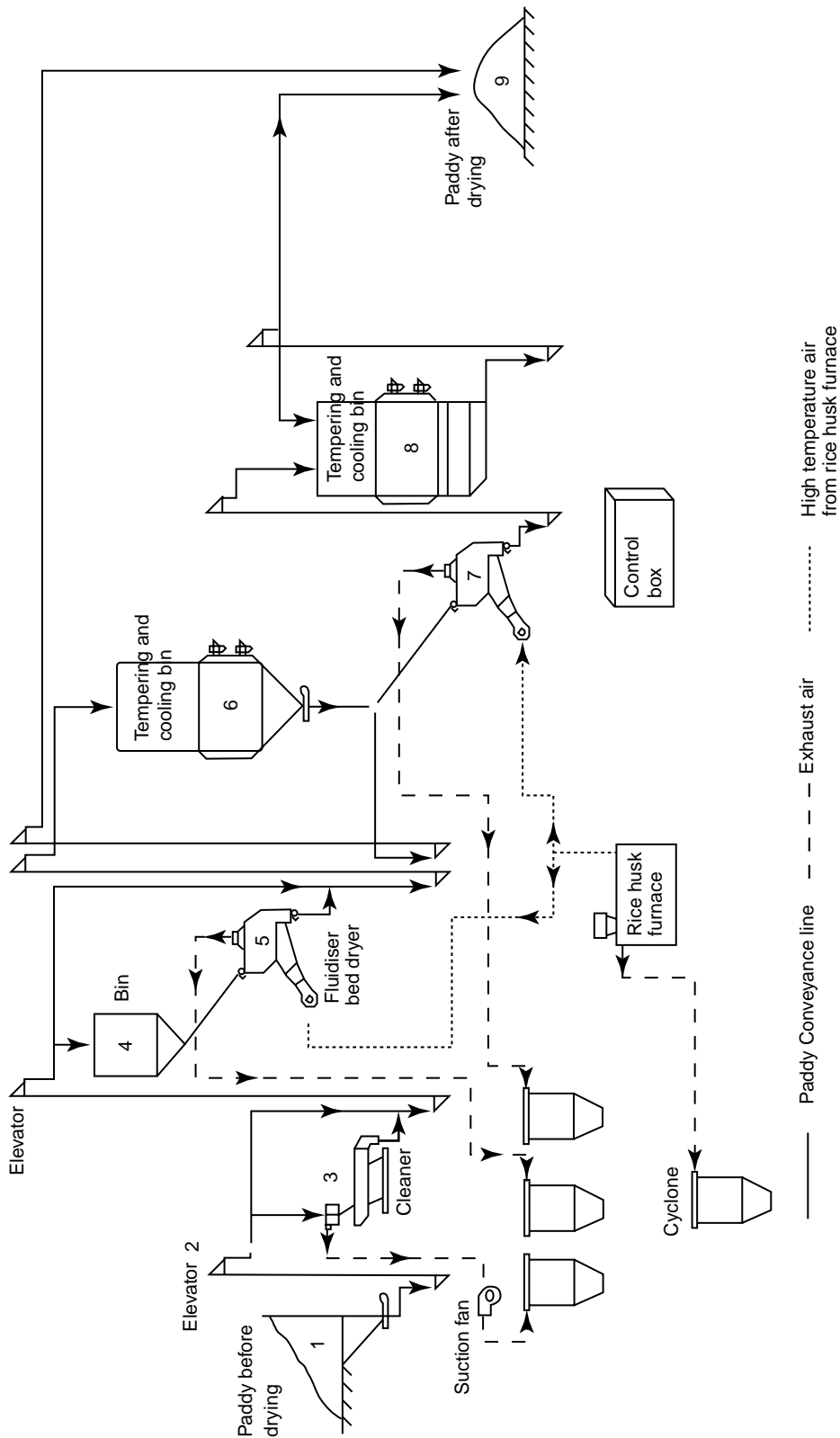




**Figure 3.** The drying system of the Kungleechan rice mill, Lardbualuang, Ayudthaya. Numbers shown on the diagram refer to stages discussed in the text.



**Figure 4.** The drying system of the Poonsinthai rice mill, U-Thong, Suphanburi. Numbers shown on the diagram refer to stages discussed in the text. Note that only one of the four cross dryers was operational during the trial.



**Figure 5.** System for drying at a rice mill proposed as a result of the study. Numbers shown on the diagram refer to stages discussed in the text.

## Other problems

1. Rotary feeders did not work well due to feed blockages caused by high pressure in the drying chamber. The exception was in the second-stage drying at the Kungleechan mill where a large bin had been installed in front of the rotary feeder.
2. The burners could not be reliably set to a fixed drying air temperature due to prolonged use of fuel oil which caused fuel nozzle blockages.
3. Using fuel oil as fuel could cause rust to accumulate inside the drying chamber.
4. Lack of knowledge about operating the dryers.

## Conclusions

Important results can be summarised as follows:

1. A fluidised bed dryer with tempering during each drying stage reduced the MC of paddy from 24% d.b. to 14% d.b. with acceptable paddy quality.
2. Partial air recirculation reduced energy consumption in the fluidised bed dryer.
3. Energy consumption of each drying system depended on the initial and final MC of paddy—i.e. higher MC, lower energy consumption.
4. The main problems at all the rice mills were rotary feed operation of the fluidised bed dryers and a lack of knowledge about operating the dryers.
5. The best drying system performance of the three rice mills—in terms of drying management, paddy quality, energy consumption and extent of other problems—was Kungleechan, followed by Nithithayakit, then Poonsinthal.

## Suggestions

As a result of this study, guidelines have been devised for designing a high performance drying system (Figure 5). Paddy with 25% d.b. MC in a paddy pit

(position 1 in Figure 5) is conveyed by an elevator (2) to a cleaner (3), a 5 t bin (4) and a 10 t/h fluidised bed dryer (5) which is expected to reduce the MC of paddy to 20% d.b. The paddy is then conveyed to a 10 t capacity tempering and cooling bin (6).

In the second-stage, paddy flows through a 10 t/h fluidised bed dryer (7) with the MC of paddy expected to be 16% d.b. at output. Then it is conveyed to a 10 t capacity tempering and cooling bin (8), and finally to a paddy bulk (9).

The use of a rice husk burner is also recommended as it allows lower energy costs.

## Acknowledgment

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## References

- Mongkonthad, J. 1994. Grain dryer of the Agriculture Division at present rice production. *Agricultural Engineering Division News*, October–December, 2–5 (in Thai).
- Soponronnarit, S. 1995. Strategy for managing moist paddy. *The Royal Institute Journal*, 20(4), 115–125 (in Thai).
- Soponronnarit, S., Yapha, M. and Prachayawarakorn, S. 1995. Cross flow fluidized bed paddy dryer: prototype and commercialization. *Drying Technology*, 13(8&9), 2207–2216.
- Soponronnarit, S., Wetchacama, S., Swasdisevi, T. and Poomsa-ad, N. 1999. Managing moist paddy by drying, tempering and ambient air ventilation. *Drying Technology*, 17(1&2), 335–344.
- Taweerattanapanich, A., Soponronnarit, S., Wetchacama, S., Kongseri, N. and Wongpiyachon, S. 1999. Effects of drying on head rice yield using fluidization technique. *Drying Technology*, 17(1&2), 345–354.

# In-store Drying under Different Climatic Conditions in China

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## Abstract

China has number of sites throughout the country equipped with grain aeration facilities used so far as a physical method of insect control in grain. Current research work on in-store drying is aimed at reducing the moisture content from 18% to 14% wet basis in north-eastern and southern China as part of the two-stage drying concept. Initial work included weather data analysis and computer simulation of in-store drying. Field experiments have been conducted to validate the predictions made using the simulation models. As a result, recommendations related to the equipment required and strategies to be used could be issued in order to optimise the drying process and improve the quality of stored grain.

THIS PAPER summarises some of the recent research aimed at developing and promoting the two-stage drying concept for grain in the People's Republic of China. China belongs to the major world producers of grain (see Figure 1), and in 1998 was the world's number one producer of paddy and wheat and number two of maize. Given the size of China's population of over 1.2 billion and dependence on rice and wheat as staple foods for humans and maize for livestock, sustained and expanding grain production is an important issue. With only about 10% of the area of the country being arable land and competition from more lucrative crops such as vegetables and fruits, a significant expansion of the area under cereal crops is not conceivable. As a result, considerable efforts are being made to reduce the postharvest losses of grain, especially those related to grain drying and storage.

The Chinese grain industry has made considerable efforts to increase grain production and to reduce post-harvest losses. Release of new, high-yielding varieties, mechanisation, and multiple cropping are among the ways to increase grain production. However, increased

production has led to new handling problems. As more grain is being harvested, increasing amounts of high moisture grain are being procured and stored by the depots of the government Grain Handling Bureaux. These bureaux procure about 30% of the total quantity of grain produced in China for human and animal consumption, and the amount of high moisture grain has been estimated at about 30 Mt (Ren Yonglin and van Graver 1996).

## Current Status of Grain Drying in China

Grain drying at the farmers' level still mainly relies on sun-drying. It is still important in the government-owned depots (Ju Jin Feng et al. 1996; Li Huojin 1996).

Genzhang Zhuge et al. 1993 claimed that delayed drying was responsible for qualitative losses, particularly in maize (moulds) and in paddy (yellowing, increased proportion of broken and decreased germination). Two types of mechanical drying are available in grain depots:

- hot air drying; and
- near ambient air drying.

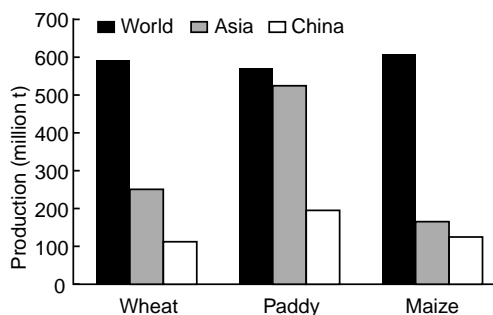
The currently predominant form of mechanical drying is using hot air. According to Ju Jin Feng et al. (1996), mechanical drying was introduced into China in the 1940s, initially in north-eastern China. In the hot

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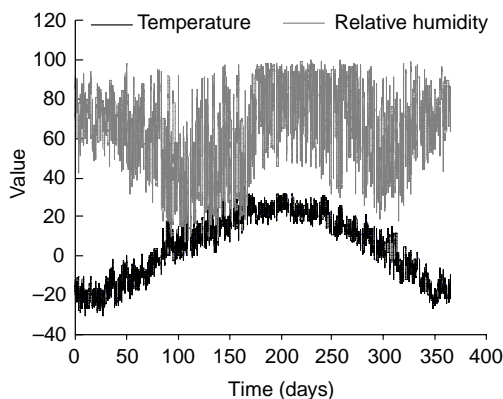
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air dryers, the heat source is generally coal, and direct as well as indirect heating is practiced. There is increasing criticism of older designs of column dryers for their excessive energy consumption as well as environmental pollution.

As for the designs used in aeration drying, there are round silos with either radial flow distribution from a central ducting or with in-floor ducting. Very common features are the horizontal warehouses with on-floor or in-floor ducting with a capacity of over 1,000 t (often 2,500 t). There is also a large number of designs of small, round aerated mud or mat silos, many of them also fitted with air distribution ducting. Such silos are, however, normally used for temperature control in grain rather than drying.



**Figure 1.** Production of major grain crops in China in comparison with Asia and the world in 1998. (Source: FAO 1999.)



**Figure 2.** Weather pattern in Zhaodong, Heilongjiang Province in 1984, showing the temperature (°C) and relative humidity (%).

Given the vast expanse of the country (from latitudes 20–50° North), cereal crops are grown under various soil and climatic conditions using a range of agronomic practices. Most of the grain is grown in eastern China, with dominance of maize in the northern, of wheat in the centre and of paddy in the southern part of the country (Ren Yonglin and van Graver 1996). China has three major grain crops in its north-eastern provinces, namely rice, wheat, and maize.

## North-eastern China

In the north-east of the country, the provinces of Heilongjiang and Jilin are among the major producers of grain. The major grain crops—according to the quantity produced—are: maize (60% of the total grain production in both provinces), followed by rice, wheat, and soybeans. The maize production in those two provinces of north-eastern China accounts for 20–25% of total national production.

The provinces of Heilongjiang and Jilin are characterised by a frost-free period of about 150 days and a short growing period, as shown in Figure 2. The transition period between autumn and winter is very short. Winter temperatures are in the range of –20 to –30°C for up to 5 months. Delays in planting or growth of the crops, especially maize, may result in a late harvest. Grain will thus not be able to attain full maturity and the moisture content at harvest may be as high as 30% wet basis (w.b.) (Szednicki and Driscoll 2000). It is harvested manually in late September–early October, in some years up to November and is initially stored on the cob after removal of sheaths. Shelling is usually done when wet maize is frozen and moisture contents are ranging from 25–35%.

The procurement by the state-owned grain handling authority starts on 15 November and lasts till the end of December. Grain procured by the grain handling authority goes initially into ‘first line’ grain collection depots, which are distributed within 30 km of each other. During receipt, first line collection depots perform quality tests such as moisture content (MC), impurities (foreign matter and broken), and thousand kernel weight determination. These depots usually do not have mechanical dryers and only limited sun-drying floors. Grain is either directly sent to intermediate or central depots, or stored temporarily in brick, mud or mat silos before being sun-dried and dispatched to these higher level depots. The latter, particularly the central depots, generally have coal-fired column dryers of a standard design (Zhengzhou

Grain Science and Research Institute, 15 t/h) as well as sunning floors, and often warehouses and small brick silos with aeration facilities. This applies not only to maize, but also to paddy, soybeans and sorghum.

In the north-eastern provinces, paddy is generally procured in August–September, followed by soybeans and sorghum, and finally by maize. Early maize is sun-dried or goes into the column dryers. Late maize often arrives at high MC (25–30%). However, being already in a frozen state it is often stored frozen until February–March.

## Southern China

Rice is the main crop in most of southern China. The postharvest problems for paddy in the southern temperate or subtropical provinces of China are similar to those in most places in Southeast Asia, where paddy is being harvested during the wet season. There is more than one crop of paddy per year, with one crop of indica and one crop of japonica rice. Throughout the region, this results in a high demand for mechanical dryers, caused by:

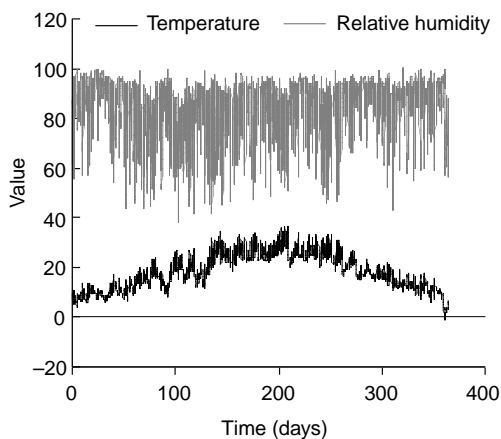
- harvesting under conditions of high relative humidity and temperature, resulting in grain having higher average MC than the dry season crop;
- the inadequacy of sun-drying to cope with the amount of grain being produced; and
- a steady increase in the amount being produced, due to advances in agronomy and farm mechanisation.

The main area targeted by the study is the province of Sichuan, which produces considerable amounts of paddy, as well as some wheat and corn. However, the results of the research are applicable to other locations in southern China with similar climatic and cropping patterns.

Weather data for 7 years (given as 6-hourly records of temperature and relative humidity) have been obtained for the city of Yibin in the province of Sichuan. Figure 3 shows the weather data for 1991.

## Logistics of in-store drying

In north-eastern China, most of the stored maize is sun-dried during spring and early summer. Aeration equipment is used for ventilation in autumn and to a limited extent for drying in spring and early summer. Since very little drying—except with high temperature column dryers—occurs in winter, there is usually a huge stockpile of wet maize and some wet paddy that has to be dried within a very short period of time as the



**Figure 3.** Weather pattern in Yibin, Sichuan Province in 1991, showing the temperature (°C) and relative humidity (%).

weather warms. Given the availability of storage space, some of which has been fitted with air distribution systems, the concept of in-store drying appears to provide an adequate solution for increasing the drying capacity of the existing system.

Trials have been conducted during two consecutive years in the Sifan depot in Zhaodong (Heilongjiang Province). In-store dryers are best suited to low-to-medium moisture products, and so would have to rely on the existence of hot air dryers, such as those already mentioned. Subsequently, the drying capacity of the latter would be artificially increased, as they would be involved in drying grain in the moisture range where they are most efficient, i.e. to MC of 18%.

As for the situation in southern China, the main grain crop, paddy, appears to be generally harvested at about 18–19% MC w.b. This creates optimum conditions for in-store drying as single-stage operation. An analysis of the weather data for the Yibin indicated that the site was suitable for in-store drying with supplemental heating (Srzednicki and Driscoll 2000). A field trial was conducted in Changning near Yibin in late 1998.

## In-store Drying Field Trials

### Zhaodong site in north-eastern China

In these field trials, conducted in April–May 1998 and 1999, round brick silos with perforated floors and a holding capacity of 220 t of maize were used. The

grain depth was 4.85 m. The variety of maize used in all experiments in Zhaodong was ‘Huangmo 417’. The first stage of drying was performed using high temperature dryers.

#### *Experiments conducted in spring 1998*

Two drying regimes were compared—ventilation with supplemental heating, and ventilation with ambient air. A 15 kW centrifugal fan with an airflow rate of 64.1 m<sup>3</sup>/h/m<sup>3</sup> of maize was used for the method with supplemental heating, and 34.2 m<sup>3</sup>/h/m<sup>3</sup> of maize for the ventilation with ambient air. In the silo with supplemental heating, the temperature was raised to 32°C and a fan was run almost continuously. The fans in the silos with ambient air aeration were operated daily for 7.5–9 h. The average ambient air temperature during aeration with ambient air was 19.3°C and the average relative humidity was 43.5%.

Grain samples were collected at three depths: 0.3 m (bottom), 2.4 m above the floor (middle), and at the top

of the stack. The MC of maize during the trials is shown in Tables 1 and 2.

In both trials there was a significant moisture gradient between the top and the bottom of the stack. Furthermore, the trial with supplemental heat was characterised by a considerable level of over-drying. Consequently, grain was transferred to another silo where it was mixed.

The drying times were as follows: 240 h for drying with supplemental heat and 295 h for the regime with ambient air.

Analysis of records of energy consumption and resulting costs have shown that there was a cost of China yuan renminbi (CNY) 10.91/t and 1% MC w.b. (i.e. the cost of removing 1% moisture w.b. from 1 t of grain) for the system with supplemental heating versus CNY 1.70/t and 1% MC w.b. for the system with ambient air. In comparison, the cost of sun-drying within the same range of moisture contents is CNY 5.20/t and that of high temperature drying is CNY 5.20/t and 1% MC w.b.

**Table 1.** Moisture content of maize samples taken from different depths in a stack ventilated with air with supplemental heat in 1998.

Date	Moisture content (% wet basis)			
	Top	Middle	Bottom	Average
26/3	17.0	17.0	17.0	17.0
31/3	17.0	16.2	15.2	16.1
01/4	16.4	17.3	12.0	15.2
03/4	16.7	12.3	12.0	13.6
06/4	15.9	9.5	8.7	11.4
08/4	14.9	9.6	8.4	10.9
10/4	14.5	11.5	9.0	11.7

**Table 2.** Moisture content of maize samples taken from different depths in a stack ventilated with ambient air in 1998.

Date	Moisture content (% wet basis)			
	Top	Middle	Bottom	Average
06/4	16.1	16.3	15.7	16.0
10/4	16.4	16.7	11.5	14.9
16/4	16.3	16.8	10.6	14.6
19/4	16.3	16.2	13.3	15.3
28/4	16.4	14.8	12.3	14.5
05/5	16.5	14.2	11.0	13.9
13/5	16.7	13.8	10.2	13.6
22/5	16.4	11.5	10.3	12.7



The results of assessment of the effects of the two drying regimes on the quality of grain are presented in Table 3.

*Experiments conducted in spring 1999*

The experiments were conducted at the Zhaodong site in April–June of 1999. The experimental conditions of the tests were similar to those in 1998. An improvement was made to the oil burner in fitting it with a more accurate fuel injection system, leading to improved temperature control and subsequent economies of energy. Fans were run daily for 7–24 h in the regime with supplemental heating at 34.3°C, and

for 8–13 h when using ambient air with an average temperature of 19.1°C and 41.8% relative humidity.

The MC of the maize under the two drying regimes is shown in Tables 4 and 5.

In these trials, as in those of the previous year, there was a significant level of over-drying in the regime using supplemental heating. This resulted in the need to transfer the grain to another silo in order to produce a more uniform moisture distribution throughout the mass of grain.

The drying times were as follows: 327 h for drying with supplemental heat, and 376 h for the regime with ambient air.

**Table 3.** Effects of the two regimes of in-store drying on maize quality in 1998.

Drying regime	Broken grains (%)		Mouldy grain (%)	
	before drying	after drying	before drying	after drying
In-store with supplemental heating	6	8	5	8
In-store with ambient air	5	5	5	10+

**Table 4.** Moisture content of maize samples taken from different depths in a stack ventilated with air with supplemental heat in 1999.

Date	Moisture content (% wet basis)			
	Top	Middle	Bottom	Average
20/4	22.0	20.4	20.0	20.8
26/4	22.0	20.6	19.2	20.6
6/5	18.6	19.2	12.2	16.7
20/5	13.8	8.2	8.6	10.2

**Table 5.** Moisture content of maize samples taken from different depths in a stack ventilated with ambient air in 1999.

Date	Moisture content (% wet basis)			
	Top	Middle	Bottom	Average
8/4	15.6	17.4	18.2	17.1
26/4	15.6	16.6	16.0	16.1
6/5	15.6	16.4	12.8	14.9
20/5	15.6	15.4	12.4	14.5
4/6	12.0	16.0	14.6	14.2
8/6	12.6	13.6	13.6	13.3

The drying cost was CNY 5.07/t and 1% MC w.b. for the system with supplemental heating compared to CNY 2.11/t and 1% MC w.b. for the system with ambient air. In comparison, the cost of sun-drying within the same range of MCs is CNY 1.61/t and that of high temperature drying is CNY 5.20/t and 1% MC w.b.

The effects of the two drying regimes on the quality of maize are shown in Table 6.

In comparison with the 1998 trials, there was a reduction in the drying cost for the regime with supplemental heat thanks to the improved fuel injection system. The effects on grain quality remained similar for both years.

### Field trials at the Changning site in southern China

Field trials were conducted in November 1998 in the grain depot at Changning City, Yibin, Sichuan Province. The store was a flat warehouse with a capacity of 300 t.

A total quantity of 282 t of a late hybrid indica rice quantity was dried. The grain depth was 2 m. Grain was harvested with MC of about 20% and no pre-drying took place, hence making in-store drying a single-step operation. Semi-circular on-floor ducting was used for the distribution of the drying air. A 3 kW fan and 22.5 kW electrical heaters (2 × 9 kW and 1 × 4.5 kW) were used in the experiment. The superficial

air velocity was 2.8 m/min and the airflow rate was 15.6 m<sup>3</sup>/h/m<sup>3</sup> of rice.

Grain samples for quality tests were taken from 0.5 m and 1.0 m above ground as well as from the surface of the stack.

The results of the experiment are shown in Table 7.

The total drying time was 211 h. The drying cost was CNY 7.59/t and 1% MC w.b. There was some over-drying which was probably due to poor temperature control of the heaters. There were no significant negative effects on grain quality. However, the drying cost appears high, mainly due to the use of electrical heaters.

### Conclusions

The field trials have shown that in-store drying is a possible option for grain drying in China. Maize in north-eastern China required a two-stage system in order to reduce the initial moisture to 18–20% w.b., whereas for paddy in southern China, in-store drying could be practiced as a single-stage operation.

As far the quality is concerned, there were no significant effects on fissuring in either of the crops. The proportion of mouldy grain in maize was excessive in the trials using ambient air. However, it appears that there was a mould infestation prior to the beginning of drying, hence a relatively long period of drying favoured further development of moulds.

**Table 6.** Effects of two regimes of in-store drying on maize quality in 1999.

Drying regime	Broken grain (%)		Mouldy grain (%)	
	Before drying	After drying	Before drying	After drying
In-store with supplemental heating	6	8	1	5
In-store with ambient air	5	5	2	10+

**Table 7.** Effects of in-store drying with supplemental heat on rice quality in 1998.

Quality attribute	Before drying				After drying			
	Top	Middle	Bottom	Average	Top	Middle	Bottom	Average
Moisture content (% wet basis)	20.2	20.2	20.2	20.2	11.5	11.3	10.8	11.2
Fatty acid content (mg KOH/100 g dry basis)	30.6	26.8	23.1	26.8	33.8	19.8	18.9	24.2
Fissuring (%)	4.7	3.5	4.5	4.2	2.6	2.8	3.1	2.8
Yellowing (%)	0.52	0.86	0.64	0.67	1.28	0.85	0.88	1.00

The drying costs using supplemental heating are somewhat excessive due to high cost of the energy source chosen. However, improvements appear possible if biomass or coal heating systems were used. In contrast, ventilation using ambient air compares very favourably with the cheapest form of drying so far, i.e. sun-drying. It appears that an automatic control system could improve the situation by making a better use of the ambient air when conditions are favourable for drying. The efficiency of the heating system could also be improved, thus reducing the cost.

Current research is looking at the possibility of using ambient air during the winter months in north-eastern China in order to reduce the spoilage of grain due to moulds and also to increase the time when in-store drying can be performed.

### Acknowledgments

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### References

FAO (Food and Agriculture Organization of the United Nations) 1999. FAOSTAT Agriculture Data, on the Internet at <<http://apps.fao.org/cgi-bin/nph-db.pl?subset=agriculture>>

Genzhang Zhuge, Renyong Chi, Yangshen He, Zuhui Huang, Yung He and Dulin Son 1993. The grain

postproduction system in China. In: Naewbanij, J.O. and Manilay, A.A., eds., Proceedings of the 14<sup>th</sup> ASEAN (Association of South-East Asian Nations) Technical Seminar on Grain Postharvest Technology, Manila, Philippines, 5–8 November 1991. Bangkok, ASEAN Grain Postharvest Programme, 21–37.

Ju Jin Feng, Liu Fang Jiu, Du Shu Xiao and Xu Zeng Tao 1996. The current situation and prospects for grain drying in Northeastern China. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., Grain drying in Asia: proceedings of an international conference held at the FAO Regional Office for Asia and Pacific, Bangkok, Thailand. ACIAR Proceedings No. 71. Canberra, Australian Centre for International Agricultural Research, 284–293.

Li Huojin 1996. The present situation and directions for development of grain drying in China. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., Grain drying in Asia: proceedings of an international conference held at the FAO Regional Office for Asia and Pacific, Bangkok, Thailand. ACIAR Proceedings No. 71. Canberra, Australian Centre for International Agricultural Research, 314–315.

Ren Yonglin and van Graver, J. 1996. Grain drying in China: problems and priorities. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., Grain drying in Asia: proceedings of an international conference held at the FAO Regional Office for Asia and Pacific, Bangkok, Thailand. ACIAR Proceedings No. 71. Canberra, Australian Centre for International Agricultural Research, 23–30.

Szrednicki, G.S. and Driscoll, R.H. 2000. Feasibility of in-store drying in China. Paper presented at the 7<sup>th</sup> International Working Conference on Stored Product Protection, Beijing, October 1998 (in press).

# Methods and Standards for Rice Grain Quality Assessment in the Philippines

J.A. Patindol\*

## *Abstract*

Changes in economic status, social structure and trade policies, and the commercial release of numerous rice varieties, have spurred the growing attention given to grain quality. In the Philippines, premium quality traits in general are: long, slender grains; high milled rice and head rice yield; and tender and smooth cooked rice with some degree of stickiness. Routine grain quality works are mainly done as part of the national research program on varietal improvement and in grains business. This paper highlights the current methods and standards employed by the key stakeholders of the Philippine rice industry—the rice varietal improvement research group, government inspectors and regulators, and private millers, traders, and retailers. Rice quality has four major aspects, namely, (1) milling potential, (2) physical attributes, (3) physico-chemical properties, and (4) organoleptic qualities. Results that show the trends in grain quality characteristics of improved Philippine rice cultivars are presented. Moreover, the paper delves into other related techniques that are important in identifying and judging the suitability of the grain for table rice consumption and for processing into other value-added products.

RICE dominates Philippine agriculture. It is a major source of employment, income and growth for the Philippine economy. It is the staple food of the country's 73.5 million people. Annual per capita consumption is about 100 kg and it constitutes 40% of energy and 31% of protein of the Filipino diet (Juliano 1995). About 7.3 million t of milled rice was produced in 1997 while actual food use reached 7.8 million t, or a deficit of half a million t (PhilRice-BAS 1999).

While rice production in the Philippines has been falling short of demand, attention given to grain quality is on the rise. Premium quality characteristics for Philippine table rice are slender and translucent grains, stable high milled rice and head rice yields, good cooking and eating quality, and aroma (Juliano 1996a). Quality preference has become evident in the domestic market (Andales et al. 1995). Some consumers are now willing to pay a higher price for the specific quality of rice that they desire. Changes in economic status, consumption pattern, and social structure spur this trend. On top of this is the commercial release of numerous rice cultivars as a result of

intensive rice breeding activities. With more varieties to choose from, farmers, consumers, and processors become more picky as well.

The ratification of the General Agreement on Tariffs and Trade—World Trade Organization (GATT—WTO) by the Philippine Government likewise brought some changes in the country's trade policies and programs. GATT—WTO requires global competitiveness. Producing quality rice and the strict imposition of national quality standards for grain marketing are some of the strategies for improving the efficiency and competitiveness of the local rice industry.

## **Grain Quality and Rice Breeding**

Varietal improvement is the surest and most economical means of improving grain quality (Juliano 1990). In the Philippine Rice Varietal Improvement Program (RVIP), grain quality is considered an important breeding objective along with higher yield and resistance to pests and diseases. A pool of chemists, food scientists and nutritionists is carrying out the quality evaluation of rice selections entered into the National Cooperative Testing (NCT) Project

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for rice. Over recent years, the methods for evaluating various quality factors have not changed substantially. Four important aspects of quality are considered—milling recovery, physical attributes, physico-chemical qualities, and organoleptic characteristics.

## Milling recovery

Milling yield of rough rice is an estimate of the quantity of head rice and of total milled rice that can be produced from a unit of rough rice (Khush et al. 1979). The moisture content of paddy rice samples to be analysed should be 12–14% to minimise grain fissures. With a 125 g sample, dehulling, polishing and grading are carried out using a Satake testing husker TH35A, McGill Miller No.2, and Satake rice grader TRG05A, respectively. Brown rice (BR), total milled rice (TMR), and head rice (HR) yield are expressed as percentage of paddy rice. Resulting values are then classified based on the grading system presented in Table 1. For a sample to pass the milling yield criteria, its BR, TMR and HR should be B75.0%, B65.0%, and B39.0%, respectively (RTWG 1997). For the varieties released since 1990 the ranges are: 75.0–79.5% BR, 61.1–69.3% TMR, and 29.4–52.5% HR (Table 2).

## Physical attributes

Physical attributes that are routinely assessed are: grain size (grain length in mm), grain shape (ratio of grain length to grain width) and percentage chalky grains. Grain length and width are measured under a Fujimoto photo-enlarger (450M-C) and then classified

based on the standards presented in Table 3. Filipinos in general prefer rice varieties with long-slender grains (del Mundo 1995). Of the 41 varieties released since 1990, only 21 are long-slender type (Table 5).

Chalky grains are whole or broken kernels with 50% or more opaque-white portions. Percentage chalky grains is measured by manual separation of the chalky kernels from the non-chalky ones in a 50 g milled rice sample. The standard specifications for chalkiness are shown in Table 3 (RTWG 1997). Starch granules in the chalky portion of the grain are less densely packed than those in translucent areas (del Rosario et al. 1968) and there are air spaces between starch granules (Khush et al. 1979). This makes the chalky areas not as hard as the translucent portion and chalky grains are more prone to breakage when milled (Khush et al. 1979). Because of this, rice samples with >10% chalky grains are considered unacceptable based on the Rice Varietal Improvement Program (RVIP) guidelines. Chalky grains of RVIP-developed varieties range from 1.9 to 11.0% (Table 5).

## Physico-chemical properties

Some grain physico-chemical properties are used as indirect indices of rice processing and eating qualities. The most notable ones are amylose content (AC), gelatinisation temperature, gel consistency, and crude protein. Amylose, the linear fraction of starch, is the major factor contributing to varietal differences in cooked rice texture (Juliano 1985). It is analysed by the simplified method of Juliano et al. (1981). Based on AC, rice is classified as glutinous (0–2% amylose) or non-glutinous (>2% amylose).

**Table 1.** Quality standards for milled rice recovery (RTWG 1997).

Milling parameter	Grade	Range	Ideal value
% brown rice	Good (G)	80.0% and above	75.0% or higher
	Fair (F)	75.0–79.9%	(F to G)
	Poor (P)	Below 75.0%	
% milled rice	Premium (Pr)	70.1% and above	65.1% or higher
	Grade 1 (G1)	65.1–70.0%	(G1 to Pr)
	Grade 2 (G2)	60.1–65.0%	
	Grade 3 (G3)	55.1–60.0%	
% head rice	Premium (Pr)	57.0% and above	39.0% or higher
	Grade 1 (G1)	48.0–56.9%	(G2 to Pr)
	Grade 2 (G2)	39.0–47.9%	
	Grade 3 (G3)	30.0–38.9%	

**Table 2.** Milling potential of Philippine rice varieties (where grades are F = fair, G1 = Grade 1, G2 = Grade 2 and G3 = Grade 3—for explanation of grading system, see Table 1).

Variety (Local name)	Year of release	Brown rice (%)	Total milled rice (%)	Head rice (%)
PSBRc1 (Makiling)	1990	77.3 (F)	65.0 (G2)	38.3 (G3)
PSBRc2 (Nahalin)	1991	78.3 (F)	66.0 (G1)	37.3 (G3)
PSBRc3 (Ginilingan Puti)	1997	76.9 (F)	66.1 (G1)	44.7 (G2)
PSBRc4 (Molawin)	1991	78.5 (F)	65.2 (G1)	42.4 (G2)
PSBRc5 (Arayat)	1997	77.6 (F)	65.6 (G1)	45.3 (G2)
PSBRc6 (Carranglan)	1992	77.7 (F)	66.8 (G1)	49.6 (G1)
PSBRc8 (Talavera)	1992	78.3 (F)	66.9 (G1)	49.6 (G1)
PSBRc10 (Pagsanjan)	1992	79.5 (F)	66.6 (G1)	40.3 (G2)
PSBRc12 (Caliraya)	1992	78.0 (F)	66.5 (G1)	52.4 (G1)
PSBRc14 (Rio Grande)	1992	77.9 (F)	65.8 (G1)	51.9 (G1)
PSBRc16 (Ennano)	1993	77.4 (F)	65.6 (G1)	51.5 (G1)
PSBRc18 (Ala)	1994	78.6 (F)	65.6 (G1)	45.2 (G2)
PSBRc20 (Chico)	1994	79.0 (F)	65.1 (G1)	47.2 (G2)
PSBRc22 (Liliw)	1994	77.7 (F)	65.4 (G1)	40.8 (G2)
PSBRc24 (Cagayan)	1994	77.4 (F)	61.3 (G2)	42.3 (G2)
PSBRc26H (Magat)	1994	79.4 (F)	63.7 (G2)	43.0 (G2)
PSBRc28 (Agno)	1995	79.0 (F)	66.5 (G1)	46.1 (G2)
PSBRc30 (Agos)	1995	78.0 (F)	64.3 (G2)	40.8 (G2)
PSBRc32 (Jaro)	1995	78.2 (F)	63.9 (G2)	40.3 (G2)
PSBRc34 (Burdagol)	1995	78.3 (F)	61.1 (G2)	43.3 (G2)
PSBRc36 (Maayon)	1995	76.5 (F)	64.4 (G2)	46.2 (G2)
PSBRc38 (Rinara)	1995	76.2 (F)	65.3 (G1)	42.9 (G2)
PSBRc40 (Chayong)	1995	76.7 (F)	65.0 (G2)	43.6 (G2)
PSBRc42 (Baliwag)	1995	77.0 (F)	63.5 (G2)	37.1 (G3)
PSBRc44 (Gohang)	1995	77.9 (F)	67.4 (G2)	52.4 (G1)
PSBRc46 (Sumadel)	1995	—	—	—
PSBRc48 (Hagonoy)	1995	76.7 (F)	64.7 (G2)	42.5 (G2)
PSBRc50 (Bicol)	1995	76.0 (F)	64.0 (G2)	45.3 (G2)
PSBRc52 (Gandara)	1997	77.5 (F)	66.7 (G1)	52.5 (G1)
PSBRc54 (Abra)	1997	78.4 (F)	69.1 (G1)	43.1 (G2)
PSBRc56 (Dapitan)	1997	77.6 (F)	68.3 (G1)	40.8 (G2)
PSBRc58 (Mayapa)	1997	77.3 (F)	67.1 (G1)	42.2 (G2)
PSBRc60 (Tugatog)	1997	76.6 (F)	63.6 (G2)	41.8 (G2)
PSBRc62 (Naguilian)	1997	76.5 (F)	64.3 (G2)	39.1 (G2)
PSBRc64 (Kabacan)	1997	77.4 (F)	67.3 (G1)	41.1 (G2)
PSBRc66 (Agusan)	1997	78.5 (F)	69.3 (G1)	36.2 (G3)
PSBRc68 (Sacobia)	1997	75.2 (F)	63.5 (G2)	29.4 (G3)
PSBRc70 (Bamban)	1997	75.0 (F)	63.2 (G2)	39.4 (G2)
PSBRc72H (Mestizo)	1997	78.5 (F)	68.7 (G1)	34.5 (G3)
PSBRc74 (Aklan)	1998	77.7 (F)	69.1 (G1)	42.6 (G2)
PSBRc76H (Panay)	1998	77.7 (F)	64.2 (G2)	48.8 (G1)

**Table 3.** Quality standards for milled rice physical attributes (RTWG 1997).

Attribute	Grade/Class	Range	Ideal value
Grain size (grain length)	Extra long (EL)	7.5 mm and above	6.6–7.0
	Long (L)	6.6–7.4 mm	(Long)
	Medium (M)	5.5–6.5 mm	
	Short (Sh)	Below 5.5 mm	
Grain shape (length/width)	Slender (S)	Above 3.0	Above 3.0
	Intermediate (I)	2.0–3.0	(slender)
	Bold (B)	Below 2.0	
Chalky grains	Premium (P)	Below 2.0%	5.0% or below
	Grade 1 (G1)	2.0–5.0%	(G1 to Pr)
	Grade 2 (G2)	5.1–10.0%	
	Grade 3 (G3)	10.1–15.0%	

Non-glutinous varieties are further classified into very-low-AC, low-AC, intermediate-AC, and high-AC type (Table 4). Intermediate-AC rices, like IR64, are generally preferred by Filipino consumers. Table 5 shows the AC of RVIP-developed rice varieties.

Gelatinisation temperature (GT) predicts the time required to cook rice. It is the temperature range within which the starch granules in milled rice begin to swell irreversibly in hot water. GT of rice may be low (55–69°C), intermediate (70–74°C), or high (>74°C) (Table 4). It is estimated by the extent of alkali spreading of milled rice soaked in 1.7% potassium hydroxide for 23 h at room temperature (Little et al. 1958). Rices with low GT disintegrate completely while those with intermediate GT show only partial disintegration. High GT rices on the other hand, remain largely unaffected in the alkali solution. GT has been used to discriminate the cooked rice texture among cultivars belonging to the same amylose class (Juliano 1998).

The gel consistency (GC) test measures the flow characteristics of milled rice flour gels. The method outlined by Cagampang et al. (1973) is being used. GC may be soft, medium, or hard (Table 4). It is useful in differentiating high-AC rices. In this group, those with soft or medium GC are more tender when cooked compared to the high GC ones (RTWG 1997).

Protein is only a secondary factor to rice eating quality but it makes a fundamental contribution to nutrition (Juliano 1979). Rice is the main source of dietary protein among Filipinos so it is important that milled rice crude protein (CP) be maintained at 7.3%

or higher (Juliano 1996a). CP is determined by the standard kjeldahl method for nitrogen determination (AOAC 1970). A conversion factor of 5.95 is used to convert kjeldahl N to CP. Gel length and crude protein contents for Rice Varietal Improvement Program (RVIP)-developed rice varieties are also shown in Table 4.

### Organoleptic qualities

Sensory evaluation is regarded as the most direct way of assessing rice eating quality since the test makes use of the human senses. Laboratory and consumer panels are employed in assessing the sensory qualities of raw and cooked milled rice samples from the National Cooperative Testing Project. The laboratory panel consists of 12 trained members who have been selected from a large group for their high acuity and consistency in recognising differences in grain attributes such as whiteness, aroma, texture, and palatability, among others. A descriptive method is used by the laboratory panel (Figures 1 and 2). Consumer panel members, on the other hand, are untrained and are picked randomly from the consuming public where the test has to be conducted. This panel rates rice samples in terms of preference scores (Larmond 1977) and acceptability. Figure 3 presents the scorecards for sensory evaluation by a consumer panel. For a rice sample to pass the test, it should obtain positive scores for preference and acceptability of at least 75% (RTWG 1997).

**Table 4.** Classification of milled rice physico-chemical properties (RTWG 1997).

Property	Class	Range	Ideal value
Amylose content (apparent)	Waxy (W)	0.0–2.0%	20.1–25.0%
	Very low (VL)	2.1–10.0%	(Intermediate)
	Low (L)	10.1–20.0%	
	Intermediate (I)	20.1–25.0%	
	High (H)	Above 25.0%	
Gelatinisation temperature (alkali spreading)	High (H)	1–2 (75–80°C)	70–74°C
	High–Intermediate (HI)	3	(Intermediate)
	Intermediate (I)	4–5 (70–74°C)	
	Low (L)	6–7 (<70°C)	
Gel length (gel consistency)	Hard (Hd)	25–40 mm	61–100 mm
	Medium (Md)	41–60 mm	(Soft)
	Soft (Sf)	61–100 mm	

## Instrumental methods and other tools

Some relatively new instruments are now in use with the intention of improving the methods for rice quality evaluation. This has been made possible through grants and collaboration with other countries like Japan, Australia, and the United States. Near-infrared spectroscopy is being used to measure milled rice moisture content, crude protein and amylose (Villareal et al. 1994; Zulueta et al. 1997; Sato 1999) in place of the conventional wet laboratory procedures. The Rapid Visco-Analyzer has been found useful in the measurement of the pasting properties of milled rice flour (Juliano 1996b; Patindol and Juliano 1996; Patindol and Ohstubo 1997a). A new model of the tensipresser is now used to assess cooked rice texture, especially when the amount of available sample is not enough for sensory evaluation. The machine has been effective in discriminating cooked rice texture among samples with a wide to narrow range of starch properties (Patindol and Ohtsubo 1997b; Patindol et al. 1998). In addition, verification studies on the screening for stable head rice yield by the crack resistance test (Juliano et al. 1993) are in progress. Also, a new scoring system for raw and cooked rice quality has been proposed by Roferos and Juliano (1997).

The system (Table 6) is based on the chemometric analysis of a sizeable amount of grain quality data. The

raw rice properties included are: % brown rice, % milled rice, % head rice, % chalky grains, grain size, and grain shape. Crude protein (B7.5), amylose content/gelatinisation temperature/gel consistency combination, and Instron cooked rice hardness are considered in obtaining the numerical score for cooked rice. Verification studies of the new scoring system are still in progress.

## Rice Quality and Marketing

Rice in the Philippines is marketed by the Government (through the National Food Authority—NFA), and the private sector (traders, processors, wholesalers, and retailers). Since rice marketing is extensive, the enforcement of uniform grading systems and specifications is necessary to regulate such business activity. The NFA is mandated to formulate and implement standards for marketing rice. Hence, the Philippine Grains Standards for Rice and Corn (NFA 1998) comes to the fore. It forms part of the NFA rules and regulations for grain business. The set of standards cover units of measurement, terminology and symbols, product and process specifications, and product and human safety. The standards also include test methods for grading and classification which are primarily based on ocular inspection of the physical characteristics of paddy and milled rice.



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 3119 Philippines

**LABORATORY PANEL SCORECARD FOR MILLED RICE**

Name: \_\_\_\_\_ Judge No: \_\_\_\_\_  
 Date: \_\_\_\_\_ Time: \_\_\_\_\_

**INSTRUCTIONS:** Carefully evaluate the samples in the order given to you and write the numerical rating corresponding to the degree of each sensory attribute specified.

SENSORY ATTRIBUTE	CODED SAMPLES			
<b>AROMA</b> 4 very aromatic 3 aromatic 2 slightly aromatic 1 none				
<b>OFF-ODOUR</b> 4 very perceptible 3 perceptible 2 slightly perceptible 1 none				
<b>WHITENESS</b> 4 white 3 creamish white 2 greyish white 1 white with coloured streaks				
<b>GLOSS</b> 4 very glossy 3 glossy 2 slightly glossy 1 dull				
<b>TRANSLUCENCY</b> 4 translucent 3 white belly 2 chalky 1 opaque				
<b>BRITTLENESS</b> 4 very brittle 3 brittle 2 slightly brittle 1 soft				

**Figure 1.** Laboratory panel scorecard for the sensory evaluation of milled rice (RTWG 1997).

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 3119 Philippines

LABORATORY PANEL SCORECARD FOR COOKED RICE

Name: \_\_\_\_\_ Judge No: \_\_\_\_\_  
 Date: \_\_\_\_\_ Time: \_\_\_\_\_

INSTRUCTIONS: Carefully evaluate the samples in the order given to you and write the numerical rating corresponding to the degree of each sensory attribute in the space provided.

SENSORY ATTRIBUTE	CODED SAMPLES			
AROMA 4 very aromatic 3 aromatic 2 slightly aromatic 1 none				
OFF-ODOUR 4 very perceptible 3 perceptible 2 slightly perceptible 1 none				
WHITENESS 4 white 3 creamish white 2 greyish white 1 white with coloured streaks				
GLOSS 4 very glossy 3 glossy 2 slightly glossy 1 dull				
COHESIVENESS 4 very cohesive 3 cohesive 2 slightly cohesive 1 separated				
TENDERNESS 4 very tender 3 tender 2 slightly tender 1 hard				
SMOOTHNESS 4 very smooth 3 smooth 2 slightly smooth 1 rough				
TASTINESS 4 very tasty 3 tasty 2 slightly tasty 1 bland				
OFF-TASTE 4 very perceptible 3 perceptible 2 slightly perceptible 1 none				

Figure 2. Laboratory panel scorecard for the sensory evaluation of cooked rice (RTWG 1997).

**A**

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Maligaya, Muñoz, Nueva Ecija  
3119 Philippines

**CONSUMER PANEL SCORECARD FOR MILLED RICE**

Name: \_\_\_\_\_ Judge No: \_\_\_\_\_  
Age: \_\_\_\_\_ Date: \_\_\_\_\_ Time: \_\_\_\_\_

INSTRUCTIONS: Carefully evaluate the samples in the order given to you. Write 'Yes' if the sample is acceptable and 'No' if otherwise. Rank the samples according to your quality preference for milled rice. The most preferred sample should be ranked '1'.

CODED SAMPLES	124	768	385	439
Acceptability (Yes or No)				
Preference (1,2,3..)				

Please check and rank the basis for choosing the most preferred sample.  
 ( ) aroma  ( ) colour  ( ) gloss  ( ) translucency  ( ) grain length  
 ( ) grain width  ( ) brittleness  ( ) other, specify \_\_\_\_\_

Thank you very much.

**B**

Philippine Rice Research Institute  
Maligaya, Muñoz, Nueva Ecija  
3119 Philippines

**CONSUMER PANEL SCORECARD FOR COOKED RICE**

Name: \_\_\_\_\_ Judge No: \_\_\_\_\_  
Age: \_\_\_\_\_ Date: \_\_\_\_\_ Time: \_\_\_\_\_

INSTRUCTIONS: Carefully evaluate the samples in the order given to you. Write 'Yes' if the sample is acceptable and 'No' if otherwise. Rank the samples according to your quality preference for milled rice. The most preferred sample should be ranked '1'.

CODED SAMPLES	124	768	385	439
Acceptability (Yes or No)				
Preference (1,2,3..)				

Please check and rank the basis for choosing the most preferred sample.  
 ( ) aroma  ( ) colour  ( ) gloss  ( ) flavour  ( ) tenderness  
 ( ) other, specify \_\_\_\_\_

Thank you very much.

**Figure 3.** Consumer panel scorecards for the sensory evaluation of (A) raw milled rice and (B) cooked rice (RTWG 1997).

**Table 5.** Physical and physico-chemical properties of Philippine rice varieties (see Tables 3 and 4 for explanation of grading systems).

Variety	Grain size <sup>a</sup> (mm)	Grain shape <sup>b</sup> (length/width)	Chalky grains <sup>c</sup> (%)	Amylose content <sup>d</sup> (%)	Gelatinisation temperature score <sup>e</sup>	Gel length (mm) <sup>f</sup>	Crude Protein (%)
PSBRc1	6.6 (L)	3.1 (S)	4.5 (G1)	21.7 (I)	3.0 (HI)	55 (Md)	6.8
PSBRc2	6.8 (L)	3.1 (S)	7.7 (G2)	28.0 (H)	3.1 (HI)	58 (Md)	8.2
PSBRc3	6.1 (M)	2.7 (I)	9.7 (G2)	25.8 (H)	4.2 (I)	45 (Md)	8.7
PSBRc4	6.2 (M)	2.9 (I)	2.7 (G1)	23.4 (I)	3.1 (HI)	53 (Md)	8.0
PSBRc5	6.4 (M)	3.0 (I)	4.8 (G1)	26.5 (H)	5.1 (I)	54 (Md)	7.1
PSBRc6	6.5 (M)	3.0 (I)	8.6 (G2)	28.2 (H)	6.7 (L)	52 (Md)	6.9
PSBRc8	6.8 (L)	3.4 (S)	4.8 (G1)	27.6 (H)	6.6 (L)	55 (Md)	6.8
PSBRc10	6.5 (M)	3.0 (I)	7.1 (G2)	26.9 (H)	4.1 (I)	38 (Hd)	8.1
PSBRc12	7.0 (L)	3.2 (S)	5.1 (G2)	23.8 (I)	4.0 (I)	67 (Sf)	8.1
PSBRc14	6.9 (L)	3.3 (S)	5.1 (G2)	24.7 (I)	2.7 (HI)	69 (Sf)	7.3
PSBRc16	6.6 (L)	3.0 (I)	8.6 (G2)	28.7 (H)	4.8 (I)	78 (Sf)	7.3
PSBRc18	6.8 (L)	3.1 (S)	3.4 (G1)	21.5 (I)	4.1 (I)	75 (Sf)	6.9
PSBRc20	6.9 (L)	3.3 (S)	4.8 (G1)	22.2 (I)	3.9 (I)	79 (Sf)	8.4
PSBRc22	7.0 (L)	3.2 (S)	7.9 (G2)	23.7 (I)	3.2 (HI)	82 (Sf)	6.8
PSBRc24	6.9 (L)	3.1 (S)	11 (G3)	26.3 (H)	4.5 (I)	49 (Md)	7.2
PSBRc26H	6.8 (L)	3.3 (S)	6.2 (G2)	26.1 (H)	4.8 (I)	89 (Sf)	8.5
PSBRc28	6.4 (M)	3.2 (S)	3.1 (G1)	20.8 (I)	3.2 (HI)	67 (Sf)	8.7
PSBRc30	6.7 (L)	3.1 (S)	2.5 (G1)	23.4 (I)	3.8 (I)	76 (Sf)	7.1
PSBRc32	6.6 (L)	3.1 (S)	3.0 (G1)	21.3 (I)	3.1 (I)	63 (Sf)	8.3
PSBRc34	6.4 (M)	3.0 (I)	5.6 (G2)	22.7 (I)	6.7 (L)	59 (Md)	7.6
PSBRc36	6.4 (M)	3.0 (I)	9.3 (G2)	27.6 (H)	3.2 (HI)	63 (Sf)	7.9
PSBRc38	6.4 (M)	3.0 (I)	9.3 (G2)	28.1 (H)	3.9 (I)	70 (Sf)	8.1
PSBRc40	6.1 (M)	2.7 (I)	3.1 (G1)	27.3 (H)	3.3 (HI)	55 (Md)	8.8
PSBRc42	6.9 (L)	3.2 (S)	6.4 (G2)	23.5 (I)	3.4 (HI)	73 (Sf)	7.1
PSBRc44	5.5 (M)	2.1 (I)	4.4 (G1)	30.1 (H)	6.0 (L)	70 (Sf)	8.3
PSBRc46	5.8 (M)	3.1 (S)	–	27.5 (H)	6.7 (L)	54 (Md)	6.7
PSBRc48	5.6 (M)	3.1 (S)	–	25.8 (H)	6.1 (L)	48 (Md)	6.6
PSBRc50	6.7 (L)	3.2 (S)	–	24.7 (I)	6.2 (L)	75 (Sf)	7.0
PSBRc52	6.3 (M)	3.1 (S)	3.5 (G1)	19.6 (L)	2.9 (HI)	56 (Md)	7.0
PSBRc54	6.5 (M)	3.1 (S)	4.9 (G1)	22.5 (I)	3.1 (HI)	55 (Md)	7.5
PSBRc56	6.6 (L)	3.2 (S)	3.2 (G1)	28.1 (H)	3.3 (HI)	61 (Sf)	9.6
PSBRc58	6.7 (L)	3.3 (S)	4.0 (G1)	22.6 (I)	3.0 (HI)	66 (Sf)	6.3

<sup>a</sup> Grain size: L = long; M = medium.

<sup>b</sup> Grain shape: S = slender; I = intermediate.

<sup>c</sup> Chalky grains: G1 = grade 1; G2 = grade 2; G3 = grade 3.

<sup>d</sup> Amylose content: L = low; I = intermediate; H = high.

<sup>e</sup> Gelatinisation temperature score: HI = high–intermediate; I = intermediate; L = low.

<sup>f</sup> Gel length: Hd = hard; Md = medium; Sf = soft.

**Table 5.** (Cont'd) Physical and physico-chemical properties of Philippine rice varieties (see Tables 3 and 4 for explanation of grading systems).

Variety	Grain size <sup>a</sup> (mm)	Grain shape <sup>b</sup> (length/width)	Chalky grains <sup>c</sup> (%)	Amylose content <sup>d</sup> (%)	Gelatinisation temperature score <sup>e</sup>	Gel length (mm) <sup>f</sup>	Crude Protein (%)
PSBRc60	6.6 (L)	3.1 (S)	3.6 (G1)	30.6 (H)	5.3 (L)	45 (Md)	6.9
PSBRc62	6.2 (M)	2.8 (I)	5.0 (G1)	23.0 (I)	3.0 (HI)	45 (Md)	7.2
PSBRc64	6.9 (L)	3.3 (S)	7.7 (G2)	22.4 (I)	3.1 (HI)	45 (Md)	6.3
PSBRc66	6.5 (M)	3.0 (I)	1.9 (G1)	28.0 (H)	3.2 (HI)	48 (Md)	6.1
PSBRc68	7.2 (L)	3.2 (S)	8.3 (G2)	24.8 (I)	3.6 (I)	43 (Md)	5.5
PSBRc70	6.7 (L)	2.9 (I)	8.3 (G2)	25.0 (I)	4.8 (I)	33 (Hd)	5.7
PSBRc72H	7.0 (L)	3.3 (S)	7.5 (G2)	21.4 (I)	6.6 (L)	46 (Md)	6.7
PSBRc74	6.6 (L)	3.1 (S)	2.5 (G1)	28.4 (H)	3.7 (I)	45 (Md)	6.2
PSBRc76H	6.5 (M)	2.9 (I)	6.4 (G2)	28.3 (H)	3.0 (HI)	34 (Hd)	9.3

<sup>a</sup> Grain size: L = long; M = medium.

<sup>b</sup> Grain shape: S = slender; I = intermediate.

<sup>c</sup> Chalky grains: G1 = grade 1; G2 = grade 2; G3 = grade 3.

<sup>d</sup> Amylose content: L = low; I = intermediate; H = high.

<sup>e</sup> Gelatinisation temperature score: HI = high-intermediate; I = intermediate; L = low.

<sup>f</sup> Gel length: Hd = hard; Md = medium; Sf = soft.

**Table 6.** Proposed scoring system for rice grain quality (Roferos and Juliano 1997).

Score	Brown rice (%) (A)	Milled rice (%) (B)	Head rice (%) (C)	Chalky grains (%) (D)	Grainsize (mm) (E)	Grain shape (length/width) (F)
<b>A. Raw rice</b>						
4	B 80.0	B 70.1	B 57.0	< 2.0	B 7.5	> 3.0
3	77.5–79.9	65.1–70.0	48.0–56.9	2.0–5.0	6.6–7.4	2.6–3.0
2	75.0–77.4	60.1–65.0	39.0–47.9	5.1–10.0	5.5–6.5	2.0–2.5
1	< 75.0	55.1–60.0	30.0–38.9	10.1–15.0	B 5.4	< 2.0
Total Score = (A) + (B) + (C) + (D) + (E) + (F) = 19–24 (Grade 1); 13–18 (Grade 2); B 12 (Grade 3)						
Score	Crude protein (%) (A)	Amylose content (%) (B)	Gelatinisation temperature score (B)	Gel consistency (mm)	Hardness, kg/cm <sup>2</sup> (C)	Score
<b>B. Cooked rice</b>						
4	B 7.5	18–20	6–7	61–100	1.2–2.0	4
3	7.0–7.4	20–22	2–5	61–100	1.4–2.2	3
		16–18	6–7	61–100	1.0–1.8	
2	6.5–6.9	23–25	2–5	61–100	1.8–2.6	2
		20–25	6–7	61–100	2.2–3.0	
1	B 6.4	25–32	2–5	41–100	2.2–3.0	1
		25–32	6–7	25–40	2.7–3.5	
Total Score = (A) + (B) + (B) + (C) = 13–16 (Grade 1); 9–12 (Grade 2); < 8 (Grade 3)						

## Specifications for paddy rice

Paddy rice is classified into long grain (>6.5 mm), medium grain (5.5–6.5 mm), or short grain (<5.5 mm), based on brown rice length. Regardless of grain type, grading of the sample is carried out by ocular inspection in terms of purity, foreign matter, and defective kernels (NFA 1998). Table 7 summarises the grade requirements for paddy rice. The highest quality grade is 'Premium' while the lowest is 'Grade 3'. A sample that does not meet the requirements specified in the standards is classified as 'Off-grade' paddy rice.

## Specifications for milled rice

Milled rice is classified according to grain length and degree of milling. With kernel length, milled rice is classified as long grain ((6.0 mm), medium grain (5.0–5.9 mm), or short grain (<5.0 mm). Samples are further classified as under-milled, regular-milled, well-milled or over-milled, based on the milling degree test of staining with alcohol-KOH solution. Quality grades for milled rice, regardless of grain type and milling degree group, are based on moisture content, extent of insect infestation, % head rice, % broken, % brewers, % defective grains and foreign matter (NFA 1998). The specific requirements for milled rice quality grades are presented in Table 8.

## Test methods in the private sector

Compliance to the NFA methods and standards for rice business by the private sector is still low. A recent survey of rice millers in Nueva Ecija (Patindol et al. 1999) revealed that only 37% of the respondents were equipped with testing devices (moisture tester, rice grader, dehuller/polisher) for grading paddy rice quality. The rest still relied on the traditional 'hampas' method (Patindol et al. 1999). This is done by wrapping a handful of rough rice in a piece of cloth and striking it repeatedly on a hard surface. The process dehulls and even polishes the paddy grains, allowing visual inspection of the resulting partially polished kernels. Moisture is usually assessed by biting the grain between incisors. The brittleness and sound of the bite are used as an index of paddy rice moisture. There is no existing grading equipment to separate good grains from damaged ones. IR64, the most popular high-quality cultivar is commonly used as the reference standard in setting the price for paddy rice. Rice classifiers identify this variety based on its long translucent grains and the presence of a small white belly. Samples without the aforementioned characteristics often command a lower price.

**Table 7.** Market quality standards for paddy rice (NFA 1998).

Parameter	Grade			
	Premium	Grade 1	Grade 2	Grade 3
Classification by grain size/length — Long/Medium/Short				
Variety— Traditional/Modern				
<b>Grading factor</b>				
Purity (min. %)	98.00	95.00	90.00	85.00
Foreign matter (max. %)	2.00	5.00	10.00	15.00
• weed/other crop seed	0.10	0.10	0.25	0.50
• other foreign matter	1.90	4.90	9.75	14.50
Defective grains (max. %)				
• damaged grains	0.25	1.00	3.00	5.00
• discoloured grains	0.50	2.00	4.00	8.00
• chalky/immature grains	2.00	5.00	10.00	15.00
• red grains	1.00	3.00	5.00	10.00
Moisture content (max. %)	14.00	14.00	14.00	14.00

**Table 8.** Market quality standards for milled rice (NFA 1998) (OVR = over-milled rice; WMR = well-milled rice; RMR = regular milled rice).

Parameter	Grade			
	Premium	Grade 1	Grade 2	Grade 3
Classification by grain size — Long/Medium/Short				
Classification by milling degree	OVR	WMR	WMR	WMR
	WMR	RMR	RMR	RMR
Variety — Traditional/Modern				
Grading factor				
Head rice (min. %)	95.00	80.00	65.00	50.00
Brokens (max. %)	4.90	19.75	34.50	49.00
Brewers (max. %)	0.10	0.25	0.50	1.00
Defectives (max. %)				
• damaged grains	0.00	0.25	0.50	2.00
• discoloured grains	0.50	2.00	4.00	8.00
• chalky/immature grains	2.00	5.00	10.00	15.00
• red grains	0.00	0.25	0.50	2.00
• red-streaked grains	1.00	3.00	5.00	10.00
Foreign matter (max. %)	0.00	0.10	0.20	0.50
Paddy rice (max. no./kg)	1.00	8.00	10.00	15.00
Moisture content (max. %)	14.00	14.00	14.00	14.00

## Future Concerns

There is a need to develop second generation methods that will allow differentiation among rice varieties with similar starch properties. In the year 2004, quantitative restrictions on rice imports will be lifted as part of the General Agreement on Tariffs and Trade–World Trade Organization (GATT–WTO) Agreement. By then, reliable methods that can identify locally grown cultivars from imported ones are a must. This will eliminate unscrupulous practices of adulteration, mislabelling, and smuggling. Objective tests that can be readily used by consumers as a basis for selection are necessary. Likewise, the tools used by the National Food Authority and private sector should be upgraded. There is a need for more practical government regulations and policies that will enable the effective enforcement of quality standards while at the same time protecting consumers' interests. The techniques and standards employed by the different stakeholders of the rice industry (researchers, government inspectors and regulators, and private sector) should be thoroughly integrated so as to keep pace with GATT–WTO and international standards.

## References

- Andales, S.C., Manebog, E.S. and Bulaong, M.C. 1995. Rice handling, storage, and distribution. A paper presented at the Rice Utilization Workshop, 27–28 March 1995, Philippine Rice Research Institute, University of the Philippines at Los Baños, College, Laguna.
- AOAC (Association of Official Analytical Chemists) 1970. Official methods of analysis, 11<sup>th</sup> edition. Washington D.C., AOAC.
- Cagampang, G.C., Perez, C.M. and Juliano, B.O. 1973. A gel consistency test for eating quality of rice. *Journal of the Science of Food and Agriculture*, 24, 1589–1594.
- Del Mundo, A.M. 1995. Quality assessment of rice for plain boiled rice and for rice food product development. A paper presented at the Rice Utilization Workshop, 27–28 March 1995, Philippine Rice Research Institute, University of the Philippines at Los Baños, College, Laguna.
- Del Rosario, A.R., Briones, V.P., Vidal, A.J. and Juliano, B.O. 1968. Composition and endosperm structure of developing and mature rice kernel. *Cereal Chemistry*, 45, 225–235.
- Juliano, B.O. 1979. The chemical basis of rice grain quality. In: *Proceedings of the workshop on chemical aspects of*

- rice grain quality. Los Baños, Laguna, Philippines, International Rice Research Institute, 69–90.
- Juliano, B.O. 1985. Criteria and tests for rice grain qualities. In: Juliano, B.O., ed., *Rice chemistry and technology*, 2<sup>nd</sup> edition. St. Paul, Minnesota, American Association of Cereal Chemists, 442–524.
- Juliano, B.O. 1990. Rice grain quality: problems and challenges. *Cereal Foods World*, 35, 245–253.
- Juliano, B.O. 1995. Some unique properties of the rice grain. A paper presented at the Rice Utilization Workshop, 27–28 March 1995, Philippine Rice Research Institute, University of the Philippines at Los Baños, Laguna.
- Juliano, B.O. 1996a. Research on rice grain quality evaluation at the Philippine Rice Research Institute. In: *Crop research in Asia: achievements and perspectives* (Proceedings of the 2<sup>nd</sup> Asian Crop Science Conference, Fukui, Japan 21–23 August 1995). Tokyo, Japan, The 2<sup>nd</sup> Asian Crop Science Conference Organizing Committee, University of Tokyo, 88–93.
- Juliano, B.O. 1996b. Rice quality screening with the Rapid Visco-Analyzer. In: Walker, C.E. and Hazelton, J.L., ed., *Applications of the Rapid Visco Analyzer*. Warriewood, New South Wales, Newport Science Pty Ltd, 19–24.
- Juliano, B.O. 1998. Varietal impact on rice quality. *Cereal Foods World*, 43, 207–220.
- Juliano, B.O., Perez, C.M., Blakeney, A.B., Castillo, D.T., Kongseree, N., Laignelet, B., Lapis, E.T., Murty, V.V.S., Paule, C.M. and Webb, B.D. 1981. International cooperative testing on the amylose content of milled rice. *Starch*, 33, 157–162.
- Juliano, B.O., Perez, C.M. and Cuevas-Perez, F. 1993. Screening for stable high head rice yields in rough rice. *Cereal Chemistry*, 70, 650–655.
- Khush, G.S., Paule, C.M. and de la Cruz, N.M. 1979. Rice grain quality evaluation and improvement at IRRI. In: *Proceedings of the workshop on chemical aspects of rice grain quality*. Los Baños, Laguna, Philippines, International Rice Research Institute, 21–32.
- Larmond, E. 1977. Laboratory methods for sensory evaluation of food. Food Research Institute, Central Experimental Farm, Ottawa, Canada Department of Agriculture Publication 1637, 74p.
- Little, R.R., Hilder, G.B. and Dawson, E.H. 1958. Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal Chemistry*, 35, 111–126.
- NFA (National Food Authority) 1998. *Primer on Philippine grains standardization program*. Quezon City, Philippines, National Food Authority, 40p.
- Patindol, J.A., Ablaza, M.J.C., Guloy, M.B., Tibayan, P.A., Roferos, L.T. and Juliano, B.O. 1999. Criteria used by rice millers in Nueva Ecija in estimating palay price. In: *Philippine rice R&D highlights 1998*. Muñoz, Nueva Ecija, Philippine Rice Research Institute, 72–73.
- Patindol, J.A. and Juliano, B.O. 1996. Effect of tempering milled rice on some properties of dry-milled flour. *Philippine Agriculture*, 79, 207–215.
- Patindol J.A. and Ohtsubo, K. 1997a. Flour pasting viscosity profiles of Philippine rices with the Rapid Visco Analyzer. In: *Philippine rice R&D highlights 1996*. Muñoz, Nueva Ecija, Philippine Rice Research Institute, 176–177.
- Patindol J.A. and Ohtsubo, K. 1997b. Measurement of cooked rice texture with the new tensipresser. In: *Philippine rice R&D highlights 1996*. Muñoz, Nueva Ecija, Philippine Rice Research Institute, 174–175.
- Patindol, J.A., Okadome, O. and Ohtsubo, K. 1998. Discriminating the quality of Philippine rice cultivars with the new-tensipresser. In: Lu, H.Y., Sung, J.M. and Kao, C.H., ed., *Asian crop science 1998* (Proceedings of the 3<sup>rd</sup> Asian Crop Science Conference, Taichung, Taiwan, 27 April–2 May 1998). Taichung, Taiwan, Chinese Society of Agronomy, 462–470.
- PhilRice–BAS (Philippine Rice Research Institute–Bureau of Agricultural Statistics) 1999. *Philippine rice statistics handbook, 1990–1998*. Collaborative project of PhilRice and BAS (unpublished).
- Roferos, L.T. and Juliano, B.O. 1997. Chemometrics of grain quality of raw and cooked Philippine milled rice. *Philippine Agriculture*, 80, 211–236.
- RTWG (Rice Technical Working Group) 1997. *National cooperative testing manual for rice: guidelines and policies*. Muñoz, Nueva Ecija, Philippine Rice Research Institute, 113p.
- Sato, T. 1999. Estimation of contents of major constituents in rice by near infrared reflectance technique: a report, 1999 24 February–9 April. Report submitted to the Philippine Rice Research Institute, Muñoz, Nueva Ecija, Philippines (unpublished).
- Villareal, C.P., de la Cruz, N.M. and Juliano, B.O. 1994. Rice amylose analysis by near-infrared transmittance spectroscopy. *Cereal Chemistry*, 71, 292–296.
- Zulueta, N.V. Tayag, C.L., Basinga D.C. and Patindol, J.A. 1997. Applications of near infrared reflectance spectroscopy in grain quality evaluation. In: *Philippine rice R&D highlights 1996*. Muñoz, Nueva Ecija, Philippine Rice Research Institute, 172–173.



# Prevention of Moisture Migration in Sealed Grain Stacks Stored in the Open in the Tropics Using Reflective Covers

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## Abstract

A sealed structure that provides protection of grain without the use of chemical pesticides and termed a 'Volcani Cube' was used in these experiments. A major advantage of the Volcani Cube is that it can be used to safely store grain outdoors when no suitable storage buildings are available. However, under tropical conditions, when grain is stored in the open with no shade, ambient diurnal temperature fluctuations can create temperature gradients within the stack that cause convection currents to carry moisture to the upper layers of the grain. To overcome this, an upper insulating layer of bags containing straw or husks was employed. Under Filipino conditions this solution enables safe storage of maize and paddy for periods of up to three months, while for more extended periods the top moistened layer of husks should be replaced with dry material. This method, although solving the problem, suffers from the inherent disadvantages of reduction in effective storage capacity, the necessity to procure and transport material to fill the bags, and the added expense of bags not used for storing grain.

In a search to develop an alternative, inexpensive and convenient method of insulating the stack from diurnal temperature fluctuations, the use of a shade screen placed above the cube was investigated. This material, described as a 'knitted thermal screen', is formed from aluminum-coated high-density polyethylene threads.

Trials in Israel and the Philippines showed that the reflective covers had a strong attenuating influence on temperature gradients and condensation at the top of the cubes on the condition that a space for the free movement of air was allowed between the cover and the plastic liner. For dry paddy, it was shown that after five months storage under a reflective cover, no perceptible increase in moisture content was found at the top of the stack and the grain remained in good condition.

TWO research and development projects carried out over the past nine years by The Bureau of Postharvest Research and Extension (BPRE) in the Philippines, with the cooperation and support of the Agricultural Research Organization (ARO) in Israel, have focused on the outdoor storage of grain inside hermetically sealed plastic liners termed 'Volcani Cubes' (Alvandia et al. 1994; Navarro et al. 1996, 1997; Caliboso et al. 1997; Donahaye et al. 1998, 1999; Navarro and Donahaye 1998). The practical outcome of the first project was to strengthen the present policy of the

Filipino Government which is directed at providing farmer cooperatives with on-site storage units so as to decentralise storage of the national grain reserve as well as provide rural communities with a higher level of food security. Implementation of this policy is under way, and already the concept of sealed storage to protect dry grain from insect infestation has been widely promoted, together with the distribution of the flexible plastic outdoor storage cubes that were developed during the course of this project. In 1998, about 200 units were distributed to farmer cooperative recipients nationwide. Presently, Government orders have been placed to purchase additional units for distribution among farmer cooperatives. The second project was designed to provide a solution to the acute regional problem where paddy-rice is harvested at

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high moisture contents (MCs) during the monsoon season. This paddy must then be dried rapidly to a safe MC in order to prevent it from molding and rotting. However, if the paddy is dried rapidly from about 30% to the required 'safe' MC, the grains suffer stress, resulting in cracking and breakage. To overcome this problem, a two-stage drying procedure is advocated where the paddy is initially dried to 18% (intermediate MC), at which stage yeast and bacterial activity are suppressed, followed by a second-stage drying from 18 to 14% MC to prevent the development of storage moulds. The technology being developed in the second project is intended to enable farmers to overcome the bottleneck that occurs at the second drying stage by providing them with a means of storing the intermediate MC paddy under tightly sealed conditions and thereby preventing spoilage for prolonged periods until drying by sun or machine is again an available option.

One significant finding of the first project was that, under Filipino conditions, for dry paddy or corn stored in cubes outdoors with no shade, the diurnal temperature fluctuations of the ambient atmosphere created temperature gradients within the cubes that caused convection currents to carry moisture to the top of the stack. To overcome this, an upper insulating layer of bags containing rice hulls or corn cobs was advocated. This method effectively solved the problem but also suffered from several inherent disadvantages, namely: reduction in effective storage capacity of the cube; necessity to procure and transport the husks or corn cobs and fill the bags; and the added expense of bags not used for storing grain. It was shown that under Filipino conditions this method enables safe storage for periods of up to three months. For more extended time periods, the wet top layer of husks or corn cobs should be replaced (Navarro et al. 1995).

In the second project, it was envisaged from the outset that when intermediate MC grain (circa 18% MC) is stored outdoors this phenomenon would also occur and would probably be even more critical, since any rise above 18% MC is liable to trigger the anaerobic metabolism of bacteria and yeasts that have a strong influence on grain quality, particularly taste and aroma.

In a search to find an alternative, inexpensive and convenient method of insulating the stack from diurnal temperature fluctuations, the use of a shade-providing awning consisting of 'Polysac-Aluminet' was investigated. This material is described by the manufacturer as a knitted shade cloth for use as a thermal screen and is formed from aluminum-coated high-density poly-

ethylene threads. The trials described here were undertaken to study the effectiveness and applicability of these screens in protecting the grain stacks. The first trials were carried out in Israel using a 10 t capacity cube containing wheat, in order to obtain preliminary data and to finetune the method. Later trials were carried out both in Israel and the Philippines.

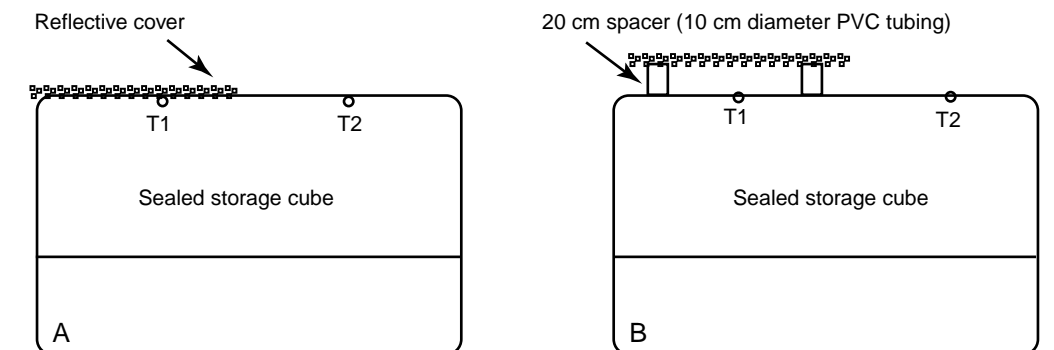
## **Trials in Israel**

### **Materials and methods**

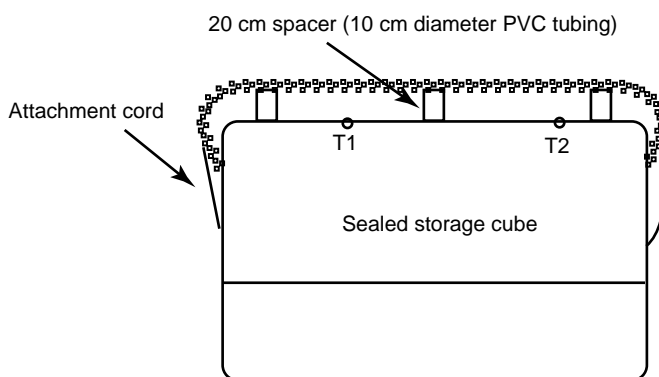
The first trial in Israel was directed at simultaneously comparing the daytime temperature gradients at the top of a storage cube between unprotected and protected segments of the upper liner. Two densities of shade material were compared during daytime only, and the insulating effect of the two types was examined both when the cover was spread directly over the top of the liner (Figure 1A) and also when it was separated from the liner by a distance of 20 cm using spacers (Figure 1B).

The results of this first trial were inconclusive, even though they indicated a decrease in the temperature gradient of the stack when protected by the cover. Therefore a second trial was undertaken in which temperature measurements were recorded using temperature loggers ('Hobo', Onset Computer Corp.) to enable temperature gradients to be monitored at night-time, when condensation problems are more acute. However, in this case, an entire cover was used, and a 7-days on and 7-days off regime was employed. Here, the problem of fixing the cover above the cube became evident. To 'solve' this problem, the edges of the cover (separated from the cube by spacers) were attached to cords that were drawn down and tied to the tension straps around the cube (Figure 2). However, in this way the sides of the space above the cube were sealed by the cover. We believe that, although we recorded a small reduction in temperature gradient due to the cover, the absence of this gap between the top surface of the cube and around the borders of the stretched cover-screen may have resulted in trapping the heat between the cover and liner during the daytime. Later, this heat dissipated rapidly upwards through the screen as the air above it cooled towards dusk. Detailed results of this trial are not given here.

The third trial in Israel was designed to overcome this problem (Figure 3). In this trial the reflective cover was stretched over the top of the cube using 20 cm spacers, and care was taken to ensure that the cover



**Figure 1.** The set-up in first Israeli trial to compare daytime temperatures at (A) the upper liner, between shadecloth-covered and uncovered sections, and (B) between the shadecloth cover with and without spacers (T1 and T2 are thermocouple points which were connected to an electronic temperature recorder).

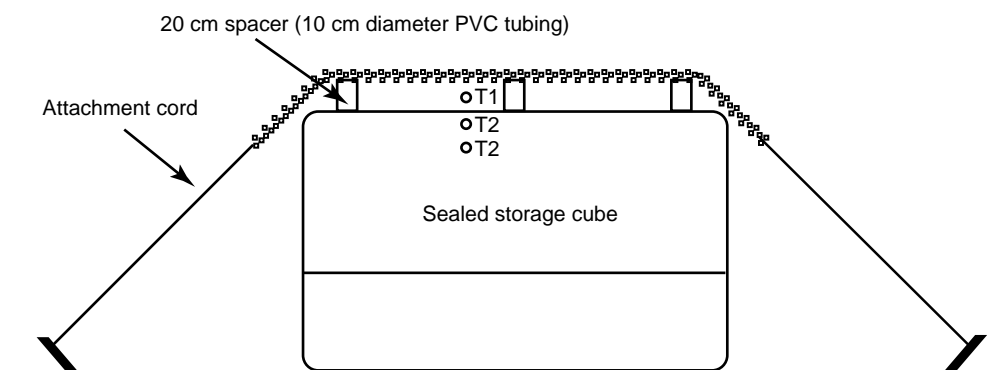


**Figure 2.** Trial using protective cover pulled down at sides and attached to tension straps (T1 and T2 are temperature loggers).

was not brought down at the sides, but remained with a gap to permit free air movement beneath the cover. At weekly intervals the cover was removed or replaced so that three alternating series of recordings (cover on, cover off) were obtained. Three temperature loggers, set to record the temperature at 1 h intervals, were placed at the centre of the cube—one above the liner, one below the liner, and one within the upper layer of bags at a depth of 10 cm. At the end of the trial the recordings were down-loaded into an Excel spreadsheet on a computer.

## Results

A summary of the amassed data is provided in Table 1, which clearly reveals the attenuation in daily temperature fluctuations caused by the reflective cover. Over the course of the trial, the average daily temperature above the liner with the cover in place was about 7°C lower than without it, and this was particularly evident during the daytime (hours of sunlight) when there was a 10–15°C temperature difference.



**Figure 3.** Trial in which air could freely move between the cover and the upper liner of the cube (T1, T2 and T3 are temperature loggers).

The temperature gradients shown in Table 1 reveal the conditions that generate a continuous rhythm of convection currents, when—during the night—moisture is transported to the surface layers, and—during the daytime—the surface layers lose moisture as they heat up. In the Israeli climate, we have shown (Navarro et al. 1996) that throughout the year there is no marked net-moisture transfer to the surface in the storage cubes, and no special precautions need be taken. However, already it has been already shown that for outdoor storage of dry grain in the Philippines,

there is a continuous, although gradual, process of moisture transfer to the surface due to the fact that the net moistening effect at night is greater than the net drying effect during the day. Therefore it was evident that trials would have to be carried out in the Philippines to verify whether this reflective liner could serve as a replacement for the insulating top layer of agricultural wastes as used in the present storage method for dry grain, or if it can effectively retard moisture migration during the storage of intermediate MC paddy under tropical conditions.

**Table 1.** Average weekly temperatures (°C) and temperature gradients recorded with and without a reflective cover placed above a 10 t capacity Volcani Cube at Bet Dagan, Israel (28 March to 10 June 1998).

Week (1998)	Reflective cover	Above liner (A)	Below liner (B)	10 cm <sup>a</sup> (C)	Ambient temperature	Temperature gradient		
						(A – B)	(A – C)	(B – C)
(A) Weekly averages of 24-hour recordings								
Average	With	22.7	22.3	21.7	21.6	0.4	1.1	0.6
Average	Without	26.9	26.1	23.9	22.6	2.4	4.6	2.2
(B) Weekly daytime averages for sunlight hours (9 am to 6 pm)								
Average	With	29.2	27.1	21.1	26.3	2.1	8.1	6.0
Average	Without	43.5	35.8	23.3	26.7	7.8	20.3	12.5
(C) Weekly night-time averages (7 pm to 8 am)								
Average	With	18.1	18.9	22.0	18.3	-0.8	-3.9	-3.2
Average	Without	18.3	19.5	24.3	19.6	-1.2	-6.0	-4.8

<sup>a</sup> 10 cm = temperature recorded within the upper layer of bags at a depth of 10 cm.

## Trial in the Philippines

### Materials and methods

This trial was carried out in conjunction with a field trial for storage of intermediate MC (approximately 18% MC) paddy in order to evaluate quality conservation, using two 10 t capacity cubes, one for a 3-month, and one for a 6-month period. An additional cube containing dry paddy at 14% MC was set up for 5 months under a separate reflective cover but was not monitored for temperature gradients.

The cubes were set up at the Bureau of Postharvest Research and Extension (BPRE) (National Post-Harvest Institute for Research and Extension—NAPHIRE) compound in Muñoz using freshly harvested paddy (IR64) that was dried to approximately 18% MC from higher MCs using a fluidised bed dryer, and using paddy sun-dried to 14% MC. In this trial the 70% density reflective covers were suspended over the cubes using a series of poles and guy ropes to create a tent-shaped awning that also

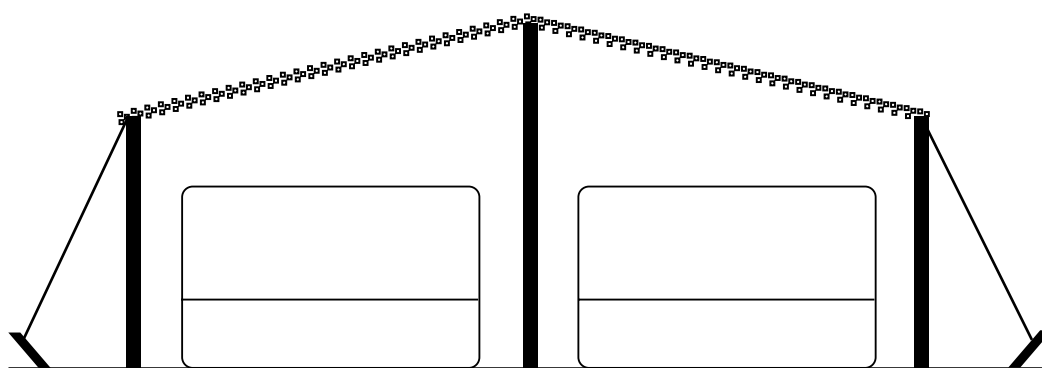
partially protected the sides. Temperatures were logged hourly above the liners, below the liners, 10 cm within the upper grain layer, and in the central core of the stacks at 18% MC. The set-ups were as shown in Figure 4. MCs of the different stack layers within the cubes were recorded at the beginning and end of both storage periods.

### Results

A summary of temperature gradients recorded over a representative 16-day period during storage (November–December) is given in Table 2. For comparison, daytime temperature gradients recorded during a previous trial without a reflective cover (July–August) are also provided. Table 2 shows that with the reflective cover set up as an awning over the cubes, temperature gradients both at night and at daytime were small and compared favourably with those recorded in Israel.

**Table 2.** Summary of 16 days of recordings taken by temperature loggers in a Volcani Cube protected by a reflective cover at Muñoz, Philippines.

Temp. (°C)	Above liner	Beneath liner	10 cm deep	Temperature gradient		
	(A)	(B)	(C)	A–B	A–C	B–C
<b>(A) Average daily</b>						
Reflective cover (23 November–7 December)						
Average daily	28.4	27.6	28.0	0.8	0.4	–0.4
Average maximum	36.6	35.2	30.4	3.0	8.1	6.9
Average minimum	23.6	22.8	26.2	–1.2	–3.4	–3.8
<b>(B) Average daytime</b>						
Reflective cover (23 November–7 December)						
Average daily	33.3	31.8	28.6	1.6	4.8	3.5
Average maximum	37.0	35.1	30.3	3.1	8.3	6.9
Average minimum	29.1	27.0	26.1	–0.9	1.2	1.4
No cover (9 July–26 August)						
Average daily	39.88	33.15	30.98	6.73	8.89	2.17
Average maximum	50.88	39.43	33.41	14.23	19.84	6.41
Average minimum	30.12	29.69	28.36	0.73	–1.12	–2.43
<b>(C) Average night-time</b>						
Reflective cover (23 November–7 December)						
Average nightly	25.3	24.9	27.6	0.4	–2.8	–2.4
Average maximum	28.9	28.9	29.9	1.2	–1.0	–0.9
Average minimum	23.6	22.8	26.0	–0.4	–3.8	–3.4



**Figure 4.** Experimental set-up of the reflective liner at Muñoz, Philippines.

Calculations based on average night temperature read-outs show that, since 18% MC paddy has an equivalent equilibrium relative humidity (ERH) of 92% RH, the water content of the air at 10 cm depth would be about  $25.1 \text{ g/m}^3$  at  $27.6^\circ\text{C}$ . If this air rises due to the night-time temperature gradient and cools at the surface below the liner to  $24.9^\circ\text{C}$ , then at 100% RH it would contain  $23.1 \text{ g/m}^3$ , i.e. there would be a condensation of  $1.8 \text{ g}$  for every cubic metre of air reaching the upper surface. Although the temperature logger

records show that, for most of the night duration, air at 92% RH (=18% grain equilibrium MC) would become saturated when in contact with the upper plastic liner, the very small temperature gradient would produce only feeble convection currents. For a direct evaluation of the net effect of moistening of the surface layer at night-time and drying during the daytime, the MCs at the top of the stack were examined after 3 and 6 months. These findings are given in Tables 3 and 4.

**Table 3.** Average moisture contents (%) of intermediate moisture content paddy hermetically stored in a Volcani Cube in the Philippines for 3 months.

Position	Composite sample (average 6 readings)	Beginning (22 Nov 98)	3 months (23 Feb 99)	Composite sample (all bags in each layer of stack)  (23 Feb 99)	Average (3 readings)
Top	1	18.0	19.3	Top 1	22.0
	2	17.9	19.8	2	20.4
	3	18.0	20.1	3	18.0
				4	18.0
Middle	1	18.0	17.2	5	18.3
	2	18.0	17.3	6	18.3
	3	18.2	17.5	Bottom 7	18.0

### 3-month storage of 18% MC paddy

From Table 3 it can be seen that after 3 months, moisture migration had caused an increase of 4% MC in the top layer and 2% MC in the second layer. Since MCs above 18% (equilibrium RH = 92%) enable the

development of yeasts and bacteria that can cause rotting and the development of unpleasant odours, the organoleptic characteristics of the paddy were also seriously affected.

**Table 4.** Average moisture contents (%) of intermediate moisture content paddy hermetically stored in a Volcani Cube for 6 months.

Position	Composite sample (average 6 readings)	Beginning (22 Nov 98)	3 months (21 May 99)	Composite sample (all bags in each layer of stack)  (21 May 99)	Average (3 readings)
Top	1	18.3	24.8	Top 1	28.5
	2	17.5	28.6	2	21.0
	3	17.6	21.4	3	18.2
Middle				4	17.7
	1	18.0	18.3	5	17.0
	2	17.9	18.6	6	17.0
	3	17.6	18.4	Bottom 7	16.7

#### *6-month storage of 18% MC paddy*

Table 4 shows that the continued upward movement of moisture resulted in even higher MCs of the upper layers at the end of the 6-month storage period. However, here again the accumulation of moisture was only noted in the top two layers.

#### *Dry grain storage*

At the end of the 5-month storage period (7 December 1998 to 5 May 1999) the stack was opened and examined, and although a comprehensive examination of MCs by stack layer was not undertaken, the spot tests at the top of the cube revealed that there was no perceptible increase in MC, and the grain was dry throughout the stack.

showed that this insulating effect was not sufficient to prevent a gradual build-up of moisture at the surface layer. However, for dry paddy, after 5 months of storage under a reflective cover, no perceptible increase in moisture content was found at the top of the stack and the grain remained in good condition.

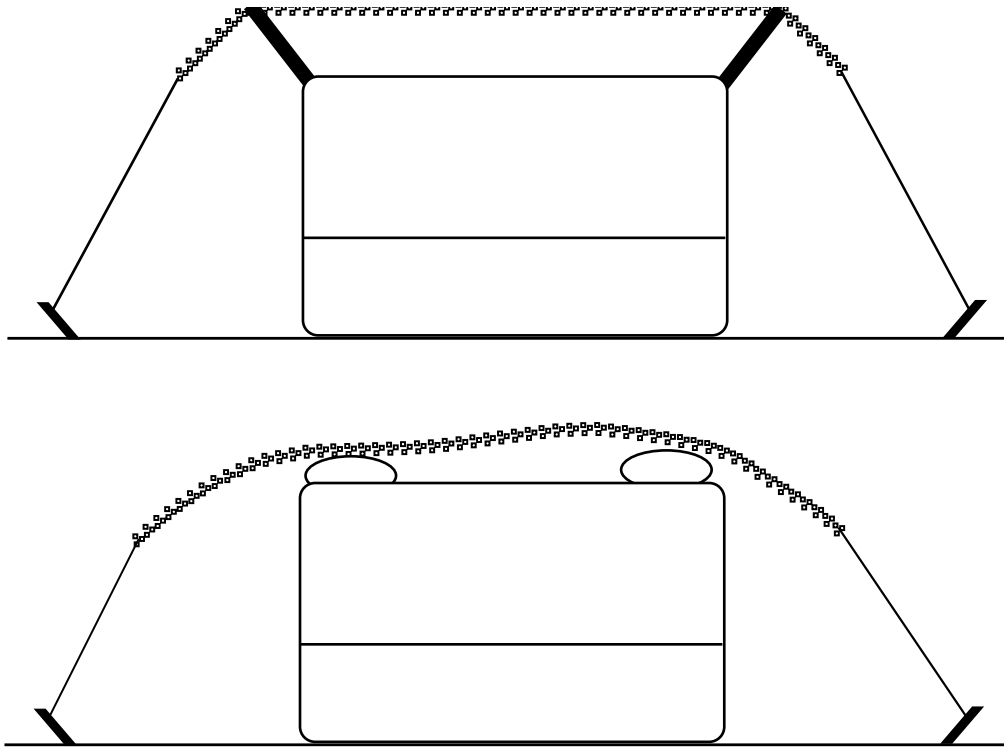
As a result of these findings, a decision was taken to discontinue recommendations for inclusion of a protective layer of agricultural wastes at the top of the stack to be replaced every 3 months (Navarro et al. 1996). Instead, a suitably sized reflective cover would be included in the carrying bag of the storage kit, and instructions on setting up the cover would be added to the manual. Two additional configurations for positioning the reflective cover are illustrated in Figure 5.

## Summary and Conclusions

The trials in Israel showed that the reflective covers had a strong attenuating influence on the development of temperature gradients and condensation at the top of the Volcani Cubes placed in the open, as long as a space for free movement of air was provided between the cover and the plastic liner. This was confirmed in the Philippines, but field trials with 18% MC paddy

## Acknowledgment

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**Figure 5.** Additional configurations for positioning the reflective cover above the storage cube.

## References

- Alvandia, D.G., Caliboso, F.M., Sabio, G.C. and Regpala, A.R. 1994. Modified atmosphere storage of bagged maize outdoors using flexible liners: a preliminary report. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., *Proceedings of the 6<sup>th</sup> International Working Conference on Stored-product Protection*, 17–23 April 1994, Canberra, Australia, Volume 1. Wallingford, CAB International, 22–26.
- Caliboso, F.M., Navarro, S., Alvandia, D.G., Donahaye, E.J., Sabio, G.C. and dela Cruz, M.T. 1997. Effect of gastight storage on growth of fungi in paddy stored outdoors. In: *Proceedings of the International Conference on Controlled Atmosphere and Fumigation in Grain Storages*, 21–26 April 1996, Nicosia, Cyprus. Nicosia, Printco Ltd, 135–144.
- Donahaye, E.J., Andales, S.C., Chernoguz, D., Navarro, S., Azrieli, A. and Rindner, M. 1998. Respiration rates of paddy at different temperatures and moisture contents. In: *Proceedings of the 18<sup>th</sup> ASEAN Seminar on Grains Postharvest Technology*, 11–13 March 1997, Manila, Philippines, 145–152.
- Donahaye, E.J., Andales, S.C., Navarro, S. and Caliboso, F. 1999. Self regulated atmospheres to prevent fungal damage in moist paddy. Final report of Project Number TA-MOU-94-C12-057 submitted to the United States Agency for International Development (USAID), 32p.
- Navarro, S., Donahaye, E., Caliboso, F.M. and Sabio, G.C. 1996. Application of modified atmospheres under plastic covers for prevention of losses in stored grain. Final Report submitted to United States Agency for International Development (USAID), CDR Project No. C7-053, August 1990–November 1995, 32p.
- Navarro, S., Caliboso, F.M., Sabio, G.C. and Donahaye, E.J. 1997. Quality conservation of paddy stored under gastight seal outdoors in the Philippines. In: *Proceedings of the International Conference on Controlled Atmosphere and Fumigation in Grain Storages*, 21–26 April 1996, Nicosia, Cyprus. Nicosia, Printco Ltd, 159–168.
- Navarro, S. and Donahaye, E.J. 1998. Outdoor storage of corn and paddy using sealed-stacks in the Philippines. In: *Proceedings of the 18<sup>th</sup> ASEAN Seminar on Grains Postharvest Technology*, 11–13 March 1997, Manila, Philippines, 225–236.



# The Quality Changes of Rice Stored Under Vacuum Conditions

M. Sidik\*

## Abstract

The National Logistics Agency (BULOG)—the Government institution responsible for maintaining reserve food stocks—encountered problems of quality deterioration of milled rice during storage, primarily due to insect infestation and microbial infection. Previous efforts to control these problems have included use of fumigants and contact pesticides, however increased concern about pesticide residues and their impact on the environment has led to the search for alternative approaches, including the application of modified atmosphere technology. In this respect, BULOG has constructed an integrated vacuum container processing plant to store rice under low oxygen conditions (less than 2%).

A study was carried out to observe the effect of low oxygen on the quality of rice during prolonged storage. Rice was stored for 16 months, either inside or outside, in 18 specially designed polyethylene plastic containers (1,000 kg capacity per container) with an oxygen level of less than 2%. Changes were recorded in: moisture content; number of insects; level of fungal and yeast infections; and quality parameters such as proportion of yellow rice, aroma, colour, and cooking factors.

The results revealed that lack of oxygen had a significant impact on the mortality of insects, and inhibited the development of fungi and yeast. The quality of rice was relatively unchanged after 16 months of storage—although, as the vacuum conditions decreased the moisture content of the rice, it absorbed more water during cooking and the rice became less sticky and fluffy. Overall, the results indicated that vacuum containers could be used to maintain the quality of rice during long-term storage. However, this technology should be supported with selection of initial good quality rice prior to storage, and accurate planning regarding the length of storage—recognising that this technology is relatively expensive.

THE INDONESIAN Government has consistently implemented a policy to ensure the availability of basic staple food commodities, particularly rice, at a stable and affordable price as an integral part of its food security policy. To realise the policy, the Government—through the National Logistics Agency (BULOG)—maintains an adequate strategic food reserve, to counter price fluctuations during the year and food shortages due to production failure caused by the impact of long droughts, floods and other natural calamities. BULOG maintains its stock in the form of milled rice rather than rough rice (paddy), and the rice is packed in jute or polypropylene bags (100 or 50 kg per bag) and stored in conventional horizontal 'godowns' (warehouses) throughout the country. A

standard BULOG godown has a 3,500 t capacity and normally consists of 12 stacks with a total quantity per stack of approximately 250–300 t.

The year-round, hot and humid climate typically found in tropical areas provides favourable conditions for the development of storage pests such as insects, rodents and fungi. This environment, coupled with inadequate postharvest processing of grain, accelerates the degradation of the quality of rice during storage, which poses a serious threat to BULOG. Annually, significant quantitative and qualitative losses occur due to an inability to prevent rice from insect infestation and preserve rice quality throughout the storage period.

Storage losses are very counterproductive to the huge amount of energy spent increasing grain production to ensure the availability of sufficient food for the people. Thus efforts should be geared toward

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improving quality maintenance and minimising losses through storage management programs. Efforts to tackle storage problems have been carried out using various measures, including chemical controls such as fumigation and the application of contact insecticides, in combination with the implementation of sanitation programs. However, a greater concern of consumers about the excessive use of pesticides—owing to their impact on environment and human health—has led to renewed interest and vigour in finding new methods to combat insect infestation and fungal invasion. Such technology includes the use of modified atmosphere and controlled atmosphere storage systems. BULOG has implemented modified atmosphere technology in the form of a vacuum container in which the concentration of oxygen is kept below 2% throughout the storage period.

The application of low oxygen levels has been known since ancient times as 'hermetic storage', and recently the principle of this storage technique (using less than 1% O<sub>2</sub>) in combination with a high concentration of carbon dioxide (above 35%) has been reported to provide good disinfestation and prevention effects against storage insects (Banks et al. 1980, 1991). However, maintaining a very low concentration of O<sub>2</sub> (below 1%) for a long period of time, although providing good control of various insect stages, is expensive. Therefore, use of oxygen concentrations within the range of 1–5% is likely to be more cost-effective in large-scale applications (Annis and Dowsett 1992).

The effect of temperature on the mortality of insects under low oxygen conditions is considered to be significant. In the tropics this effect is more dramatic than in temperate zones, given that insect metabolism is much slower in cold areas than in warm climates (Navarro et al. 1994).

This paper aims to review the results of field-testing storage of milled rice under vacuum conditions, with particular emphasis on its quality changes based on several criteria. The prospects and further application of this technology in different forms are also briefly outlined.

## Materials and Methods

### Vacuum storage containers

Specially designed plastic containers with a capacity of 1,000 kg of rice per container were used. The plastic used was polyethylene, with anti-oxidation

and anti-ultraviolet chemicals added during the moulding process to make the containers more resistant to the impact of the sun's rays. The dimensions of the containers were 100 × 100 × 120 cm, with the plastic approximately 1–3 mm thick and resistant to cold and hot temperatures (–60°C to 60°C). All of the processes involved—manufacture of the containers (from plastic grain), filling the containers with rice, applying the vacuum conditions, and sealing the containers—were carried out in an integrated manner in an automatic processing plant which was constructed in East Java, with a capacity of 100,000 t/year. A schematic diagram of the overall process is shown in Figure 1.

### Materials

Milled rice of the 'Cisadane' variety (a mixture of International Rice Research Institute and local varieties) was procured by BULOG. The rice had met the quality standards of this organisation, which included the following criteria:

- moisture content, maximum 14.0%;
- milling degree, minimum 85%;
- percentage of broken kernels, maximum 25%; and
- chalky kernels and yellow kernels, maximum 2% and 3%, respectively.

18 containers (18,000 kg) were randomly selected for this study, and samples were drawn at 60-day intervals for a period of 16 months. Nine containers were stored inside, and the rest were stored outside.

At each time interval, samples of 5 kg were taken from one container from each storage condition and sent to the laboratory for analysis of moisture content (MC), insect counts, microorganism identification and counts, quality analysis (odour/aroma, colour, appearance/translucency) and organoleptic tests of the cooked rice.

### Methods of analysis

The MC of the rice was determined by a forced-air oven method—drying 10 g rice samples at 120°C for 24 h. For insect observations, 100 g samples were analysed visually to count the number of dead and live insects. The percentage of yellow kernels was determined by hand-picking discoloured kernels from a 25 g milled rice sample.

For identification of microorganisms (fungi and yeast), 25 rice kernels were plated onto potato dextrose agar (PDA) media in petri dishes after surface-disinfecting the rice by rinsing for 5–10 seconds in 95%

ethanol, shaking for 1 min in 2% NaOCl (bleaching agent), and then rinsing in sterilised distilled water. The species of fungi were identified and counted to determine the percentage of rice kernels infected by microorganisms. The average of two replicates was used to determine the results of each analysis.

The quality of the raw rice was determined through panel tests, using 10 panelists to detect changes in odour (aroma), colour and translucency of the rice kernels. Similarly, cooked rice was subjected to organoleptic tests covering odour, colour, stickiness and mouth-feel (softness). Panelists were requested to score each parameter from 1 to 7 (the higher the score the better).

## Results and Discussion

### Moisture content

The MC of the rice declined throughout the observation period of 16 months. The initial MC of the rice was 14.20% and after 16 months the MC was 12.87% for rice stored inside and 11.95% for rice stored outside. The results indicate that temperature had a significant effect on the MC of the rice and the difference between the final MCs of rice stored at the two locations was significant. The variations in MC between individual sampling times were not significant, however the difference between the initial and final MC of the rice after 16 months of storage was significant. Thus, it seems likely that vacuum conditions significantly altered the MC of rice, particularly rice stored outside, which showed a >2% decrease in MC (Tables 1 and 2, Figure 2).

Together with temperature, MC is considered to be one of the most important factors in determining the quality retention of stored grains, including rice (Juliano 1994), and 14.00% MC is the maximum safe level for the storage of cereals. In this study, the MC of milled rice under vacuum conditions decreased gradually with storage time, to a level of nearly 12% in open storage and slightly above 12% for rice stored inside. At these low MCs the milled rice quality was maintained, as indicated by the low percentage of yellow kernels and quality of the cooked rice, even though the temperatures were relatively high throughout the storage period (the temperature of the

inside storage was 27–35°C and outside storage was 30–35°C).

### Number of insects

There were three species of insects found in the rice at the beginning of the study, namely *Sitophilus zeamais*, *Tribolium castaneum* and *Oryzaephilus surinamensis*, and the numbers were relatively low (less than 5 per 100 g rice sample) with *T. castaneum* being the most common. Live insects were only found at the beginning of the study. After that, only dead insects were found throughout the 16 months of storage, indicating that the low level of oxygen had killed all species of insects (Tables 1 and 2, Figure 2). This shows that lack of oxygen is an important factor in increasing the mortality of storage insect pests and is in agreement with the observations made by Bailey (1965) and Caliboso and Sabio (1999). Interestingly, *Sitophilus* sp. had been thought to be resistant to low oxygen levels, however in this study no *Sitophilus* sp. were found alive after 2 months of storage.

### Percentage of yellow kernels

Statistical analysis showed no significant difference in the percentage of yellow kernels over time or between locations (Tables 1 and 2, Figure 2). Yellow rice kernels are assumed to be a result of a non-enzymatic browning reaction rather than due to microbial action (Phillips et al. 1988). This may be caused by delayed drying of rough rice harvested at high MC (above 20%) (Phillips et al. 1988, 1989). Although the occurrence of a moderate proportion of yellow kernels has no adverse effects on rats and broiler chicks in nutritionally balanced diet tests (NRI 1991), in practice, the presence of yellow kernels above the maximum tolerable level (>3%) leads to a significant drop in price in the rice market. With a maximum of 3.05%, the proportion of yellow kernels in outside storage was slightly above this level, while in inside storage the highest proportion was 2.56% which is below the maximum allowable level. Our results indicate that the yellowing process almost stopped under low oxygen conditions, even though the relatively high temperatures (up to 35°C) throughout the study period provided otherwise suitable conditions for discoloured grain development.

**Table 1.** Changes in quality parameters of milled rice stored inside under vacuum conditions over a 16-month period.

Parameter	Months of observation								
	0	2	4	6	8	10	12	14	16
Moisture content (%)	14.20	14.60	13.89	13.72	13.50	13.40	13.21	13.03	12.87
Number of insects <sup>a</sup> (/100 g rice sample)	4	3	4	4	2	2	3	3	3
Yellow kernels (%)	2.52	2.54	2.50	2.56	2.54	2.50	2.34	2.40	2.30
Fungal infection (%)	100	80	80	40	0	0	0	0	0
Yeast infection (%)	100	100	100	80	80	80	60	60	60
Organoleptic tests <sup>b</sup>									
a) Raw rice									
aroma	4.78	4.74	4.34	4.16	4.01	3.85	3.70	3.55	3.50
colour	4.72	4.68	4.61	4.60	4.59	4.58	4.55	4.50	4.50
appearance	5.02	5.00	4.98	4.97	4.89	4.86	4.81	4.78	4.75
b) Cooked rice									
aroma	4.85	4.80	4.75	4.67	4.62	4.57	4.56	4.50	4.46
colour	5.45	5.40	5.38	5.24	5.18	5.10	4.97	4.90	4.83
smoothness	4.89	4.81	4.66	4.63	4.60	4.57	4.53	4.49	4.43
stickiness	4.95	4.82	4.75	4.66	4.65	4.54	4.48	4.41	4.34

<sup>a</sup> Note that after the initial measurement, all insects found were dead.

<sup>b</sup> Organoleptic qualities were rated on a scale of 1–7 (the higher the score the better).

**Table 2.** Changes in quality parameters of milled rice stored outside under vacuum conditions over a 16-month period.

Parameter	Months of observation								
	0	2	4	6	8	10	12	14	16
Moisture content (%)	14.20	14.00	13.84	13.54	13.40	12.55	12.20	12.07	11.95
Number of insects <sup>a</sup> (/100 g rice sample)	4	3	3	2	3	3	2	2	2
Yellow kernels (%)	2.83	2.80	2.85	2.99	2.89	3.02	3.05	3.00	2.95
Fungal infection (%)	100	100	100	80	40	0	0	0	0
Yeast infection (%)	100	100	100	100	80	80	60	60	60
Organoleptic tests <sup>b</sup>									
a) Raw rice									
aroma	4.75	4.65	4.04	3.92	3.59	3.36	3.50	3.01	2.90
colour	4.75	4.72	4.67	4.63	4.40	4.12	4.00	3.80	3.60
appearance	4.97	4.93	4.88	4.78	4.71	4.64	4.58	4.50	4.43

<sup>a</sup> Note that after the initial measurement, all insects found were dead.

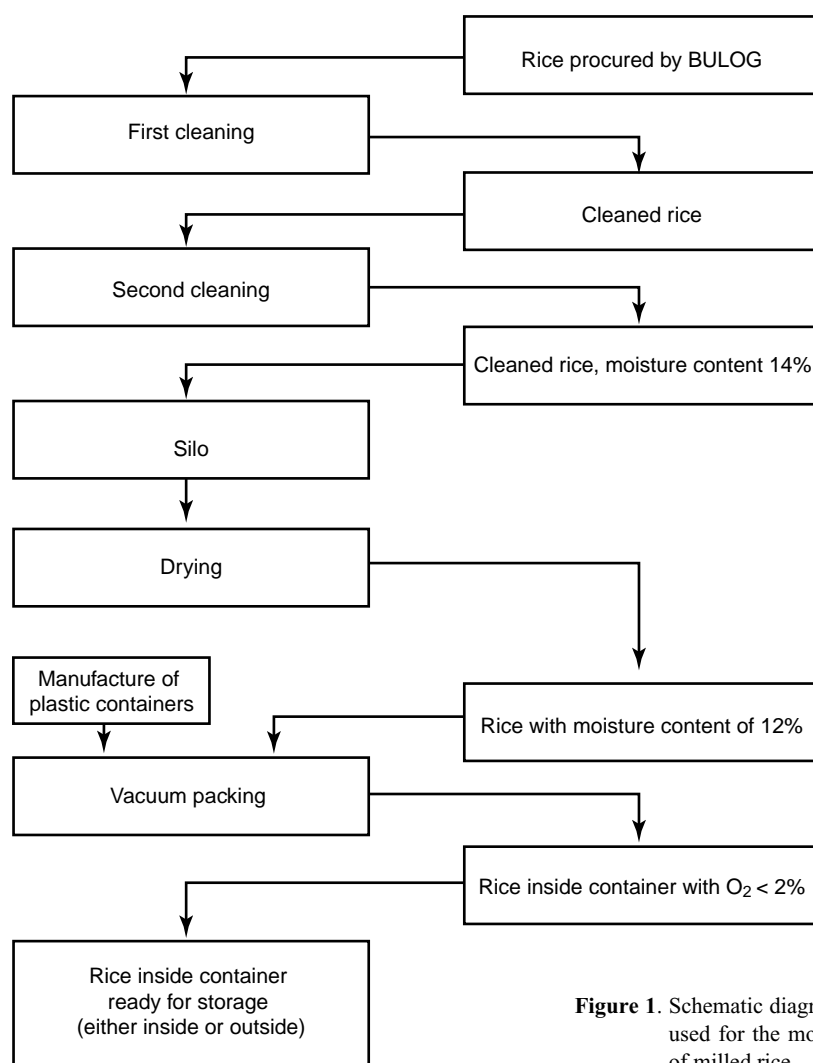
<sup>b</sup> Organoleptic qualities were rated on a scale of 1–7 (the higher the score the better).

**Table 2.** (Cont'd) Changes in quality parameters of milled rice stored outside under vacuum conditions over a 16-month period.

Parameter	Months of observation								
	0	2	4	6	8	10	12	14	16
b) Cooked rice									
aroma	4.82	4.70	4.68	4.44	4.22	4.14	4.02	3.80	3.59
colour	5.07	5.01	4.97	4.81	4.70	4.59	4.43	4.27	4.11
smoothness	4.69	4.69	4.52	4.43	4.29	4.18	4.03	3.90	3.70
stickiness	4.80	4.77	4.64	4.55	4.46	4.37	4.28	4.20	4.20

<sup>a</sup> Note that after the initial measurement, all insects found were dead.

<sup>b</sup> Organoleptic qualities were rated on a scale of 1–7 (the higher the score the better).



**Figure 1.** Schematic diagram of the vacuum process used for the modified atmosphere storage of milled rice.

## Fungal infection

The rice was infected by various species of storage fungi at the beginning of the study. The percentage of fungal infection declined significantly after 2 months in the inside storage, and 6 months in the outside storage. There was no fungal infection in the rice after 8–10 months of storage (Tables 1 and 2, Figure 3), which showed that the low oxygen level (and low MC) was unsuitable for fungal survival. However, there was no proof that fungal spores were completely killed, and a return to aerobic conditions may allow reinfection via these spores. Therefore, to avoid this possibility, rice should be promptly distributed after prolonged storage under vacuum conditions.

The species of fungi found in this study were mostly storage fungi rather than field fungi, and the species were: *Aspergillus glaucus*, *A. flavus*, *A. niger*, *A. versicolor*, *A. candidus*, and *Penicillium* spp. Only two species of field fungi were present, namely *Fusarium* spp. and *Eurotium* spp. These findings are in agreement with the studies of Sidik and Cahyana (1992) and Dharmaputra et al. (1992). Dharmaputra et al. (1992) observed various species of both field and storage fungi in maize stored for a short period after fumigation with phosphine. Trigo-Stockli and Pedersen (1994) found similar species in their study on the effects of storage conditions on the quality of milled rice using rough rice stored for a maximum of

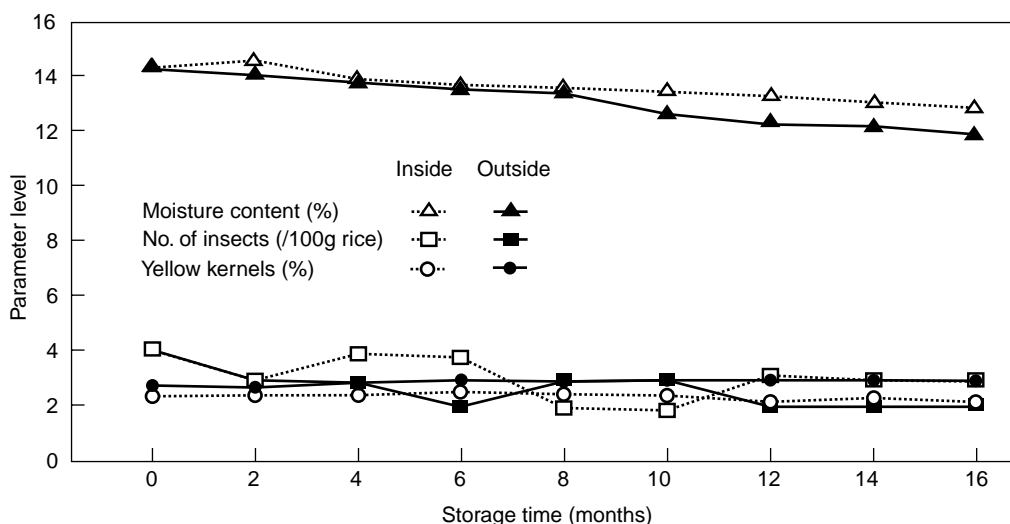
30 days. Most of the fungi found were associated with heat accumulation, particularly in rough rice with high MC (26%).

## Yeast counts

Yeast was found in almost all samples drawn both storage locations, but the percentage declined through the first 12 months of storage, after which time its level stabilised (Tables 1 and 2, Figure 3). The persistence of some yeast throughout the 16-month storage period indicates that this microorganism is resistant to low oxygen conditions.

## Organoleptic tests

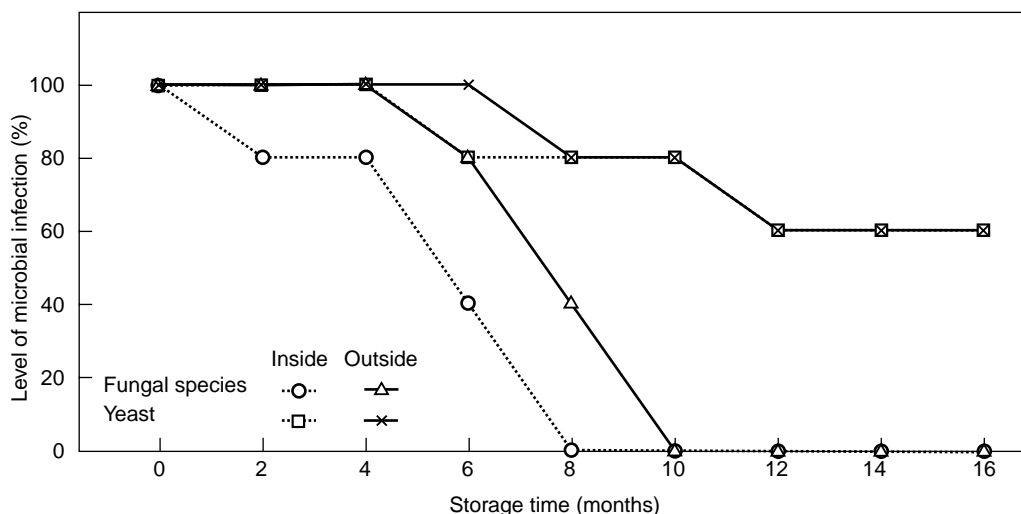
Organoleptic tests of raw rice, as indicated by the scores given by 10 panelists, showed that the rice remained of good quality under the vacuum conditions, even after 16 months of storage (Tables 1 and 2, Figure 4). The quality of the rice tended to decline towards the end of the study, as shown by the decline in scores based on aroma, colour and translucency, but the degradation of quality was not significantly different over time or between locations. Even the lower scores given by the panelists at the end of the 16 months were within the acceptable range, showing that the rice retained its quality even after storage for a relatively long period of time. It should be pointed out,



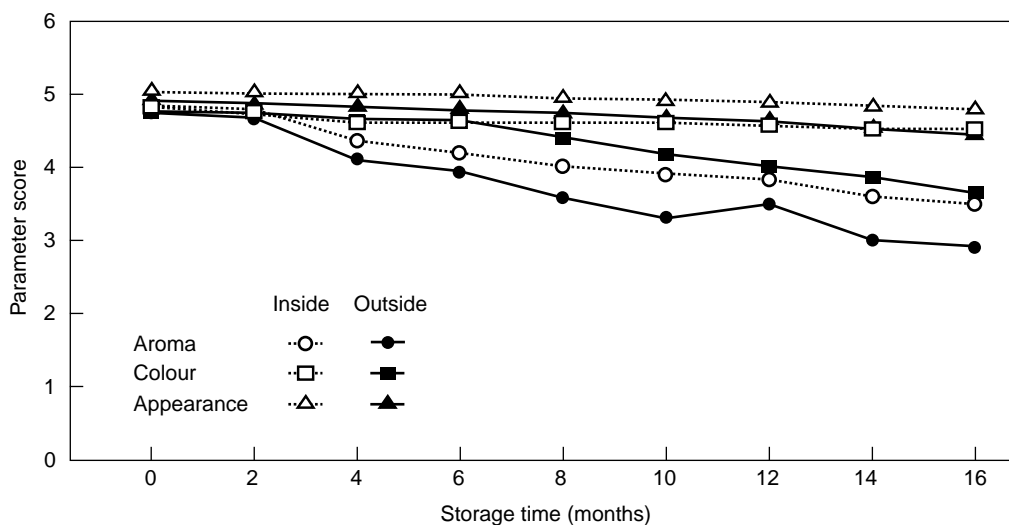
**Figure 2.** Changes in moisture content, number of insects and percentage of yellow rice kernels during the inside or outside storage of rice over a 16-month period under vacuum conditions. Note that after the initial count, all insects found in the samples were dead.

however, that the rice started to lose its aroma after 8 months of storage (outside), when panelists gave it only half of the maximum score possible (Tables 1 and 2, Figure 4). As Juliano (1994) stated, one of the characteristics of rice is its aroma and people in rice-eating countries prefer to consume rice immediately after harvest, when the aroma level is still high. The longer the rice is stored, the greater chance it has to lose its aroma.

Organoleptic tests of the cooked rice gave similar results, with the quality of the cooked rice at the beginning of the study not significantly different to that stored for 16 months, in terms of the aroma and colour of the rice. Although the colour of the aged rice after cooking was slightly creamy rather than white, it did not cause any rejection by the testers. The panelists, however, gave lower scores for the stickiness and smoothness of the cooked rice, and the difference



**Figure 3.** Changes in levels of microbial infection in milled rice stored inside or outside under vacuum conditions over a period of 16 months.



**Figure 4.** Changes in quality parameters of raw rice after storage inside or outside under vacuum conditions over a period of 16 months.

seemed to be more significant towards the end of the storage time (Tables 1 and 2, Figure 5).

The stickiness of the rice declined more rapidly in rice stored outside compared to inside, indicating that temperature and solar radiation had a significant impact on the changes in stickiness, although in both locations the lowest scores for stickiness were still at an acceptable level (more than 4 out of 7). Similar findings were made by the panelists on the mouth-feeling/softness of the cooked rice (Tables 1 and 2, Figure 5). The scores tended to decline towards the end of the 16-months' storage, but were still within the acceptable range (above 4 for inside storage and above 3 for outside storage).

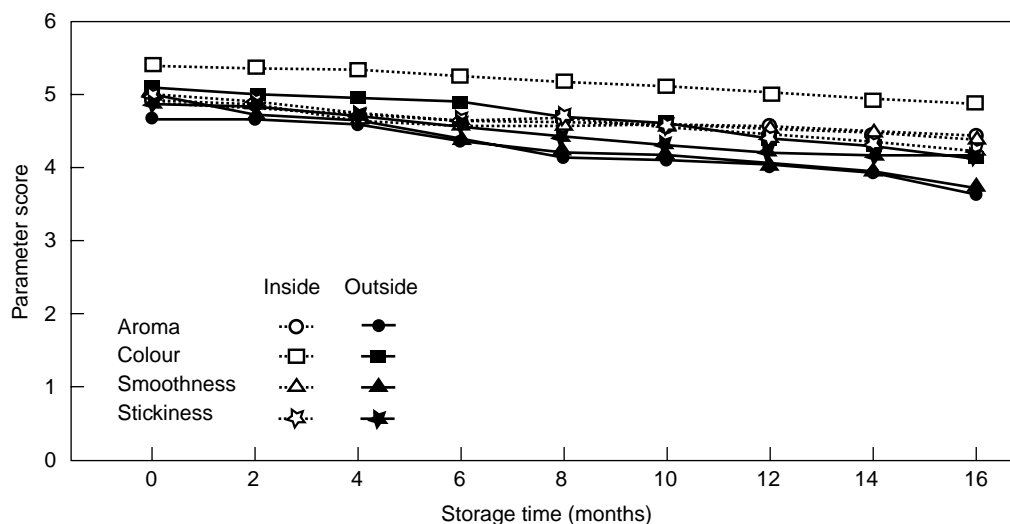
The aged milled rice absorbed more water during cooking compared to freshly harvested rice, resulting in more expansion and less sticky or more flaky cooked rice. Rice stored under low oxygen conditions seemed to take longer to age, although it tended to absorb more water during cooking and the cooked rice was considered a little bit tasteless, as compared to newly harvested rice. This was reinforced by the panelists who gave relatively low scores for smoothness and stickiness of the rice stored for 16 months, probably because the panelists had a preference for sticky rice over the non-sticky and flaky one. As Juliano (1994) stated, the stickiness of rice is very much influenced by the amylose content of the rice and in this study—after prolonged storage under low oxygen—it is likely that the amylose content

increased to a level that brought about the lack of stickiness after cooking.

## Conclusions

From this study, we conclude that the quality of milled rice stored under low oxygen conditions (less than 5%) for 16 months was not significantly different from its original state, as indicated by changes in MC, yellow kernels, fungal infection, insect infestation and organoleptic tests. Slight changes in stickiness, aroma and mouth-feeling of the cooked rice may, however, have an effect on consumer preference, particularly for rice eaters who prefer sticky rice over flaky rice.

The study revealed that lack of oxygen gave almost complete control of insect pests and fungal invasion that are associated with quality deterioration during storage. Near-vacuum containers, as used by BULOG, give good control over quality degradation which commonly occur during a long storage period (more than 6 months). It should be pointed out, however, that this type of modified atmosphere storage should be supported with good initial quality of rice prior to storage, otherwise the advantage of this technology would not be economically feasible, since vacuum container technology is indeed a capital-intensive venture. Therefore the length of storage time, quality and value of the product should be considered to justify the implementation of this technology.



**Figure 5.** Changes in quality parameters of cooked rice after storage inside or outside under vacuum conditions over a period of 16 months.



## References

- Annis, P.C. and Dowsett, H.A. 1992. Low oxygen disinfestation of grain: exposure period needed for high mortality. In: Navarro, S. and Donahaye, E. ed., Proceedings of the international conference on controlled atmosphere and fumigation in grain storages, Winnipeg, Canada, 11–13 June 1992, 70–82.
- Bailey, S.W. 1965. Air-tight storage of grains: its effect on insects *Rhyzopertha dominica* (F) and some other Coleoptera that infest stored grains. *Journal of Stored Products Research*, 1, 25.
- Banks, H.J., Annis, P.C., Henning, R.C. and Wilson, A.D. 1980. Experimental and commercial modified atmosphere treatment of stored grains in Australia. In: Shejbal, J. ed., *Controlled atmosphere storage of grains*, 207–224.
- Banks, H.J., Annis, P.C. and Rigby, G.R. 1991. Controlled atmosphere storage of grains: the known and the future. In: Fleurat-Lessart, F. and Ducom, P. ed., *Proceedings of the International Working Conference on Stored Products Protection*, Bordeaux, September 1990, 695–707.
- Caliboso, F.M. and Sabio, G.C. 1999. Hermetic storage of grains in the tropics. In: Nawa, Y., Takagi, H., Noguchi, A. and Tsubota, K. ed., *Postharvest technology in Asia*. Proceedings of the 5<sup>th</sup> JIRCAS (Japan International Research Centre for Agricultural Sciences) Symposium, Tsukuba, Japan, 9–10 September 1998, 59–72.
- Dharmaputra, O.S., Tjitrosomo, H.S.S, Sidik, M. and Halid, H. 1992. The effects of phosphine on storage fungi of maize. In: Sidik, M. et al., ed., *Proceedings of the Symposium on Pests of Stored Products*, SEAMEO-BIOTROP, Bogor, Indonesia, 29–31 January 1991, 107–118.
- Juliano, B. 1994. Concerns for quality maintenance during storage of cereals and cereal products. In: Highley E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., *Proceedings of the 6<sup>th</sup> International Working Conference on Stored-product Protection*, 17–23 April 1994, Canberra, Australia, Volume 1. Wallingford, CAB International, 17–24.
- Navarro, S., Donahaye, E. and Fishman, S. 1994. The future of hermetic storage of dry grains in tropical and subtropical climates. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., *Proceedings of the 6<sup>th</sup> International Working Conference on Stored-Product Protection*, Canberra, Australia, 17–23 April 1994. Wallingford, CAB International, 130–138.
- NRI (Natural Resources Institute) 1991. Postharvest discoloration of cereal grains. In: *Report on operational programmes 1989–1991*. Chatham Maritime, NRI, 256–258.
- Phillips, S., Widjaja, S., Wallbridge, A. and Cooke, R. 1988. Rice yellowing during post-harvest drying by aeration and during storage. *Journal of Stored Products Research*, 24, 173–181.
- Phillips, S., Mitfa, R. and Wallbridge, A. 1989. Rice yellowing during drying-delays. *Journal of Stored Products Research*, 25, 155–164.
- Sidik, M. and Cahyana, Y. 1992. Storage pest problems and their management in Indonesia. In: Sidik, M. et al., ed., *Proceedings of the Symposium on Pests of Stored Products*, SEAMEO-BIOTROP, Bogor, Indonesia, 19–31 January 1991, 75–87.
- Trigo-Stockli, D.M. and Pedersen, J.R. 1994. Effect of rice storage conditions on the quality of milled rice. In: Highley E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., *Proceedings of the 6<sup>th</sup> International Working Conference on Stored-product Protection*, 17–23 April 1994, Canberra, Australia, Volume 1. Wallingford, CAB International, 706–711.

# Quality Changes in Farm-stored Sorghum Grain Grown in the Wet or Dry Season in Southern India—a Technical and Social Study

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## Abstract

In the last 20 years, production and consumption of sorghum in parts of southern India have declined. To understand the factors responsible for this, a survey of postharvest practice was undertaken which included a participatory rural appraisal with farmers and sampling to test the quality of grain in their stores. Twelve villages were chosen which grow sorghum during the monsoon rains (kharif season) or after the rains (rabi season). The grain samples were taken from stores both before and after the monsoon, analysed for quality, and tested for mycotoxins.

Overall, grain storage problems of farmers in southern India seem not to be a disincentive to sorghum cultivation. Both crops suffered mycotoxin contamination but this was below limits likely to represent a health hazard. Hybrid sorghum varieties, by virtue either of the season in which they grow or intrinsic characteristics, suffered considerable quality decline in storage, although this is clearly not an issue in the current scenario of farming practice. This does not mean that these traits are not impacting on the wider sorghum economy, but only that they are not impacting on the components of the sorghum production and utilisation system examined. A related project has shown a different picture for storage by wholesale traders and industrial users. So, while the current study has certainly laid to rest many concerns relating to farm storage, components of the utilisation chain where these factors now seem to be more critical remain to be studied in detail. In addition, if farmers in the future wish to retain stocks between seasons, in order to market grain strategically, then current practice may be inappropriate since grain quality at the end of the storage season was poor.

SORGHUM production and consumption has either stagnated or declined in many areas of southern India over the last 20 years (Hall and Brough 1997; Marsland 1998). In an effort to address agricultural policy needs and future research priorities for sorghum, a study was undertaken of postharvest quality issues to determine whether or not these are involved in the apparent decline in production. Two other projects, not reported here, considered sorghum utilisation and marketing issues.

The extent of storage losses and quality deterioration were investigated in sorghum grain from farmers' stores, and a study made of farmers' perceptions of these parameters, and of the relative importance of these to household food security, using participatory rural appraisal. The study was undertaken in 12 selected villages in the states of Karnataka, Maharashtra and Andhra Pradesh. In addition to assessing the visible grain quality characteristics, further insights into postharvest problems were gained by an analysis of mould and mycotoxin contamination, since these can have an important bearing on issues of human and animal health. During a rapid rural appraisal in March 1997, it was established that farmers considered most grain deterioration to occur during the period of the monsoon. In view of this, a decision was made to collect grain samples before the rains in June and after the rains in October (Table 1).

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**Table 1.** Summary of season of origin and age in store of sampled grain.

	Samples taken (date)		
	June 1997	October 1997	January 1998
Kharif (harvested October '96)	7–8 months	12 months	Not sampled
Rabi (harvested February '97)	4–5 months	7–8 months	11 monthd

The working hypotheses identified during the rapid rural appraisal were that: measurable losses in quantity are small and much lower than the figure stated by many postharvest scientists (e.g. 20% weight loss); quality deterioration is unlikely to present any health hazard (especially in relation to mycotoxin contamination); and farmers' perceptions were that losses occurred in storage but that these were low and not a major constraint in production and utilisation systems. These hypotheses conflict with the views of many agricultural workers (other than farmers) who expressed the view that postharvest problems are a serious constraint in sorghum agriculture.

## Methods

### Selection of districts and villages for participatory rural appraisal and grain sampling

Twenty-seven major sorghum-producing districts were identified. These had the area planted to kharif or rabi crops at 15% or more of the total cultivated area. A purposeful selection of six of these districts was made to represent a good cross-section of production and utilisation scenarios. Within each of these districts, two sub-districts were chosen at random and within each of these one village was selected at random but rejected if it was on a main road, was excessively urbanised or was atypical in some other characteristic. This yielded a total of 2 villages for each district and 12 villages in all (details of the villages are given in Hodges et al. 1999).

A small team of socio-economists, together with two grain survey staff, visited villages in June 1997 just before the start of the monsoon. A second sample survey was undertaken in October 1997, after the monsoon, when samples were taken mostly from the same farmers and same stores as in June. At the second visit some farmers were absent or no longer had any stock. Where this occurred, replacement farmers with stored grain were selected to ensure that not less than four samples were taken per village. A final sample

was taken in January 1998 to examine the quality of the 1997 rabi crop just before the new harvest.

### Selection of farmers and assessment of farmers' perceptions

During the initial village visit, group meetings were used to gain an understanding of the storage practices of farmers, their store types and usual storage periods. From these discussions it was apparent that storage of grain from one season to another was uncommon apart from the case of a limited number of rich households. Subsequent wealth ranking exercises were used to classify households into 'rich', 'medium' and 'poor' and, in a number of cases, into an additional category of 'very poor'. These categories broadly correlate with the area of landholding. Rich farmers harvested sufficient grain to retain some in store for the entire period between harvests. Generally, farmers were storing grain for up to 6 months and in the case of poor households perhaps only 2–3 months.

Farmers were selected across the range of storage periods, but with more chosen from the shorter storage periods. It was hoped this would capture the poor households, but for a number of reasons this was not entirely successful. Despite these efforts to select households predominantly from the poor category, subsequent wealth ranking exercises indicated that the selection was biased towards farmers from the richer wealth categories (Table 2). It is also the case that the poorest of the poor are landless labourers and as such, unless they are paid in grain, have no need to store grain. Farmers' perceptions concerning grain and quality losses were assessed as part of a wider participatory rural appraisal survey that examined aspects of both production and utilisation. Wealth ranking exercises were used to stratify farmers and a series of ranking, scoring and diagramming exercises were used to gain an understanding of the sorghum economy in the context of the farming and livelihood systems. Farmers chosen for grain sampling were the subjects of in-depth interviews. Additional households from the poor wealth categories were used to supplement these case studies to provide a more balanced

picture, correctly weighted for the socioeconomic profile of the selected villages. The findings of these in-depth interviews form the basis of the discussion presented in this report.

### Sampling from farm stores

Samples of 5 kg were extracted from farm stores using sampling probes of appropriate dimensions and then placed in a double layer plastic bag for return to the laboratory. Multiple sub-samples were taken from across the width and depth of each store to provide the best possible representative sample. Where there was open access to the grain bulk, such as in mudded baskets or loose grain piles, a five-compartment probe (80 cm long by 2.5 cm diameter) was used. Where access was more difficult, such as in bag stacks of gunny (jute) bags, a short probe (27 cm by 1.5 cm diameter) was employed. A total of 73 samples was collected in June 1997, 68 in October and 13 in January 1998. Farmers were paid for their grain at the current market rate. Care was taken not to mention to farmers that a further sample would be taken at a later stage. This was done to ensure that their subsequent behaviour would not be influenced by the opportunity to sell grain to the researchers.

### General grain quality assessment

On return to the laboratory the grain was fumigated with phosphine to kill all infesting insects. Each 5 kg sample was then separated using a Boerner divider into three 1 kg portions for general quality analysis, mould and mycotoxin analysis. The remaining 2 kg, plus about 1 kg remaining after general analysis, was recombined and stored in a cool, dry place pending any further requirement for analysis.

One of the 1 kg samples was subdivided to give a sub-sample of 600 g. From this, three 30 g sub-samples were taken to determine moisture content (MC) using a ventilated oven (3 h at 130°C) and a 200 g sample taken to estimate insect numbers. The remainder of the sample was weighed and then carefully sorted to give the following quality refractions by weight: % discoloured grain, % shrivelled grain, % mould damaged grain, % insect damaged grain, % foreign matter and % sound grain.

To provide a convenient means of comparing samples a quality index (QI) was developed. The QI was calculated as the sum of the percentage value of each of those quality characteristics listed above (except % sound grain) and weighted for the more important characteristics by multiplying insect damaged by two and mould damaged by three (as shown in Equation 1). The reciprocal of this value was taken so that a fall in grain quality would be registered by a fall in QI.

$$QI = \frac{1}{\% \text{ discoloured} + \% \text{ shrivelled} + \% \text{ foreign matter} + (\% \text{ insect damage} \times 2) + (\% \text{ mould damage} \times 3)} \times 100 \quad (1)$$

Weight lost as a result of insect infestation was estimated for 10 samples of rabi grain (variety 'Maldandi'), using the count and weigh method (Adams and Schulten 1978) on two 50 g sub-samples. These data were used to prepare a calibration so that an estimate of weight loss could be made of all samples for which an estimate had been made of the % insect damage. Since there was little difference in grain size between crops and varieties, it was assumed that this rough estimate would be applicable to all the samples taken during the current study.

**Table 2.** Mean percentage (%) ± standard deviation (s.d.) of sampled farmers in various wealth categories compared with the village communities from which the samples were drawn.

	Socioeconomic profile of sample			
	Rich	Medium	Poor	Very Poor
Farmer sample	40 ± 19	46 ± 16	14 ± 13	0
Village sample	16 ± 8	38 ± 9	37 ± 14	9 ± 9

## Mycotoxin analysis

Mycotoxin analysis was undertaken for the June and October samples. The 1 kg samples from each of these two occasions were combined by village. Flour was prepared from these bulk samples using a hand-mill. This flour was thoroughly mixed and a 1 kg sub-sample scooped from this mixture, placed in a plastic bag and air-freighted to the United Kingdom (UK) for mycotoxin analysis. In the UK, 500 g portions of the June or October mycotoxin samples were combined according to their similarities, giving a total of 7 samples in June and 13 samples in October. Each sample was checked for *Alternaria* toxins, T-2 toxin and deoxynivalenol, fumonisin B<sub>1</sub> and a number of aflatoxins—B<sub>1</sub>, B<sub>2</sub>, G<sub>1</sub>, and G<sub>2</sub>. As all mycotoxin concentrations appeared to be very low it was decided that analysis of grain from individual stores was unnecessary. The analytical methods used are described in Hodges et al. (1999).

## Data analysis

Data were subjected to Pearson's correlation analysis, linear regression or analysis of variance. Where necessary, data were transformed to  $\ln(\text{count} + 1)$  or to arcsine prior to analysis in order to meet the assumptions underlying analysis of variance.

## Results

### Farmers' perceptions on grain variety and store type

While farmers clearly differentiated between the storage characteristics of rabi versus kharif grain (rabi better and kharif worse) and between varieties (hybrid varieties noticeably worse), these characteristics were not necessarily used in selection of varieties or store type. The choice of rabi versus kharif was generally predetermined by climatic conditions and prevailing soil types in a specific location. In the case of kharif varieties, despite the clear dissatisfaction of farmers concerning both storage and eating characteristics of hybrid varieties, these still dominated in most of the kharif-producing areas. Yield outweighed all of these factors, which partly reflects the fact that kharif varieties are produced for sale as well as home consumption, indeed in one district kharif grain was produced exclusively for sale. However, during crop decision-making exercises with farmers, it was

noticeable that sorghum scored highly for its value as a source of food (less so as a source of cash), but storage and postharvest characteristics were not considered of sufficient importance to be mentioned by farmers.

Farmers' discussions concerning choice of store type indicated that a range of issues was important. These included cost of the storage structure, ease of use, amount of grain to be stored and the availability of appropriate store construction skills. Production season also played a role in the choice of store type since, compared to rabi, kharif yields are higher, so larger storage structures are required. The use of underground pits—which had once been prevalent in both rabi and kharif areas—had been largely abandoned. Underground water seepage had become a problem, although it was not clear why it had arisen. In such pits, checking the grain for insect attack is difficult and time consuming and the smaller quantities of grain produced by individual farmers caused them to seek smaller, more convenient above-ground structures, usually in the home. In the kharif areas, traditional mudded baskets (kangis) were preferred over gunny (jute) bags. Although they were more expensive to construct, these structures were perceived to last longer—up to twenty years, whereas a gunny bag may only last 5–6 months if it suffers rat damage. However, households from the poor wealth category, with little to store, often relied on gunny bags because of the low initial investment.

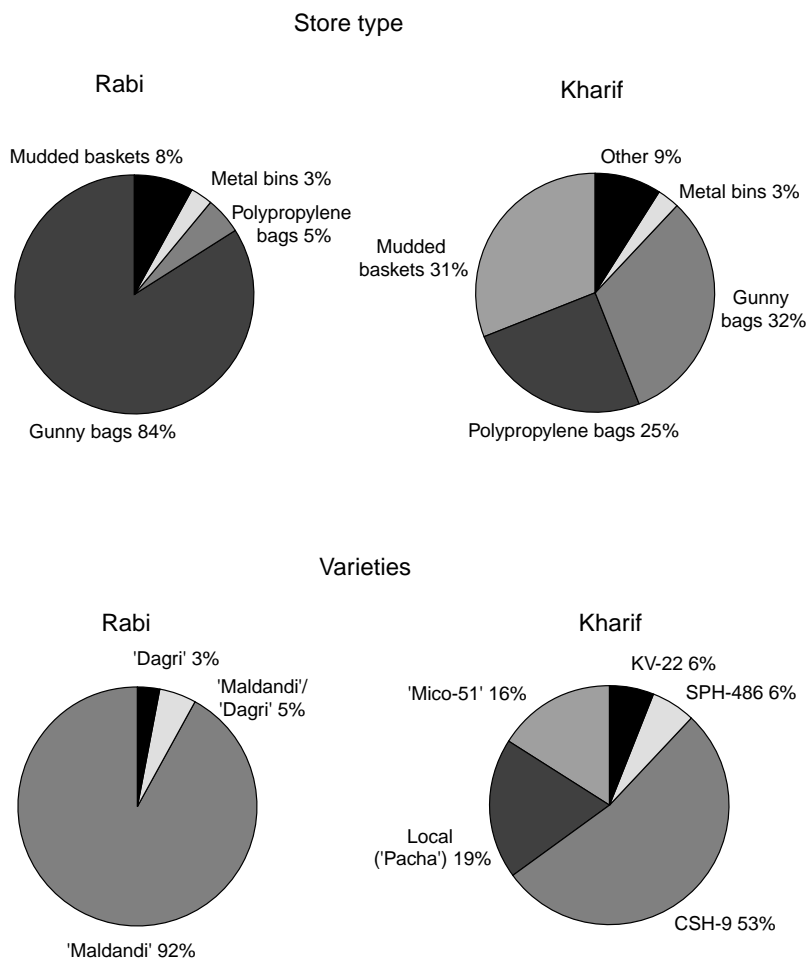
It was apparent from discussion with farmers that both underground stores and mudded woven baskets (despite their advantages) were declining in use, due to the difficulty of finding skilled artisans for their construction. Increasingly, metal bins were being used because of their low cost, availability and durability.

### Direct observation of store types and grain varieties

In June 1997, 73 grain samples were taken, comprising 33 samples of kharif grain harvested in October–November 1996 and 40 samples of rabi grain harvested in February–March 1997. Generally, villages had either a rabi or a kharif crop, but in one case, grain from both harvests was in store in June, though only the rabi crop remained in October (village No. 6 in Table 4). In a few cases, some rabi grain was in underground pits in June but none was sampled as the grain being consumed at that time was in gunny bags and the pits were not due to be opened for several weeks. The grain in these pits, which would subse-

quently be transferred to gunny bags, was sampled as a matter of course in October. In October, samples were obtained from 30 of 40 farmers who had contributed rabi grain samples in June 1997 and 23 of the 33 farmers who had contributed kharif samples. At the time of sampling, most farmers still had some grain in store, although stocks were lower than we had expected from farmers' June estimates for time to stock exhaustion. Of the 40 original farmers storing rabi grain, 6 (15%) no longer held any grain and a further 9 (26%) had less than 10% of the grain observed in June. Only 10 of the sampled farmers (29%) thought that they still had enough rabi sorghum to last until the next harvest, although 13 still actually had rabi sorghum in January 1998.

From the frequencies of store types and grain varieties observed in June, it is clear that the rabi farmers have a strong convergence of practice (Figure 1). Nearly all were growing the improved variety, 'Maldandi', and storing it in gunny bags. In contrast, farmers harvesting sorghum in the kharif season grew a wider range of varieties and used a more diverse selection of storage structures; gunny bags, polypropylene bags and mudded baskets were about equally common (Figure 1). The varieties grown and the store types used by the sampled farmers are consistent with the prevailing practices of farmers as indicated in the participatory rural appraisal survey.



**Figure 1.** Store types and grain varieties of the rabi and kharif sorghum harvests (June 1997).

## Postharvest handling practices

Farmers indicated that the postharvest handling practices for rabi and kharif grain are similar. After threshing and drying, at the home or other convenient place, the grain is placed in the chosen storage container. Neem leaves and ash may be admixed and Gammexane (benzene hexachloride or lindane) powder sprinkled on store surfaces, particularly on gunny bags. Insect infestation is noticed after 4–5 months in kharif grain and 6–7 months in rabi grain. Frequent sun-drying and cleaning by picking and winnowing (every 2–3 months) is used to control insect infestation. Farmers said that, by using this method, rabi sorghum could be stored safely for up to one year after harvest.

Women were responsible for the management of household grain stores in all the case-study villages. The usual period of storage is determined mainly by farmers' wealth category and by whether the grain is of the kharif or rabi harvest. Discussions with farmers suggest that only those from the rich wealth category were able to store from one harvest to the next. Households from the medium and particularly the poor wealth category often had insufficient land resources (both quantity and soil types) to produce enough grain for household consumption throughout the year. The usual storage period was 2–6 months depending on the land available for individual farmers. It was apparent that for most of the poorer households the length of grain storage was such that insect infestation and mould damage was rarely a problem (grain blackening being the exception as discussed below).

## Grain quality analysis

The June rabi sample, which had been stored for 3–4 months, had a significantly higher QI than the kharif grain which by June had been in store 8–9 months (Table 3) ( $F_{(1,72)} = 101.2, p < 0.0001$ ). The difference seemed to be due to the kharif crop having significantly more mouldy grains ( $F_{(1,72)} = 8.6, p < 0.0001$ ), as no insect damage was apparent as at this time.

The grain samples from both harvests were equally dry, the highest MC was only 10.7% and the average 8.9%, and there was no evidence of any significant difference between the moisture values for the two crops. Thus with neither harvest was there any obvious cor-

relation between MC and mould damage at the time of sampling. It therefore seems likely that the conditions promoting mould growth on the kharif grain occurred preharvest and/or early in the storage season. Farmers' responses lead us to believe that this damage was the 'grain blackening' that occurs on kharif sorghum, especially hybrids, dampened by unseasonal rain in the field. The degree of blackening varies from year to year and occurs to a significant extent at least once in every three years, depending on the amount of rainfall. Despite the blackening, much of this grain is used for home consumption; farmers from the medium and poor wealth categories indicated that they have little choice but to eat it. For this purpose it is washed and sun-dried. Despite this, farmers did suggest that the blackened grain is associated with health problems. Blackened grain has a low market price and the worst affected is used for animal feed (both on farm and by those purchasing it in the market).

Grain sampled in October had been stored through the monsoon period and, as expected, this had resulted in a rise in grain MC. Both crops exceeded 11% (Table 3) and the small difference between them, only 0.3%, was significant ( $F_{(1,62)} = 4.48, p < 0.038$ ). This suggests that the kharif crops were grown in areas where the monsoon is more prolonged. The difference in QI between crops was large and statistically significant ( $F_{(1,65)} = 85.7, p < 0.0001$ ). For both crops there was a large October fall in QI, both because insect damage was apparent for the first time (Table 3) and because there was an increase in % mouldy grain. For the crops combined, there was a strong significant correlation between the incidence of mould damage and insect damage ( $r = 0.539, p < 0.01$ ), suggesting that either mould attack facilitates insect attack or the same factor(s) may predispose the grain to both types of damage. The overall differences between the two crops are reflected in the average values for mould damage and insect damage observed in the villages (Table 4). There was no evidence of significant differences between store types in the incidence of mould, insect damage or for values of the QI (Table 5); however, the small numbers of observations on most of the store types precludes any firm conclusions on this matter.

**Table 3.** Mean quality parameters for the 1996 kharif and 1997 rabi harvests of sorghum grain for samples taken in June and October 1997.

	Moisture content	Discoloured grain	Mould damage	Insect damage	Foreign matter	Shrivelled grains	Sound grain	Quality index
Percentage								
<b>June</b>								
Kharif	8.90	1.74	9.61	0.00	4.64	2.13	80.75	2.67
Rabi	8.93	1.08	1.10	0.00	1.88	0.78	95.15	14.20
<b>October</b>								
Kharif	11.49	8.25	15.11	8.62	1.60	0.65	62.98	1.36
Rabi	11.16	1.83	1.44	2.86	1.22	0.51	92.30	7.30

**Table 4.** Village averages for the incidence (%) ( $\pm$  standard deviation) of insect and mould damage to grain in the rabi and kharif harvests sampled in October 1997.

Village no.	Rabi			Village no.	Kharif		
	Insect damage (%)	Mould damage (%)	Quality index		Insect damage (%)	Mould damage (%)	Quality index
1	4.0 $\pm$ 2.7	0.3 $\pm$ 0.3	10.9 $\pm$ 5.1	6	Kharif crop all consumed		
2	4.2 $\pm$ 4.3	1.4 $\pm$ 1.0	16.0 $\pm$ 7.7	7	11.9 $\pm$ 12.6	22.3 $\pm$ 16.8	2.3 $\pm$ 1.0
3	2.0 $\pm$ 1.0	0.6 $\pm$ 0.5	9.9 $\pm$ 2.8	8	4.5 $\pm$ 2.8	13.2 $\pm$ 3.8	3.5 $\pm$ 2.3
4	3.0 $\pm$ 2.5	1.7 $\pm$ 0.9	15.3 $\pm$ 2.0	9	11.5 $\pm$ 5.1	14.6 $\pm$ 8.9	3.36 $\pm$ 1.7
5	2.8 $\pm$ 1.1	5.0 $\pm$ 4.7	24.9 $\pm$ 14.5	10	8.4 $\pm$ 3.4	15.4 $\pm$ 3.1	5.3 $\pm$ 5.7
6	3.2 $\pm$ 2.3	0.7 $\pm$ 0.6	12.2 $\pm$ 7.4	11	7.6 $\pm$ 5.6	8.2 $\pm$ 5.7	3.7 $\pm$ 1.5
12	5.4 $\pm$ 5.8	0.6 $\pm$ 0.4	6.9 $\pm$ 4.9				

**Table 5.** Store type averages for the incidence (%) ( $\pm$  standard deviation) of insect and mould damage to grain in the rabi and kharif harvests sampled in October 1997.

Crop	Store	No. in sample	Insect damage (%)	Mould damage (%)	Quality index
Rabi	Gunny bag	34	2.9 $\pm$ 2.4	1.45 $\pm$ 2.3	10.5 $\pm$ 6.7
	Metal bin	1	2.0	0.9	7.1
Kharif	Gunny bag	8	6.9 $\pm$ 3.8	16.0 $\pm$ 12.6	1.6 $\pm$ 0.7
	Metal bin	1	6.6	17.4	1.4
	Polypropylene bag	5	4.7 $\pm$ 3.5	7.7 $\pm$ 5.6	2.6 $\pm$ 1.0
	Mudded basket	9	9.7 $\pm$ 6.0	17.8 $\pm$ 10.3	1.4 $\pm$ 0.6
	Box store <sup>a</sup>	1	33.7	20.8	0.7
	Corner of house	2	9.6 $\pm$ 11.8	12.4 $\pm$ 1.9	0.7 $\pm$ 1.1

<sup>a</sup> Brickwork box built in house



## Insect infestation and associated grain weight loss

The primary pests *Rhyzopertha dominica* (Fabricius) and *Sitophilus oryzae* (L.) were the most numerous insects and the most likely to cause damage and weight loss in the rabi and kharif grain samples taken in October 1997 (Table 6). The percentages of rabi and kharif samples infested by *R. dominica* were very similar (about 84%) but the numbers of this species were about three times greater on kharif grain. In contrast, *S. oryzae* clearly preferred rabi grain, since about 20% more rabi samples were infested and numbers of this species were about six times greater than on kharif grain. The secondary pest *Cryptolestes ferrugineus* (Stephens) was considerably more numerous on kharif samples while the two harvests were similar in the extent of infestation by *Tribolium castaneum* (Herbst) (Table 6). Sorghum grain weight losses due to insect damage were determined for 10 samples of 'Maldandi' grain taken in October 1997. The regression of these weight losses with their corresponding percentages of insect damaged grain was

statistically significant ( $r^2 = 0.79$ ,  $df = 8$ ,  $p < 0.001$ ). The regression equation from this relationship was used to estimate what the likely weight losses were for other grain samples for which only estimates of % grain damage had been made. The mean values of these estimates were weight losses of  $0.88 \pm 0.30\%$  for the rabi crop and  $1.71 \pm 1.17\%$  for the kharif.

## Quality decline in rabi sorghum through to January 1998

Only 13 of the rabi stocks first sampled in June 1997 were still available for sampling in January 1998. The quality assessment of these samples showed evidence of continued quality decline (Table 7). In the 3 months between June and October 1997, through the monsoon, the QI fell by about 63% and in the following 3 months to January 1998 it fell again by 15% of its June value. Although the major reduction in quality occurred during the period of the monsoon, thereafter there were increases in mould and insect damage and a noticeable increase in the proportion of discoloured grain (Table 7).

**Table 6.** Percentage of rabi and kharif sorghum samples infested by insects and mean numbers of live and dead insects/kg ( $\pm$  standard deviation), from samples taken in October 1997.

Harvest	<i>Rhyzopertha dominica</i>	<i>Sitophilus oryzae</i>	<i>Tribolium castaneum</i>	<i>Cryptolestes ferrugineus</i>
Rabi	% samples infested			
	83	70	36	3
	Mean no./kg			
	135 $\pm$ 245	170 $\pm$ 300	10 $\pm$ 20	0.5 $\pm$ 40
Kharif	% samples infested			
	84	50	31	13
	Mean no./kg			
	365 $\pm$ 470	30 $\pm$ 45	15 $\pm$ 25	30 $\pm$ 85

**Table 7.** Mean values for quality factors of rabi season grain from the same 13 stores sampled on 3 occasions during a storage period of about 11 months.

Quality factor	June 1997	October 1997	January 1998
% discoloured	1.0	1.9	2.8
% mouldy	0.9	1.1	1.7
% insect damage	0	3.1	4.9
% foreign matter	1.5	1.4	2.7
% shrivelled	0.8	0.6	0.8
Quality index	26.6	9.6	5.7

There was also an increase in foreign matter by January 1998, possibly due to contamination with stones, soil etc. as farmers re-dried their sorghum stocks after the monsoon. Insect damage increased to the extent that the stocks remaining in January had probably suffered a weight loss of about 1.25%, an increase of 42% on the mean loss estimated for all the rabi samples (30) taken in October 1997.

## Mycotoxin contamination

Mycotoxin contamination in June and October (Table 8) was low and certainly below the levels that would be expected to constitute a health risk. There was no evidence of any increase in contamination rates as a result of the monsoon period, i.e. no increase between June and October. Low levels of aflatoxin contamination were typical of both the rabi and kharif harvests and although four toxins were tested for, only aflatoxin B<sub>1</sub> was evident. Contamination with fumonisin B<sub>1</sub> was almost exclusive to the kharif crop; of the 11 rabi bulk samples only 1 showed any signs of fumonisin B<sub>1</sub>, whereas all 8 kharif bulk samples were contaminated. *Aflatoxin* and *Alternaria* toxin contamination was very low and differed little between the two harvests.

## Farmers' perceptions of grain losses

In the context of wider concerns in the farming and food systems, farmers did not generally perceive losses of grain quantity or quality during storage to be of major importance. The exception to this was the issue of grain blackening. Although a preharvest problem, mould formation appears to continue during storage (Table 3). This is not to say that farmers did

not recognise that grain and quality losses occur during storage. Insect damage illustrates this point. Farmers knew when it began to occur and had adopted sun-drying and neem and ash admixture as a means of combating it. Estimates of the extent of losses varied widely, but 3–5% for rabi grain and 5–10% for kharif, over a year in storage, were the commonly perceived levels.

Kharif-producing farmers did, however, indicate that losses could be as high as 20% in years of severe grain blackening. It was also indicated that poor households took extra care of the little stored grain that they had. As a result, actual losses during the few months in which this group stored grain is probably even lower than the figure of 5–10% they quoted.

Farmers did not specifically mention mould damage (except in the context of grain blackening discussed above). However, they did discuss changes that took place to the grain over time in storage. They indicated that the 'lustre' of grain was lost during storage. Of most significance were the changes in the cooking and eating qualities. It was indicated that the stickiness of dough made from grain was lost over time. This change took place after about 6 months and was more pronounced in kharif grain, particularly hybrid varieties. This was also associated with a loss of taste. The relative importance of these issues needs to be judged in the light of the fact that these changes are taking place after 6 months. Since this is the limit of storage for most households, most will only rarely experience such problems. This suggests that while these problems are undoubtedly impacting on consumers of sorghum (particularly for kharif consumers), they are not responsible for changes in the relative proportion of sorghum in cropping patterns.

**Table 8.** Maximum observed mycotoxin contamination (parts per billion—ppb) in sorghum samples taken from the rabi and kharif harvests in southern India in June and October 1997. Numbers given in brackets = number of store samples contributing to the bulk sample analysed for mycotoxins.

	Total number of stores	Aflatoxin B <sub>1</sub>	<i>Alternaria</i> toxins			<i>Fusarium</i> toxins
			AtOH	AltOMe	Altenuene	Fumonisin B <sub>1</sub>
<b>June</b>						
Kharif	27	2.7 (12)	23 (15)	33 (15)	36 (15)	87 (12)
Rabi	45	1.5 (17)	11 (16)	9 (16)	0 (16)	25 (16)
<b>October</b>						
Kharif	27	0.5 (4)	33 (4)	40 (4)	55 (6)	177 (2)
Rabi	35	0.6 (5)	12 (5)	6 (5)	8 (5)	0 (35)

Note: health risk—aflatoxin >5 ppb, *Alternaria* toxins >1,000 ppb, fumonisin B<sub>1</sub> >1,000 ppb

## Conclusions

It is clear that rabi sorghum enters storage with better quality characteristics than its kharif counterpart, which may suffer some moulding prior to storage. The monsoon period is associated with a major decline in quality for both crops, in particular a rise in mould damage and the start of insect attack. Both these factors were somewhat greater for kharif sorghum, presumably due to the rather lower quality of kharif grain at the onset of the monsoon. However, an intrinsically greater susceptibility of kharif varieties to mould and insect attack cannot be ruled out. Both grain types are of rather poor quality by the end of the storage season, whether it be October in the case of the kharif crop or January in the case of the rabi.

Although farmers of kharif sorghum appeared to use a wider range of storage methods, this appeared not to be a factor affecting the grain quality, since QI values for kharif grain in gunny bags, the storage technique of most rabi farmers, differed little from the grain stored by other methods. It appears that choice of storage method is dependent on a wider set of factors than storage efficiency alone. Differences between rabi and kharif can be explained to some extent by the amount of grain to be stored, particularly the larger kharif crop. Ease of use, availability of appropriate artisanal skills and costs are among the issues mentioned by farmers. Regional preferences also undoubtedly play a role.

In the period under study, grain weight losses due to insect attack were relatively low and in October, at the end of the kharif storage season, amounted to an average of only 1.7%, while at the same time the rabi crop appeared to have lost only 0.9%. The losses in the kharif crop due to insect damage were low considering that the estimate was made on grain that was close to the end of the storage period. It might be considered that the technique used to estimate the grain weight loss, the count and weigh method, could have resulted in an underestimate of loss. This tends to happen if grains are removed completely from the store, e.g. when they are reduced to dust, as may be the case with some of the kharif or rabi grain. However, applying the end-of-season loss figure to the whole stock is likely to give an overestimate of loss since much of the grain is sold or consumed long before the monsoon, i.e. before the time when insect attack becomes prevalent. Thus the weight losses of the entire stock were probably somewhat smaller than our estimate.

The two crops differed with respect to the predominant insect pests, with *R. dominica* and *S. oryzae* equally common on rabi but *R. dominica* predominant on the kharif. Although the two species differ in their

abilities to tolerate dry conditions (Haines 1991), with *S. oryzae* being seriously limited on grain with MC below 11%, it seems that this is not a major consideration in this case as *S. oryzae* was more common on the drier crop. The predominance of *R. dominica* on the kharif crop is presumably a reflection of the susceptibility of the different grain varieties to the two species. In connection with this, it is interesting to note that Reddy and Nusrath (1988), studying insect infestation and mycotoxin production in kharif sorghum varieties, list *R. dominica* as a major pest of this grain and make no mention of any *Sitophilus* spp. Furthermore, Kishore et al. (1977) noted that in high-yielding kharif varieties the percentage damage caused by *R. dominica* was many times greater than that caused by *S. oryzae*.

Mycotoxin contamination generally remained below levels that would represent a human health hazard. Similar low contamination rates were reported from earlier surveys in southern India (Bhat and Rukmini 1978; Sashidhar et al. 1992). In the current study, there was no notable increase in prevalence of mycotoxins after the monsoon season even though mould attack rose significantly during this period. Fumonisin B<sub>1</sub> was almost exclusively restricted to the kharif crop where it was found in all samples, even prior to the monsoon. It seems likely that this mycotoxin is associated with preharvest mould damage. The picture given here, of relatively slight mycotoxin contamination, should not be taken to imply that there are no potential problems with mycotoxicosis, as other researchers have reported significant aflatoxin (Mall et al. 1986), *Alternaria* toxin (Anasari and Shrivastava 1990) and fumonisin (Bhat et al. 1997) contamination in kharif crops in India. In the case of fumonisin, a disease outbreak was reported in a few villages on the Deccan Plain in households where rain-damaged mouldy grain was being consumed (Bhat et al. 1997). In the storage system we investigated, mycotoxin contamination rates may sometimes be higher in those years where weather conditions are less favourable or otherwise due to poor storage by individual farmers. Preharvest grain blackening, therefore, remains an issue of concern both for reasons of health and for the marketing of kharif grain. Research on 'hard' varieties of sorghum with a high degree of resistance to fungal attack, particularly to *Fusarium moniliforme*, show that specific anti-fungal proteins are involved (Kumari and Chandrashekar 1994). The possibility of transferring this characteristic to sorghum varieties, that otherwise already have good agronomic characteristics, presents one possible approach to the problem

of grain blackening. This may be particularly successful when transferred to varieties whose morphology does not favour mould growth, e.g. those with panicles that hang downwards which are less prone to moisture accumulation.

Overall, the grain storage practices of farmers in southern India do not appear to be a constraint to the production and consumption of sorghum. Mycotoxin contamination and grain losses due to insect attack appear to remain low, although towards the end of their respective storage seasons the kharif and rabi crops have suffered a considerable decline in quality. This appears not to be a significant problem as this decline was limited to only a small portion of the remaining stock. However, if farmers wish to retain stocks between seasons, to market grain strategically, then their current practices are likely to be inappropriate. By all accounts the major issue facing sorghum grain would appear to be the preharvest mould damage sustained by kharif varieties.

Farmers' perceptions of the nature and extent of grain weight and quality losses are entirely consistent with the findings of the technical study. Farmers are certainly aware that quantitative and qualitative changes take place. They have developed practices to keep these changes within acceptable limits and what changes do occur apparently do not influence farmers' choice of crop or variety. This reflects to a certain extent the fact that, for many households, the ability to store grain for periods of more than 6 months is constrained by production resources rather than postharvest practice. To be more specific, those farmers who might be significantly affected by serious grain quality deterioration towards the end of the harvest are those without grain at this time. There are undoubtedly characteristics of hybrid sorghum grain which cause it to store poorly and its qualities to decline, although this is clearly not an important issue in the current scenario of farm practice. This does not mean that these traits are not impacting on the wider sorghum economy (and therefore on farmers), but only that they are not impacting on the components of the sorghum production and utilisation system examined. Storage by wholesale traders and industrial users shows a different picture—this has been highlighted by other parts of this study (Kleih et al. 1998). So while the current study has certainly laid to rest many concerns relating to farm storage, it is clear that components of the utilisation chain need more detailed study.

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## References

- Adams, J.M. and Schulten, G.G.M. 1978. Losses caused by insects, mites and micro-organisms. In: Harris, K.L. and Lindblad, C.J., ed., Post-harvest grain loss assessment methods. Washington DC, American Association of Cereal Chemists, 83–89.
- Anasari, A.A. and Shrivastava, A.K. 1990. Natural occurrence of *Alternaria* mycotoxins in sorghum and ragi from North Bihar, India. Food Additives and Contaminants, 7, 815–820.
- Bhat, R.V. and Rukmini, B. 1978. Mycotoxins in sorghum: toxigenic fungi during storage and natural occurrence of T2 toxin. Proceedings of the international workshop on sorghum diseases, Hyderabad, India, 1–15 December 1978. Patancheru, Andhra Pradesh, India, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).
- Bhat, R.V., Shetty, P.H., Amruth, R.P. and Sudershan, R.V. 1997. A foodborne disease outbreak due to the consumption of mouldy sorghum and maize containing fumonisin mycotoxins. Journal of Toxicology—Clinical Toxicology, 35, 249–255.
- Haines, C.P. (ed.) 1991. Insects and arachnids of tropical stored products: their biology and identification, 2nd edition. Chatham, United Kingdom, Natural Resources Institute, 246p.
- Hall, A.J. and Brough, S. 1997. Sorghum utilisation in India: emerging patterns and research needs. Natural Resources Institute, unpublished project document.
- Hodges, R.J., Hall, A.J., Jayaraj, K., Jaiswal, P., Potdar, N., Yogand, B. and Navi, S.S. 1999. Quality changes in farm-stored sorghum grain grown in the wet or dry season in south India—a technical and social study. Natural Resources Institute (NRI) report 2412. Chatham Maritime, Kent, NRI, 33p.

- Kishore, P., Jotwani, M.G. and Sharma, G.C. 1977. Relative susceptibility of released high-yielding varieties and hybrids of sorghum to insect attack in storage. *Entomologists' Newsletter*, 7, 14–15.
- Kleih, U., BalaRavi, K. and Dayakar, B. 1998. Industrial utilisation of sorghum in India. Natural Resources Institute, unpublished report document.
- Kumari, S.R. and Chandrashekar, A. 1994. Isolation and purification of three antifungal proteins from sorghum endosperm. *Journal of Food Science*, 64, 357–364.
- Mall, O.P., Pateria, H.M. and Chauhan, S.K. 1986. Mycoflora and aflatoxin in wet harvested sorghum. *Indian Phytopathology*, 39, 409–413.
- Marsland, N.K. 1998. Factors influencing the consumption of sorghum as food in India. Natural Resources Institute (NRI) socio-economics series No. XX. Chatham Maritime, Kent, NRI.
- Reddy, B.N. and Nusrath, M. 1988. Relationship between the incidence of storage pests and production of mycotoxin in jowar. *National Academy Science Letters*, 11(10), 307–308.
- Sashidhar, R.B., Ramakrishna, N. and Bhat, R.V. 1992. Moulds and mycotoxins in sorghum stored in traditional containers in India. *Journal of Stored Products Research*, 28, 257–260.

# Research on the Sensitivity of Maize Varieties to *Sitophilus zeamais* M.

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## Abstract

This paper reports on two years of research into the *Sitophilus zeamais* M. sensitivity of 25 maize varieties, among them 20 hybrids. Some obtained results are as follow:

- 72 hours after placing samples of maize and *S. zeamais* (imago) 50 cm apart, the frequency of appearance of *S. zeamais* was highest in variety B9681 (19.1%), followed by NEP.HN (*Zea mays* var. *ceratina*) (17.6%) and LVN10 (14.4%); it was lower in 4728 (5.3%), P11 (3.4%), and 3024 (2.4%). Green pea was used as the control sample (1%).
- The preference of *S. zeamais* for different maize varieties clearly varied over the period of 60 days. In all of four experiments, two maize varieties — B9681 and NEP.HN — were damaged by *S. zeamais* to the highest extent possible (100%); two varieties — 3024 and LVN28 — were damaged to a lesser extent (60–70%). After a period of 60 days the weight decreases of these samples were different. The highest weight decrease was found in two varieties — NEP.HN (31.3%) and B9681 (20.4%); a lower weight decrease was measured in 3024 (1.6%) and LVN28 (1.3%). After a period of 90 days, almost all the varieties of maize were damaged to a high degree: 7 varieties to 100%, 11 varieties to 91–99%, and 4 varieties to 80–90%, with LVN28 having the lowest level of damage (80%).
- After a period of 60 days, numbers of *S. zeamais* (imago) increased in three maize varieties — NEP.HN, LVN20, and B9681 (3–6 times the initial number) and fell in three varieties — 3024, LVN31, and 4728 (0.5–0.7 times).

AT PRESENT, high productivity has been achieved with over 70% of the hybrid maize varieties grown in Vietnam. However, farmers believe that the hybrid maize varieties are more easily damaged by insects during storage. Thus, this study was carried out to answer two questions.

- Are hybrid maize varieties more susceptible to insect damage than local varieties?
- Do different maize varieties differ in their attractiveness to the maize weevil, *Sitophilus zeamais*?

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## Materials and Methods

### Materials

#### *Maize varieties*

Twenty-five maize varieties were studied:

- LVN4, LVN5, LVN6, LVN10, LVN17, LVN18, LVN20, LVN24, LVN27, LVN28, LVN29, LVN3L, 2891, 3012, 3023, 3024, 4728, P11, Q2 and SC95.30 were collected by the Maize Research Institute; and
- NEP.HN, B9681, 'Pioneer', TSB2 and VM1 were cultivated in Hanoi and Ha Bac.  
Q2, NEP.HN, TSB2 and VM1 are open-pollinating varieties; the rest are hybrids.

Black beans and green peas were used as controls. Maize, black bean, and green pea samples were dried to a moisture content (MC) of 14% and cleaned to remove damaged grains.

#### *Insects*

*Sitophilus zeamais* Motsch adults bred in the laboratory were used in the study. The experiments were carried out during 1997–1999.

### Specifications

The analyses made were:

- ratio of damaged grains after 30, 60, and 90 days;
- ratio of live and dead adult *S. zeamais* individuals after 30, 60, and 90 days; and
- penetration of maize varieties by *S. zeamais*.

### Methods

To assess the sensitivity of maize to *S. zeamais*, six experiments (numbered 1, 2A, 2B, 3, 4, and 5) were carried out as described below.

#### *Experiment 1*

A mixture was made of six maize varieties (100 grains of each) and 60 adult *S. zeamais* individuals in a bottle. The amount of damaged grains was estimated after 30, 60 and 90 days.

#### *Experiments 2A and 2B*

The objective of these experiments was to study the attraction of *S. zeamais* to different maize varieties.

Experiment 2A: A box was separated into eight compartments. 100 grains of maize were placed in each compartment. A petri dish of 80 adult *S. zeamais* individuals was placed in the centre of the box, and the *S. zeamais* were then free to choose their preferred maize variety.

Experiment 2B: This experiment was similar to 2A, but with only 10 adult *S. zeamais* individuals introduced into the box.

The amount of grain damage caused by *S. zeamais* was assessed after 30, 60 and 90 days.

#### *Experiment 3*

In order to assess the level of damage to maize grains caused by *S. zeamais*, maize varieties with the same moisture content were separated into bottles. Each bottle included 100 grains and 10 adult *S. zeamais*. The numbers of live and dead *S. zeamais* individuals were counted after 30, 60 and 90 days.

#### *Experiment 4*

In order to assess the level of damage to maize varieties caused by a single pair (male + female) of adult *S. zeamais*, maize varieties with the same moisture content were separated into bottles. Each bottle contained 100 grains and one pair of adults. The numbers of live and dead *S. zeamais* individuals were counted after 30, 60 and 90 days.

#### *Experiment 5*

To study the role of maize odour in attracting the insects, eight locations were marked on the bottom of a glass cabinet (measuring 1 × 1 × 1 m), each of equal distance from the centre. Different maize varieties (50 g of grain/variety) were placed in each of the eight locations. An open jar containing 60 adult *S. zeamais* individuals was placed at the centre. Every 48 hours, the maize varieties were rotated clockwise to the next location until each variety had occupied all positions. At each rotation, the number of *S. zeamais* individuals in each of the eight maize varieties was counted, then a fresh jar of 60 adult *S. zeamais* individuals was introduced.

## Results and Discussion

The results of the experiments are shown in Tables 1A, 1B, 2A, 2B, 3, 4 and 5—the table numbers coinciding with the experiment numbers.

Table 1A shows the following.

- After 30 days, the NEP.HN and B9681 varieties were the most damaged (74.0% and 71.7% damage, respectively). The 3024 and LVN28 varieties were the least damaged (49.5% and 15.0%, respectively).
- After 60 days, the number of adult insects increased 2–3 times, and the percentage of damaged grains increased accordingly. More than 95% of NEP.HN, B9681, LVN4, LVN6, and LVN24 grains were damaged. Varieties with more than 80% damage included VM1, 3023, LVN31, LVN20 and LVN10. The LVN28 grains were least damaged at 42%.
- After 90 days, among 22 maize varieties, 21 varieties were damaged in the range of 95–100%. The LVN28 variety was least damaged at 80.5%.

The data in Table 1B reinforce these findings.

**Table 1A.** Preference of *Sitophilus zeamais* for different maize varieties as measured by the proportion of damaged grains in a sample (experiment 1).

Damaged grains (%)	After 30 days Av. live individuals = 6.7 Av. dead = 3.3	After 60 days Av. live individuals= 29.9 Av. dead = 6.6	After 90 days Av. live individuals= 83.1 Av. dead = 11.0
95–100		NEP.HN, B9681, LVN4, LVN6, LVN24	NEP.HN, B9681, LVN4, LVN6, LVN24, VM1, 3023, LVN31, LVN20, LVN10, SC95.30, 3012, P11, LVN5, 2891, LVN17, LVN18, LVN19, 4728, LVN27, 3024
80–94.9		VM1, 3023, LVN31, LVN20, LVN10, SC95.30, 3012, P11, LVN5, 2891, LVN17, LVN29, LVN18, 4728	LVN28
65–79.9	NEP.HN, B9681, LVN4, LVN6, VM1, 3023	LVN27, 3024	
50–64.9	LVN24, LVN31, LVN20, LVN10, SC95.30, 3012, P11, LVN5, 2891		
40–49.9	LVN17, LVN29, LVN27, 3024	LVN28	
<40	LVN18, 4728, LVN28		
Average (%)	55.85	85.58	98.57
σ (variance of varieties)	± 14.63	± 11.27	± 4.12

**Table 1B.** Preference of *Sitophilus zeamais* for different maize varieties as measured by the decrease in grain weight (%) in a sample (experiment 1).

Number	Maize variety	After 60 days	After 90 days
1	NEP.HN	31.32	49.30
2	B9681	20.35	40.59
3	VM1	5.81	28.98
4	LVN4	6.15	21.70
5	LVN24	7.84	21.25
6	LVN5	4.20	20.98
7	LVN6	9.70	19.30
8	LVN20	4.90	15.38
9	2891	4.79	15.09
10	SC95.30	6.34	14.84
11	LVN17	4.14	13.59
12	LVN10	4.07	12.40
13	LVN18	3.68	12.40



**Table 1B.** (Cont'd) Preference of *Sitophilus zeamais* for different maize varieties as measured by the decrease in grain weight (%) in a sample (experiment 1).

Number	Maize variety	After 60 days	After 90 days
14	P11	2.98	12.12
15	LVN27	3.30	11.97
16	LVN31	3.41	11.69
17	LVN29	3.05	10.17
18	4728	3.90	10.00
19	3032	2.38	9.19
20	3012	2.38	8.67
21	3024	1.63	7.79
22	LVN28	1.26	6.74
Average		6.25	17.00

**Table 2A.** The attractiveness of different maize varieties to *Sitophilus zeamais* (experiment 2A: 60 *S. zeamais* individuals).

Damaged grains (%)	After 30 days Av. live individuals = 5.7 Av. dead = 4.3	After 60 days Av. live individuals= 19.9 Av. dead = 4.7	After 90 days Av. live individuals = 37 Av. dead = 8.2
95–100		B9681, LVN20, NEP.HN, 3012, P11	B9681, LVN20, NEP.HN, 3012, P11, LVN6, LVN17, LVN18, LVN10, LVN31, 3023, LVN4, LVN27, LVN24, LVN5, SC95.30, 4728, 3024
80–94.9	B9681, LVN20	LVN6, LVN7, LVN18, LVN10, LVN31, 3023, LVN4, LVN27	VM1, LVN29, LVN28
65–79.9	NEP.HN, 3024, P11, LVN6, LVN17, LVN18	LVN24, VM1, LVN5, SC95.30, 4728, 3024, LVN29	2891
50–64.9	LVN10, LVN31, 3023, LVN4, LVN24	LVN28	
40–49.9	LVN27, VM1, LVN5, SC95.30, 4728, LVN29	2891	
<40	2891, 3024, LVN28		
Average (%)	55.84	81.82	96.90
σ(variance of varieties)	± 18.58	± 12.72	± 4.94

The following conclusions can be drawn from the results given in Table 2A.

- After 30 days, the B9681 and LVN20 varieties had the highest damage (92% and 88.3%, respectively). The 3024 and LVN28 varieties had the least damage (25.8% and 16.0%, respectively).
- After 60 days, the proportion of damaged grains had increased, with the B9681, LVN20, NEP.HN and 3012 varieties having the highest damage (97.9%, 96.0%, 96.0% and 95.5%, respectively). The LVN28 and 2891 maize varieties had the lowest damage (55.8% and 45.0%, respectively).
- After 90 days, almost all of maize varieties had damage of over 95%. The LVN29, LVN28 and 2891 varieties were the least damaged (90.0%, 89.0% and 78.5%, respectively).

The results given in Table 2B permit the following conclusions.

- After 30 days, LVN20, B9681 and NEP.HN had the highest damage (83.0%, 75.9% and 67.4%, respectively). The 2891 and LVN28 varieties were the least damaged (25.8% and 20.8%, respectively).
- After 60 days, levels of damage had increased. The LVN20, B9681 and NEP.HN were the most damaged (97.5%, 94.9% and 93.1%, respectively), and the LVN28 and 2891 varieties least (52.8% and 49.1%, respectively).
- After 90 days, the maize varieties showing over 95% damage were LVN20, B9681, NEP.HN, LVN6, 3012, LVN 10, LVN 24, SC95.30, LVN 5, LVN 29, 3023 and LVN 27. The 2891 variety was the least damaged (63.3%).

**Table 2B.** The attractiveness of different maize varieties to *Sitophilus zeamais* (experiment 2A: 10 *S. zeamais* individuals).

Damaged grains (%)	After 30 days Av. live individuals = 6.6 Av. dead = 3.4	After 60 days Av. live individuals= 17.8 Av. dead = 7.6	After 90 days Av. live individuals = 33.1 Av. dead = 10.4
95–100			LVN20, B9681, NEP.HN, LVN6, 3012, LVN10, LVN24, SC95.30, LVN5, LVN29, 3023, LVN27
80–94.9	LVN20	LVN20, B9681, NEP.HN, LVN6, 3012, LVN10, LVN24, SC95.30, LVN18, LVN5, LVN29	LVN18, LVN4, VM1, LVN6, LVN31, 4728, P11, LVN28
65–79.9	B9681, NEP.HN, LVN6, 3012	LVN4, 3023, VM1, LVN17, LVN27, LVN31, 4728, P11	3024
50–64.9	LVN10, LVN24, LVN4, 3023	3024, LVN28	2891
40–49.9	SC95.30, LVN18, LVN5, LVN29, VM1, LVN17, LVN27, LVN31, 4728, P11	2891	
<40	3024, 2891, LVN28		
Average (%)	49.21	79.51	90.67
σ(variance of varieties)	± 15.57	± 13.43	± 9.77

The results given in Table 3 show the following.

- After 30 days, grains of several maize varieties were damaged at a low level. Among these, the damage to B9692, LVN20, and NEP.HN was the highest (84.5%, 81.5% and 76.25, respectively). The 2981, P11, LVN28, and 3024 varieties had the lowest damage (35.5%, 34.5%, 33.3%, and 26.0%, respectively).
- After 60 days, grains of the NEP.HN and LVN20 varieties were damaged over 95% (98.4% and 97.5%, respectively). The 3024 variety was the least damaged (46.0%).
- After 90 days, almost all of maize varieties were damaged over 95%. The LVN28, LVN4 and 3024 were the least damaged (77.0%, 67.0% and 55.5%, respectively).

**Table 3.** Level of grain damage to different maize varieties caused by *Sitophilus zeamais* (experiment 3) (L = number of live insects, D = no. of dead insects).

Damaged grains (%)	After 30 days		After 60 days		After 90 days	
	<i>S. zeamais</i>	Maize varieties	<i>S. zeamais</i>	Maize varieties	<i>S. zeamais</i>	Maize varieties
95–100			L: 111.5 ± 20.1 D: 33.5 ± 13.5	NEP.HN, LVN20	L: 133.9 ± 75.8 D: 29.1 ± 11.9	LVN20, NEP.HN, B9681, SC95.30,3012, LVN6, LVN10, LVN17, VM1
80–94.9	L: 17.5 ± 1.5 D: 7.5 ± 1.5	B9681, LVN20	L: 45.0 ± 17.5 D: 15.8 ± 3.2	B9681, SC95.30,3012, LVN6, LVN10, LVN5, LVN17, LVN24, VM1, P11	L: 51.7 ± 27.2 D: 23.9 ± 2.0	LVN5, LVN24, P11, LVN31, 2891, 3023, LVN29, LVN18, LVN27
65–79.9	L: 14.4 ± 6.1 D: 9.8 ± 3.6	NEP.HN, SC95.30,3012, LVN6, LVN10	L: 21.0 ± 7.0 D: 19.0 ± 0.8	LVN31, 3023, 2891	L: 31.7 ± 12.3 D: 22.7 ± 1.3	4728, LVN28, LVN4
50–64.9	L: 11.2 ± 3.9 D: 9.6 ± 3.4	LVN5, LVN17, LVN24, VM1, LVN31	L: 20.8 ± 4.9 D: 18.3 ± 2.5	LVN29, LVN18, LVN27, 4728, LVN4, LVN28	L: 24.0 D: 32.0	3024
37–49.9	L: 7.6 ± 2.2 D: 13.8 ± 1.9	3023, LVN29, LVN18, LVN27, 4728, LVN4	L: 9.0 D: 29.0	3024		
<37	L: 5.8 ± 1.5 D: 13.8 ± 1.9	2891, P11, LVN28, 3024				
Average (%)		54.84		77.37		89.53
σ(variance of varieties)		± 16.89		± 15.20		± 11.74

Experiment 4 was carried out with adult pairs (male + female) of *S. zeamais* and the different maize varieties (Table 4). Data on damaged grains after 30, 60, and 90 days were similar to those shown in Table 3 for experiment 3.

Table 5 summarises the results of experiment 5. They show that: among 22 maize, 1 black bean, and 1 green pea varieties, *S. zeamais* penetrated into the B9681, NEP.HN, and LVN20 varieties at highest levels (19.1%, 15.9%, and 14.2%, respectively), and the LVN4, 2891, 4728, P11, and 3024 varieties at the lowest levels (6.1%, 6.1%, 5.3%, 3.4% and 2.4%, respectively). Black bean and green pea were not as attractive to *S. zeamais* (with only 0.4–1% damage). All 5 of the more resistant varieties are hybrids. Among the five most highly damaged varieties, three were hybrid and two were open-pollinated varieties.

Overall, the maize varieties shown to be most attractive to *S. zeamais* in experiment 5 were also those most highly damaged in experiments 1, 2A, 2B, 3, and 4. In addition, the maize varieties least damaged in experiment 5 were also the least damaged ones in experiments 1, 2A, 2B, 3, and 4.

## Conclusion and Recommendation

The results reported here confirmed the following.

*S. zeamais* responded differently to different maize varieties (hybrid and open-pollinated ones). When *S. zeamais* were low in numbers and they had a large choice for feeding, then the frequency of appearance

of insects and the amount of damaged grains found were not significant. The NEP.HN, B9681 and LVN20 were the most attractive to and damaged by the insects. The LVN28, 2891 and 3024 were the most secure from *S. zeamais* damage.

After longer periods of storage (90 days) under the same conditions (grain moisture, temperature, air humidity) *S. zeamais* numbers became very large and most maize varieties used in these experiments (separately or combined) were damaged to high levels (over 95%). Some maize varieties such as LVN28, 3024, 2891 and Q2 suffered less damage.

Adult *S. zeamais* could distinguish the odours of different maize varieties and select their preferred ones accordingly. The varieties 3024, P11, and 4728 varieties were the least attractive to *S. zeamais*, while B9681, NEP.HN, and LVN20 varieties were the most attractive. Also, in the other experiments, the latter varieties suffered greater damage. The results of this initial research on the relative attractiveness and resistance of different maize varieties to *S. zeamais*, showed that most hybrid maize varieties were not sensitive to *S. zeamais*, and that some hybrid maize varieties, for example LVN28, 2891, 3024 and 4728, were less sensitive than the open-pollinated varieties. To determine the reasons for the differences between varieties it will be necessary to study factors relating the structure and nutrient composition of these maize varieties to *S. zeamais* damage.

**Table 4.** Level of grain damage to 15 different maize varieties caused by each *Sitophilus zeamais* couple (experiment 4) (L = number of live insects, D = no. of dead insects).

Damaged grains (%)	After 30 days		After 60 days		After 90 days	
	<i>S. zeamais</i>	Maize varieties	<i>S. zeamais</i>	Maize varieties	<i>S. zeamais</i>	Maize varieties
95–100			L: 34.8 ± 14.7 D: 0.8 ± 0.5	B9681, P11, LVN4, LVN5, NEP.HN, 'Pioneer', VM1, TSB2, SC95.30	L: 64.1 ± 30.3 D: 5.0 ± 2.5	B9681, P11, LVN4, LVN5, LVN24, NEP.HN, 'Pioneer', VM1, TSB2, SC95.30, LVN6, 3012
80–94.9			L: 10.9 ± 6.9 D: 15.8 ± 3.2	LVN6, 3012, LVN27, LVN28	L: 16.7 ± 5.0 D: 2.3 ± 2.1	LVN27, LVN28, Q1
65–79.9	L: 4.5 ± 2.9 D: 9.8 ± 3.6	B9681, P11, LVN4, LVN5, LVN24, LVN6	L: 4.0 D: 0	Q1		

**Table 4.** (Cont'd) Level of grain damage to 15 different maize varieties caused by each *Sitophilus zeamais* couple (experiment 4) (L = number of live insects, D = no. of dead insects).

Damaged grains (%)	After 30 days		After 60 days		After 90 days	
	<i>S. zeamais</i>	Maize varieties	<i>S. zeamais</i>	Maize varieties	<i>S. zeamais</i>	Maize varieties
50–64.9	L: 8.5 ± 6.5 D: 9.6 ± 3.4	NEP.HN, 'Pioneer'				
38.6–49.9	L: 2.2 ± 1.6 D: 0.6 ± 0.5	SC95.30, 3012, LVN27, LVN28				
<38.6	L: 1.8 ± 0.4 D: 0.3 ± 0.4	P11, 2891, LVN28, 3024				
Average (%)		54.77		88.57		97.80
σ <sup>2</sup> (variance of varieties)		± 16.07		± 14.84		± 4.02

**Table 5.** The attractiveness of different maize varieties to *Sitophilus zeamais* (experiment 5).

Number	Maize varieties	<i>S. zeamais</i> in samples
1	B9681	19.1 ± 4.85
2	NEP.HN	15.4 ± 4.78
3	LVN20	14.2 ± 4.31
4	LVN10	12.4 ± 2.77
5	VM1	11.0 ± 1.38
6	LVN24	10.8 ± 3.95
7	LVN6	9.8 ± 6.89
8	LVN17	9.4 ± 2.96
9	LVN27	9.2 ± 2.67
10	3012	8.9 ± 1.48
11	LVN18	8.8 ± 2.27
12	LVN5	8.7 ± 2.37
13	LVN28	8.0 ± 1.70
14	LVN31	7.4 ± 2.99
15	3023	7.4 ± 2.82
16	LVN29	7.1 ± 1.12
17	SC95.30	6.4 ± 2.19
18	LVN4	6.1 ± 1.89
19	2891	6.1 ± 1.61
20	4728	5.3 ± 1.78
21	P11	3.4 ± 1.58
22	3024	2.4 ± 2.02
23	Green peas (control)	1.0 ± 1.16
24	Black beans	0.4 ± 0.55
Average <i>S. zeamais</i> in the sample (%)		8.28
σ <sup>2</sup> (variance of maize varieties)		± 4.27

# Protecting Grain Without Pesticides at the Farm Level in the Tropics

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## Abstract

Three types of sealed structures for modified atmosphere storage of cereal grains stored in the open in tropical and subtropical climates were investigated. The advantage of sealed storage lies in the generation of an oxygen-depleted and carbon dioxide-enriched inter-granular atmosphere of the storage ecosystem to arrest insect development. The three types of structures assessed were: (a) weldmesh-walled silos; (b) frameless flexible envelopes (Volcani Cubes); and (c) a sealed granary (GrainSafe). These structures are based on different logistic principles but have a common structural component, namely, a flexible liner.

A series of experiments carried out in Israel to develop the plastic structures included studies on the permeability of plastic sheeting to oxygen and carbon dioxide, and resistance to insect and rodent penetration. Weldmesh-walled silos are suitable as medium-sized silos with a capacity of 60–1,000 t. A circular bag of plastic liner contained within a vertical wall consisting of galvanised weldmesh is used. The frameless flexible envelopes (Volcani Cubes) are designed for bag storage of small quantities (10, 20 and 50 t) of cereal grains. The plastic liner is made of an upper and a lower section which can be zipped together to form a gastight seal. The granary (GrainSafe) was designed to hold 540 kg nominal capacity of grain, and consists of a gastight cylindrical flexible plastic bag. The bag is inserted into a rigid white polypropylene board curved into a cylinder that forms a sheath surrounding the vertical sides of the flexible bag. Trials conducted with all three types of structures described in this paper in tropical and subtropical climates showed that sealed storage protected grain by maintaining the number of live insects below the threshold of economic damage without the need for pesticides.

STORAGE is an integral part of food security and its importance in many countries has been well documented (Anon. 1986; Bonner and Hirdy 1987; O'Dowd et al. 1987). Food grains consisting of cereals and pulses—stored at moisture contents permissible for safe storage—are the principal commodities dealt with in this presentation. Moisture content (MC) is the major factor determining the storage behaviour of grain (Pixton 1982). Initial grain deterioration due to moulds can be prevented if the MC is sufficiently low. However, the amount of moisture in dry grain bulks is sufficient to permit development of most stored grain insects (Howe 1965). Therefore, particularly in warm climates, periodic insect control measures are usually required to prevent loss of quality and quantity of stored grain (Semple 1985).

Throughout the developing world, the on-farm storage of harvested grain by small-scale farmers is critically important in providing food security for rural communities. In the past, traditional storage structures provided some protection against storage losses, particularly by insects and rodents, although annual losses at the village level—which are estimated to run at between 5 and 10%—were usually considered as inevitable. Attempts to reduce these losses through the introduction of modern storage technologies have consistently failed—being either socioeconomically unacceptable, or inappropriate to local climatic conditions and agro-technical practices (Donahaye and Messer 1992). A different approach has been the modification of existing structures or the construction of new structures in the conventional style but employing modified technologies to improve grain conservation without causing disturbing changes to village life. This was termed by Guggenheim (1978) as 'invisible' technology and the following study is based on this concept.

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A method considered for the prevention of storage losses is airtight storage. The considerable literature on sealed storage of grain termed 'airtight storage' or 'hermetic storage' is well summarised by Hyde et al. (1973) and De Lima (1980). The intrinsic advantage of the airtight storage of dry cereal grains lies in the generation—by the aerobic metabolism of insect pests and microorganisms—of an oxygen-depleted and carbon dioxide-enriched inter-granular atmosphere of the storage ecosystem. In this way, development of pests and diseases is arrested and storage damage minimised. This principle has been used since prehistoric times, perhaps unwittingly, in traditional underground storage structures that are still used, particularly in semi-arid regions of the Mediterranean basin and Sahel (Gilman and Boxall 1974; Curried and Navon 1986).

A phenomenon that discourages the use of airtight storage in hot climates is moisture migration and condensation, and this is especially accentuated in metal silos. So far, two approaches are known to reduce the intensity of this phenomenon: equalising grain temperatures, and insulation of the roof. Equalising grain temperatures by aeration is limited to climates with a cool season. Comparative data on the efficacy of aeration and the effect of insulation in preventing moisture migration in metal silos in the tropics is lacking.

Above-ground silos (concrete and metal) have also been constructed with specifications to provide a seal for hermetic storage. Earlier designs did not provide a sufficiently effective seal (De Lima 1980). The present approach to sealing existing above-ground structures is more successful (Ripp et al. 1984).

Plastic structures suitable for long-term storage, as well as intermediate grain storage for cooperatives and subsistence farmers, for grain in bags or in bulk, have been developed in Israel (Navarro et al. 1990). The influence of insulation materials in reducing the intensity of moisture migration under subtropical (Israel) and tropical (Philippines) climates has been investigated (Navarro and Caliboso 1996).

In referring to the use of plastic structures for the storage of grain we have considered that (a) loss prevention methods should not be very sophisticated; and (b) capital investment for the storage structure should be kept at a minimum. In addition, on-farm or farm-level storage of small quantities of grain are considered as important supporting aspects in that they supply source material for food reserves that are stored in bags in warehouses. In areas of development or where bumper crops are expected, extra storage space

should be provided near the production site. Therefore, rapid construction and possible translocation of the storage facilities from one site to another would be advantageous.

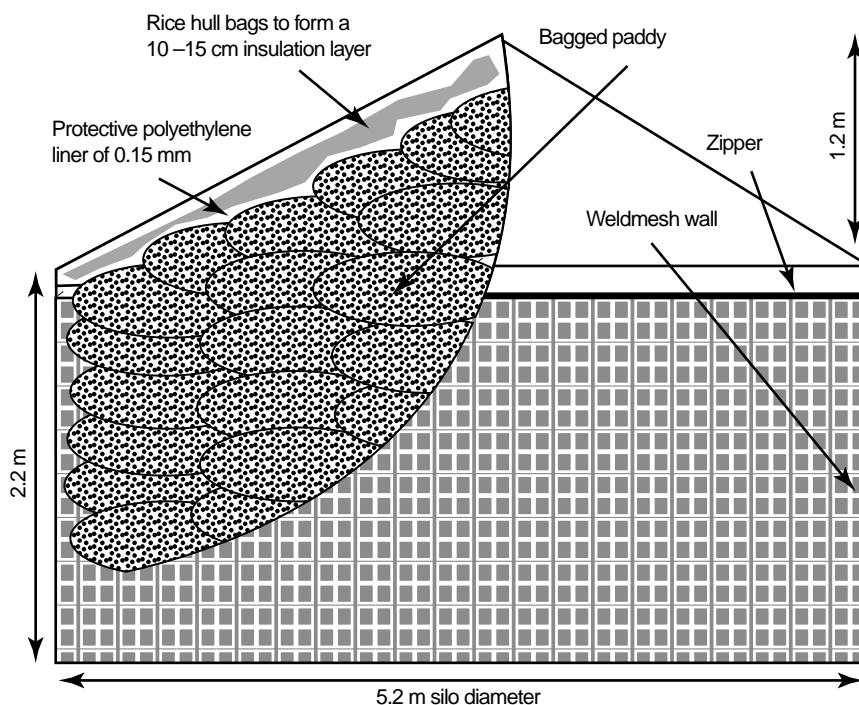
This report forms part of a more comprehensive study designed to provide outdoor, alternative, temporary or emergency storage facilities for use by farmers' organisations, cooperatives, village grain merchants and other intermediary parties in the Philippines and other countries, where countryside storage forms an important component of the national grain reserve (Navarro and Caliboso 1996). Other sections of the study have been reported elsewhere (Alvinda et al. 1994; Caliboso et al. 1997; Navarro et al. 1997).

The storage facilities described in this report were designed as gastight structures to provide affordable and user-friendly systems for grain conservation without the need for chemical pesticides.

## Materials and Methods

### Weldmesh-walled silos

The silos were made up of two components—a weldmesh circular wall formed from sections bolted together to provide the structural enclosure, and an inner liner made of heavy-duty plastic tarpaulin—ultraviolet light-protected, and of food-grade quality. The lining came in two parts: the lower liner welded to form a continuous wall–floor unit and an upper liner forming a roof cone (Figure 1). After the ground was leveled and cleared of stones, weldmesh sections were bolted into place to form a circle around a floor–wall package within the perimeter. The package was then opened and the walls of the liner were tied to the weldmesh. These silos could then be equipped with aeration systems and loaded with grain, exactly from the centre point. The roof section was placed evenly over the grain using a pre-attached rope to pull and unfold the polyvinyl chloride (PVC) liner, which was zipped to the wall to obtain a gastight seal. The roof cone was secured to the metal weldmesh walls by ropes. The enclosures were also provided with hooks to be fixed to the wire mesh. The silos were designed to enable bulk storage or bag storage, with mechanical loading or unloading, with the intention of providing a useful transition phase between bag and bulk handling. The silos used in the experiments reported in this paper had a diameter of 5.2 m and a height of 2.2 m with a storage volume of 52 m<sup>3</sup> and a capacity of 35–40 t (Figure 1). Larger capacities from medium-size silos up to 1,000 t are also available.



**Figure 1.** Weldmesh-walled silo for the gastight storage of grain in bags. Schematic representation of a 52 m<sup>3</sup> capacity silo suitable for storage of approximately 35 t of paddy.

### Frameless flexible envelopes (Volcani Cubes)

Frameless flexible envelopes were designed for stack storage in which the stack itself forms the rigid structure of the system (Figure 2). The cube-shaped structures were planned for use on open ground, and under rigorous field conditions. The Volcani Cubes consisted of two sections: a lower floor-wall and an upper roof-wall. The lower section was laid on the ground and the bags of grain were placed directly on the tarpaulin. Pallets were not required. The dimensions of the floor section determined the size of the stack to be built. After the stack had been built to the required height, the top tarpaulin was then placed over the stack to meet the lower section halfway up the side. Both the upper and lower sections were provided with a gastight multiple tongue and groove zipper, used to zip the sections together to form a continuous envelope.

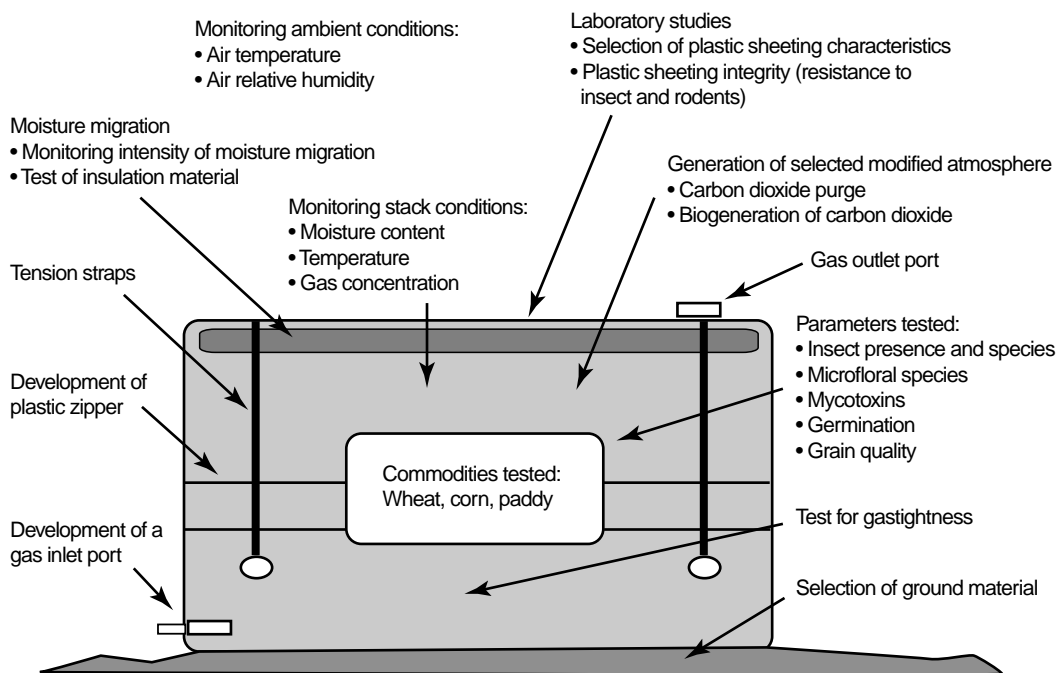
The design was intended to be user-friendly with dimensions that did not require mechanical loading or

high stacking. Special tension straps situated around the cube were designed to take up slack in the walls and pull the liner tight around the curve of the sacks at floor level (Figure 2). This was done to prevent rodents from gaining a tooth-hold on the slippery surface, thereby preventing damage to the hermetic seal.

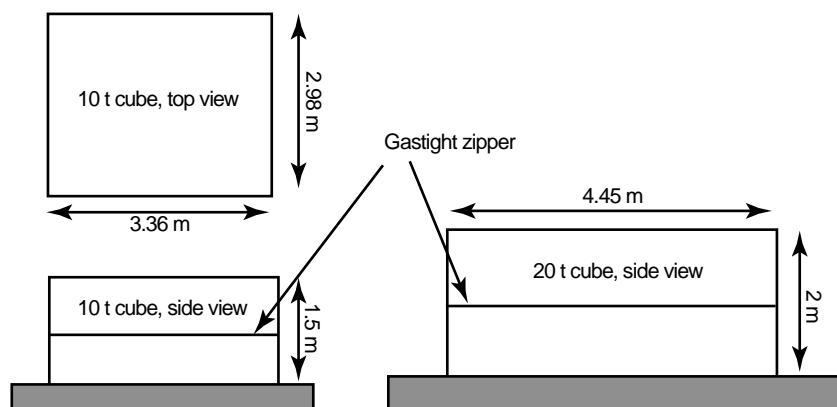
The cubes were intended for bag storage in small quantities of approximately 10, 20 and 50 t of cereal grains. Dimensions of the 10 t cubes were 336 × 298 × 150 cm (length × width × height), giving a maximum storage volume of 15 m<sup>3</sup>, and weighing 43 kg when empty. The 20 t cubes measured 447 × 336 × 200 cm (length × width × height) with a maximum storage volume of about 30 m<sup>3</sup> and weighing about 76 kg when empty (Figure 3).

The cubes were easy to erect and dismantle. For trucking operations, they could be transported with the grain load, and the sacks could be off-loaded directly into the cubes at their destination.





**Figure 2.** Schematic representation of the different experimental steps and parameters used in the development of the Volcani Cube for gastight storage of bagged grain.



**Figure 3.** Plan of 10 t and 20 t capacity Volcani Cubes for gastight storage of grain in bags.

## Sealed granary (GrainSafe)

The GrainSafe granary (Figure 4), for which a patent application has been submitted, was developed over a series of previous trials during which progressive modifications were carried out. It consisted of a cylindrical bag made from a PVC formulation, 110 cm high and 90 cm diameter (volume = 700 L), and had an upper conical collapsible sleeve for in-loading the grain. This sleeve was equipped with a welded strap and buckle so that when loading was completed the sleeve could be rolled over a horizontal wooden strut and firmly sealed using the pressure of the strap. The bottom of the bag was equipped with a cylindrical flexible sleeve (for unloading), 50 mm in diameter and terminating in a rigid, PVC screw-on cap. The bag was supported inside a rigid white polypropylene (PP) board, 115 cm high, 560 cm long and 1 mm thick, that was curved into a cylinder to form a sheath surrounding the vertical sides of the flexible bag.

To provide stability to the granary and to close the cylindrical PP sheath, the overlapping edges of the sheath were screwed together onto a wooden strut 135 cm long, 40 mm wide and 30 mm thick. An identical strut was then screwed to the outside of the sheath diametrically opposite the first one.

One necessary design aspect was the need to prevent the accumulation of rainwater on top of the bag where an inverted cone forms at the upper surface when grain is removed from the bottom. This was achieved by lifting the horizontal strut that seals the loading sleeve, and positioning it across the top of the granary. In this way the two holes at each end of the strut were fitted over pins screwed into the top of the vertical struts that serve to stabilise the PP sheath. Consequently, as grain was removed from below and the grain level dropped, the top of the bag remained suspended beneath the horizontal strut, but collapsed from the sides so that the volume of headspace remained minimal.

## Results and Discussion

### Weldmesh-walled silos

To date, most of our experience with such silos has been with bulk-stored wheat. In a trial carried out in the semi-desert region of southern Israel, 548 t of locally grown wheat was stored over a 30-month period (Calderon et al. 1989). The grain was aerated during three winters, to cool it while taking advantage of the arid environment, and the silo was sealed during the summers. The aeration regime cooled the grain to

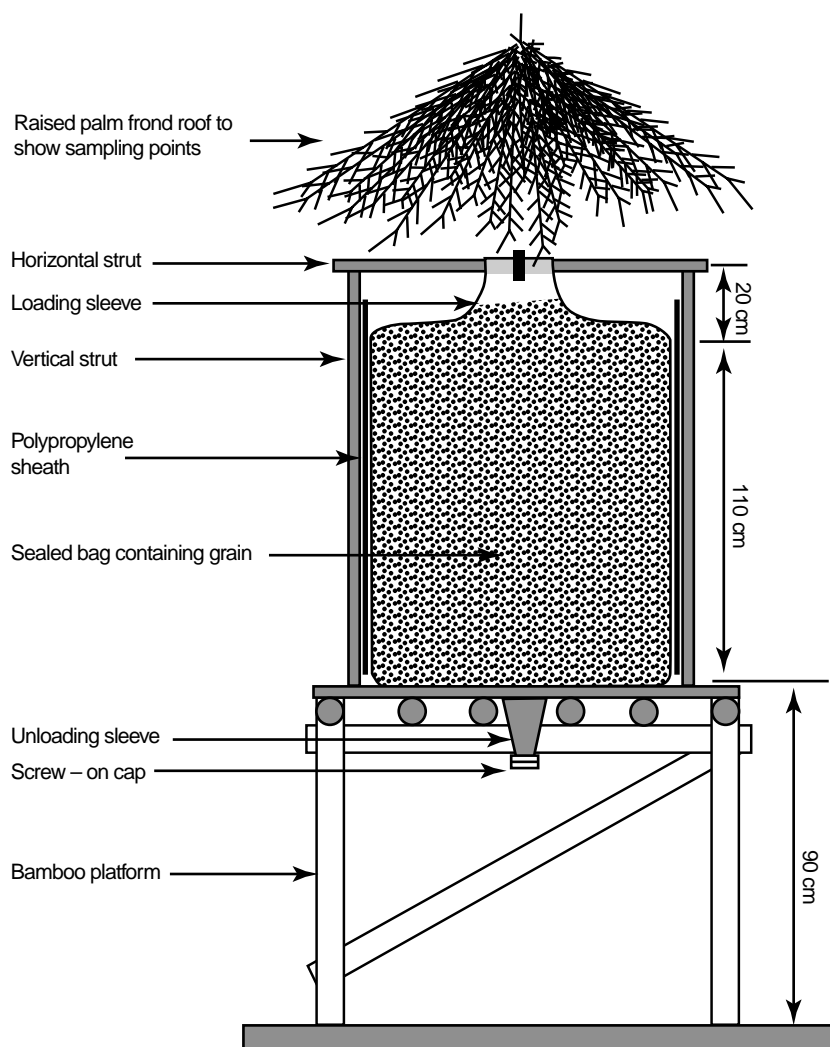
temperatures below 17°C, while the highest carbon dioxide and the lowest oxygen concentrations during hermetic storage were 10.6% and 5.8%, respectively. The overall loss of stored grain was 0.24% on an annual basis. Safe storage in this arid region using this type of storage structure was shown to be feasible.

In another study carried out in Israel, storage of 73 t of locally grown wheat for 48 months within a plastic silo was investigated (Navarro and Caliboso 1996). The silo was 7 m in diameter, formed by a structured wall consisting four sections of weldmesh forming a circumference of 22 m. The carbon dioxide concentration increased gradually up to about 10% and was accompanied by a decrease in oxygen concentration to a minimum of about 5%, followed by a gradual increase over the 48 months of storage. During the summer months, average temperatures ranged from 25–35°C and during the winter months they decreased to about 15–22°C. No significant moisture migration was observed. The average MC of samples taken during loading and unloading of grain showed very little change, varying between 10.6% at the start and 10.7% at the end of storage. During the second year there was a localised pocket of increase in MC close to the peak of the silo where recordings in November registered 12.7–13.0%. The average germination of initial samples of wheat was 99.5%, falling to 97% after 48 months of storage. An initial infestation, principally by *Rhyzopertha dominica*, was observed. Although, during the second year, there was an increase in the number of dead insects, at the end of storage period no live insects were detected in the deep layers of the bulk, while the average number of dead insects/kg was 3.7.

### Summary of the trials carried out in the Philippines with corn and paddy

#### Corn

Temperatures recorded in the core of the silo were in the range of 28–30°C, but during the day they reached 35–40°C below the liner at the top of the silo. The initial average MC of the corn was 13.5% and after 6 months of storage it was 13.3%. Condensation was apparent at the top of the silo after storage for 4 months. The density of insects found at start of the trial was 3.0 live insects/kg of corn and 0.3 dead insects/kg, while at the end of storage the level of live insects/kg was 0.7 and dead insects/kg was 2.7. Weight loss in corn after 6 months of gastight storage was 0.37% compared with 5.07% in the control stack (Navarro et al. 1998a).



**Figure 4.** Section of a granary (GrainSafe) for sealed storage (700 L capacity) showing design features and sampling positions.

### Paddy

The overall MC of paddy in bulk storage under gastight conditions in the silo did not change significantly during the trial. The rice hulls forming the top insulation layer initially absorbed water that condensed below the liner. This is evidenced by the fact that the MC of the rice hull, which initially averaged 7.97%, had more than doubled to 18.58% at the end of the 43-day trial. The initial density of live insects was reduced from 10.3 insects/kg to 1.3

insects/kg at the end of the trial. Germination of paddy did not change significantly over the storage period—the initial 95.3% was reduced to 94.8%. Weight loss was 0.13% in the gastight silo, compared with 3.75% in the control stack (Navarro et al. 1998a).

## Frameless flexible envelopes (Volcani Cubes)

These envelopes have been developed to provide storage facilities at the farmer-cooperative level where bag storage is practiced. Much effort has been expended to render these envelopes 'user-friendly', so those members of the international aid community and others can use them without previous experience in grain storage.

A trial was carried out in Sri Lanka on the outdoor storage for 6 months of locally grown paddy using two such hermetically sealed flexible liners of 10 and 20 t capacity. Insect infestations failed to develop in either cube and only 0.33–0.64% dry weight was lost due to metabolic activity. One of the cubes contained paddy with a higher MC which caused condensation, mould development and losses estimated at 1.24%. Means for obviating this phenomenon were proposed (Donahaye et al. 1991).

In another trial carried out in Israel, 10.4 t of wheat heavily infested with common stored-product insect pests was stored in bags. Samples taken after 3 weeks of storage showed complete insect mortality. The average MC remained unchanged at about 11%. After 15 months of storage there was no indication of moisture migration. Germination was not impaired and remained at the level of >95%.

### *Summary of the trials carried out in the Philippines with corn and paddy*

#### Corn

Recordings of mean weekly daytime temperatures logged from the observed cubes revealed that temperatures inside the control stack kept under tarpaulins (28°C) were much lower than those of the cubes (ranging from 35 to 42°C). The temperatures recorded 10 cm below the insulation were in the range of 29–31°C. During the opening of the cubes, moisture condensation was observed below the liners, especially on stacks stored for more than 4 months. This moisture condensation could have been due to low temperatures prevailing at night, which were not monitored. There was no increase in the average MC of corn held under gastight storage (Navarro et al. 1998a).

In the gastight cubes, the CO<sub>2</sub> level rapidly increased to 12% while the O<sub>2</sub> concentration sharply declined over the first 2 weeks of storage to around 7%. Carbon dioxide concentrations in the most of the gastight cubes rose to 12–16% and fluctuated within that range for most of the storage period. In two cubes,

CO<sub>2</sub> concentrations reached 18% and 22%. These high concentrations indicate that mould activity occurred, due probably to moisture condensation. Because of the extended period of storage in these cubes (6 months), the rice hulls, that also served as an insulator, became saturated, leading to wetting of the top layer and sides of the cubes. The respiration of the wet grain and moulds contributed to the depletion of the oxygen and the increased evolution of CO<sub>2</sub>. This lethal atmosphere subsequently led to the mortality of the insects in the cubes.

The insects found in corn were *Sitophilus zeamais*, *Rhyzopertha dominica*, *Oryzaephilus surinamensis*, *Latheticus oryzae*, *Lophocateres pusillus*, *Carpophilus* spp., *Tribolium castaneum*, *Cryptolestes* spp., *Typhaea stercorea*, and species of ants, crickets and cockroaches. No significant increase in the population density of insects was noted in the gastight sealed corn cubes, whereas the populations in the control cubes increased considerably. On the basis of insect infestations and in comparison with control stacks, storage in the gastight cubes was considered successful.

The results indicate that weight loss in corn may be effectively reduced through gastight sealed cube storage. The control stacks suffered serious insect attack and consequently loss in weight was significantly higher than the treated stacks. The control stacks, in addition to insect infestation, suffered from mould infection and from rodent and bird attack (Navarro et al. 1998a).

#### Paddy

A similar pattern of temperature levels was observed in paddy stacks as in the corn trials. The temperature recorded at various points inside the gastight cubes indicated that temperature fluctuations were reduced due to the insulating properties of the grain mass (Navarro et al. 1998a). The average MC of gastight sealed paddy in two stacks increased slightly from the beginning to the end of storage, whereas no increase was noted in the rest. There was a real trend towards increase in MC in the two control stacks stored during the wet season and a decrease in MC of the control stacks stored in the dry season. These differences indicate the importance of having gastight sheet to avoid moisture diffusion. Field trials showed that there was no critical moisture build-up or localisation in any of the treatments or the control, except for one stack that exceeded the critical MC of 14% by 0.24%.

The average CO<sub>2</sub> concentrations recorded in the cubes of paddy were in the range of 10–15%. Lower CO<sub>2</sub> concentrations (6–7%) reported in three cubes were due to leaks in the plastic sheeting caused by mechanical damage.

Initial and final counts of live insects revealed no population increase in the gastight sealed paddy cubes, whereas in the control stacks there was a marked increase in insect density, many of which were alive at the end of the storage period. The results show that complete disinfestation of paddy in all the gastight sealed cubes was not achieved. In spite of the presence of a few live insects at the end of storage, all treatments in the trials were successful. This was matched by a much lower percentage weight loss in the treated cubes compared with the control stacks. The magnitude of loss recorded from the gastight sealed paddy cubes was about 18 times lower than in the control stacks, resulting in weight loss of 0.231% for the gastight cubes and 4.307% for the control stacks (Navarro et al. 1998a).

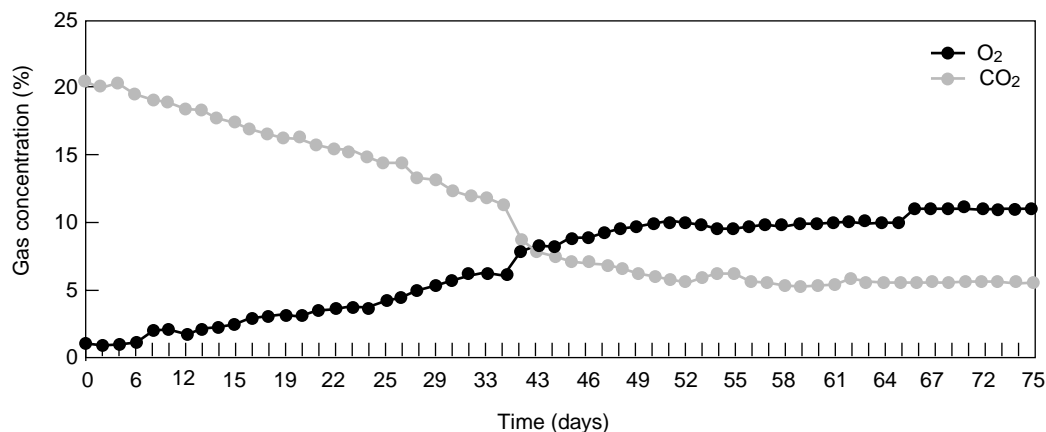
### Sealed granary (GrainSafe)

In a test carried out with GrainSafe containing corn, insect infestations were established by introducing laboratory-reared lesser grain borer, *Rhyzopertha dominica*, and red flour beetle, *Tribolium castaneum*, at an infestation level of 1,800 individuals of each species (6 insects/kg) (Navarro et al. 1998b). Daily readings of CO<sub>2</sub> and O<sub>2</sub> concentrations in the granary showed that after the insects had been introduced,

there was a gradual drop in O<sub>2</sub> concentration to 5.5% within 40 days, coupled with an increase in CO<sub>2</sub> concentration to 11%. For the following 20 days both O<sub>2</sub> and CO<sub>2</sub> concentrations remained stable (Figure 5).

Calculation of these changes in oxygen concentration in hermetic storages was based on a model developed to determine the influence of different initial insect populations (Navarro et al. 1994). For this purpose a fixed O<sub>2</sub> ingress rate equivalent to about 0.24%/day was chosen for a structure with a volume of 10 m<sup>3</sup>. For these given values, changes in oxygen concentration in response to different initial insect populations are illustrated in Figure 6. Accordingly, a cyclic change in concentration is obtained as a result of O<sub>2</sub> ingress and the ability of insects to survive at low O<sub>2</sub> levels. These theoretical cyclic changes in O<sub>2</sub> concentration were also observed in different laboratory and field studies (Oxley and Wickenden 1963; Hyde et al. 1973; Navarro et al. 1990). Under the conditions governing the numerical experiment, the model calculates that there is a residual insect population even after an extended storage period of 1 year. This is shown by the continuing fluctuations in O<sub>2</sub> levels before a steady-state is reached (Figure 6). This result is corroborated by field observations that a residual population may remain when the grain is re-exposed to normal atmospheric air, though under the hermetic conditions and restricted O<sub>2</sub> supply their reproductive capacity is limited.

Daily average temperatures within the granary (10 cm below the top and bottom centre) over the 2-month storage period dropped from 36°C to 26°C. These



**Figure 5.** Oxygen and carbon dioxide concentrations in the granary (GrainSafe) during 10 days of hermetic storage without insect infestation, and 64 days storage following the introduction of adult *Rhyzopertha dominica* and *Tribolium castaneum* at a population level of 6 adult insects/kg.

findings indicate that, for the first month, grain temperatures were favourable for development of both the insect species used to infest the grain. Average daily temperature gradients from the outer surface at the north, south and top centre, to a depth of 10 cm, showed that for the most of the storage period, average temperature gradients were no greater than 2.5°C. This low gradient reduced or eliminated the possibility of moisture migration to the upper surface.

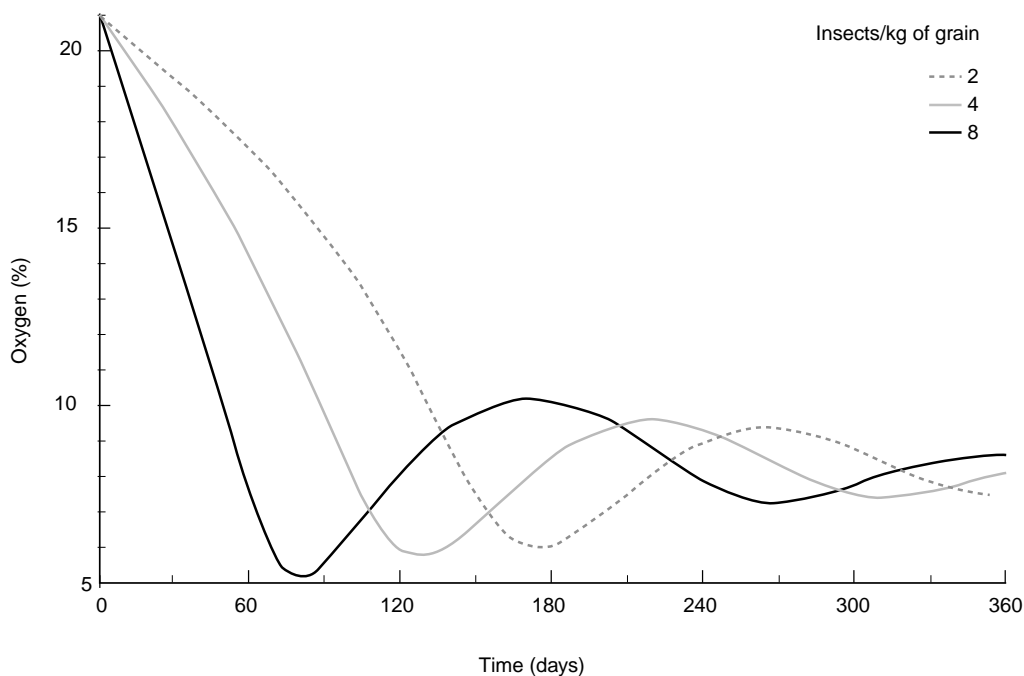
The atmospheric compositions in the granary over the 6-week unloading period showed that the increases in O<sub>2</sub> concentration after each grain removal were relatively small, amounting to a maximum of 1.8%, with a similar decrease in CO<sub>2</sub> concentration of up to 1.4%.

In spite of favourable temperatures for the development of insects, at the end of 2 months of storage and during the 6 weeks of unloading, the initial populations of *Tribolium castaneum* and *Rhizopertha dominica* were successfully controlled without the use of pesticides.

## Conclusions

### Weldmesh-walled silos and Volcani Cubes

1. For dry corn and paddy stored in sealed plastic enclosures outdoors in the Philippines, moisture migration was observed.
2. This was effectively prevented by an insulating upper layer of bags containing rice husks.
3. The gastight storage trials provided acceptable protection by reducing live insect populations below the threshold of economic damage.
4. Analysis of quality parameters showed that gastight storage in plastic enclosures is safe and feasible for the outdoor storage of corn and paddy.



**Figure 6.** Calculated oxygen concentrations in a 10 m<sup>3</sup> grain mass containing different infestation levels of insects—having an oxygen intake of 157 μL/insect/day—using a sealed liner with an oxygen ingress rate of 0.24%/day (Navarro et al. 1994).

5. Under Philippine climatic conditions the period of safe storage without significant condensation damage did not exceed 4 months.
6. The technology has strong potential for adoption by farmers and cooperatives in their postharvest operations.

### GrainSafe granary

1. This trial clearly showed that, under Israeli conditions, dry corn could be safely stored for 5 months in the sealed granary, without the need for chemical control, even though it was periodically opened to permit partial removal of its contents.
2. The level of gastightness and the construction design contributed to a minimal change in gas composition within the granary during each unloading.
3. A residual insect population survived, but could not develop to a level causing economic damage.
4. Gas concentrations indicate adequate sealing to a level that prevented grain damage.
5. Gas losses throughout the emptying process of 100 kg per week caused an increase in O<sub>2</sub> concentration at an average rate of 1.8% per discharge. However, this unloading rate did not adversely influence the storage potential of the corn.
6. The granary was shaded with a roof cone of plant material, resulting in minimal temperature fluctuations, while condensation was not detectable at the top surface of the granary.
7. The initial 10.1% MC of the corn did not significantly change throughout the storage period.
8. The granary still has to be field tested in target countries, both to examine it under local conditions and to evaluate its acceptability from the socioeconomic viewpoint.

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### References

- Alvindia, D.G., Caliboso, F.M., Sabio, G.C. and Regpala, A.R. 1994. Modified atmosphere storage of bagged maize outdoors using flexible liners: a preliminary report. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., Proceedings of the 6<sup>th</sup> International Working Conference on Stored-Product Protection, Canberra, Australia, 17–23 April 1994. Wallingford, CAB International, 22–26.
- Anon. 1986. Warehouse management of bag storage of grains. Food and Agriculture Organization of the United Nations/United Nations Development Programme (FAO/UNDP) and Department of Food, Ministry of Food and Civil Supplies, New Delhi, India, 359p.
- Bonner, R.R.M. and Hirdy, W. 1987. RRC grain storage in Welo region, northern Ethiopia. Survey results and recommendations, Sep–Dec 1987, Addis Ababa, 56p.
- Calderon, M., Donahaye, E., Navarro, S. and Davis, R. 1989. Wheat storage in a semi-desert region. *Tropical Science*, 29, 91–110.
- Caliboso, F.M., Navarro, S., Alvindia, D.G., Donahaye, E.J., Sabio, G.C. and dela Cruz, M.T. 1997. Effect of gastight storage on growth of fungi in paddy stored outdoors. In: Proceedings of the International Conference on Controlled Atmosphere and Fumigation in Grain Storages, 21–26 April 1996, Nicosia, Cyprus, 135–144.
- Curried, D.J. and Navon, A. 1986. Iron Age pits and the Lahav (Tel Halif) grain storage project. In: PhD dissertation (Curried), Archaeological investigations into the grain storage practices of Iron Age Palestine. Chicago, University of Chicago, 67–78.
- De Lima, C.P.F. 1980. Requirements for the integration of large-scale hermetic storage facilities with conventional systems. In: Shejbal, J., ed., Controlled atmosphere storage of grains. Amsterdam, Holland, Elsevier Scientific Publishing, 427–444.
- Donahaye, E., Navarro, S., Ziv, A., Blauschild, Y. and Weerasinghe, D. 1991. Storage of paddy in hermetically sealed plastic liners in Sri Lanka. *Tropical Science*, 31, 109–121.
- Donahaye, E.J. and Messer, E. 1992. Reduction in grain storage losses of small-scale farmers in tropical countries. Research Report RR-91-7, The Allan Shawn Feinstein World Hunger Program, Brown University, USA, 19p.
- Gilman, G.A. and Boxall, R.A. 1974. The storage of food grains in traditional underground pits. *Tropical Stored Product Information*, 28, 19–38.
- Guggenheim, H. 1978. Of millet, mice and men: traditional and invisible technology solutions to postharvest losses in Mali. In: Pimentel, D., ed., World food, pest losses and the environment. AAAS Selected Symposium 13. Boulder, Colorado, Westview Press, 109–162.

- Howe, R.W. 1965. A summary of estimates of optimal and minimal conditions for population increase of some stored products insects. *Journal of Stored Product Research*, 1, 177–184.
- Hyde, M.B., Baker, A.A. and Ross, A.C. 1973. Airtight grain storage. FAO (Food and Agriculture Organization of the United Nations) Agricultural Service Bulletin No. 17, 71p.
- Navarro, S. and Caliboso, F.M. 1996. Application of modified atmospheres under plastic covers for prevention of losses in stored grain. Final Report submitted to United States Agency for International Development, Cooperative Development Research (CDR) Project No. C7-053, August 1990–November 1995, 32p.
- Navarro, S., Caliboso, F.M., Sabio, G.C. and Donahaye, E.J. 1997. Quality conservation of paddy stored under gas-tight seal outdoors in the Philippines. In: *Proceedings of the International Conference on Controlled Atmosphere and Fumigation in Grain Storages*, 21–26 April 1996, Nicosia, Cyprus, 159–168.
- Navarro, S., Donahaye, E., Rindner, M. and Azrieli, A. 1990. Airtight storage of grain in plastic structures. *Hassadeh Quarterly*, 1(2), 85–88.
- Navarro, S., Donahaye, E. and Fishman, S. 1994. The future of hermetic storage of dry grains in tropical and subtropical climates. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., *Proceedings of the 6<sup>th</sup> International Working Conference on Stored-Product Protection*, Canberra, Australia, 17–23 April 1994. Wallingford, CAB International, 130–138.
- Navarro S., Donahaye, E.J., Caliboso, F.M. and Sabio, G.C. 1998a. Outdoor storage of corn and paddy using sealed-stacks in the Philippines. In: *Proceedings of the 18<sup>th</sup> Association of South-East Asian Nations (ASEAN) Seminar on Grains Postharvest Technology*, 11–13 March 1997, Manila, Philippines, 225–236.
- Navarro, S., Donahaye, E.J., Ferizli, A.G., Rindner, M. and Azrieli, A. 1998b. A sealed granary for use by small-scale farmers. In: *Proceedings of the 7<sup>th</sup> International Working Conference on Stored-Product Protection*, 14–19 October, Beijing, China.
- O'Dowd, E.T., New, J.H., Bisbrown, A.J.K., Hallam, J.A. and Joy, C. 1987. An evaluation of structures suitable for emergency storage in tropical countries. *Overseas Development Natural Resources Institute Bulletin No. 10*, 78p.
- Oxley, T.A. and Wickenden, G. 1963. The effect of restricted air supply on some insects which infest grain. *Annals of Applied Biology*, 51, 313–324.
- Pixton, S.W. 1982. The importance of moisture and equilibrium relative humidity in stored products. *Tropical Stored Product Information*, 43, 16–29.
- Ripp, B.E., Banks, H.J., Bond, E.J., Calverley, D.J., Jay, E.G. and Navarro, S. (ed.) 1984. *Controlled atmosphere and fumigation in grain storages. Developments in agricultural engineering 5*. Amsterdam, Elsevier Scientific Publishing, 798p.
- Semple, L. 1985. Pest control in grain storage systems in the ASEAN region. Philippines, Association of South-East Asian Nations (ASEAN) Crops Post-Harvest Programme, 77p.





# Developing a Computer-assisted Learning (CAL) System to Improve Training of Staff in Grain Quality Management in the ASEAN Region

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## *Abstract*

An important aspect in grain storage is the need for all people, from chief executive to labourer, to understand clearly the actions and events involved in pest management and quality control. Any improvements made in the decision-making processes leading to these actions should increase their efficacy.

A collaborative project involving Indonesia, the Philippines, Thailand, Vietnam, and Australia has developed a computer-assisted learning (CAL) system to strengthen conventional training methods. The package includes tutorial and reference systems and ranges across the most important issues facing pest management staff: grain drying, moulds and mycotoxins, and pest management. The package also includes simulation models that allow users to explore the consequences of using different management strategies.

Courses have been conducted in which this approach to training has been integrated with conventional lectures and practicals. Benefits arising from this project can spill over to other countries in the region, and adoption and integration of CAL by organisations should lead to more effective training systems and substantial reductions in the cost of training pest management staff, particularly where there are geographically-distributed workforces.

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EVEN though effective methods for managing the quality of grain in storage exist, they are not always used in the best manner. We believe that one reason for this is a failure to integrate the technical, economic, and management issues involved in grain storage. Decision tools of various sorts can help to overcome such difficulties by identifying key issues. Expert systems have been used to try to address part of this problem. However, specific computer-assisted learning (CAL) packages have the potential for more effective communication of complex concepts to trainees. These systems allow users to explore all available grain quality management options and discover the consequences of applying them (Longstaff 1997).

Based on these principles, a project was developed to produce a series of decision-support tools to facilitate the rational and sustainable management of quality of grain in storage in the Association of South-East Asian Nations (ASEAN) region.

For example, the Indonesian grain storage system relies on the combined use of fumigants and spraying stack surfaces and the fabric of the storage structure with contact insecticides. However, the management of BULOG (National Logistics Agency) has always aimed to improve cost efficiency and to reduce residues in the commodity. A project, funded by the Australian Centre for International Agricultural Research (ACIAR), was directed at achieving more effective integration of pest management strategies by evaluating existing management practices and by developing a series of decision tools, presented in both Bahasa Indonesia and English, to provide a better understanding of the issues involved in making pest management decisions and thus allowing better decisions to be made. This project has been described in detail elsewhere (Halid et al. 1997; Sardjono et al. 1998).

In this short report, we describe the extension and refinement of the CAL system, through incorporation of additional tutorials and languages, together with the validation exercise of developing and conducting training courses.

## Implementation

### Course development

The course structure and content were developed primarily through two workshops, held in Bangkok, Thailand, in August and December 1998, which were

attended by representatives from each of the four participating ASEAN countries; Indonesia, the Philippines, Thailand and Vietnam. At each workshop, working groups were assembled to develop tutorials on integrated commodity management, mycology and mycotoxins, and grain drying.

During the first workshop, tasks were assigned to particular collaborators and the draft English version of the content constructed. This was completed before the second workshop, where progress was reviewed and changes made, where appropriate. Timing of the courses was also agreed upon. In between the two workshops, the Australian collaborators visited each of the participating countries to collect video footage and photographs for incorporation into the system, and to discuss country-specific issues. The Australian collaborators later visited Jakarta and Bogor, in January 1999, for on-the-spot development of the Indonesian system and to organise the Indonesian training course, scheduled for March. An Indonesian collaborator from BULOG subsequently spent two weeks in Canberra, Australia, helping to finalise the translation of the Bahasa Indonesia version.

### Course delivery

The Australian collaborators arrived in Indonesia one week before the course was due to be held at BIOTROP, in Bogor, and installed the trial version of the system on 12 computers. This allowed last-minute changes to be made to the system code, and remove 'bugs' found whilst testing the newly-installed package. The course was attended by 22 participants from various parts of Indonesia.

The course, which was conducted in both Bahasa Indonesia and English, consisted of five sections (Figure 1). After the introduction and overview, there were sections dealing with integrated commodity management (e.g. Figure 2), grain drying, and moulds and mycotoxins. The course ended with a review and debriefing session. Each of the three main sections consisted of a theory session, a CAL session and a practical session (Figure 3). During the evenings, participants were able to explore the CAL system freely and informally with the instructors on call for assistance. Inevitably, further 'bugs', inconsistencies and omissions were found during this, the first course, and corrected immediately.



**Figure 1.** Opening ceremony for the Bogor training course.



**Figure 3 (above and at right).**

The Bogor course emphasised the integration of the computer-assisted learning (CAL) methods with traditional training techniques.



**Figure 2.** A screen from the computer-assisted learning (CAL) package illustrating the use of multimedia.

In the final review and debriefing session, participants were encouraged to express their views on the course and offer suggestions about content and delivery. This was a very rewarding process as most participants expressed their support for the approach being adopted and made many valuable comments on how the CAL system, and the course in general, could be further improved. This was the first use by inexperienced users and proved particularly successful in exposing the shortcomings of the system. It allowed us to make substantial improvements to the English and Indonesian system content in the following months.

## The Future

The system has now been converted into Vietnamese. We conducted a training course in Ho Chi Minh City in November 1999, attended by a range of personnel from the Post-Harvest Technology Institute (PHTI) and the Vietnamese grain industry. An

example of the Vietnamese content is shown in Figure 4.

During 2000, a course will be conducted in the Philippines, with Philippines-specific content incorporated into their English-only version. Currently, a Thai language version is being developed and a course for Thai people (and others from Laos) will be conducted in Thailand. An example of the Thai content is shown in Figure 5.

The examples presented in this paper highlight the flexibility of the CAL approach, both from a content and a language point of view. We hope to extend the coverage of this system to encompass broader issues, such as quarantine, in the near future. Here, as with grain quality management, there are problems of standardising accreditation procedures for disinfection procedures that have both economic and, potentially, political ramifications. CAL can play an important role in addressing these problems.



Figure 4. An example of the Vietnamese content.

The choice of CD-ROM as the medium of delivery is worthy of further comment. This software package has been targeted at countries in the ASEAN region, but could equally well be used in any country. The great advantage of the CD-ROM over more recent technologies, such the Internet and the digital video disc (DVD) is that it is cheap and widely available in most developing countries. The Internet is not yet a suitable medium for displaying significant amounts of video material in developed countries, let alone developing countries, because of the lack of adequate bandwidth. It will be many years before such infrastructure issues will be adequately addressed in the countries targeted in this study. DVDs offer the possibility of having all four language versions of the system on a single disc, but there is no common standard, as yet, and this technology is not yet widely available. It is considered that the CD-ROM will

continue to provide an invaluable function for many years to come. Because of the low cost of the medium, updates are inexpensive to produce on a regular basis. However, the Internet could have a role to play in the distribution of minor updates.

It is important to understand that CAL should not be seen as a replacement for conventional training methods, but rather as a powerful new tool now available to trainers that should be integrated with other methods. It is likely to be particularly valuable for distance learning and can provide a new level of reference material for busy practitioners of pest management. It could become the technique of choice for the extension of research results, from a variety of disciplines, to extension personnel and growers, and thereby function as a capacity-building tool.



Figure 5. An example of the Thai content.

## References

- Halid, H., Longstaff, B.C., Annis, P.C., Sidik, M. and Turner, J. 1997. Grain quality maintenance in the ASEAN region: a role for decision-support tools. In: Sidik, M. et al., ed., Pest management for stored food and feed. BIOTROP Special Publication No. 59, 83–93.
- Longstaff, B.C. 1997. Decision tools for grain storage pest management. *Journal of Stored Products Research*, 33, 99–114.
- Sardjono, T., Halid, H., Longstaff, B.C., Sidik, M. and Annis, P.C. 1998. Improving the quality of pest management in ASEAN grain storage systems through the use of computer-aided learning (CAL). In: Villapando, I., Ramos C.L. and Salcedo, B.G.A., ed., Postharvest technology towards attaining food security. Proceedings of the 18<sup>th</sup> ASEAN Seminar on Grains Postharvest Technology held Manila, Philippines, 11–13 March 1997, 153–160.

# Information Network on Post-harvest Operations

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## Abstract

The Information Network on Post-harvest Operations (INPhO) is a project led by the Food and Agriculture Organization of the United Nations (FAO) in partnership with the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and French Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD). Furthermore the project is supported by international, regional and national institutions dealing with postharvest operations. It provides information on postharvest systems from harvest to consumption. INPhO disseminates useful information through new media such as the Internet (see website at <<http://www.fao.org/inpho/>>) and CD-ROMs.

IN THE past, much effort has been devoted to improving different aspects of postproduction systems covering major staple crops in developing countries. This has resulted in the accumulation of a large amount of research results, useful practical experiences, technical information, and products. Until recently, however, most of this know-how was not easily accessible since work has been carried out without central coordination or a focal point for dissemination.

Following requests from donor agencies, development organisations, and research and training institutions, the Food and Agriculture Organization of the United Nations (FAO) established a secretariat which collects, collates and disseminates information on proven technologies, practical information, experiences and other details of the postharvest systems of a great number of products. The name of the secretariat is the Information Network on Post-harvest Operations (INPhO). It acts as a reference forum and plays an important role in giving a better direction to post-production endeavours. The program is being supported by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ—Germany Agency for

Technical Cooperation) GmbH and the French Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD).

## Methods

The INPhO program uses methods of information transfer that are based on computerised communication facilities. The standard access to the databank and additional features of the program is through the INPhO website on the Internet at <<http://www.fao.org/inpho/>>. INPhO is composed of a growing number of small databases (DBs), such as “Who is Who in PH”, “Cookbook-Processing for Profit”, “Training DB” and the “Link DB”. All the small DBs are connected via a central search function. At present, this central function deals with one key word, but in the near future it will allow a choice of commodity, country and topic. Users who do not have access to the Internet may obtain the database part of the INPhO site on a CD-ROM that is regularly updated. INPhO is available in English, French and Spanish. The design is very basic in order to assure acceptable retrieval times even in developing countries.

## Achievements and Discussion

Since its launch online in May 1998, the pilot version of the INPhO site has been considerably expanded. It

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includes a databank, interactive communication services, and links with other libraries and databases.

The databank elements cover the following areas:

- postproduction facts (including product files for different groups of commodities such as cereals, roots and tubers, fruits, vegetables etc., a resource list, country information and postproduction technologies including pest control and other topics);
- archives (including bibliographic references from the Agris database of FAO, document highlights, numerous full documents in four languages, proceedings, pictures and movies);
- decision-support tools (in areas including project preparation and evaluation, investment costs and feasibility, marketing, and postproduction analysis); and
- related information such as phytosanitary issues and farming systems.

The communication services consist of a question and answer service, operating in collaboration with the International Network for Technical Information (INTI), e-mail conferences on relevant topics, and forums that involve setting up electronic exchange sites. Finally, INPhO invites users to provide their

information to the database through special data input areas.

The Link DB contains more than 200 connections to libraries, databases and static webpages dealing with postharvest and related issues. The Link DB leads out of the information area directly organised and structured by INPhO and completes the wealth of information available through this site.

INPhO provides users with consolidated and fully integrated information on all aspects of postharvest systems. This information is currently area and/or region specific. In future it will be country specific in order to assist in formulating better national policies for agricultural development and improvement of food security. Since the establishment of INPhO, a better exchange of information between donors and recipient institutions has become possible, allowing improved channelling of the limited resources available and minimising duplication. Users include people working in the agricultural production and marketing sector, such as producers, researchers, policy-makers, private investors, donors etc.

For full information on the INPhO program visit the website at <<http://www.fao.org/inpho/>>.

# Research and Development on Postharvest Handling of Fruits and Vegetables in Malaysia

Abdullah Hassan\*

## *Abstract*

There are several institutions in Malaysia involved in research and development (R&D) activities on the postharvest handling of fruits and vegetables, including the Malaysian Agricultural Research and Development Institute (MARDI), Universiti Putra Malaysia, Universiti Kebangsaan Malaysia, University Malaya, Universiti Sains Malaysia and the Malaysian Institute of Nuclear Technology. MARDI is considered the focal point, with the most comprehensive R&D program and activities on food and agriculture. One of the main objectives of the program is to establish packaged technologies on postharvest handling of fresh fruits and vegetables for both local and export markets. This is considered vital in our attempts to develop the Malaysian horticultural industry. The research activities cover a wide range of handling aspects, including harvesting, storage, transportation, packaging and ripening. Over the past 20 years, many significant achievements have been made. Some of the technologies have been transferred to target groups, including individuals, farmers, exporters, relevant government agencies and the private sector. The postharvest group at MARDI has also been actively involved in regional activities, especially through the Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program and the Australian Centre for International Agricultural Research. Research collaborations have also been established with the International Atomic Energy Agency, United States Department of Agriculture, Japan International Cooperation Agency, and other agencies.

TWENTY FOUR years ago, in September 1975 in New York, the United Nations General Assembly passed the following resolution:

“The further reduction of postharvest food losses in developing countries should be undertaken as a matter of priority, with the view to reaching at least a 50% reduction by 1985. All countries and competent international organizations should cooperate financially and technically in the effort to achieve this objective”.

This resolution drew the attention of the highest levels of government authorities around the world and marked a turning point in the recognising the importance of postharvest food losses (Bourne 1986). Many governments and other organisations have developed comprehensive programs to ensure that consistent

attention is given to the problems of caring for food, including fruits and vegetables. Malaysia is no exception.

Today, the research and development (R&D) activities on postharvest handling of fruits and vegetables in Malaysia are conducted at several institutions, including the Malaysian Agricultural Research and Development Institute (MARDI), Universiti Putra Malaysia, Universiti Kebangsaan Malaysia, University Malaya, Universiti Sains Malaysia and the Malaysian Institute of Nuclear Technology. MARDI is considered to be the focal point, since the institute has had the most comprehensive R&D program and activities on food and agriculture for more than 20 years. While earlier studies were targeted mainly at the reduction of postharvest losses, the current research is emphasising technology development to support and strengthen the horticultural industry in the country. Due to time constraints, the following discussion will focus on MARDI.

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## Research and Development at MARDI

The R&D activities on postharvest handling of fruits and vegetables at MARDI are conducted by the Postharvest Handling and Minimal Processing Programme at the Horticulture Research Centre. The main objective of the program is to establish packaged technologies on the handling of fruits, vegetables and flowers for both domestic and export markets. The specific aims are:

- i. to enhance quality and reduce postharvest losses of horticultural produce by the application of more efficient handling techniques;
- ii. to establish effective and economical handling procedures for transportation of horticultural produce by sea;
- iii. to assist marketing of horticultural produce through improvements in harvesting, grading, packaging, handling, storage, ripening and disinfection; and
- iv. to cooperate with industry in providing advisory services, consultancy, contract research, training and extension materials related to postharvest handling.

The research activities under the Postharvest Handling and Minimal Processing Programme at MARDI cover many aspects—from harvesting to the consumer. The research areas can be divided as follows:

- i. preharvest treatments for quality improvement;
- ii. maturity indices and harvesting;
- iii. grading and quality evaluation;
- iv. storage;
- v. treatments to extend storage life;
- vi. ripening and degreening;
- vii. minimal processing and quality assurance systems;
- viii. postharvest diseases and disorders
- ix. quarantine treatments and disinfection of fruit flies and other insects for fruits and vegetables intended for export; and
- x. handling and transportation.

## Some Research Achievements

### Refrigerated storage

Research activities conducted for more than 20 years at MARDI have generated comprehensive infor-

mation and technologies on the storage of major types of fruits and vegetables. The technologies combine the various aspects of handling, especially suitable maturity indices, pre-cooling, disease control, physical and chemical treatments, and control of temperature and relative humidity. The temperature and humidity requirements of some selected Malaysian fruits are shown in Table 1. Most of these fruits have a very short storage life of around 1–4 weeks. Therefore, their marketability is somewhat restricted. However, there are several fruits with a relatively longer storage life, such as carambola, guava and pummelo, which provide greater market flexibility and opportunities.

### Atmosphere modification

Applications of modified atmosphere techniques on some fruits have been investigated since the 1980s. These studies have established techniques to store several varieties of bananas, i.e. 'Mas', 'Berangan', 'Cavendish' and 'Intan', for up to 8 weeks. The storage techniques involve pre-cooling, partial air evacuation, selection of appropriate packaging materials, use of ethylene absorbents, and low temperature storage. Modifying the atmosphere has also allowed increased storage of 'Eksotika' papaya for up to 5 weeks.

In 1995, a new controlled atmosphere (CA) facility was installed. The facility is considered to be one of the best CA research facilities in the world. Storage studies using this facility have been conducted on bananas, sapota, pineapple, papaya and mango, with some promising results. The potential to store other fruits and vegetables using CA will be investigated in the future.

### Handling and transportation by sea

There is always a need to verify the results obtained in the laboratory to commercial practices. In 1985, MARDI conducted the first ever successful shipment of fresh fruit by sea from Malaysia. A trial shipment of 'Mas' bananas packed under modified atmosphere conditions was conducted from Port Klang to Hong Kong. The successful shipment has created a national interest in expanding the horticultural industry in Malaysia. Since then, many trial shipments have been conducted on various types of produce to various destinations in Asia and Europe (Table 2).

**Table 1.** Temperature, relative humidity and storage period of selected Malaysian fruits.

Fruits	Temp. (°C)	Relative humidity (%)	Storage period (weeks)
Carambola			
B10	5	85–90	5–9
B17	5	85–90	6
Papaya			
‘Batu Arang’	10	85–90	3–4
‘Eksotika’	10	85–90	2–3
Sapota			
‘Jantung’	13	85–90	2–3
‘Subang’	13	85–90	1–2
Durian	10	85–90	1–3
Guava			
‘Taiwan’	5	90–95	6–7 <sup>a</sup>
‘Kampuchea’	5	90–95	3–4 <sup>a</sup>
‘Seedless’	5	90–95	4–5 <sup>a</sup>
Pummelo	7–10	85–90	8
Mango	15	85–90	2–3
Pineapple			
‘Sarawak’	10	85–90	3–4
‘Mauritius’	8	85–90	3–4
N36	10	85–90	4–5
‘Josapine’	10	85–90	4–5
Banana	14	85–90	1–3
Rambutan	10	85–90	1–2 <sup>a</sup>
Mangosteen	5	85–90	3–5
Melon			
Watermelon			
‘Fengshan’	10	85–90	2–4
Honey dew	7	90–95	2–3
Duku langsung	10	90–95	1–1.5

Source: Abdullah and Mohd. Salleh (1992); Abdullah (1999).

**Table 2.** Trial sea shipments of fruits and vegetables conducted by the Malaysian Agricultural Research and Development Institute (MARDI).

Produce	Destination	Year
Banana ‘Mas’	Hong Kong (× 5)	1985–1986
	Japan (× 5)	1986–1987
	Denmark	1988
Banana ‘Intan’	United Arab Emirates	1999
Papaya ‘Eksotika’	Hong Kong	1991
	Saudi Arabia	1993
	United Arab Emirates	1994
Pineapple ‘Mauritius’	Saudi Arabia	1992
Pineapple N36	United Kingdom	1997
Pineapple N36 and ‘Josapine’	Germany	1998
Starfruit B10	Hong Kong	1987
	Belgium	1988
Watermelon ‘Fengshan’	Hong Kong (× 2)	1992–1993
Muskmelon	Hong Kong	1994
Ginger	United Kingdom	1993

## Minimal processing

Minimal processing has been identified as one area which will become very important in Malaysia in the future as a result of changes in the socioeconomic status of the population. Minimally processed (MP) fruits and vegetables are fresh produce, nicely packed and ready for immediate consumption. The technology on minimal processing of several fruits and vegetables has been investigated over the past three years. Some of the fruits studied are jackfruit, pineapple, durian and pummelo, whereas the vegetables include onion, chilli, cucumber and long bean. A project on a quality assurance system for MP jackfruit is now being carried out under the Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program (AAECP). This technology will provide convenience and safety to the consumers.

## Disinfestation

The expansion of the Malaysian fresh fruit market to rich countries like Japan, the United States and Australia is hampered by several factors including strict quarantine regulations in those countries. Devel-

opment of protocols for disinfestation of selected fruits will help future expansion of the industry. Disinfestation studies have been conducted on mango, papaya and starfruit. Some of the treatments tested are chemicals (methyl bromide), vapour heat, gamma irradiation, modified atmosphere and low temperature. Future work will include disinfestation of minimally processed fruits such as jackfruit.

## Cooperation

MARDI has been working very closely with many relevant institutions and agencies inside and outside the country. In the local scene, MARDI has cooperated with the Federal Agricultural Marketing Authority, the Department of Agriculture, the Malaysian Pineapple Industry Board, the Malaysian Institute of Nuclear Technology, the Standards and Industrial Research Institute of Malaysia, the Federal Land Development Authority, Federal Land Consolidation and Rehabilitation Authority, some universities and other institutions. Cooperation is in the form of research collaborations and technology transfer.

At the international level, MARDI has been involved with many agencies, including International Atomic Energy Agency, AAEC, the Australian Centre for International Agricultural Research (ACIAR), United States Department of Agriculture, Japan International Cooperation Agency, Queensland Department of Primary Industries, Postharvest Institute of Perishables, Codex and the Tropical Fruit Network.

Close cooperation has also been established with many private companies inside and outside the country. This kind of cooperation is very important, especially in evaluating the effectiveness or suitability of a technology or system for commercial application. Most of the trial shipments were conducted with

support from the local exporters and importers in the respective countries.

## Conclusion

Postharvest handling is a very important research area in Malaysia, especially for fruits and vegetables. There are several institutions and agencies involved in R&D activities in this area with MARDI taking the leading role. Many research achievements have been made but the real achievement is only when the technology can be translated into financial gains for the benefit of the people and the nation.

## Acknowledgment

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## References

- Abdullah, H. (ed.) 1999. Pengendalian lepastuai buah-buahan dan sayur-sayuran tropika [Postharvest handling of tropical fruits and vegetables]. Serdang, Malaysian Agricultural Research and Development Institute, 120p (in Bahasa Malaysia).
- Abdullah, H. and Mohd. Salleh, P. 1992. Improvement on postharvest handling system of fruits and vegetables in Malaysia. *Food Technology in Malaysia* 13, 46–51.
- Bourne, M.C. 1986. Overview of postharvest problems in fruits and vegetables. In: Bourne, M.C., Zonglun, Y. and Liu, F.W., ed., *Proceedings of the United States–China seminar on handling, storage and processing of fruits and vegetables*, 6–9 November 1984, Hangzhou, China. Washington DC, National Academy Press, 1–18.

# The Effectiveness of the BPRE Training Program as a Technology Transfer Strategy for the Adoption of Grains Postharvest Technology

H.F. Martinez\*

## *Abstract*

The effectiveness of training as a technology transfer strategy for the adoption of grains postharvest technology was evaluated. A total of 87 farmer-leaders from the major rice-producing regions of the Philippines, who attended the Bureau of Postharvest Research and Extension (BPRE) training course on grains postharvest technology, served as respondents of the study. The effects of trainee-related characteristics, training factors and extension/communication factors on the level of adoption of recommended postharvest practices at the farm and cooperative levels were determined. Results showed that, among the trainee-related characteristics, the position/designation of the farmer in the cooperative had a significant relationship to the level of adoption of recommended practices at the cooperative level. Among the training factors, the perceived competence of trainers had a significant effect at the cooperative level. Among the extension/communication factors, contact with technicians of the Department of Agriculture was found to be significantly related to the level of adoption, both at the farm and cooperative levels. Moreover, the availability of postharvest-related reading materials to farmers had a significant effect. On the whole, BPRE's strategy of training farmer-leaders was found to be effective in influencing the adoption of recommended postharvest practices. It is therefore recommended that key farmer-leaders of the cooperatives should be continuously trained by BPRE. The BPRE researchers who are experts in their fields of specialisation must be continuously tapped as lecturers and their teaching skills should be enhanced to become more effective in delivering lectures to farmers. Training on grains postharvest technology of field technicians of the Department of Agriculture should be sustained, since farmers frequently ask them for technical assistance. Likewise, postharvest-related reading materials should be made more readily available to farmers.

## **Background**

TRAINING is an integral part of the technology transfer activities of the Bureau of Postharvest Research and Extension (BPRE, formerly known as NAPHIRE—National Post-Harvest Institute for Research and Extension). It serves as a channel for disseminating research findings and other development information on postharvest technology.

In 1993, the training activities of BPRE increased due to the growing number of farmer cooperatives interested in the acquisition of postharvest facilities under the Grains Production Enhancement Program

(GPEP) of the Department of Agriculture. Eight batches of training entitled "Training Course on Grains Postharvest Technology for Farmer-Leaders" were conducted in the different grain-producing regions of the Philippines. The course aimed to increase the capability of farmer cooperatives to adopt and utilise postharvest innovations.

There has been no study conducted in the past to evaluate the effects of training on the adoption of proper postharvest practices. Although some observational evaluations were made for the purposes of accomplishment reports, no extensive evaluation has yet been conducted.

This study therefore attempted to evaluate the effects of the postharvest technology training among the BPRE-trained farmer cooperative leaders. The

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study aimed to: (1) determine the trainee-related characteristics, training factors and extension/communication factors that affect the technology transfer process; (2) assess the effectiveness of the BPRE training as a channel for communicating postharvest technologies to farmer cooperative leaders; (3) ascertain the relationships of trainee-related characteristics, training factors and extension communication factors to training effects; and (4) find out the problems of farmers on postharvest technology training and their suggested solutions.

It was envisioned that the results of this study widen the insight of the training management staff of BPRE in modifying and repackaging training modules suited for farmer cooperative leaders, making the BPRE training program more relevant to the needs of its target clientele. The results may also provide directions for BPRE researchers who are tapped as subject matter specialists during training to further enhance their skills in teaching postharvest technologies to farmer cooperatives.

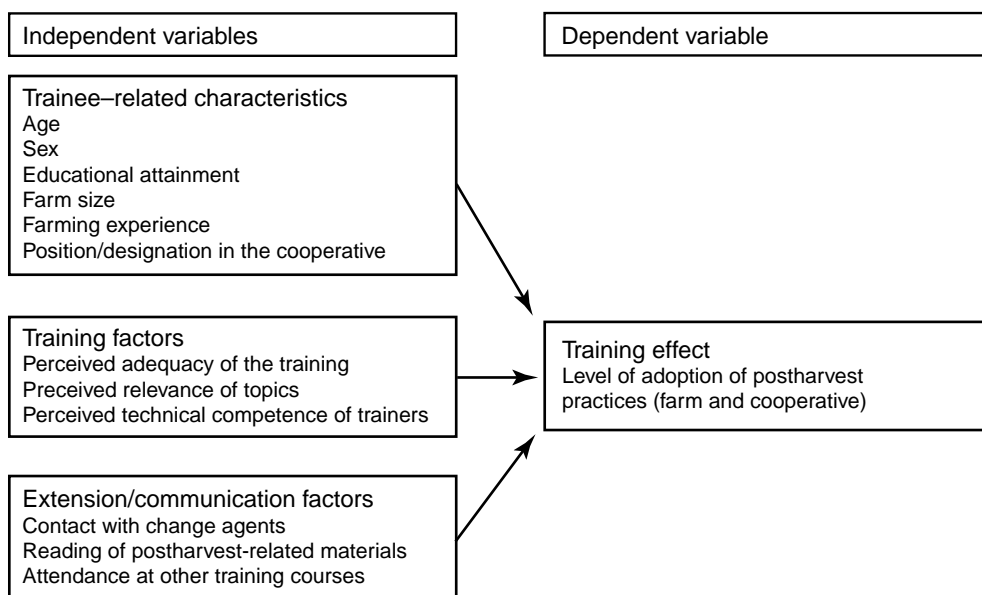
## Methodology

The study was conducted from 1995 to 1996. The respondents were selected from the list of participants who attended the eight batches of the training course

entitled “Training Course on Grains Postharvest Technology for Farmer-Leaders” conducted nationwide in 1993, in collaboration with the Agricultural Training Institute of the Department of Agriculture. The evaluation made a complete enumeration of trained farmer-leaders who met the following criteria: (1) the respondent must be a cooperative member; (2) at least two members of the cooperative attended the training; (3) the cooperative must be a recipient of a mechanical dryer grant under the GPEP; and (4) the cooperative must be accessible by land transportation.

A survey questionnaire was used to elicit the needed data. It was initially pre-tested on 10 trainees, who were later dropped from the list of respondents. After the pre-testing, the survey questionnaire was modified and finalised. A total of 87 respondents were interviewed. The interview was done by 10 technical staff of the Agricultural Training Institute, who were thoroughly briefed on the administration of the questionnaire in their respective areas of coverage. The details of the questionnaire can be found in Martinez (1996).

In this study, the effectiveness of the training as a technology transfer strategy was considered as a function of three independent variables, namely: the trainee-related characteristics; training factors; and extension/communication factors (Figure 1). The



**Figure 1.** Conceptual model showing the relationship between the independent and dependent variables of the technology transfer process.

trainee-related characteristics included age, educational attainment, farm size, farming experience and position/designation in the cooperative.

The training factors considered were: perceived adequacy of training, perceived relevance of training and perceived technical competence of trainers. Perceived adequacy referred to the trainee's perception regarding the adequacy of the topics discussed, teaching methods used, and the equipment and facilities used in the training. Teaching methods used included lecture, practical/laboratory exercises, workshop/discussion, demonstration of facilities/equipment and field trip/visit. Facilities and equipment used covered the training centre facilities, staff, food and the equipment used during laboratory exercises and actual demonstration. The perceived adequacy was measured using an arbitrary number categorisation: 4 = very adequate; 3 = adequate; 2 = moderately adequate; and 1 = least adequate.

The perceived relevance of the training referred to the usefulness of the topics discussed in relation to the postharvest practices of the respondents. This covered harvesting, threshing, drying, storage, milling and marketing of grains. The perceived relevance was measured using an arbitrary number classification: 4 = very relevant; 3 = relevant; 2 = moderately relevant; and 1 = least relevant.

The perceived technical competence of trainers referred to the trainers' ability and technical competence in presenting the topics discussed. This included mastery of the subject matter, process skill and awareness of research findings. The perceived technical competence was rated as follows: 4 = very good; 3 = good; 2 = fair; and 1 = poor.

The extension/communication factors included other activities that the respondents encountered which may have some effect on their adoption of the postharvest technology. These included contact with change agents, the respondents' habit of reading postharvest-related subjects, and attendance at other training. Contact with change agents referred to the respondents' information seeking habit to people, agencies, or organisations from which they could seek advice on their farm.

In this study, the adoption of the recommended postharvest practices at the farm and cooperative levels was considered as the training effect (dependent variable). The on-farm operation covered harvesting, threshing and drying, while the cooperative operation included drying, storage, milling and marketing.

The relationship of the independent variables (trainee-related characteristics, training factors and

extension/communication factors) and the dependent variable (level of adoption of recommended postharvest practices) was determined through statistical analyses. The Pearson Product Moment Correlation was used to analyse the relationship of the following independent variables: (1) age, farm size and farming experience (trainee-related characteristics); (2) perceived adequacy of training, relevance of topics discussed and technical competence of trainers (training factors); and (3) contact with change agents, reading of postharvest-related materials and other training attended (extension/communication factors). On the other hand, the chi-square test was used to analyse the effect of sex, educational attainment and position/designation in the cooperative (trainee-related characteristics).

## Results and Discussion

### Trainee-related characteristics

Table 1 shows the distribution of age, sex and educational attainment of the respondents. Results revealed that the mean age of the respondents was 42.8 years. Most of the participants (83.9%) were males and college graduates (43.7%). The mean farm size was 2.8 ha, while the average farming experience was 19.2 years. About 33.3% of the respondents were elected officials and 26.4% were managers.

### Training factors

Table 2 shows the distribution of trainees' perception on the adequacy of the training. Results revealed that in terms of topics discussed, teaching methods employed, and facilities and equipment used, the respondents rated the training as adequate, with an overall mean score of 3.36. As shown in Table 3, the trainees also perceived the topics discussed as relevant, with an overall mean score of 3.43. Some of the topics, namely, 'Storage principles and systems (physical aspects)' and 'Storage principles and systems (biological aspects)', were rated as very relevant. Apparently, the proper storage practices taught were simple, practical and made a good impression on the participants.

Finally, trainees perceived the competence of trainers as good, with an overall mean score of 3.30 (Table 4). The results implied that the selected lecturers were technically competent. BPRE researchers, who are experts in their field of specialisation in entomology, agricultural engineering, agricultural economics and agricultural extension, were frequently tapped as lecturers.



**Table 1.** Distribution of respondents based on their trainee-related characteristics.

Trainee-related characteristic		Mean	Percentage of respondents
Age (years)		42.8	
Sex	Male		83.9
	Female		16.1
Educational attainment	Below college level		29.8
	College level		26.4
	College graduate		43.7
Farm size (ha)		2.8	
Farming experience (years)		19.2	
Position/designation	Elected official		33.3
	Manager		26.4
	Employee		24.1
	Member		11.5

**Table 2.** Distribution of trainees' perception on the adequacy of the training.

Factor	Percentage of respondents per score <sup>a</sup>				Mean score <sup>a</sup>	Description <sup>a</sup>
	4	3	2	1		
Topics discussed (10 topics)	35.1	44.7	9.1	1.1	3.26	A
Teaching methods (5 strategies)	40.9	40.9	9.4	0.2	3.34	A
Facilities and equipment used (6 factors)	48.9	36.8	3.8	0.4	3.49	A
Overall mean					3.36	A

<sup>a</sup> Note: 4 = very adequate, mean score range = 3.50–4.00; 3 = adequate (A), mean score range = 2.50–3.49; 2 = moderately adequate, mean score range = 1.50–2.49; 1 = least adequate, mean score range = 1.00–1.49.

**Table 3.** Distribution of trainees' perception on the relevance of the topics discussed during the training.

Topic	Percentage of respondents per score <sup>a</sup>				Mean score <sup>a</sup>	Description <sup>a</sup>
	4	3	2	1		
Anatomy and physical properties of grains	44.8	44.8	5.7	1.1	3.38	R
Factors affecting grain quality deterioration	47.1	44.8	2.3	–	3.48	R
Harvesting and threshing	43.7	44.8	5.7	–	3.40	R
Drying principles and systems	43.7	47.1	3.4	–	3.43	R
Postharvest economics	43.7	42.5	6.9	–	3.40	R
Milling principles and systems	48.3	39.1	5.7	–	3.46	R
Storage principles and systems (physical)	58.6	31.0	4.6	–	3.57	VR
Storage principles and systems (biological)	58.6	29.9	5.7	–	3.56	VR
Storage pest biology and control	42.5	42.5	6.9	3.4	3.30	R
Laboratory/demonstration	48.3	29.9	13.8	–	3.38	R
Mean					3.44	R

<sup>a</sup> Note: 4 = very relevant (VR), mean score range = 3.50–4.00; 3 = relevant (R), mean score range = 2.50–3.49; 2 = moderately relevant, mean score range = 1.50–2.49; 1 = least relevant, mean score range = 1.00–1.49.

**Table 4.** Distribution of trainees' perception on the technical competence of trainers.

Training factor	Percentage of respondents per score <sup>a</sup>				Mean score <sup>a</sup>	Description <sup>a</sup>
	4	3	2	1		
Mastery of subject matter (3 factors)	37.2	53.3	6.1	–	3.32	G
Process skill (3 factors)	32.9	56.2	7.7	0.4	3.25	G
Awareness of research findings (3 factors)	39.5	49.8	6.5	0.4	3.33	G
Overall mean					3.30	G

<sup>a</sup> Note: 4 = very good, mean score range = 3.50–4.00; 3 = good (G), mean score range = 2.50–3.49; 2 = fair, mean score range = 1.50–2.49; 1 = poor, mean score range = 1.00–1.49

**Table 5.** Distribution of respondents based on the type of change agents contacted.

Change agent	Percentage of respondents <sup>a</sup>	Rank
Department of Agriculture technician	75.3	1
Co-farmers	37.6	2
BPRE GPEP <sup>b</sup> teams	31.8	3
Private agencies	31.8	3
Mass media	25.9	4
Other government agencies	20.0	5

<sup>a</sup> Note: multiple responses.  
<sup>b</sup> BPRE = Bureau of Postharvest Research and Extension, GPEP = Grains Production Enhancement Program.

**Table 6.** Distribution of respondents based on the number of change agents contacted.

Number of agents contacted	Percentage of respondents
0	9.2
1	23.6
2	24.1
3	26.4
4	9.2
5	4.6
6	1.1
Average no. contacted =	2.2

**Table 7.** Distribution of respondents based on the reading of postharvest-related materials.

Factor	Percentage of respondents	Rank
Do you read postharvest-related materials?		
Yes	87.3	
No	10.3	
If yes, indicate source <sup>a</sup>		
Postharvest training	60.9	1
BPRE GPEP <sup>b</sup> team	58.6	2
Department of Agriculture personnel	44.8	3
Private agencies	16.1	4
Other government agencies	8.0	5

<sup>a</sup> Note: multiple responses.  
<sup>b</sup> BPRE = Bureau of Postharvest Research and Extension, GPEP = Grains Production Enhancement Program.

**Table 8.** Distribution of respondents based on the number of postharvest-related materials read.

Number of materials read	Percentage of respondents
0	10.3
1	23.0
2	35.6
3	20.7
4	8.0
Average no. of materials read =	1.9

**Table 9.** Distribution of respondents according to the number of other training courses attended.

Number of other training courses attended	Percentage of respondents
0	25.3
1	39.1
2	20.7
3	11.5
4	1.1
No answer	2.3
Mean no. of other training courses attended =	1.2

**Table 10.** Level of adoption of recommended post-harvest practices at the farm level.

Postharvest practice adopted	Percentage of respondents
<b>Harvesting</b>	
Harvest grains at maturity date	64.7
Harvest grains when 80% golden yellow	77.6
Harvest grains at 20–24% moisture content	47.1
Harvest grains during good weather conditions	69.4
Use of small piles for field storage	65.9
Mean	64.9
<b>Threshing</b>	
Use of mechanical thresher	84.7
<b>Drying</b>	
Use of underlay	68.2
Use of concrete pavement	45.9
Turning of grains every 15–30 min	67.1
2–4 cm thickness of grain layer	65.9
Use of moisture meter	45.9
Mean	58.6
Overall mean	63.8

**Table 11.** Level of adoption of recommended post-harvest practices at the cooperative level.

Postharvest practice adopted	Percentage of respondents
<b>Drying method</b>	
Use of mechanical dryer	37.6
<b>Sun-drying practices</b>	
Use of concrete pavement or underlay	68.2
Turning of grains every 15–30 minutes	69.4
2 – 4 cm thickness of grain layer	69.4
Use of moisture meter	47.1
Mean	63.5
<b>Storage practices</b>	
Storing grains at 14% moisture content	75.3
First-in first-out method	64.7
Separation of old stocks from new stocks	63.5
One metre spacing between piles and walls	54.1
Treatment of infested stocks	69.4
Use of pallets	63.5
Maintenance of cleanliness	76.5
Mean	66.7
<b>Milling practices</b>	
Use of rubber-roll hullers	83.9
One-half of grain thickness huller clearance	67.6
Mean	75.8
<b>Marketing practices</b>	
Marketing of milled rice	75.8
Overall mean	64.1

## Extension/communication factors

Table 5 shows the various change agents that the respondents have contacted and sought for advice concerning problems related to postharvest operations. The results showed that majority of the respondents (75.3%) sought the advice of the Department of Agriculture technicians. This could be attributed to the regular presence of these personnel in the area. Table 6 shows that the mean number of change agents contacted by the respondents was 2.2. Table 7 shows that the majority of the respondents (87.3%) read postharvest-related materials. About 60.9% of them obtained these materials during their attendance at postharvest training, while some (58.6%) obtained the materials from BPRE teams implementing the GPEP. Table 8 shows that the mean number of postharvest-related materials read was 1.9. It was noted that about 10.3% of the respondents were not able to read any postharvest-related material at all. Finally, in terms of other training attended, most of the respondents (39.1%) have attended only one other training course (Table 9). About 25.3% of the respondents have not attended any other training at all. This implies that farmer-leaders are given very limited opportunities to attend training courses.

## Training effects

Table 10 shows the level of adoption of the 11 recommended postharvest practices at the farm level, which covered harvesting, threshing and drying operations. Results revealed that the mean level of adoption was 63.8%. Among the three operations examined, the adoption of recommended threshing practice obtained the highest level of adoption at 84.7%. This implies that majority of the farmers are now using mechanical threshers instead of the traditional 'hampasan' (manual) method. Under the recommended harvesting practices, the use of moisture content as a harvesting index was adopted only by 47.1% of the respondents. This could be due to the limited availability and high cost of moisture meters. Finally, the adoption of recommended drying practices obtained a relatively low mean of 58.6%. This result could be attributed to the increasing dependence of farmers on the cooperative to perform their drying operation, because of the greater availability of drying facilities in the cooperative compared to at the farm level.

Table 11 shows the level of adoption of the 15 recommended postharvest practices at the cooperative level of operation, which covered drying, storage, milling and marketing. Results revealed that the mean level of adoption was 64.1%. Among the four postharvest operations considered, both the adoption of recommended milling practices and the marketing of milled rice were among those practices which obtained the highest level of adoption (both 75.8%). This implies that the respondents favour the use of rubber-roll hullers over traditional hulling equipment to obtain higher milling recovery, and prefer to sell their produce in the form of milled rice rather than in paddy form to gain higher profit. In the drying operation, the use of mechanical dryers obtained the lowest level of adoption (37.6%), despite the cooperatives being recipients of mechanical dryer grants from GPEP. The reasons for the low level of adoption included the high cost of operating mechanical dryers, the poor performance of some installed units, and their preference to use sun-drying over mechanical drying during good weather conditions (Martinez 1997).

## Relationship of the independent variables to training effects

Tables 12 and 13 show the relationships between the independent variables (trainee-related characteristics, training factors, and extension/communication factors) and the dependent variable (level of adoption of recommended postharvest practices at the farm and cooperative levels). Among the trainee-related characteristics, age, sex, educational attainment, farm size and farming experience have no significant relationship with the level of adoption of recommended postharvest practices. On the other hand, position/designation in the cooperative was found to be significantly related to the level of adoption at the cooperative level, but not at the farm level. This result suggests that trainees who hold key leadership positions are more likely to influence the adoption of proper practices in the cooperative operation. The result could be attributed to the presence of more postharvest facilities at the cooperative for drying, milling, storage and marketing, greater volume of grains being handled, and the increasing dependence of farmer-members on the cooperative for processing and marketing of their products.

**Table 12.** Pearson Moment Correlation Coefficient of some independent variables and their relationship with the level of adoption at the farm and cooperative levels.

Independent variable	Correlation coefficient	
	Farm level	Cooperative level
<b>Trainee-related characteristics</b>		
Age	0.122	0.108
Farm size	0.176	0.070
Farming experience	-0.145	-0.008
<b>Training factors</b>		
Perceived adequacy of training	-0.045	-0.000
Perceived relevance of training	0.025	0.023
Perceived technical competence of trainers	0.114	0.024 <sup>a</sup>
<b>Extension communication factors</b>		
Contact with change agents	0.380 <sup>b</sup>	0.284 <sup>b</sup>
Reading of postharvest-related materials	0.178	0.220 <sup>a</sup>
Other training attended	0.156	-0.082

<sup>a</sup> significant at the 5% level  
<sup>b</sup> significant at the 1% level

**Table 13.** Chi-square test of some independent variables and their relationship with the level of adoption at the farm and cooperative levels.

Independent variable	Chi-square value	
	Farm level	Cooperative level
<b>Trainee-related characteristics</b>		
Sex	0.190	0.128
Educational attainment	0.403	0.202
Position/designation in the cooperative	3.516	9.670 <sup>a</sup>

<sup>a</sup> significant at the 5% level

Among the training factors considered, the perceived adequacy and perceived relevance of training were found to have no significant relationship with the level of adoption of recommended practices. However, the perceived technical competence of

trainers was found to have significant effect at the cooperative level, but not at the farm level.

Among the extension/communication factors considered, contact with change agents had a very significant effect on the level of adoption of recommended practices both at the farm and cooperative levels. This could be attributed to the role of change agents (extension personnel) as facilitators and catalysts of technology adoption (Swanson and Claar 1984). Results also showed that reading of post-harvest-related materials had a significant effect on the level of adoption at the cooperative level, but not at the farm level. Finally, attendance at other training was found to have no significant relationship with the level of adoption at either level.

### Problems encountered and suggestions made to improve the training course

The most common problem cited was the limited time allotted to some topics, practical exercises and workshops. Others mentioned that some topics were too technical. Respondents suggested that the time allotted to topics on rice milling operation, practical exercises and workshops be extended. Respondents also suggested that topics on marketing linkages should be included, that technical topics should be related to farmers' experience, and that the training schedule should include visits to model cooperatives with complete postharvest facilities. Some participants said that the three-day duration of training was too short and that there were instances when the training schedule fell within their months of peak farm operation (planting and harvesting seasons). The respondents suggested that the training should be conducted over five days to allow more time for each topic and hands-on exercises. Training should be conducted once or twice a year to enable farmers to continuously update their knowledge and skills. Finally, they suggested that training should be conducted during the lean months of farm operation to encourage greater participation.

Other suggestions given were: (1) provision of handouts for all the topics discussed; (2) participation of more women in the training; (3) reduction in the number of trainees to a more manageable size; (4) use of more visual aids in lectures and discussions; and (5) provision of regular copies of postharvest-related reading materials to cooperatives.

## Conclusions and Recommendations

On the basis of the findings, the following conclusions and recommendations were drawn:

1. Position/designation in the cooperative was significantly related to the adoption of recommended postharvest practices in the cooperative operation. Training the most influential members of the organisation resulted in greater adoption since these individuals are the ones responsible for the operation and management of the cooperative. They also have greater opportunities to apply the knowledge gained from the training, because of the presence of more postharvest facilities, greater volume of grains handled, and growing dependence of farmer-members on the cooperative for processing and marketing of their produce.
2. The perceived technical competence of trainers was significantly related to the adoption of recommended practices at the cooperative level. BPRE researchers who are experts in their respective fields of specialisation must be continuously tapped as lecturers. Their teaching skills should be further enhanced to enable them to become more effective in delivering lectures to farmers.
3. Contact with change agents is significantly related to the level of adoption of recommended practices both at the farm and cooperative levels. Training of Department of Agriculture technicians should be sustained since they are the ones frequently contacted by farmers for technical assistance.
4. The habit of farmers to read postharvest-related materials had a significant effect on the level of adoption of recommended practices in the cooperative operation. These materials should be made more readily available to farmers, since they serve as ready references and supplement knowledge and skills gained from training courses.
5. Training should be conducted for five days during lull periods of farm operation. This will allow more time for each topic, practical and workshop, and provide greater participation among farmer-leaders.
6. On the whole, BPRE's strategy of training farmer cooperative leaders was found to be effective in influencing the adoption of grains postharvest technology.

## References

- Martinez, H.F. 1996. Evaluation of training as a communication strategy on grains postharvest technology transfer process. Unpublished Masters thesis, Central Luzon State University, Nueva Ecija, Philippines.
- Martinez, H.F. 1997. Effectiveness of NAPHIRE training courses conducted in support to the development of the postharvest industry. Terminal Report, Bureau of Postharvest Research and Extension, CLSU Compound, Nueva Ecija, Philippines.
- Swanson, B.E. and Claar, J.B. 1984. The history and development of agricultural extension. In: Swanson, B.E., ed., *Agricultural extension, a reference manual*. Rome, Food and Agriculture Organization of the United Nations, 1–19.

# The Quality Assurance Challenge: Can Village Marketing and Cooperatives Respond?

N. Masajo-Manalili\*

## *Abstract*

This paper reviews the changing agricultural scenario amidst current global developments and pressing environmental issues with emphasis on the quality assurance requirements for agricultural produce. An evaluation and analysis of village marketing and cooperative practices, as they relate to postharvest handling and quality concerns, is undertaken to establish gaps, capacities, and potentials for further growth and development. Highlights of the paper are the country experiences depicting varying response modalities of village marketing and cooperatives in the Association of South-East Asian Nations (ASEAN).

Modern strategies for product quality maintenance and their cost efficiencies are also elaborated leading to conclusions as to how best strategic policy and systems approaches can be devised to meet the expectations of diverse stakeholders.

With concerns such as enhanced cost efficiencies, product handling, and emerging forms of structures, suggestions on how the village marketing and cooperative responses could be made more appropriate and responsive to the heightened call for quality assurance in agricultural produce are similarly tackled.

FOOD AVAILABILITY remains the major concern— at varying levels—of rich and poor countries alike. It was known as ‘food supply’ at the time when availability was greatly dependent on enhancing production and productivity. Today, it is termed ‘food security’, as production and productivity improvement have proven inadequate in addressing the problem of food availability. Whatever term is used and at whatever stage it may be in, food security will be a continuing global thrust.

Despite periodic concern about the world’s ability to feed itself, it has been in fact doing so at ever-improving levels and at lower real prices even with a much larger population (Duncan 1997). These past decades, for instance, developing Asia has made remarkable progress since the food crisis years of the 1960s, with substantial gains in food security, poverty reduction, and per capita income growth despite a 60% (one billion) population growth (ADB 1999). What

has made the transformation remarkable, according to the Asian Development Bank (ADB), is that an increase in yield was obtained with barely a 4% change in area harvested and was accompanied by a 25% reduction in the total number of poor people, from 930 million in 1975 to 700 million in 1995.

With such economic transformation, however, came a declining agricultural share in the national income, but only in terms of its relative importance to the other sectors, namely, manufacturing and services. Despite this declining contribution of agriculture, the agro-industrial sector of developing countries noticeably has maintained or increased its share of economic output (Manalili 1998a).

Developing countries try to sustain agricultural growth, not only to feed the growing population, but also to continuously trigger growth and development in the rural, non-farm sector. The fact is, farm income remains the primary source of rural purchasing power which, when enhanced, extends demand for basic staple foods to demand for variety in products and services. Consumers who decades ago took most of their cereals as rice or maize, now demand wheat products such as bread and noodles, as well as more

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meat, fruits and vegetables (Pingali et al. 1997). Likewise, canned goods such as tomato paste, condensed milk, and tinned fish find their way into village stores and weekly markets in the most remote regions (Baun and Tolbert 1985).

As farm diversification continues and the demand for product variety increases, production of basic staple foods such as rice, fish, meat, fruits, and vegetables has to be made more profitable and efficient for it to compete with more lucrative options for farm resources. Otherwise, food security will again be at stake.

The battle for food security and production efficiency was felt more significantly in 1997 as the majority of the countries in the region were severely hit by the Asian financial crisis eroding whatever agricultural gains that may have been achieved earlier. Weather disturbances caused by the El Niño and La Niña phenomena added to the onslaught of the region resulting in, again, declining agricultural production. The production efficiency and profitability, crisis or no crisis, however, is greatly dependent on market functionalities, thus—in the agricultural sector's case—on agricultural marketing. This paper, therefore, examines the state of agricultural marketing in the Asia–Pacific region, mostly carried out at the village and cooperative levels to see whether there is still a role for them in the heightened quality assurance challenge in ensuring food security in a fast-transforming agricultural sector.

## **Agricultural Marketing and Food Security**

While initial thrusts on food security were geared to productivity issues, efforts these past decades have been focused on the long-neglected marketing and postharvest sectors. These sectors basically ensure not only the availability but also the quality of agricultural products. In as much as quality, specifically at post-production stages, is a function of the postharvest sector, agricultural marketing when referred to in this paper already includes postharvest concerns. This is supported by Baun and Tolbert (1985) when for brevity they referred to the postharvest system of collecting, storing, transporting, processing and retailing farm surpluses as marketing.

The efficiency and effectiveness of the marketing system should move at the same rate as the increase in

food supply. Otherwise, the farmers and the economy will be hurt if resources are used to produce output that can not be sold (Deomampo 1997). Generally, the efficiency of the marketing system can be gauged by the quality, quantity, and price of goods available as well as the cost of performing the marketing functions (Deomampo 1997). Quantity and price are likewise tied up with marketing, as the absence of a market is a disincentive to enhance production volume, the same way that price, to a large extent, is a function of marketing efficiencies/inefficiencies.

Marketing accounts for a greater share of total production through delivery costs in areas where producers are more dispersed. Improving the marketing system can be as important as introducing farming methods that increase yields, which may otherwise be ineffective without an improved marketing system (Baun and Tolbert 1985). Even in richer countries, consumers pay more for the value of parts of the system of non-agricultural origin, including the cost of storage, processing, marketing, and catering, than for the cost of agricultural products themselves (Tsubota 1999). Postharvest technology that prevents crop losses during storage and transportation and that adds value to agricultural products is as important as increasing the yield of crops for sustainable food supply (Kainuma 1999).

Two previous regional conferences of the Asian Productivity Organization (APO) in 1989 and the Food and Agriculture Organization of the United Nations (FAO) in 1998, almost a decade apart, tackled the issues of agricultural marketing in the Asia–Pacific region. Foremost of the identified problems (Table 1) are related to postharvest and marketing infrastructure inadequacies. These problems are further compounded by limited production scale, unplanned production systems and poor delivery of extension services. Suggested measures to address these problems were put forth at the aforementioned conferences (Table 2). While considerable gains may have been reported, such as the promotion of the market-oriented approach, enhancement of markets and marketing activities, and provision of appropriate policy support, the problems persist even after decades of continued effort in most countries in the region. This implies that the problems are of a large magnitude and that efforts undertaken, although commendable, need to be made more sustainable.



**Table 1.** Agricultural production and marketing issues in Asia–Pacific, 1989 and 1998.

Marketing systems for farm products regional conference (APO <sup>a</sup> , March 1989)	Promotion of market-oriented production systems, regional expert consultation (FAO <sup>b</sup> , October 1998)
<b>Production</b>	<b>Production</b>
<ul style="list-style-type: none"><li>• Small-scale production</li><li>• Lack of regular supply of appropriate volume and quality</li></ul>	<ul style="list-style-type: none"><li>• Small-scale production</li><li>• Seasonality of production</li><li>• Unplanned production systems</li><li>• Poor cultivation and management practices</li></ul>
<b>Productivity</b>	<b>Productivity</b>
<ul style="list-style-type: none"><li>• Farmers' attitude/readiness for change</li><li>• Appropriateness of government programs</li></ul>	<ul style="list-style-type: none"><li>• Poor extension and other support services to agricultural production</li></ul>
<b>Marketing</b>	<b>Marketing</b>
<ul style="list-style-type: none"><li>• Small domestic market which posed special problems for island economies (South Pacific)</li><li>• Substantial marketing losses (poor handling, packing)</li><li>• Inadequate market infrastructure and facilities (roads, transportation, storage, warehouses, packaging and processing facilities)</li><li>• Inadequate collection, analysis and dissemination of timely and relevant marketing information</li><li>• Production bias of institutional credit resulting in limited loans for marketing purposes</li></ul>	<ul style="list-style-type: none"><li>• Lack of wholesale market</li><li>• Poor packaging of the produce</li><li>• Lack of or poor infrastructure facilities/poor postharvest handling facilities</li><li>• Lack of market information</li><li>• Overlapping marketing channels</li></ul>

a APO = Asian Productivity Organization  
b FAO = Food and Agriculture Organization of the United Nations

## Cooperatives and Village-level Marketing

Marketing is still the foremost problem in Asian agriculture, given the high rate of production losses and product rejects. For a sector already saddled with a high risk of spoilage due to high perishability of agricultural commodities, its problems are further compounded by a lack of capital and inadequate transport and postharvest facilities.

Usually, there are three major institutional players in agricultural marketing, namely, the government, the private sector, and farmer cooperatives. Of the three, the last is usually at a disadvantage from the perspective of financial capability. The only thing working in its favour is that it specifically caters to farmer-member requirements by the nature of its incorporation. Cooperatives are user-owned and user-controlled businesses that bring net income to users on the basis of patronage. This is in contrast with

corporate business which brings net income to investors on the basis of shareholding.

In the Asia–Pacific region, which is characterised by small and widely-dispersed agricultural farm operations, agricultural cooperatives and farmer associations serve as the major conduit for farm-to-market product transfer.

Marketing cooperatives develop to gain leverage from downstream asset utilisation and pooling of resources to improve the bargaining power of many individual sellers. The collective ability to construct the infrastructure necessary for downstream processing is a common reason for cooperative formation in areas such as dairy, sugar, fruit and vegetable processing, and cotton (SEARCA and Hassals 1997).

Despite the dismal failures of cooperatives in most parts of Asia (unlike their strong counterparts in China and Korea), cooperative marketing is still being promoted as one approach to meet the problems of smallness of marketable surplus and dependence on

**Table 2.** Suggested measures to improve agricultural marketing resulting from two conferences held in 1989 and 1998 (also see Table 1).

	APO <sup>a</sup> conference, 1989	FAO <sup>b</sup> conference, 1998
A. Farm level	<ul style="list-style-type: none"> <li>• Adopt a market-oriented approach to selection of product/crop for production</li> </ul>	<ul style="list-style-type: none"> <li>• Promote market-oriented production systems with production planning based on market potentials aided by improved market information, group marketing activities, direct marketing assistance</li> </ul>
B. Market level	<ul style="list-style-type: none"> <li>• Assist farmers in securing market outlets</li> <li>• Improve marketing practices</li> <li>• Provide adequate marketing credit (short and medium term)</li> <li>• Develop rural market</li> </ul>	<ul style="list-style-type: none"> <li>• Establish/improve assembly and trading centres or wholesale markets</li> <li>• Introduce new and improved processing techniques</li> <li>• Gather appropriate market information</li> <li>• Appreciate the role of traders in development</li> </ul>
C. National/policy level	<ul style="list-style-type: none"> <li>• Promote group action by farmers</li> <li>• Encourage specialisation in product/area (product estates)</li> <li>• Provide adequate marketing extension service</li> </ul>	<ul style="list-style-type: none"> <li>• Introduce appropriate price and non-price policies</li> <li>• Train extension workers in marketing</li> <li>• Conduct relevant market research</li> </ul>

<sup>a</sup> APO = Asian Productivity Organization

<sup>b</sup> FAO = Food and Agriculture Organization of the United Nations

private traders (APO 1990), and about 65% of the 765 million member cooperatives and 26% of the 95 member countries of the International Cooperative Alliance are accounted for by the Asia-Pacific region (Figure 1).

The problems, however, do not end when marketing activities are relegated by producers to cooperatives. The latter often lack clear planning objectives, good leadership, and member participation. Given their popularity despite their wanting performance, the potential of cooperatives far outweighs their weaknesses. The issue, though, is whether the potential will hold amidst rising challenges—the quality assurance challenge included.

## The Quality Assurance Challenge

One of the major objectives of efficient marketing practices is to ensure quality as well as minimise losses from harvest to consumption points. The problem, however, is that quality is relative and, as such, has to be appropriately defined before related problems can be addressed. The varying definitions of ‘quality’, as condensed from Satin (1997), are:

- Generic definition—a combination of characteristics that are critical in establishing a product’s consumer acceptability.
- Food industry definition—an integrated measure of purity, flavour, texture, colour, appearance and workmanship.
- Highly-competitive market definition—value or a consumer’s perception of the worth of the product based upon the funds available for it.
- When referring to a standard—a product’s consistent adherence to that standard.

As if the quality challenge arising from inefficient marketing activities, lack of capital, and non-integrated farm activities is a problem not yet big enough, the mandatory adherence of individual countries to the World Trade Organization (WTO) requirements is changing the nature of world trade in agricultural products, including high quality requirements of products traded. As condensed from Satin (1997), the

quality standards in international trade (with a focus on the food industry) include:

- Legal standards
  - safety-related minimum standards of quality commonly established by national government
  - assurance that products are not adulterated and are free from dangerous contamination (i.e. undesirable microorganisms, insects, pesticides)
- Labelling standards
  - standard information presented to consumers
- Industry standards
  - set by an organised industry association to establish a reliable identity for a particular product
  - seldom related to safety, but more on characteristics to establish credibility for the market (commodity standards/standards of identity)
- Buying decision standards
  - non-health standards—based on perception of overall appearance and taste for the purposes of easier buying decisions

While WTO is trying to ‘level the playing field’ in agricultural marketing worldwide, it has likewise opened the field to competition. The challenge, therefore, is for domestic producers to be on a par with their global competitors in terms of quality, volume, and reliability. Failure to do so would mean less room for local players in postproduction and value-adding activities—the agro-industrial component that absorbs

most of the agricultural produce of the global market. In an era of financial crisis, the agricultural sector is seen still as the potential economic saviour. This crisis-saving job of agriculture can only be achieved if products are produced and delivered at a time and quality specified by the market.

### Quality Assurance—Can Village-level Marketing and Cooperatives Respond?

Given the increasing clamour for quality as an offshoot of changing societal consciousness and global competition, is there still a role for village marketing through cooperatives to service this quality requirement, or is the task better left to big-time food handlers?

Previously, efforts have been made to address marketing problems at different points and levels. In the case of government or state marketing (usually applicable to grains), government intervention, although of good intention, has not been effective in most instances, as it is engaged in actual trading as well as advisory, promotional, or regulatory roles. As it is, substantial budgetary outlays are required, aside from the fact that they make proper coordination more difficult. In the case of the Philippines, for instance, government intervention in grain marketing is seen as a contributory factor that distorts the decisions of traders to invest in large drying and storage facilities as traders would rather sell to the National Food Authority (NFA) (illegally) at higher prices than store it themselves (SEARCA 1999).

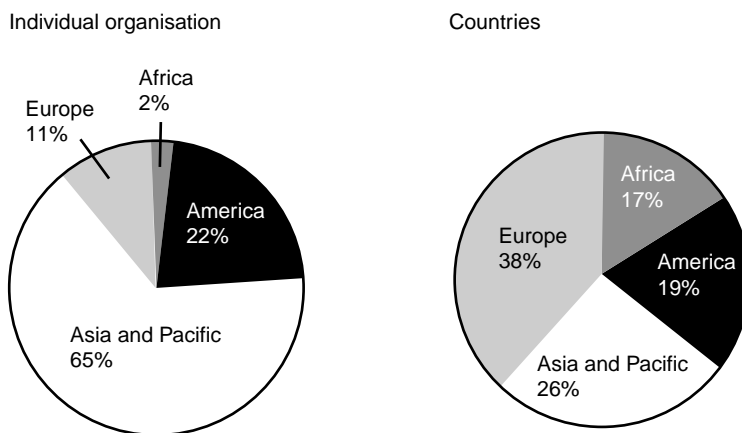


Figure 1. International Cooperative Alliance membership by region, 1996.

Private sector marketing, on the other hand, is associated with large marketing margins. Considering that private sector enterprises are usually owned by traders and non-producers, relying on them for marketing agricultural products often diminishes the farmers' share in the price paid by the consumer. While the key role of traders in agricultural marketing is duly recognised, the ideal is to keep them to a minimum in any given chain. Thus the field is left open to cooperatives.

The assessment of capability of a village-level marketing unit or cooperative usually focuses on the issue of size, appropriateness, and responsiveness to the demands of the time. Size is considered owing to the degree of sophistication it connotes. Appropriateness, on the other hand, is considered as a measure of level of fit to varying requirements, while responsiveness, as a measure of one's ability to meet changing requirements.

### **Size and level of sophistication**

Often, the notion is that anything that is big, sophisticated, or technically advanced, is the best option, if ever choices are available. The problem with this thinking is that one loses sight of the flexibility of small marketing units, cooperatives included, that leads to a more focused approach for technological options. This flexibility on focused operations make the small marketing units more effective than big ones for catering to the requirements of smaller farms.

### **Technical appropriateness**

In less-developed nations, postharvest technologies are severely constrained by poor infrastructure. Large-scale processing may therefore not be applicable unless a stable supply of electricity, water, and well-trained technicians is guaranteed (Tsubota 1999). While large-scale operations may benefit from expensive handling machinery or from technologically-advanced postharvest systems, simpler, low-cost technologies can be more appropriate for smaller volume, resource-limited commercial operations (FAO 1998). According to the same FAO report, the key in reaching the desired postharvest objectives of quality and loss reduction is effective management during the postharvest period more than the level of sophistication of any given technology.

### **Responsiveness to the demands of the times**

In developed countries, where infrastructure and facilities are far more developed than in the Asia-Pacific region, cooperatives had been prophesied to disappear altogether. However, cooperative movements are still growing in these countries—in fact, they are surpassing the records of those in Asia-Pacific in terms of membership development. In the United States (US), for instance, Agriculture Undersecretary for Rural Development, Jill Long Thompson, reported in 1997 that farmer-oriented cooperatives market about one-third of US farm commodities and handle more than one-quarter of all farm supplies sold in the US. She said that the cooperatives' popularity stems from the fact that they are turning farmers' produce into value-added goods which helps keep more farm dollars at home in rural areas.

The International Cooperative Alliance (ICA) Asia-Pacific regional assembly in 1997 sent the message to WTO that liberalisation of agricultural trade should not be regarded as an end in itself. Instead, it should also aim to improve the functioning of agricultural markets, increase farm incomes, eradicate poverty, and promote socially and environmentally sustainable programs. Given that agriculture in the region is usually carried out by family members, it is the ICA's belief that more than ever they need to strengthen cooperative relationships to protect members' interests in the light of the WTO agreements.

Cooperatives still play a major role, even during a period where strategic alliances between small and large enterprises are already in place. In a study of 71 agri-business enterprises, Manalili (1998b) found that the small and medium enterprises (SMEs) are still usually powerless, even if they are allied with large corporations (LCs), as they are still dependent LCs in reaching their intended market. The study results show that cooperative endeavours afford SMEs greater competency to directly shape their strategic options and market their produce. Through cooperatives, SMEs have facilitated raw material bulk purchases that reduced operating costs and collective bargaining that improved prices for their produce. As competencies have been acquired, the potential of cooperatives in the areas of market information sourcing as well as in technical, operational, and financial enhancement, has increased.

Thus, based on the preceding discussion, there is still a role for village marketing and cooperatives to

play in developing countries as far as quality and marketing requirements are concerned. Having established the importance of village-level marketing and cooperatives, and given the challenges with which they now are confronted, how can they be made more responsive to the needs of the times?

### Village-level Marketing and Cooperative Enhancement

As the Asian economy continues to develop and urbanise, it will require production of specialised, high value, and market-oriented crops which in turn will require intensive promotion, packaging, and grading to satisfy the needs of the urban sectors.

To make them more responsive to the quality requirements of the food sector, cooperatives can identify a number of entry points along the traditional areas that require new approaches, emerging trends, and potentially promising areas. Cooperatives may also look at the varying marketing channels of selected Association of South-East Asian Nations (ASEAN) countries and at the challenges of food processing sectors, to where a large percentage of the produce goes as raw materials.

### Traditional areas, new approaches

Four critical levels have traditionally been identified, from harvest to consumption points, where quality-related measures can be adopted: farm, assembler, trader, and wholesaler/retailer (Table 3). Added to these is the critical area of trucking or transporting produce from one distribution channel to another. These critical areas are usually handled by individual farmers or private traders, but are potential areas for cooperatives to handle as well.

Ideally, cooperatives should be able to provide services that producers are unable to efficiently undertake by themselves. Quality-related efficiencies come with acquisition of adequate knowledge and skills with which cooperatives should assist members. Collective effort leads to volume and bargaining advantages that facilitate better pricing and enhanced marketability of produce. Beyond the quality-ensuring activities, cooperatives should likewise be able to undertake research and development, not only on the technical requirements of buyers, but information on maintaining, expanding and developing markets as well.

**Table 3.** Levels at which the various processes of quality assurance and marketing are undertaken.

Process	Level			
	Farm	Assembler	Trader	Wholesaler/Retailer
<b>Quality assurance</b>				
Inspection/selection	•	•		•
Sorting	•	•		
Grading	•	•		•
Meeting buyer quality/condition specifications	•	•		
Packaging	•	•	•	•
Handling and distribution				•
Sufficient postharvest facilities			•	•
Storage			•	•
Appropriate transport system			•	
<b>Marketing</b>				
R&D <sup>a</sup> —expand, maintain and develop markets	•			
a. Market information (specialised market supply, prices)	•	•	•	•
b. Project feasibility	•			
Sourcing		•	•	•

<sup>a</sup> R&D = research and development

Providing information to members—e.g. knowing their market fully, including quality requirements—is one of the most important services that cooperatives can offer. The usual problem with agricultural marketing is that buyer specifications are usually only known at a stage where varietal decisions can no longer be reversed, resulting in produce not meeting buyer requirements and consequently being rejected.

## Emerging trends

The traditional way to reduce marketing losses is for firms to situate processing facilities close to the point of production. The purpose of this is to reduce raw material damage, thereby enhancing the quality of the finished product. While there is logic in this approach, it may not always be possible for technical reasons, thus variations occur.

Taking into account the fact that cooperatives have high failure rates, the strategy is to identify entry points that will capitalise on current strengths while simultaneously requiring competency in weak areas. One strategy is to build partnerships with other sectors.

### *Private sector linkages*

*Village-level tie-up (Thailand).* In Thailand, a fruit and vegetable processing firm employs villagers without the need for the latter to report daily to the factory. The raw materials to be processed, such as tomatoes for peeling, longan for seed removal, or baby corn for leaf removal, are brought to a village near the harvest area and are picked up at collection points every 30 min by the factory vehicle. Usually a village leader is appointed to coordinate these activities. The villages selected for this kind of tie-up are usually 5–10 km from the factory production sites.

The village-level preliminary processing activities (washing, peeling, seeding) could very well be undertaken by a village cooperative in the same manner, and the trucking activity could likewise be a potential entry point. The key, however, is for cooperatives to acquire the quality and reliability (timely delivery) competencies that such firms so consistently require.

*Strategic alliances (Philippines).* Strategic alliances were a predominant feature of the Philippine agribusiness sector in past decades, specifically in the Mindanao area. While initially all aspects of a large corporation's (LC's) operations were company-owned and managed, individuals, groups or small-to-medium enterprises were later contracted to perform tasks for LCs at a lesser cost but comparable quality. These were mostly in the areas of supply, channel, and

physical distribution systems. The move was in response to an LC's need to cut costs, enhance operations and to stay in competition, i.e. getting value for the least cost (Manalili 1998b).

There are cases where employee associations or farmer-growers form cooperatives to service the said requirements of a large corporation. The advantage of this arrangement is that cooperatives are provided with opportunities at a reduced cost and risk level for reasons that the market is assured and quality specifications are provided (monitored/maintained) by the allied firms.

Long-term supply arrangements between parties are likewise considered as strategic alliances, as in the case of banana and pineapple contract growers in the Philippines. Similarly, cooperative formation among growers is not uncommon. Cooperatives could play a greater role only if they equip themselves with full knowledge of contract-growing arrangements so as to protect their members from unscrupulous practices and potential abuse by allied companies.

### *Research and development linkage*

In remote areas where raw materials abound and processing facilities are limited, the only other producer option aside from selling fresh at low prices is to process produce through cooperative endeavour. Chances are these village-level cooperative enterprises will have difficulty in accessing markets where product quality is a primary consideration for reasons of poor product quality. Being new in the processing business they still lack required competencies.

To address quality problems, a technology transfer and marketing tie-up between a research and development institution and a potential village cooperative is an option, as in the case of Vietnam's Post-Harvest Technology Institute (PHTI). As PHTI is a recognised institution in food technology generation, a number of its mature technologies were proposed for transfer to a village-level cooperative enterprise in collaboration with Southeast Asian Ministers of Education Organization (SEAMEO) Regional Center for Graduate Study and Research in Agriculture (SEARCA) and the College of Agriculture and Forestry. In the "Strengthening Marketability and Transfer of Technology for Sustained Food Processing at a Village Level in Vietnam" project, the approach is to equip the village cooperatives with economic and technical tools, leading to a high level of quality. On a sustainable basis, these economic activities in rural villages can progress to a higher level where the cooperative bene-

ficiaries will become the precursors of agro-industrial development in their respective communities.

#### *A potentially promising area*

Cooperatives have recently abandoned the traditional sectors of agriculture or retail distribution in favour of financial services. This is either because they have been 'squeezed out' of operation by competitors, or because they have recognised the potential of the financial service sector.

In the Asia-Pacific region, usually accompanying a lack of marketing options for farmers is a lack of funds to support marketing activities. The tightness of credit is associated with the rigid requirements of formal lenders (bank) and the high interest rates of informal ones. To address this, cooperatives can serve as a conduit for providing financial services that is a cross between formal and informal lending. Instead of contract growers individually applying for loans directly from the bank, a cooperative can apply for loans and re-loan to grower members at rates high enough to cover service and fund handling. The cooperative will thus reduce the rigidity of formal lending by shouldering the risk, which is at a reduced level compared to banks owing to the cooperative's proximity to growers and buyers which facilitates regular harvest monitoring and payment collection.

### **Conclusion**

Village-level marketing through cooperatives still has a role to play in the quality assurance requirement of agricultural produce. Despite high failure rates, cooperatives—by virtue of their size, technology requirements, and proximity to and knowledge of their area of production—are still the better option to service the marketing needs of rural agricultural producers.

The key to successful marketing is effective management rather than the level of sophistication of the marketing system. Measures should therefore be geared towards enhancing cooperatives' organisational management and operational efficiencies. Strategies should capitalise on competency-enhancing linkages that enable cooperatives to acquire the competencies of their partners while at the same time 'learning the ropes' of the business. This will gradually prepare them for the bigger role they need to play in their village's bid for agro-industrial enhancement and sustainable development.

### **References**

- ADB (Asian Development Bank) 1999. Rural Asia: beyond the green revolution. Prepared for the 32<sup>nd</sup> Annual Meeting Seminar, 29 April 1999.
- APO (Asian Productivity Organization) 1990. Marketing systems for farm products in Asia and the Pacific (report of APO seminar held in Japan in 1989). Tokyo, Asian Productivity Organization.
- Baun, W. and Tolbert, S. 1985. Investing in development—lessons of World Bank experience. Oxford, Oxford University Press.
- Deomampo, N.R. 1997. Agricultural marketing systems in Asia and the Pacific region. Marketing systems for agricultural products—a seminar report. Tokyo, Asian Productivity Organization.
- Duncan, R. 1997. World food markets into the 21<sup>st</sup> century. Paper presented at the 41<sup>st</sup> Australian Agricultural and Resource Economics Society Conference, Pan Pacific Hotel, Gold Coast, Australia.
- FAO (Food and Agriculture Organization of the United Nations) 1998. Regional expert consultation on the promotion of market oriented production system report. Bangkok, Food and Agriculture Organization.
- Kainuma, K. 1999. Role of postharvest technology research for sustainable food supply. In: Postharvest technology in Asia, symposium proceedings. Japan International Research Centre for Agricultural Science (JIRCAS) and Ministry of Agriculture, Forestry and Fisheries.
- Manalili, N.M. 1998a. Development of agro-industries and rural-urban linkages in developing countries. Paper presented at the Asian Productivity Organization's Seminar on Measures for Rural Employment Generation held in Hanoi, Vietnam.
- Manalili, N.M. 1998b. Strategic alliances between small or medium scale agribusiness enterprises and large corporations. Doctoral dissertation, University of the Philippines, Diliman, Quezon City (soon to be published in the Asian Academy of Management Journal).
- Pingali, P., Hossain, M. and Gerpacio, R. 1997. Asian rice bowls—the returning crisis? Published by CAB International in association with the International Rice Research Institute.
- Satin, M. 1997. Food quality and international trade. Food and Agriculture Organization of the United Nations (FAO) Internet site: <<http://www.fao.org/waicent/faoinfo/agricult/ags/AgSI/AGSI.htm>>.
- SEARCA (SEAMEO Asian Regional Center for Graduate Study and Research in Agriculture) 1999. Terminal report—technology, trade and policy imperatives for international competitiveness in corn. College, Laguna, SEARCA.

SEARCA (South-East Asian Regional Center for Graduate Study and Research in Agriculture) and Hassall & Associates Pty Ltd 1997. Final report for All China Federation of Supply and Marketing Cooperatives (ACFSMC) Project—TA No. 2539-PRC. Unpublished report, People's Republic of China, Asian Development Bank.

Tsubota, K. 1999. Relation between postharvest technologies and economic development. In: Nawa, Y., Takagi, H., Noguchi, A. and Tsubota, K., ed., Postharvest technology in Asia—symposium proceedings. Japan International Research Centre for Agricultural Sciences (JIRCAS) and Ministry of Agriculture, Forestry and Fisheries, Japan.



# The Philippine Rice Postproduction Consortium: Needs Assessment of the Postproduction Industry

D. de Padua\*

## *Abstract*

The Philippines is a net importer of grains, but the Philippine Department of Agriculture believes the country has the resources and the capability to be self-sufficient in rice and maize to meet the needs of its increasing population. The postproduction sector—that brings the harvest from the farms to its processing plants, processes the grain and distributes the milled products to consumers—plays an important role in the country's food security program. There are many stakeholders in the rice and maize processing and marketing industry, and it is expected that they have many concerns. The International Rice Research Institute and four other government agencies have mandates in the development of the postproduction sector. These institutions have formed a consortium to work in collaboration with each other on priority projects. The issues and concerns raised in a needs assessment workshop of the consortium can be categorised as dealing with information development and dissemination, technology development, adaptation and commercialisation, policy studies and advocacy, and systems study. An indication of problems in the industry is the poor quality of milled rice produced. Grain quality is a function of many factors, but the basic technical cause of poor milled rice quality is traced to the lack of drying capability for the wet-season harvest. Providing the needed drying capacity is a complex issue that involves not only technology, but involves economic, social and political considerations which has confounded researchers for a long time.

THE PHILIPPINES has always been a net cereal grain importer, and the government's food security program's aim is "to ensure that rice and maize is available, accessible, and affordable to the people at all times". This policy has many implications. Researchers from the Philippine Rice Research Institute, however, believe that the country has what it takes to be self-sufficient in rice. From what can be gathered from the different pronouncements of government, the strategic plan is to modernise agriculture to improve farm productivity, and improve the capability of farmers to handle their harvest. The operative policy is to transform the grain industry from a resource-based to a technology-based industry. For those charged to make things happen, this is understood to mean that farm production and grain processing yields have to be increased and losses decreased in the harvesting, processing and marketing

chain of operations, through the application of locally appropriate, proven, and acceptable technologies. Where the farmers are concerned, the plan is to provide them with certified seeds, irrigation water, farm machinery, farm to market roads, and primary postharvest facilities. With regard to the last item—postharvest facilities—it has been suggested that drying service centres be provided under the management of local government units. These are public sector investments, where users will be charged fees, presumably to cover direct operating costs. The Philippine Rice Postproduction Consortium, a research group, is responding to the challenge.

The rice and maize industry scenario has changed a lot in the last three decades. Since the green revolution in the late 1960s, postproduction research was initially trying to cope first with how to handle the increased volume of farm yields under adverse weather conditions, and now the pressure is on how to improve food security—read this as the marketing functions—for an increasing population. Land reform has shifted focus on the production and postproduction needs of the

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many small farmers liberated from landlords. Farmer organisations have mushroomed and are the new clients. The cost of farm labour has increased to the point that processors see the need for increasing levels of mechanising grain handling.

The Consultative Group for International Agricultural Research (CGIAR) is the highest international body that gives policy direction and financial allocations to 16 international research centres, such as the International Rice Research Institute (IRRI) in Los Baños. In the past, postharvest or postproduction research was given low priority. In the words of a governor of the CGIAR, the grain postharvest systems were already highly developed in the developed economies, private sector research initiative has been actively pursuing opportunities, and the need was simply “the transfer of technology” from the West to Asia. The CGIAR has never been so off in its prognosis of priorities, and lately the CGIAR has directed its centres to look at the agricultural commodities as a system from the farm to the consumer’s table. At IRRI’s Agricultural Engineering Division, postproduction research has been revitalised.

IRRI does its work in collaboration with the National Agricultural Research System, and so colleagues in the industry and stakeholders were invited to discuss postproduction problems and priorities. Many problem issues and constraints were raised by interest groups and are summarised below.

## **Needs Assessment: Issues and Concerns**

### **Farmers and farmer groups (cooperatives)**

- The lack of access to information vis-à-vis new technology, due to limited sources of information, lack of extension material or qualified extension officers.
- The lack of knowledge in choosing new and appropriate technology, foisted on them by government, e.g. mechanical dryers.
- The lack of postharvest facilities for handling wet harvest, resulting in grain quality deterioration or outright loss.
- The high investment cost (to farmers) of postproduction facilities (e.g. mechanical dryers).
- The lack of knowledge in business management by farmer groups encouraged to go into rice processing and trading.

- The lowering of the farm-gate price of paddy every time rice is imported to protect consumers.
- Increasing farm labour costs in some locations due to other employment opportunities.
- Non-payment of loans by farmers from government financing institutions leading to the suspension of access to credit, and high cost of credit from informal sources.

### **Rice processors and traders**

- No access to information on technology for upgrading processing facilities.
- Poor quality or inappropriate technology from some local sources.
- Imported technologies for drying and milling are expensive, with no after-sales service.
- Poor-quality milled rice due to poor quality palay or obsolete processing facilities.
- High cost of electric power or energy.
- High losses due to lack of drying capacity.
- Processing facilities operating below capacity.
- Plant operators have no formal training on the basic principles of rice processing.

### **Manufacturers of processing facilities**

- High cost of manufacturing; high cost of raw materials.
- Poor quality or obsolete manufacturing tools and equipment.
- Low impact of research and development on the manufacturing industry.
- Government policy and programs do not support the local manufacturing sector.
- No engineering design capability for postharvest equipment. (Reference made to drying equipment.)

### **Research and development**

- Lack of research funds.
- Lack of understanding of industry needs; fragmented approach.
- Lack of research focus on priorities.
- Lack of participation of end users.
- Too much research not adopted or has no relevance to industry; inappropriate designs.
- No understanding of implications of small farm production to the processing and trading sector.
- Insistence on farm drying where palay traders and millers have taken over the responsibility for drying.

- No quantification of benefits of the use of mechanical dryers.
- Loss assessment studies have not captured the real losses due to the lack of drying capacity or due to antiquated facilities.
- No understanding of the technology requirements of grain handling and storage in tropical climates.
- No local design standards.
- Designs not globally competitive.
- No protection for intellectual property rights.

### **Extension and training**

- No information on tested technologies.
- No proper evaluation of technologies before they are promoted.
- Researchers acting as extension agents for their own designs.
- No extension capability at the local government levels.

### **Government programs and policy**

- Policy on rice importation: consumer protection versus farmer support.
- Tariff on raw materials higher than finished products.
- Public sector investment for postharvest facilities is undefined.
- No program on industry development for the private sector.
- No technology assistance provided to private sector processing industry.
- Continuing 'life support systems' for not viable or unsustainable cooperatives in rice processing and trading.

In summary, the response to all these needs may be categorised under (1) information synthesis and dissemination; (2) appropriate technology development or adaptation; (3) policy research and advocacy; and (4) systems study. The issues are varied and require multidisciplinary and multi-sectoral collaboration.

### **Public Institutions Involved in Postproduction Systems**

There are many agencies of government mandated to look after the health and welfare of the different sectors of the rice industry. The National Food Authority has the most comprehensive responsibility to support the farmers in the marketing of their produce, of protecting the consumers, and are also

charged with the responsibility of regulation and development of the rice processing and trading sector. The Bureau of Postharvest Research and Extension of the Department of Agriculture has taken upon itself to look after the postharvest technology requirements of farmer-based cooperatives. The Philippine Rice Research Institute has focused on the postharvest requirements of farmers. Academe-based researchers, such as those at the University of the Philippines Los Baños have been looking at the more basic, theoretical aspects. IRRI Agricultural Engineering Division focused on technology hardware development in the past, but has now expanded its work to include post-production systems research, with emphasis on analysis of systems as they relate to improving grain quality. It became very clear that if we had to make headway in the development of the grain postproduction industry, the five agencies had to collaborate with each other, lending each other their expertise and field experience. Thus was born the Philippines Rice Postproduction Consortium. The collaboration has been formalised with a Memorandum of Agreement between the agencies involved. The Consortium meets quarterly to report and review progress of work taken on by the different agencies.

### **Reports of Consortium Institutions on Current Postproduction System Activities**

A peer review of the activities of the different agencies was undertaken. The different agencies have not been lacking in activities.

#### **Bureau of Postharvest Research and Extension (BPRE)**

- Design and development of a high-temperature fluidised bed dryer.
- Industrial utilisation of by-products: rice hull and straw.
- Advanced systems: development of a computer-aided management tool for bulk storage systems.
- Establishment of an electronic trading information system.
- Development of controlled atmosphere storage technology for prolonging the storage life of 18% moisture content paddy.
- Assistance to three pilot cooperatives, by providing BPRE-trained managers.

- Technical assistance to the rice industry:
  - distribution of paddy moisture meters
  - promotion of Volcani cubes storage technology
  - promotion of in-store drying technology
  - review of postharvest proposals of local governments
  - assistance to local governments in postproduction systems projects.
- Software development: decision support system in drying and pest management in storage.
- Impact assessment of postharvest facilities distributed to farmer cooperatives.

### **University of the Philippines at Los Baños/College of Engineering and Agro-industrial Technology/Agricultural Processing Engineering and Processing (AGPET)**

- Design and development of a recirculating dryer.
- Design and development of a three-stage, high-temperature dryer.
- Resistance to airflow of local paddy varieties.
- Adsorption drying with rice hull.
- Improving eating quality of rice with pandan leaves.
- Improving head rice recovery through cooling in the polishing stages.
- Testing and evaluation of the rice hull furnace.
- Optimisation of the rice-drying process.
- Utilisation of rice bran for feed formulations.

### **National Food Authority-Technology Resource Department (TRD)**

- Milled rice mist polishing studies: for improvement in appearance and monitoring of quality in storage.
- Evaluation of the double-pass mist polisher.
- Pile (paddy and rice in bags) control system for inventory control and liquidation.
- Evaluation of plastic pallets with respect to preventing insect infestation.
- Validation of feasibility of Volcani cube technology.
- Evaluation of recommended fumigants for pest control in storage.
- Evaluation of sealed enclosure fumigation storage technology (SEFUST) (controlled atmosphere storage technology—CAST) technology.
- Evaluation of organoleptic properties and preservation of packaged milled rice.

- Design and development of receiving tanks for recirculating dryers.
- Evaluation of the effect of insulating liners for roofs of warehouses in minimising stock deterioration.
- Evaluation of gamma irradiation technology of rice for insect disinfestation.
- Evaluation of moisture meters for milled rice.
- Review and revision of Philippine Grades and Standards for Palay and Milled Rice.
- Upgrading of rice milling facilities.

### **Philippine Rice Research Institute**

- Evaluation of harvesting technology:
  - stripper gatherer
  - LS 600 stripper harvester
  - LS 120 stripper harvester
  - rotary reaper
  - combine harvesters.
- Evaluation and promotion of farm drying technology:
  - Vietnam model flat-bed dryer—4, 6, 10 t capacity
  - bamboo bin dryer (Vietnam SRR dryer).
- Development of paddy grain cleaner.
- Evaluation and promotion of rice flour mill.
- Evaluation and promotion of micro-mill.
- Evaluation and promotion of Department of Science and Technology rice hull gasifier technology.
- Impact assessment studies:
  - analytical tools for grain quality evaluation
  - improvement of rice food products
  - field tests of milled rice flour for major rice products
  - determinants of grain quality.

### **IRRI Agricultural Engineering Division**

- Production of information series bulletins:
  - maintaining paddy quality in harvest operations
  - inventory and application of paddy drying technology
  - rice quality—seed to seed
  - rice quality—increasing head rice recovery by preventing fissuring
  - inventory of new rice milling technology for upgrading rice mills.
- Development and building of database on rice postharvest technology.
- Development of a decision support system package in rice production engineering.
- Development of seed processing technology.

- Research and development programs in:
  - Bangladesh—introduction of rice harvesting and processing technology
  - Bangladesh—survey of rice products and by-products utilisation among rice farming households.
- Grain quality management research:
  - harvest and quality
  - storage and discoloration
  - quality assessment of rice in the retail markets.

## Consortium Work Program

A collaborative work program for the consortium has evolved based on the identified priorities. These are:

- A continuing validation and definition of the problems of the different stakeholders to guide the research agenda of the consortium. The capability of engineering researchers to undertake needs assessment studies through a training course is being worked out with social scientists.
- Undertaking of case studies of successes and failures in the introduction or application of technologies in postproduction systems.
- The development of a computer-based databank on the different technologies available locally and abroad.
- Undertaking of studies on the basic thermodynamic properties of rice and maize to help design engineers.
- Development of information bulletins on the different technologies available to help those wishing to upgrade their processing plant or efficiency of their operations.
- Support of the National Food Authority effort in the wider use of grain standards in the trading and marketing of grain.
- Development of grain drying capability both at the farm level by farmers and processing plant level by millers.
- Support of government policy studies relevant to the development of the grain industry.

## Rice Grain Quality Assessment

The rice quality characteristics that the rice-eating countries of Asia prefer are well-formed, polished head rice that is white and translucent, and free of contaminants. The quality deviations from this are the discoloration, breakage, immature grains, pest damage, and contaminants. The cooking and eating characteristics which are inherent in the biochemical properties

of varieties differ with different cultures. Grain quality improvement in breeding, production, and processing are important in the business of rice as it increases the market potential of the rice. This is true for both domestic and export markets.

## Consumer preferences

Rice is a staple food in Southeast Asia, and the preferred rice properties depend on geographic locations and what the people are used to eating. Some cultures prefer parboiled rice, others the glutinous waxy rice, and still others, such as in the Philippines and Indonesia, serve steamed raw rice. Generally, countries that produce surpluses for export like Thailand go for 'better quality' rice even in the domestic markets. Higher income groups pay substantially higher prices for the quality characteristics they prefer. Market research indicates that in the rural areas they prefer the softer-textured rice that clumps together, while the restaurants in the urban communities prefer the fluffier rice. This kind of information is important to processors and traders finding niches for their products.

## Inherent varietal characteristics

Grain quality is many things to different people, but mostly 'the proof of the pudding is in the eating'. It is not unusual for farmers in the Philippines to plant a portion of their farms to traditional varieties they are used to eating for their own household consumption and the rest to modern varieties. Commercial farmers look for varieties that yield not only higher for their farming conditions, but varieties that will also sell at higher prices. Varieties that have established a 'good quality' reputation in the markets command significantly higher prices, to the point that a certain amount of mislabelling is practised by unscrupulous farmers and traders. IR64, a long grain rice that is soft and moist when freshly cooked, is preferred by many in the Philippine market, and sells 2 to 4 pesos higher per kilogram. This kind of information is generated too by market research.

## Head rice recovery

Grain quality is an economic measure. Like all the good things in life, quality has a cost. Milled rice that is referred to as 'better quality rice' in the market is very much a subjective judgement. Rice retail marketing does not as yet follow any set of grades and

standards. In general, however, milled rice with a high percentage of head rice, or few broken grains, is preferred in the higher end markets. The cooking and eating quality is reported by Japanese researchers to be affected by grain breakage. Head rice sells at premium prices, while the broken grains sell at about half the premium price. Maximising head rice recovery starts at the farm, and all the technologies in the chain of processing operations can affect positively or negatively the head rice recovery. Fissuring due to mechanical stresses, fissuring during the drying process, and breakage during milling have not been fully explored by researchers for different cultivars.

### **Grain discoloration**

Discoloration of grain from its natural translucent white colour is known to be caused by postharvest conditions. Delay in drying wet harvest is observed to result in a general darkening of the starchy endosperm and erroneously referred to as fermented rice in the Philippines. Cereal chemists explain the discoloration as due to staining of the starchy endosperm by the rice bran and husk. Yellow kernels are attributed to heat and mould damage. It has been shown that field stacking overnight of unthreshed grain results in heat build-up, resulting in yellow kernels. 'Hot spots' in storage induced by insect infestation and subsequent moisture migration, also explain discoloration of grain in storage. Discoloured grains are considered damaged grain and severely discounted in the markets. The true nature and specific environmental limits for grain discoloration have not been established.

### **Damaged grain**

The rice kernel can be damaged in the field during the production stage resulting in immature kernels, half-filled grains, or formation of chalky belly grains. In the processing and storage plants, insect pests also inflict damage to the grain. Weed seeds, small stones, and other foreign matter that cannot be readily removed reduce the quality assessment of milled rice. Technologies have not been developed to completely separate the damaged grain and contaminants. Processors employ a platoon of women facing belt conveyors to manually sort out the damaged grain.

### **Incentives for grain quality improvement**

Economic incentive or increased profitability to a stakeholder is the driving force for grain quality improvement. For example, drying is a key operation for maintaining quality of paddy. In some instances farmers do not realise any benefit from investing or even using a mechanical drying facility, but millers do. It pays for millers to invest in a drying facility. An economic analysis of paddy and milled rice trading might show who benefits most, aside from society in general, in a rice grain quality improvement program.

### **Public Sector Investment in Grain Dryers**

Many of the issues and concerns raised are related to drying of the wet harvest. Rice and maize have to be harvested as soon as they reach maturity to prevent field losses. The high moisture harvest has to be stabilised to prevent bio-deterioration. Drying of the harvested grain is the key technology for preservation. The harvested grain can either be dried at the farm level by farmers or farmer groups, or at the mill level by processors. The traditional method is sun-drying, but increased yields and double cropping where harvest coincides with the rainy season has accentuated the need for more reliable mechanical dryers.

Paddy drying is a critical operation that has to be done in a timely fashion to minimise losses, and done properly to prevent damage to the milling quality. Postharvest losses that are normally attributed to drying are in the order of 5% of the crop yield. These are due to spillage, or a reduction in milling yields due to grain breakage. The loss due to sprouting, rotting, or qualitative loss due to lack of drying capacity are unaccounted for.

Since the introduction of higher yielding varieties in 1964, the demand for appropriate drying technology was identified and has increased. There are two system types—one category is for farm-level drying by farmers or farmer groups, and the other category is plant-level drying by rice millers or traders. There are about 25 dryer models that have been introduced in the country. Out of this number of designs only 3 or 4 have the potential to be adapted and adopted. These are all heated-air, forced-convection systems.

National Food Authority (NFA) statistics indicate that despite all these designs, our mechanical drying capacity is only for about 10% of production. Government has

pursued many schemes to provide drying capacity to farmers. NFA provides incentives to farmers to dry their harvest for delivery to NFA. The Department of Agriculture has also directed the distribution of mechanical grain dryers to farmer cooperatives. This refers to the mechanical flash dryers of BPRE. Reports in an e-mail conference in 1997 indicated that the recipients, for various technical and economic reasons, were not using these dryers.

An NFA internal report indicates that 600 million Philippine pesos—proceeds of the 1993 Thailand rice importation—was authorised for the purchase and distribution of some 830 mechanical flash dryers, 670 multipurpose drying pavements, and other postharvest facilities. A monitoring report indicates that “several mechanical dryers were non-operational from the time of award due to manufacturing defects”. A more formal survey indicated that 47% of respondents were not satisfied with the mechanical flash dryer, noting that they preferred a dryer that could dry their palay down to 14% moisture, while 38% indicated they were satisfied with their mechanical flash dryers. Others indicated they preferred the use of a multipurpose pavement (for drying). The majority of respondents observed that the dryer’s capacity is not large enough to handle the volume of palay of the cooperative. On the positive side, the dryer provided employment to some, and others claim having reduced postharvest losses. Some indicated good drying results, while others indicated uneven drying, discoloration of grain, and grain breakage when milled. No additional income realised was also reported because of the high cost of operating the dryers. In general, a reading of the report gives the impression that the mechanical flash dryer has an inherent design limitation, quality of manufacture was defective in some instances, and the program implementation procedure was found wanting.

Grain drying remains a key problem of the industry, and the Consortium is studying how to provide the needed grain drying capacity in support of the food security program of government. Naturally, we were interested to obtain a deeper understanding of the flash dryer story, first hand. Our findings are summarised below and confirm the NFA statistical survey.

1. The flash dryer was designed as a first-stage dryer to skin dry palay, for a second-stage in-storage drying system. It was therefore designed to dry the grain to 18% moisture content (MC). The flash dryers were distributed without the second-stage system, and most of the farmers interviewed did not comprehend why, with the

flash dryer, they had to sun-dry a second time before it could be milled. Forcing the flash dryer to dry to 14% MC resulted in heavy grain breakage, because of the high operating temperature, and this further aggravated the farmers’ dislike for the flash dryer.

2. The farmers only used the flash dryer in a typhoon situation when there were endless days of rain, and their grain was in danger of souring. They preferred sun-drying if the option was possible. It cost them 4–5 pesos/44 kg sack to dry, while it costs 25–30 pesos per sack to use the flash dryer, because of gasoline and kerosene costs. In some instances where a cooperative would handle some 2,000 bags of grain in a season, only about 50 to 200 bags were reported to have been dried using the flash dryer. It might be noted that the grain dried with the flash dryer might have otherwise been lost due to spoilage—representing 2.5–10%.
3. The batch capacity of the flash dryer per load is 10 bags (44 kg), which takes about 3 hours to skin dry. In a 24 hour day, only 6 batches could be skin dried, or 60 bags. A typical cooperative handles 100 to 200 bags a day for its members, and they find the dryer capacity too small for their requirements.
4. Farmers’ cooperatives are basically farm production cooperatives. The cooperatives provide the farmers with production loans, which they repay in kind. The cooperative in turn cleans, dries, and stores the palay delivered as payment for their loans by the farmers, and later sells the palay to millers with a slight mark-up. There is a definite need for mechanical grain dryers to allow farmer groups to dry their harvest, particularly during the monsoon harvest season.
5. It may be impossible to compete with sun-drying cost-wise, and while the farmers do not directly realise the benefits of improved grain quality with proper mechanical dryers, consumers benefit with better grain quality. Millers, however, pay discounted prices for palay that is damaged due to delayed or improper drying, or better prices for good quality palay.
6. Despite the minimal usage of the flash dryer, since it was given to them by government for free, most of the farmers interviewed were happy to keep the dryer as insurance for their wet harvest in case of prolonged rainy days.

## Batch recirculating dryers

For the private millers, the most popular dryers are now sourced from Taiwan, Korea, and Japan. These are 6 t batch recirculating dryers. They cost about half a million pesos each, delivered and installed. Users applaud its simplicity, performance, and automated features. They are, however, flimsy in structure and estimated to have a serviceable life of only two years. There is no local comparable technology. The local manufacturing industry that manufactures the heavier, higher capacity, and more expensive drying systems have taken notice.

## Consortium and Private Sector Collaboration

The Metals Industry Association of the Philippines (MIAP)—a private sector association of industrial manufacturers—has come forward to claim that they can manufacture batch recirculating grain dryers that

the industry needs, produce them cheaper and of better quality, and provide the after-sales service needed. Providing the drying capacity for 50% of production, and putting the needed grain dryers in place is worth 3 billion pesos. A local dryer-manufacturing program could provide employment to thousands of skilled metal workers, and boost local research and the service industry. The manufacturers, however, bewail the government policy that favours importation of finished agricultural equipment. Imported agricultural equipment, including dryers, are taxed 3%, while raw materials used by manufacturers are taxed 7–10%.

Given the technical capability of our manufacturing sector, the Consortium has therefore undertaken a dryer design program for local manufacturing in collaboration with MIAP.

## Drying Systems

The Consortium has identified four categories of drying systems for different levels of application.

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### System 1

Target users	Individual farmers
Drying capacity range	0.5–2 t/batch
Technologies	Low-cost modified SRR dryer, 0.5 t batch capacity Flatbed dryer, 1–2 t batch capacity
Optional items	Platform scale Moisture meter, portable Grain cleaner, sifter with aspirator Prefabricated working shed

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### System 2

Target users	Farmer groups Primary cooperatives Local government unit service centres
Drying capacity range	2–8 t/batch, (4–16 t/day)
Candidate technologies	Flatbed dryer: 2, 4, 6 t/batch Batch recirculating dryer: 4, 6 t/batch
Optional items	Rice husk furnace Platform scale Moisture meter Grain cleaner Prefabricated working shed

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<b>System 3</b>	
Target users	Local government unit service centres Farmer Federation of Cooperatives Small to medium scale millers with 2 t/h mills
Drying capacity range	10–30 t/day
Candidate technologies	Batch recirculating dryer: 4, 6, 8, 12 t Two-stage dryer: redesigned flash dryer, in-store bin dryer
Optional items	Rice husk furnace Wet grain holding bins, aerated Insulated outdoor silos for dried grain Platform scale Truck scale Moisture meter Prefabricated service building
<b>System 4</b>	
Target users	Large-scale commercial millers, 8 t/h mills
Drying capacity range	20–100 t/day
Candidate technologies	Batch recirculating dryer: 12, 20 t LSU multistage continuous flow dryer, 2–4 t/h Two-stage dryer: fluidised bed dryer in-store silo dryer
Complementary technologies	Truck scale Palay cleaner Aerated wet palay storage Insulated dried palay storage silos In-line auto weighers Unloading bin Prefabricated drying plant building

Each system is envisioned to be a complete set of technologies to receive wet grain of at least four different varieties, clean, dry, and bulk-store dried palay efficiently at the lowest cost possible. The design team of the Consortium is composed of design engineers from all the agencies who were detailed at IRRI.

The Metal Industry Association of the Philippines (MIAP) is committed to manufacture prototype units for extensive technical performance testing. The Department of Agriculture has indicated interest in funding the setting up of prototype systems for commercial testing, before MIAP goes into mass production.

### **Lessons Learned by the Philippine Rice Postproduction Consortium**

There is strong interest and motivation within the Consortium to pursue its projects, and the mother agencies are strongly supporting their participation. The Consortium provides an interactive collaboration that shares the rich experience of everyone. There are lessons that have been learned in this partnership of institutions.

1. The rice industry engages hundreds of thousands of small farmers, processors, and entrepreneurs. They represent a political force that cannot be ignored by government.

They have many social problems, which are the responsibility of government. Thus any government program mandated to provide the rice industry with the technologies needed has to contend with the political and social realities of the local rice industry.

2. Farmers, the traders and processors, and the consumers view grain quality differently. Farmers naturally want higher yields and disease resistant varieties. Processors want higher milling recoveries. Consumers want varieties to which they are accustomed. Rice trading has to be market-oriented, and market orientation requires backward linkages all the way to the farmer. Grain quality, therefore, requires a systems orientation.

3. Technology has to be appropriate to the social structure of the end user, must have a strong foundation in science, and yet must be cost-competitive. Requirements for the acceptance and utilisation of technology—particularly by the farmers—must demonstrate an added economic benefit to them, must help them handle a biological product prone to deterioration, and must meet the volumes of product handled. Usually, to be able to cover all these bases, researchers must establish a strong participation or consultative process with the farmers.

There will be many more lessons to be learned in working with the rice industry and with each other in the Consortium.

# The Role of Quality Assurance in the Pooled Marketing of Horticultural Produce from Smallholders

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## Abstract

In the Philippines, most horticultural crops are raised by a single grower, in an area averaging 0.5–1 ha. As a consequence, the volume of the produce is small and its quality is variable. Non-uniformity of produce could be a result of: non-certified planting materials; inappropriate cultural techniques; or unsatisfactory handling by the grower. Moreover, traders dealing with produce from small farms try to cut costs to the extent of sacrificing quality. One big concern is that most growers have no identified market before planting. Thus, there is no clear definition of the market quality requirements.

Through their research experiences, the Postharvest Horticulture Training and Research Center (PHTRC) has underscored the role of the people, product and operations in defining product quality. Even if technological interventions are in place, quality assurance will not be realised if one element is missing. This paper illustrates the observations that quality assurance can be incorporated into the pooled marketing of fruits, vegetables and cut flowers from smallholders.

QUALITY ASSURANCE (QA) is when a customer can buy a product with confidence that the product will meet his or her expectations. QA, however, is easier to achieve in non-biological products such as appliances, cars, computers and the like. A control in the process itself effects acceptable quality. In contrast, QA in biological products, such as fruits, vegetables and cut flowers, is harder to attain. This is because we are dealing with a live specimen which may have experienced a range of environmental conditions during the growing period. Food reserves accumulated during this period are used to retain the freshness and wholesomeness of the produce after harvest. Improper post-harvest handling can cause injuries to produce, leading to early deterioration.

QA in biological produce begins with the choice of variety to be planted. Its quality in terms of visual,

textural, flavour and nutritional factors must be considered. QA should be market-driven rather than production-driven. It must answer the following: What do customers want? How much are they willing to pay for a particular product? If the volume required can be delivered with acceptable quality, given the right price at the right time, then it can be said that QA has been attained.

This paper illustrates that QA can be incorporated in the pooled marketing of fruits, vegetables and cut flowers from smallholders.

## The Elements of Quality Assurance

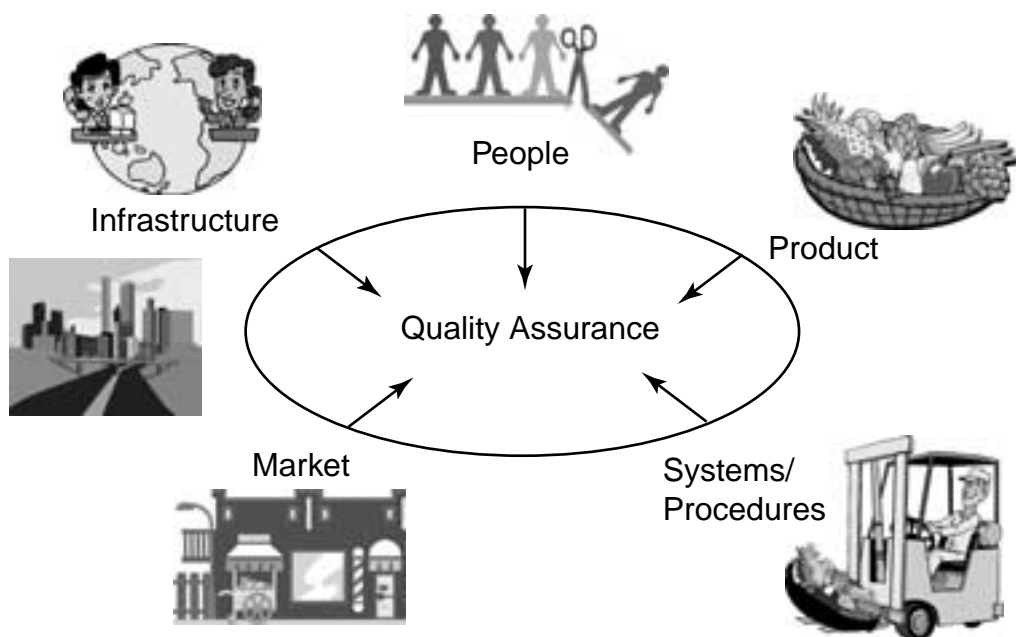
The successful implementation of a quality assurance program involves a planned and systematic integration of the people, produce, systems/procedures, market and infrastructure (Figure 1).

A critical factor to assure the quality of agricultural produce is the availability of infrastructure such as irrigation, farm-to-market access, an efficient communication system, functional postharvest facilities and equipment etc.

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**Figure 1.** Quality assurance: a planned and systematic integration of a number of elements.

Another element of QA is the produce or commodity itself. The unique characteristics of biological produce can affect the operations of buyers (Sandoval 1983). These include: the seasonal nature and perishability of horticultural crops; erratic supply due to environmental risks such as El Niño, La Niña, pests and diseases; and lack of standardised produce. The present set-up, where the production of fresh horticultural crops is based on smallholders, results in variable quality, e.g. varieties planted may differ from one farm to another, and cultural management, if implemented at all, may also vary. No amount of post-harvest technology can improve the quality of harvested inferior commodities. But with less injury during handling or minimising the handling steps, shelf life could be extended. Towards this end, there is increasing awareness of the critical importance of training on proper postharvest procedures and 'getting to know' the produce for ensuring quality.

### **Smallholder Farming in the Philippines**

In the Philippines and in most developing countries, farms are backyards with an area of 0.5 to a little over 1.0 ha. Farming is a 'hand-me-down' activity for most

producers, with the tradition being to grow what was grown by one's ancestors. If ever a crop is changed, it is because someone has seen his neighbour raise and make a profit from that crop. Eventually, everyone plants the same crop during the next season, resulting in glut of produce and consequently a low price is paid for that produce. Most farmers are thus not encouraged to plant the same crop the following season, but those who stick with it are rewarded by higher profits.

Farming to many is production-driven rather than market-driven. This set-up makes it hard for the producers to cope with market demands. As a consequence, farmers become prone to the dictates of traders with respect to buying the produce at a low price. This does not encourage the farmers to produce quality goods, since all their produce will be bought at the same price, with no premium price set for good-quality produce. In other words, the farmers' concern usually ends as soon as the produce is bought from them.

### **The Grower as a Member of a Cooperative**

It is very seldom that cooperatives in the Philippines are successful and cooperatively market their

products. Firstly, the objective of joining or forming the cooperative is not based on the principle of cooperation and commitment. Seemingly, commitment follows the more popular adage of members having 'one foot in and the other foot out'. This scenario is aggravated by the fact that leadership is quite weak. In Korea, as cited by Sun-Hoon (1983), the seven elements necessary for a marketing group to be successful are:

- strong leadership from a devoted and self-sacrificing leader;
- a shared need felt by village members to improve the livelihood gained from their farms;
- mutual trust among members, who are all relatively young in age, highly educated and belong to the same family clan;
- continuing improvement in farming technology by the villages working as a group;
- rational decision-making procedures and scientific farm management planning and implementation;
- an honest and sincere trade relationship with the merchants; and
- timely support received from the district primary cooperative.

The usual practice of farmers is that they look for a market only when their crops are ready for harvest. This leaves them with only a very limited time to sell their crops. Farmers single out the market as being the problem, however they do not commit to efforts made to link them to it. Farmers need to understand that the market should be considered before planting—what do the markets/consumers want? If they can supply crops at the right time, in sufficient volumes, of acceptable quality, and at a reasonable price, then they are 'in business'.

According to the farmers, another reason why traders are buying at low prices is that farmers are not in the position to demand the price they deem reasonable. This is because they have no records as to their inputs in terms of labour, irrigation, disease control or fertilisation—thus there is no basis for saying whether a profit was made. Aside from this, price is dictated by the traders according to previous credit marketing arrangements. In addition, a trader may buy from a farmer but not pay him/her upon receipt of the produce. Delay in payment makes farmers frustrated.

Those who become successful are the private grower-entrepreneurs who serve as marketers for the small producers. They pool the produce and demand the quality required of them by their market. They can

then require that only a certain variety is to be planted with standard cultural practices and proper postharvest handling.

## **Attaining Quality of Pooled Produce: the PHTRC Experience**

The Postharvest Horticulture Training and Research Center (PHTRC) has been assisting the fresh horticultural produce industry since the unit's establishment in 1977. Sites where the PHTRC has assisted in the improvement of the postharvest systems are indicated in Figure 2.

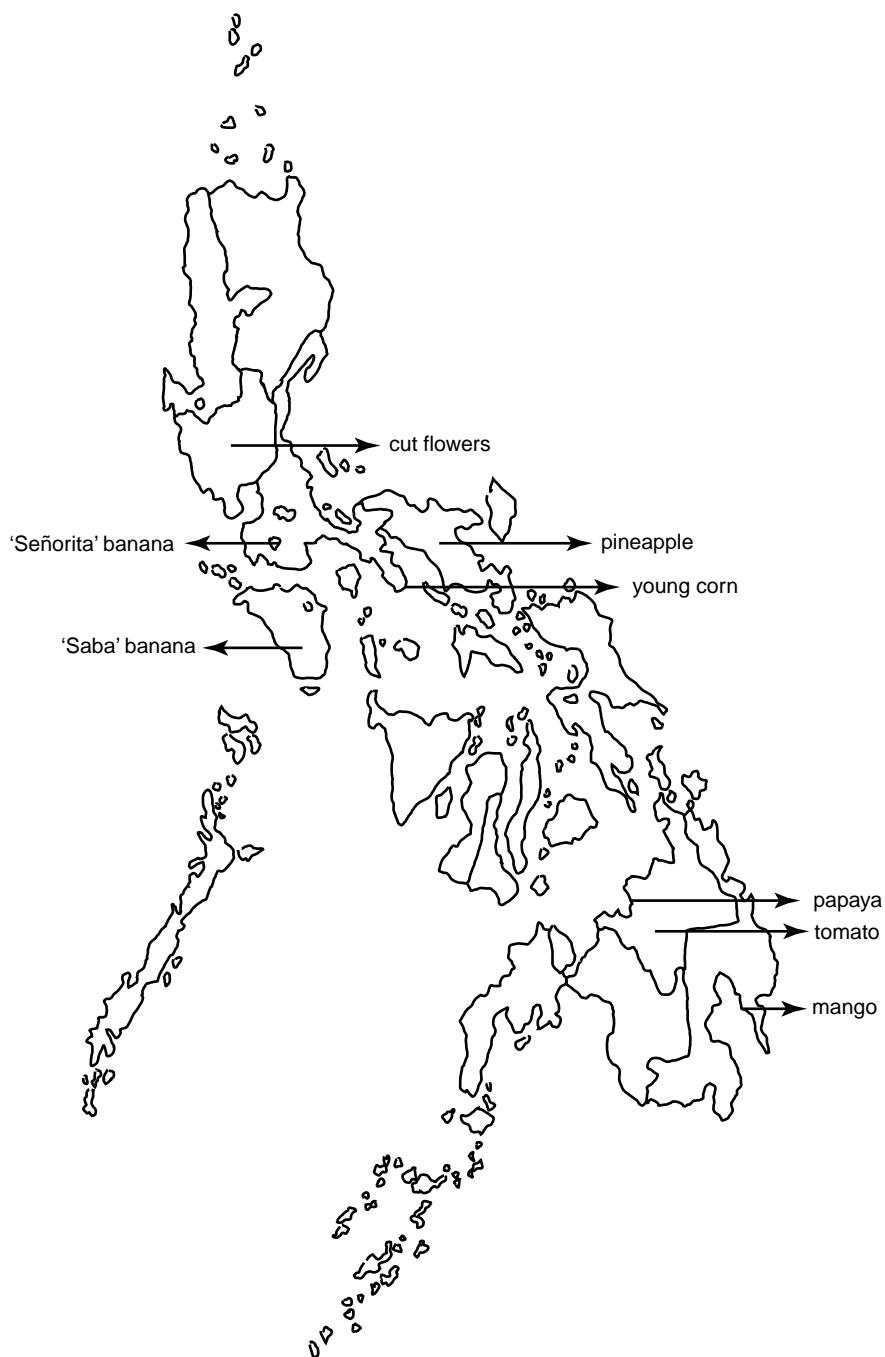
### **Papaya in Balingasag, Misamis Oriental**

'Solo' papaya is commercially cultivated in small farms in the southern islands of the Philippines, particularly Mindanao. This area is free of the papaya ring spot virus, a disease that devastated the papaya farms in Luzon.

Earlier loss assessment studies conducted by PHTRC showed that with the traditional handling of papaya coming from Mindanao and marketed in Manila, losses of 40% were usually incurred. Reasons for rejection included compression, diseases, 'ever-green' fruits, and over-ripening. With PHTRC interventions, such as improving the handling system and establishing a packinghouse where pooled produce is prepared for marketing by small grower cooperatives, losses have been substantially reduced from 40 to 14%. The wholesaler from Manila who buys the cooperative's produce no longer re-sorts the fruit prior to retail.

### **'Queen' pineapple in Camarines Norte**

This variety of pineapple is grown on small farms under coconut trees, particularly in Camarines Norte. About 3,000 ha are devoted to this crop with a fruit yield of 45,000 t. Based on farm and market visits, the problems aired by pineapple growers in the area included: lack of finances to buy inputs, lack of production technologies, the short shelf life of pineapple, lack of postharvest technologies, lack of processing technologies, low buying prices, no product standards, lack of market outlets, low consumer demand, lack of storage facilities, production area far from urban centres, fruit too small for a family of five, difficulty in removing the fruit peel, and lack of a way to determine the presence of brown spot at the core without opening the fruit.



**Figure 2.** Some of the sites in the Philippines where the Postharvest Horticulture Training and Research Center, University of the Philippines at Los Baños, has assisted in the improvement of the postharvest systems for various commodities.

With the traditional handling of pineapple, 10% of the produce was wasted during transport due to mechanical damage and over-ripening, 20–30% because of diseases and over-ripening in storage, and 28–40% during marketing when fruit were not immediately sold and subsequently deteriorated.

The following postharvest interventions were implemented for the improvement of the handling system: establishment of appropriate maturity indices for both fresh and minimally processed fruit; development of a wax formulation for the ‘Queen’ pineapple to prolong its shelf life (Serrano 1994, unpublished report); establishment of a packinghouse; and modification of the transport vehicles (provision of horizontal dividers to minimise transport-related mechanical damage).

The pineapple growers were linked with wholesalers and retailers in Manila and Lucena. They now constitute regular market outlets for the fresh fruit.

### **Cut flowers in La Trinidad, Benguet**

The traditional handling of cut flowers from Benguet is rather crude. Harvested roses are dumped on the ground in make-shift packinghouses, pre-cooled by applying water directly to the pile of stems while still on the ground, then trimmed and packed in used wholesale cigarette carton boxes which hold about 30 bundles. In the cartons, bundles of roses are arranged without any liners or sleeving materials. The flowers are all in direct contact with one another. Cartons are loaded into non-air-conditioned buses or trucks and transported to Manila—a distance of 260 km.

The postharvest intervention suggested by PHTRC and now practised by grower-traders is the use of sleeving materials to protect bundled roses during transport. Sleeving is done by wrapping bundles of approximately two dozen roses in newsprint.

### **Mango in Mati, Davao Oriental**

Although mango is an export crop, the fruit are grown mostly on small farms. The limited volume necessitates the pooling of produce for marketing. A critical component for the successful marketing of pooled produce is a system for managing quality. To provide a mechanism for ensuring uniformity of quality mango, packinghouses were established in Mati, Davao Oriental and Argao, Cebu for Menzi Farmers’ Cooperative and the Farmers’ Association

for the Rational Management of Ecological Resources, Inc. (FARMER), respectively.

The packinghouses were provided with sorting and packing tables and hot water tanks. Hot water treatment (52–55°C, 10 min) reduced postharvest disease incidence by as much as 70%. The treatment is simple, safe and environmentally friendly. The hot water treatment is thus of indispensable assistance to the mango industry.

### **Bananas in Cavite and Mindoro Oriental**

The handling of ‘Señorita’ and ‘Saba’ bananas in Cavite and Mindoro Oriental, respectively, were assessed. Both varieties were handled similarly in the two areas. Harvested bananas were dehandled and dumped onto the bare ground in the field, with or without leaves as liners, before transportation by ‘weapon’ truck or an animal-driven cart to the collection area. Counting was in multiples of five and the fruit in a hand which were in excess of these multiples were discarded in counting. Buyers also counted two small-sized fruit as a single fruit. Bulk-loading in jeeps was the mode of transport from the production area to the market. However, ‘Saba’ bananas in jeepneys<sup>1</sup> coming from Mindoro were transported by ship for about 3 hours. The jeeps containing the ‘Saba’ bananas travelled to Metro Manila markets.

Problems associated with bananas were: lack of fruit-quality consciousness among growers and traders, with the price based solely on size; and a high incidence of handling-related injuries (bruises and compression damage).

In ‘Señorita’ bananas, bagging while still on the tree was recommended for better quality produce. Adoption of the improved system resulted in superior quality fruit which were marketed in the upscale markets and fetched a premium price. It would have been a success story for the ‘Señorita’ growers today had it been that land conversions in the area were controlled. Moreover, diseases such as bunchy top virus contributed to the devastation of the farms.

In ‘Saba’ banana grown in Mindoro Oriental, training on the basic principles and use of packinghouses is being implemented in preparation for the domestic marketing of the cooperative’s produce.

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<sup>1</sup> Jeepneys are vehicles which are open at the back, used to ferry people and produce. They are unique to the Philippines.

A packinghouse with sorting tables was established for ‘Saba’ growers in Mindoro. This facilitates the quality maintenance of their produce. One activity that we find very useful is documentation of the traditional handling and practical demonstrations during training. The training serves as an opportunity to pinpoint where their handling is going wrong. With time, all the handlers of bananas will become conscious of their handling technique—with the result being fruit of acceptable quality. The overall result or impact of this training will be known as soon as commercial trials have been undertaken.

### **Tomato in Claveria, Misamis Oriental**

Over-packing of tomatoes is practiced in the south where tomatoes are sourced during the off-season in Luzon, i.e. from July to December. Over-filling wooden crates is a way of making up for damaged fruit. However, this further worsens the condition of the tomato fruit upon arrival in Manila. Losses due to cracking, abrasion, compression and diseases are common. The PHTRC demonstrated to the farmers and traders the proper way of packing. This was adopted for some time before they shifted back to their old ways.

### **Baby corn in Sariaya, Quezon**

Contract growing of young corn was done by a private entrepreneur. Assistance was sought from the PHTRC regarding proper market preparation. Shelves and sorting tables with magnifying lens were recommended. This helped in complying with the quality requirements of the importing country. However, the growers were lured by the price offered by another entrepreneur for the domestic market to the detriment of the first. Consequently, the exporter was not able to supply his clientele, leading to the closure of his deal. Farmers only sold to the other trader for a ‘fleeting moment’. When this type of ‘pole vaulting’ occurs it ruins the relationship between the farmers and the entrepreneur, as trust is lost. This spreads very quickly, leaving everyone as ‘victims’ of a closed shop. If growers would really aim for a long-term relationship with the market rather than a one-shot bigger profit, the situation would be more stable. If we work on quality before profit—then profit automatically follows.

## **Important Lessons Learned**

- In the Philippine setting, it is better to be reactive rather than pro-active in the field of postharvest horticulture. This way, the technical assistance extended will not go to waste.
- However, in some cases, such as at piers and ports, being pro-active is much more effective as the people otherwise have no information on how to handle produce properly.
- It is the private sector/entrepreneur who makes full use of our (PHTRC) expertise.
- With most cooperatives experiencing a range of problems, technical expertise is generally not fully utilised. There are, however, a few success stories.
- In almost all activities involving the producer cooperatives, the most frequently cited problem is the market.
- However, efforts to link cooperatives with the market are not always fruitful. The reason is that producers cannot deliver the required quality or volume of the produce at the right time.
- No amount of postharvest technologies can improve the quality of the produce after harvest.
- Rough roads from the production areas to the packinghouse (if any) or market contribute to the poor quality of produce.
- Awareness training on the proper handling of the produce is very important among the growers, handlers and consumers.
- Values, attitudes and culture in general add to the constraints in producing acceptable quality in produce. However, the PHTRC experience has shown that the provision of entrepreneurial skills is fundamental.
- Local government units must be involved to ensure continuity of projects.

Although we at the PHTRC are aware that being reactive in this endeavour produces better results, we see the need to be pro-active through awareness training. This not only informs all concerned in the postharvest chain of the basic principles on the handling of horticultural crops, but develops in them a culture of quality. Lastly, the desired quality can be attained if each and every person involved becomes conscious and put efforts to attain it.

*Quality only happens when you care enough to do your best.*



## References

- Sandoval, P. 1983. Fruit/vegetable marketing development in the Philippines. In: Proceedings of an international seminar on producer-oriented marketing: strategies and programs, Seoul, Korea. Food and Fertilizer Technology Center for the Asian and Pacific Region, 41–59.
- Sun-Hoon, K. 1983. The HA-EE village crop unit: a case study of a successful farmers' cooperative in Korea. In: Proceedings of an international seminar on producer-oriented marketing: strategies and programs, Seoul, Korea. Food and Fertilizer Technology Center for the Asian and Pacific Region, 130–142.

# Impact Assessment of Utilisation of an Improved Maize Sheller in Three Major Maize-producing Provinces in the Philippines

R.P. Estigoy\*

## *Abstract*

This study was conducted to assess the consequences or effects of grain postharvest technology utilisation at the end-user level in three major maize-producing provinces in the Philippines. Specifically, a number of variables—personal, social, physico-economic, attributes of the improved maize sheller (IMS), and technology transfer—were related to the use of this technology. It likewise determined the effects of utilisation on the technological, socioeconomic and institutional milieus of IMS users.

Respondents to this study were composed of 169 IMS users from Bukidnon, Cotabato and Lanao del Sur. Data were gathered through the use of an interview schedule.

Correlation analysis showed that both training through an agricultural program and membership of an organisation were significantly and highly significantly related to levels of IMS utilisation, respectively. Infrastructure, especially accessibility of roads, was also found to be significantly correlated with utilisation, as were technical, social, ecological and educational attributes.

Multiple regression analysis showed that the following are determinants or predictors of IMS utilisation: accessibility of roads; mobility of the sheller; and the availability of the IMS and its spare parts in the market. These factors can therefore predict utilisation of the IMS at the farm-level.

Z-tests and t-tests revealed that IMS utilisation had impacted positively on the technological (quality of shelled maize, efficiency and shelling time), socioeconomic (income, shelling costs) and institutional (harvesting payment, shelling payment and shelling location) milieus of the end users. Also, cultural management in maize production, such as land preparation, drying practice, storage practice and harvesting practice were also modified and changed significantly by the use of the IMS.

ONE OF the most important means of accelerating rural development in agricultural economies like the Philippines is the adoption of new agricultural technologies by the farming sector. Adoption and eventual diffusion of these technologies can lead to higher incomes of farmer-producers, lower prices of food products, and greater economic efficiency and growth. The adoption and use of new technologies—especially research and development (R&D) results—have spurred the economic development of agriculturally based economies in the Third World.

There are two ways in which agricultural development take place, according to Valdez and Drilon (1979). Firstly, agricultural development takes place when there is an increased use of new inputs like fertilisers, improved seeds, pesticides, irrigation, and implements. Secondly, new and improved institutional arrangements affect such things as land tenure, agricultural credit, inputs and product markets, public safety, and the generation and dissemination of technical knowledge, extension services, price supports, crop insurance and government subsidies. Another avenue for agricultural development is adoption of research results by the intended users. The late J. Drilon Jr, a prominent Filipino R&D administrator, once said: “Development is research put to use, made a part of the country’s productive efforts”.

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The Bureau of Postharvest Research and Extension (BPRE), formerly the National Post-Harvest Institute for Research and Extension (NAPHIRE), shifted its focus from postharvest technology generation to research results utilisation in 1989. In doing so, BPRE aimed to have its designs and technologies reach the end users by making them available in the market. With this target, the Bureau mapped out a strategy that would serve as a linchpin between technology generation and commercialisation, and eventual utilisation—the BPRE Industrial Promotion Program (BIPP). This program involved the private sector, especially the local agricultural machinery manufacturers, in commercialising BPRE designs and making them available in the market.

In 1989, an improved maize sheller (IMS) was designed by BPRE and promoted under BIPP. This paved way for the adoption of the IMS in the major maize-producing areas of Mindanao, Philippines' southern island. The Land Bank of the Philippines initially financed multi-purpose farmers' cooperatives to purchase 20 IMSs. The wide use of new sheller was also attributed to the presence of a IMS manufacturer based in Mindanao. As a result of these factors, there are already over a hundred IMS units used by cooperatives and farmer-producers in Bukidnon and the neighbouring provinces of Lanao del Sur and North Cotabato. The IMS won the Best Technology for Commercialisation Award given by the Department of Science and Technology in 1995.

Five years after the introduction of the IMS, there is a need to assess its effects on the agricultural sector, particularly on the farm-level users. It is also worth assessing the contribution of this new technology to the maize industry and to agricultural development in general.

## Objectives of the Study

1. To describe the personal, social, and physico-economic profile of IMS users and how these relate to IMS use.
2. To determine the attributes of the IMS and components of technology transfer affecting the level of IMS use.
3. To ascertain the effects of IMS use on the technological, socioeconomic and institutional milieus of users.
4. To determine what factors predict IMS use.

## Scope and Limitations of the Study

This study covered three provinces in Mindanao—Bukidnon, Cotabato and Lanao del Sur—where utilisation of the IMS took place between 1992 and 1995. Since there was no benchmark information established before the use of the IMS, the recall method was used. Considering that farmers do not keep records of their farm activities, the recall method might not accurately reflect the information before the utilisation of the IMS or even the information after its introduction. Also, this study covered only the observable and measurable effects of utilisation on technological, socioeconomic and institutional milieus of users. Deeper and more far-reaching impacts, such as social, psychological and other possible effects or consequences, were beyond the scope of this study.

## Methodology

### Locale and respondents

The respondents of this study were the users of IMSs from Bukidnon, North Cotabato and Lanao del Sur who made use of the IMS between 1992 and 1995.

A complete list of IMS owners who purchased within this period was furnished by the local manufacturer of the shellers. 50% of these 117 owners assisted in obtaining a short list of farmer-users who would answer the survey. A proportional sampling method was used to determine the number of respondents. An interview schedule was used to gather the data. Descriptive design was used to describe the qualitative variables and correlational design was used to establish the relationships of several variables under study. Descriptive statistics were used to describe the quantitative variables, while the t-test and Z-test were used to measure the significance of variables before and after the use of the IMS. The Pearson Product-Moment Correlation coefficient and the chi-square value were used to analyse the relationship between the independent and dependent variables. Regression analysis (general linear model) was used to test predictor variables of IMS use.

### Theoretical framework

The study was based on Parson's equilibrium theory which states that when a force is impressed upon a certain system, resultant modifications will take place within that system. When a technology is introduced

into a given farming system, there will be a resultant technical and material change, with corresponding changes in attitudes, thoughts, beliefs, values and behaviours in the long run. Technology adoption brings about resultant changes in technological, social, institutional, and economic conditions of the adopters. Often, all these changes result in social change. Social change occurs when something happens either within the system or impinging upon it from without, or because a force is impressed upon it. Several factors can bring about social changes, namely, technological, industrial, economic, ideological and religious factors (Juarez 1987). In the case of the adoption and use of the IMS, the precursor of social, economic and institutional changes is technological in nature. The framework of the study is shown in Figure 1.

When the IMS was introduced and utilised, technological, socioeconomic and institutional changes took place. These changes were considered as impacts or effects of IMS adoption and use. Figure 2 shows the relationship of the different variables under study. The study hypothesised that there were no relationships between the independent variables with the dependent variables.

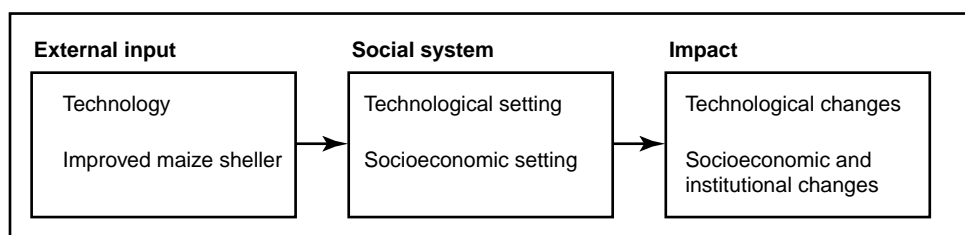
## Results and Discussion

### Personal, social and physico-economic profile of IMS users

The proportions of respondents considered to be 'young' or 'old' were similar, with a mean age of 41.3 years. 69% of IMS users were male. Almost 66% of IMS users had at least high school education, and almost one-third had reached college. The majority had no training related to maize farming and limited farming experience (Table 1).

The majority of IMS users were members of an organisation, however only 43% were involved in agricultural programs. A typical user was a member of the Roman Catholic Church and had ethnicity belonging to either Cebuano, Bukid or Ilonggo. 60% had lived in the community for a long period (Table 1).

The majority of IMS users were landowners and had bigger farm sizes compared to a typical Filipino farmer. 65% had a small household size. According to the majority of the respondents, credit was available for IMS purchase (Table 1).



**Figure 1.** Paradigm showing the process of change.

**Table 1.** Distribution of respondents according to personal characteristics.

Factors	Number of respondents	Proportion of respondents (%)	Figures for each factor
<b>Age (years)</b>			
Young	86	50.89	Mean = 41.3 s.d. <sup>a</sup> = 10.3 Range = 22.0–72.0
Old	83	49.11	
<b>Sex</b>			
Male	117	69.23	
Female	52	30.77	

**Table 1.** (Cont'd) Distribution of respondents according to personal characteristics.

Factors	Number of respondents	Proportion of respondents (%)	Figures for each factor
<b>Educational attainment</b>			
High	83	49.11	Mean = 8.2 s.d. = 5.3 Range = 1–14
Low	86	51.89	
Elementary (1–6 years)	58	34.32	
High school (7–10 years)	56	33.13	
College (11–14 years)	51	30.18	
Postgraduate (over 14 years)	4	2.37	
<b>Training</b>			
With training	75	44.38	
Without training	94	55.62	
<b>Farming/business experience</b>			
Short	96	56.80	Mean = 14.8 s.d. = 11.9 Range = 1–50
Long	73	43.20	
<b>Ethnicity</b>			
Cebuano	51	30.18	
Tagalog	1	0.59	
Ilocano	8	4.73	
Bukid	65	38.46	
Ilonggo	41	24.26	
Other	3	1.78	
<b>Religion</b>			
Roman Catholic	150	88.76	
Protestant	6	3.55	
Muslim	1	0.59	
Others	12	7.10	
<b>Years of stay in community</b>			
Short	101	59.76	Mean = 15.5 s.d. = 13.0 Range = 1–61
Long	68	40.24	
<b>Membership of an organisation</b>			
Members	110	65.09	
Non-members	59	34.91	
<b>Involvement in agricultural programs</b>			
Not involved	96	56.80	
Involved	73	43.20	

**Table 1.** (Cont'd) Distribution of respondents according to personal characteristics.

Factors	Number of respondents	Proportion of respondents (%)	Figures for each factor
<b>Tenurial status</b>			
Tenant	38	22.49	
Lease holder	19	11.24	
Share tenant	9	5.33	
Owner	103	60.94	
<b>Farm size (ha)</b>			
Small	105	62.13	Mean = 3.8
Large	64	37.87	s.d. = 3.6 Range = 1–30
<b>Household size (no. of people)</b>			
Small	110	65.09	Mean = 5.8
Large	59	34.91	s.d. = 3.6 Range = 1–30
<b>Credit</b>			
Available	121	71.60	
Not available	48	28.40	

<sup>a</sup> s.d. = standard deviation

### Attributes of the IMS and technology transfer factors

The majority of the respondents revealed that the IMS had all the technical, economic, social, educational and ecological attributes needed in a sheller. These attributes had significantly influenced the wide and massive utilisation of the IMS in the three Mindanao provinces studied.

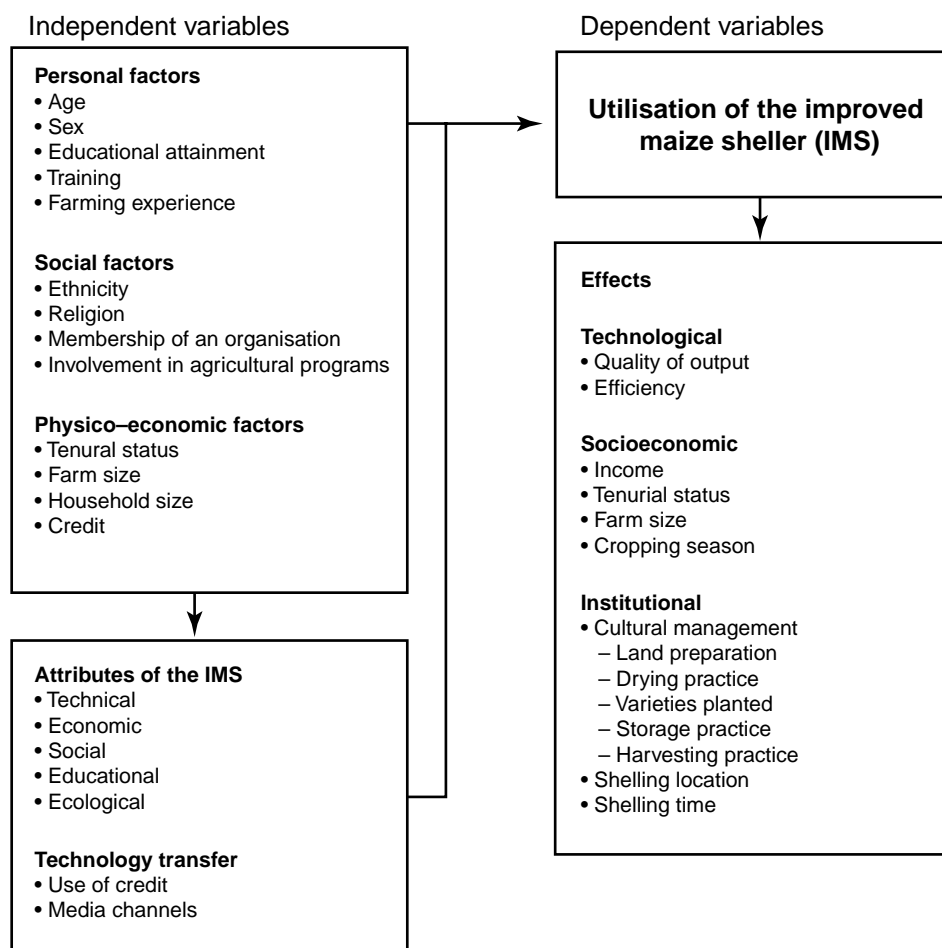
Also, the majority of respondents did not avail themselves of credit since the users relied on the custom services of the owners of IMS. 60% reported that media channels were not available for information dissemination on the IMS.

### Level of utilisation of the IMS

Determination of the level of utilisation was based on the number of times the IMS was used by the respondents. The mean level of utilisation of IMS was considered high at 5.6. This means that a typical

respondent had used the sheller more than once a year between 1992–1995 (i.e. over 4 years). The level of utilisation ranged from 1–12 times with a standard deviation of 2.3 (Table 2). Maize is planted twice a year in the areas of study. A typical IMS user can be characterised as a regular customer or sustained user who employs the services of the machine to shell his maize harvest.

Results confirm the report and observation of the IMS manufacturer that the IMS is now being widely used in the three provinces of Mindanao in this study. Some of those who purchased a unit from him in 1992 had purchased another one or two units for custom shelling. The wide utilisation of the IMS can be linked with its technical superiority—such as efficiency, quality of output, durability and capacity—over other maize shellers in the area. Other factors which contributed to the wide utilisation of the IMS include technical, economic, social, educational and ecological attributes.



**Figure 2.** Paradigm showing the relationship between the independent and dependent variables in the improved maize sheller (IMS) study.

**Table 2.** Level of utilisation of the improved maize sheller (IMS) among respondents, 1992–1995.

Level of utilisation	Number of respondents	Proportion of respondents (%)
High	149	88
Low	20	12
Mean = 5.6		
s.d. <sup>a</sup> = 2.3		
Range = 1–12		

<sup>a</sup> s.d. = standard deviation

**Personal, social, and physico-economic attributes of the IMS and technology transfer factors that affected utilisation**

Personal and social factors that affected utilisation were training and membership of an organisation (Table 3).

**Table 3.** Correlation coefficient and chi-square values between independent variables and improved maize sheller (IMS) utilisation (where \* = significant, \*\* = highly significant at the 0.05 level, and n.s. = not significant).

Factors	Correlation coefficient	Chi-square value
<b>Personal factors</b>		
Age	0.142 n.s.	
Sex	0.045 n.s.	
Educational attainment	0.020 n.s.	
Training	0.154 *	
Farming experience	0.083 n.s.	
Ethnicity		8.28 n.s.
Religion		4.70 n.s.
<b>Social factors</b>		
Membership of an organisation	-0.130 **	
Involvement in an agricultural program	0.034 n.s.	
<b>Physico-economic factors</b>		
Tenurial status		5.78 n.s.
Income	0.040 n.s.	
Farm size	0.075 n.s.	
Size of household	0.033 n.s.	
Credit	0.025 n.s.	
Infrastructure		
Farm to feeder road	0.024 n.s.	
Farm to market	0.078 n.s.	
Type of road	0.032 n.s.	
Accessibility	0.214 **	
Irrigation	0.008 n.s.	
Transportation	-0.051 n.s.	
Postharvest facilities	0.062 n.s.	
<b>Attributes of the IMS</b>		
<i>Technical</i>		
Quality of output	17.87 **	
Durability	0.96 n.s.	
<i>Economic</i>		
Profitability	2.89 n.s.	



**Table 3.** (Cont'd) Correlation coefficient and chi-square values between independent variables and improved maize sheller (IMS) utilisation (where \* = significant, \*\* = highly significant at the 0.05 level, and n.s. = not significant).

Factors	Correlation coefficient	Chi-square value
<i>Social</i>		
Mobility	5.26 n.s.	
Availability in the market	84.79 **	
Availability of spare parts	61.47 **	
Participation of children and females	80.49 **	
<i>Educational</i>		
Ease of operation	100.08 **	
Simplicity of design	4.28 n.s.	
<i>Ecological</i>		
Noise emitted	55.17 **	
Pollutants emitted	3.49 n.s.	
<b>Technology transfer</b>		
Credit availability	0.35 n.s.	
Media channels	3.91 n.s.	

Training was found to be an important factor in utilisation of the IMS. Training attended by IMS users on maize production-related courses might have emphasised the value of mechanical shelling. It corroborates with the finding of Marasigan (1977) that attendance at information gatherings was associated with adoption of recommended maize production practices.

Membership of an organisation was significantly related to IMS utilisation. The finding could be attributed to IMS owners being members of cooperatives or farmers' organisations which offered custom services to farmer-members. Often, farmer-members of the cooperative were the first to be serviced by the IMS before it could be custom-hired by the other farmers.

Among the physico-economic factors studies, accessibility of roads was significantly related to use of the IMS, probably due to the mobile nature of the sheller. If the road network going to and from the farm is not accessible, the IMS cannot reach the farmer-customer. This reduces the chance of using the IMS, resulting in a low level of use. The mobile features of the IMS enabled the owner to service areas that were remote and far-flung, provided roads were accessible.

This result is similar to that of Cruz (1981) when she noted the importance of the biophysical environment—such as physical condition of the farm, its location and ecological setting, availability of

resources, and other facilities such as roads, market, and transportation—to the adoption of an innovation.

### Technical attributes

Based on the chi-square test, the attributes of the IMS that had affected the level of utilisation were: technical attributes (quality of output); social attributes (availability in the market, availability of spare parts, and participation of children); educational attributes (ease of operation); and ecological attributes (noise emitted) (Table 3).

The quality of output of shelled maize coming from the IMS influences its level of utilisation. This finding can be attributed to the respondents' findings that the IMS has good quality output. Customers of the IMS look for this attribute when choosing which sheller to use in their operations. This finding runs parallel to the findings of other researchers that, to be acceptable to farmers, inputs must be technically effective. The level of utilisation of 5.6 times in a four-year period connotes relative advantages over other types of sheller.

Availability in the market was found to be significantly related to IMS use—the extent of IMS use increases as more IMS units are available in the market and can consequently service more customers. The clearly demonstrates the importance of having shellers available for sale in the market. The presence of

Mindanao-based manufacturers was one of the factors responsible for its wide use in the area as they assure this availability.

The availability of spare parts was also significantly related to the IMS utilisation level. This is attributed to the dependence of a machine on its breakable parts. When spare parts are available in the market, broken parts of the sheller can be replaced immediately thus maximising its level of use.

Participation of children and females also affected the level of utilisation. A highly significant relationship exists between these two variables. This means that when a technology is ‘gender friendly’, its chances of being used are greater than when the use is restricted only to males.

The social attributes of the IMS were found to be significantly related to its use at the end-user level. This confirms previous studies that show that, on the whole, agricultural innovations are accepted when they are technically and economically feasible, socio-culturally acceptable or compatible with the community’s condition.

### Educational and ecological attributes

Ease of operation affects use of the IMS. If the IMS is easy to operate and maintain, it can service more customers than a less ‘user-friendly’ machine. Noise emitted was found to have big effect on the level of use— if the operation of the sheller becomes noisy, a customer will not want to use it, not the least because of the hearing impairment it could cause.

### Factors that predict IMS utilisation

The multiple regression analysis showed that accessibility of roads and mobility of the IMS were

significant determinants of utilisation. Furthermore, the same analysis indicated that availability of the IMS in the market and availability of spare parts affected utilisation.

The better the accessibility of the road network to the end user, the higher the level of utilisation. This is attributed to the mobile feature of the IMS that requires access to road networks to be able to penetrate maize-farming areas. Mobility of the IMS was a significant predictor of utilisation since this is one of the most popular features of the machine. The mobility of the sheller enhanced effective and efficient utilisation.

Availability of the IMS in the market was a highly significant predictor of IMS utilisation and emphasises the importance of always having them available to encourage wider use. Availability of spare parts was likewise a highly significant predictor, the most probable reason being that when broken parts can be replaced immediately, utilisation is maximised as there is no time wasted in waiting for parts to arrive.

### Technological effects

The Z-tests and t-tests revealed that the quality of shelled maize significantly changed before and after utilisation (Table 4)—shelled maize quality improved after using the IMS. This result conforms with the reports of previous users that the IMS produces good-quality shelled maize. This can be attributed to the aspiration system which is a unique feature of the IMS. This system cleans shelled maize from impurities like chaff, dust and other grains. It is also now generally accepted by the National Food Authority in these areas that maize coming from these provinces is of better quality than before the massive utilisation of the IMS.

**Table 4.** Effects of utilisation of the improved maize sheller (IMS) using Z-tests and t-tests (where \* = significant, \*\* = highly significant at the 0.05 level, and n.s. = not significant).

Effect	Z-test	T-test
<b>Technological</b>		
Quality of shelled maize	1.735 *	
Efficiency	3.3959 **	
Shelling time		3.2083 **
<b>Socioeconomic</b>		
Income		4.5547**
Cropping season		0.000 n.s.
Shelling losses	-11.323 **	
Farm size		0.4452 n.s.

**Table 4.** (Cont'd) Effects of utilisation of the improved maize sheller (IMS) using Z-tests and t-tests (where \* = significant, \*\* = highly significant at the 0.05 level, and n.s. = not significant).

Effect	Z-test	T-test
<b>Institutional</b>		
Harvesting payment	6.873 **	
Shelling payment	6.227 **	
Shelling location	-9.992 **	
<b>Cultural management</b>		
Land preparation	7.566 **	
Drying practice	11.688 **	
Storage practice	10.305 **	
Harvesting practice	23.917 **	
Varieties of maize planted	1.159 n.s.	

Another effect attributed to the use of the IMS was the efficiency of the shelling operation compared to other existing shellers, particularly old models (without an aspiration system) and the traditional ones. IMS users claimed there was a marked difference (highly significant) in the efficiency of the shelling operation using the IMS compared to these other methods. This supports claims of the designer (Mañebog 1987) that the IMS has an efficiency of 99.6% when shelling ear-maize.

Similarly, shelling time was reduced significantly (highly significant) when the IMS was used. This is ascribed to the efficiency and capacity of the sheller which can produce a higher output in less time than other shellers. According to Mañebog (1987), the IMS has a capacity of 3–4 t/h, depending on the hopper type. Also, according to Mr Agapito Puerto, BPRE's accredited IMS manufacturer in Bukidnon, his commercial models come in various capacities ranging from 4–8 t/h.

This finding affirms the report of Eala and Benozza (1986) that, in an ideal sense, technology adopted by end users has direct effects, either observable and measurable, such as productivity, efficiency, improved product quality, and possibly greater revenue.

### Socioeconomic effects

The Z-tests and t-tests showed that only income and shelling losses were significantly affected by IMS utilisation. The income of IMS users registered a marked increase (highly significant) after using the IMS. Better quality output from the IMS can command a better price in the market. Also, there was an increase

in shelled maize volume as a result of better shelling recovery from the IMS, giving higher production/ha. Shelling losses were also found to have been significantly reduced, as indicated by its negative sign (Table 4), suggesting that use of the IMS incurs lower losses than other shellers. Shelling losses resulting from use of the IMS were reported by Mañebog (1987) to be minimal or nil.

These results corroborate Juarez's (1987) report that the use of mechanical rice threshers in Laguna and Iloilo had an impact on adopters, users, landless workers and the society as a whole. Impacts of her study were measured as either socioeconomic or institutional changes.

### Institutional effects

Harvesting payment was one of the institutional effects handed down by the use of IMS with a highly significant value. This means that the arrangement of paying for harvesting operations was altered by the use of the IMS. The change in shelling payment was also found to be highly significant change using the t-tests and Z-tests. The result connotes that the method of payment in shelling operation was altered by the introduction of the IMS. Before the utilisation of IMS the typical method of payment was per volume of shelled maize and payment was done in kind. However, after IMS use, payment can be either in cash or in kind depending on the customer or owner of the sheller. Similarly, shelling location was also transformed by the use of IMS, according to the results of the analysis. Before the use of the IMS, shelling generally took place off-farm, as ear-maize was hauled from the farm to stationary shellers in the town proper. However,

since the introduction of the IMS, shelling is now being done on the farm, because the sheller is mobile and can service farms with accessible road networks.

## Effects on cultural management

It was hypothesised that cultural management, such as land preparation, varieties planted, harvesting, drying, and storage practices were not significantly affected by IMS utilisation. However, the Z-test revealed that all these factors were significant, with the exception of varieties planted (Table 4):

- *Land preparation.* The usual practice of land preparation was changed to partly mechanical because of the proliferation of small-type hand tractors, thus this change was not solely attributed to the use of the IMS but to other factors affecting land preparation.
- *Drying practice.* Before introduction of the IMS, ear-maize was partially dried in the field because most shellers could not shell ear-maize with a high moisture content of 22–35%. However, partial field drying was no longer necessary after IMS utilisation as this sheller can shell ear-maize even with a relatively high moisture content. Moreover, shelled maize with high impurities must be dried immediately as the presence of impurities predisposes the grains to agents of deterioration like fungi, insects and other microorganisms. With the advent of the IMS, this practice is not necessary because IMS's output is of good quality and need not be dried immediately.
- *Harvesting practice.* Traditionally, a typical farmer had to harvest his maize crop by lot to allow for field drying and availability of shellers. After this, the harvest was hauled to the nearest stationary sheller for maize-shelling. The use of IMS has minimised the time spent drying maize before shelling. Hauling time from the farm to the nearest stations or centres is also reduced.
- *Storage practice.* Traditionally, shelled maize was stored only for a short time at farmers' warehouses for fear of contamination due to impurities. However, using the IMS allows shelled maize to be kept for longer because the risk of fungal infection is low due to the good quality of grain.

## Conclusions

1. The improved maize sheller (IMS) is now widely utilised in Bukidnon, Cotabato and Lanao del Sur because of its outstanding

features and its local manufacture. IMS users had tested the technical, economic, social, educational and ecological attributes of the sheller. The IMS was found to be better and more efficient than the existing types as well as traditional manual shelling.

2. Training and membership of organisations enhanced the IMS level of utilisation. Training is still an appropriate strategy in technology utilisation, information and education of farmers. Membership of an organisation widens the knowledge and horizons of farmers as they interact with other members.
3. Roads, as part of the physico-economic environment of the IMS users, affected the level of utilisation. This shows that infrastructure such as roads is needed in technology utilisation. Road networks open avenues for all human, technological and social development.
4. Availability of machines in the market is a predictor of IMS utilisation. This implies that technology promotion is easier if the technology is easily accessible.
5. The utilisation of the IMS has, to some extent, had effects on the technological, socioeconomic and institutional milieus of its users. From these effects, further consequences will rebound to more far-reaching impacts on the maize farming system, agricultural and rural development, and the society as a whole, as its supra system. These consequences can be felt in the long run after the technology has reached its ultimate objective of serving the greatest good for the greatest number of people.

## Recommendations

1. It is recommended that the IMS be aggressively promoted and extended to other Mindanao provinces as well as in the maize-growing areas in Visayas and Luzon. Local manufacturers must be identified, accredited and supported. Based on the results of this study, there is a strong indication that maize production in Mindanao can be mechanised.
2. A well-funded, continuous and massive IMS promotion and commercialisation must be done in the country to compensate for the amount used to generate the technology. The experiences in the three Mindanao provinces

- shed light on the usefulness of this technology. Similarly, a massive technology promotion and extension program via varied communication modalities, particularly radio, television and print media, such as posters, leaflets and flyers, and newspapers, must be pursued. In addition, an awareness campaign through demonstrations and symposia to attract cooperatives and other organised groups to invest in the IMSs must complement the multi-media approach.
3. Training of farmers in postharvest technologies is still much needed as it showed a significant relationship with the level of technology utilisation. BPRE should continue to conduct on-site or on-farm training using local or indigenous resource persons to talk on their experiences and effects of the use of the IMS. Success stories on the use of the IMS could be written as comics or other popular formats.
  4. Accessible road networks at the end-users level influenced IMS utilisation. It is therefore recommended that this complementary physical infrastructure must be in place so that technologies can reach the end users. It is imperative that technologies be introduced and acceptable to local government units and officials so they can provide the necessary environment for technologies to be utilised. Road construction opens avenues for all human and physical development.
  5. One of the major predictors of IMS utilisation was the availability of the machine in the market. It is recommended that BPRE continuously select, screen and accredit local manufacturers in each area where the IMS is introduced. They must be assisted and monitored in order to be a source of good-quality postharvest technology.
  6. The findings on the consequences or effects of technology utilisation provide guarantees to Department of Agriculture and related organisations that government research and development (R&D) programs are paying off well at the end-user level. It is thus important to disseminate these findings to the appropriate decision- or policy-makers so that agricultural policies will support increased funding for agricultural R&D and extension.
  7. Agencies of the government like the Department of Agriculture, Land Bank of the Philippines, Agricultural Credit Policy Council and related entities must continue to support the adoption of research-based technologies through credit support facilities with lesser interest rates.
  8. For further research work, the other consequences of technology utilisation like impacts, which entail more in-depth analysis, are areas worth researching. Similarly, a study on unintended consequences of technology utilisation—e.g. displacement of labour, changes to indigenous practices—would also be beneficial. This would include social, psychological and environmental consequences.

## References

- Cruz, T.S. 1981. A communication analysis of rice–fish technology dissemination and utilisation. Unpublished PhD dissertation. College, Laguna, University of the Philippines at Los Baños.
- Eala, R.C. and Benozza, B.E. 1986. Technology impact assessment. Paper presented during the region III Seminar-Workshop on technology impact assessment held at San Fernando, Pampanga, Philippines, 19–21 November 1986.
- Juares, F.S. 1987. The institutional and economic impact of mechanical rice thresher in Laguna and Iloilo, Philippines. Unpublished Masters thesis. College, Laguna, University of the Philippines at Los Baños.
- Mañebog 1987. Development and pilot testing of improved corn sheller. CLSU Muñoz, Nueva Ecija, National Post-Harvest Institute for Research and Extension (NAPHIRE).
- Marasigan, M.S. 1977. Some factors associated with the adoption of recommended corn production practices in Region XI, Philippines. Unpublished Masters thesis. College, Laguna, University of the Philippines at Los Baños.
- Valdez and Drilon, J. 1979. Economics and the small farmer technology, first edition. Ames, Iowa State University Press.

# National Postproduction Loss Assessment for Rice and Maize

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## *Abstract*

This project assessed the state and magnitude of postproduction losses in both rice and maize in the Philippines at the farmers' and traders/millers' levels of operation. Actual measurements of these losses at both on-farm and off-farm operations were made for both wet and dry cropping seasons in 13 major rice-producing regions in the country. Surveys of the farmers' and traders/millers' postproduction practices were likewise conducted in order to be able to explain the reasons behind these measured losses.

For paddy, losses from harvesting to milling averaged 14.84% with a range from 1.13 to 31.94%. The most critical operation was drying—with an average loss estimated at 4.50%, constituting about 30% of the total losses, while the next highest loss was incurred during the milling operation with an average loss of 3.10% (21% of the total losses).

These losses were compared with those measured in 1974 and in 1984, although the latter was conducted on a more limited scale. The total losses from harvesting to milling measured in 1974 averaged 23.5% with a range of 10–37%, while those measured in 1984 had an average estimated at 16% with a range of 9–23%. These results indicated declining losses attributable to advances in technologies for postproduction operations in rice and maize.

For maize, the average estimated losses for the country were 12.7% and, again, drying was the most critical among the various postproduction operations—assessed at 4.6% (constituting 37% of the total losses), followed by storage with an average of 3.1% (24% of total losses).

Based on the results of the surveys, there were a number of socioeconomic and technical factors found to have influenced the magnitudes of losses for both rice and maize.

In 1993, the Department of Agriculture implemented the Grains Production Enhancement Program (GPEP), later renamed the 'Gintong Ani' Program (which translates to 'Golden Harvest' Program). The program consisted of different aspects of the agriculture sector, one of which is postharvest, which the Bureau of Postharvest Research and Extension (BPRE), our agency, was mandated to lead. In supporting this program, BPRE conceptualised and conducted a national assessment of rice and maize postproduction losses and technologies in order to document the present rice and maize postharvest situation in the country. The project results were to serve as the basis for identifying

specific problems and solutions for increasing and sustaining grain production through the reduction of losses.

There is very little information available regarding paddy loss measurements, and consequently how much losses have been reduced with the adoption of modern postproduction technology, if any, especially by farmers.

## **Objectives**

The aim of the project was to generate a wealth of information on the state and magnitude of losses in typical rice and maize postproduction systems in the Philippines that would serve as the basis for formulating government programs and policies needed to further develop the grains postproduction sector. Moreover, the results could also serve to measure tech-

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nological deficiencies and thus provide appropriate solutions to the problems identified. Finally, the experience gained from these activities, and the national network of researchers established, could be an effective way of regularly monitoring the state and magnitude of the grains industry in terms of technologies and losses.

## Study Paradigm

Figure 1 shows the study paradigm which outlines the relationships between the inputs applied in the project with a number of processes conducted in order to attain the different expected outputs and finally their effects on the grain postharvest industry.

Inputs applied externally included activities such as networking and collaboration with the different players in the industry, the State Colleges and Universities' research and development human resources and expertise as well as some of their facilities, and the GPEP resources. With these inputs, different processes were implemented such as the benchmark surveys, measurements of quantitative and qualitative losses for rice and maize, hands-on training on project methodology, consultative meetings and workshops, monitoring visits, and the integration of the final reports from each region.

The expected outputs from these processes were: the identification and measurement of postproduction losses in each region and at the national level; the identification of postproduction systems and practices for rice and maize in each region; and the different socio-economic, technical and institutional factors that caused the postproduction losses.

The effects of all these are either short-term or long-term. The short-term effects include loss reduction recommendations, feedback/feed-forward mechanisms for the system, and support for policy formulation. The long-term effects include reduced losses, increased awareness of postproduction losses, and personal and professional benefits for the collaborators.

## Methodology

Postproduction losses were assessed at the on-farm (farmers) and off-farm (traders/millers) levels of operation for rice and maize. Actual grain losses from harvesting, piling, threshing/shelling/cleaning, drying, storage and milling operations at both levels were measured during the wet and dry cropping seasons in 1994–1995. The loss assessment studies covered 41

rice-producing municipalities in 23 provinces and 22 maize-producing municipalities in 14 provinces located in Luzon, Visayas and Mindanao. The project was undertaken in collaboration with 12 State Colleges and Universities and a Regional Field Unit of the Department of Agriculture (Region 8).

In addition to the actual loss measurements, qualitative losses were assessed through laboratory analyses of samples obtained after each postproduction operation. Field surveys of the postproduction practices and problems encountered by the farmers and traders/millers were also conducted, through personal interviews, to determine the various causes of the grain losses. Losses were assessed at each postproduction operation and the regional results were aggregated to obtain national grain loss statistics.

Figures 2 and 3 show the sampling procedures used for the laboratory analysis of paddy and milled rice and maize samples. All the grain samples taken from the field with moisture contents (MCs) above 14% were cleaned and dried in the laboratory dryers or air dried until the MC was between 13 and 14%—the safe level for storage without significant quality deterioration. Also enumerated in Figures 2 and 3 are the parameters analysed.

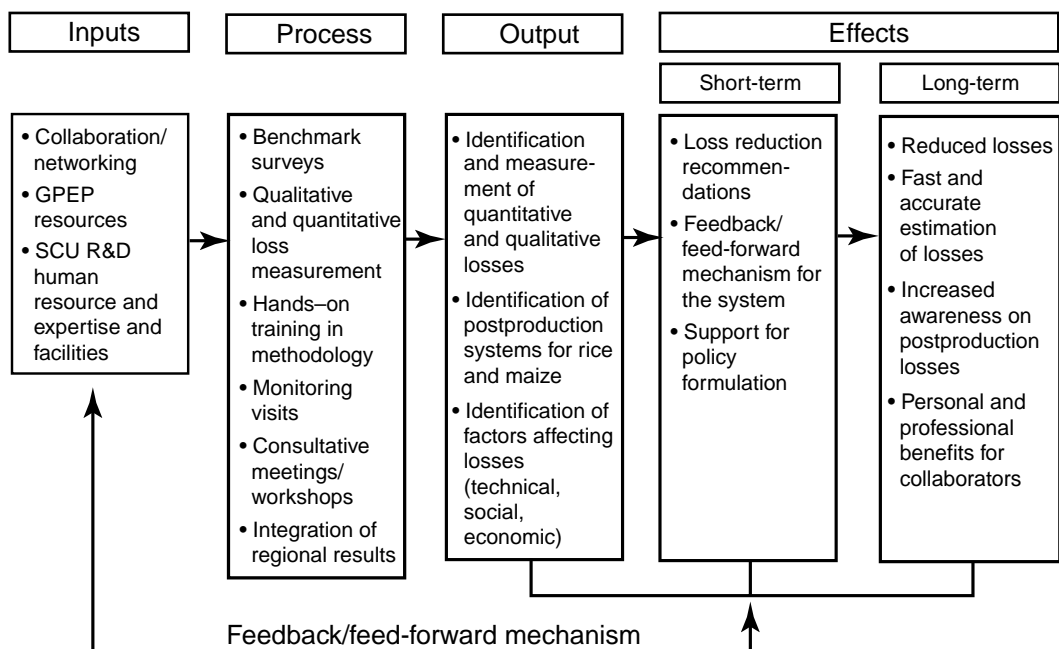
## Results and Discussion

### Paddy losses

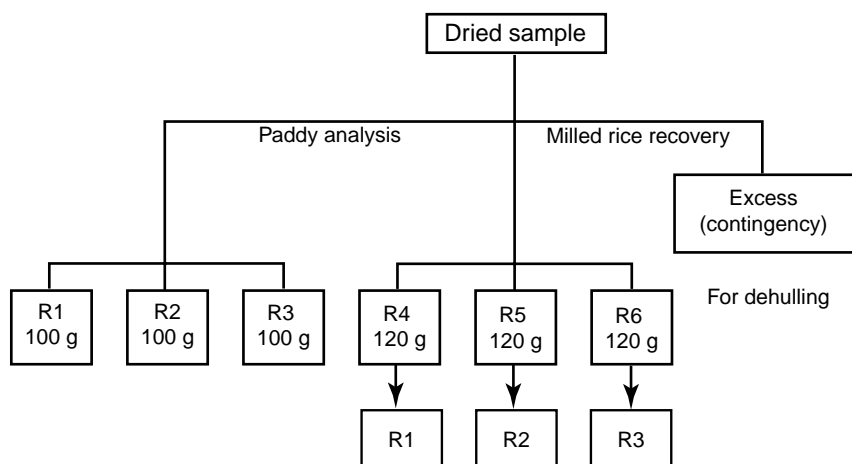
For paddy, the total loss from harvesting to milling ranged from 1.13–31.94% with an average of 14.84% (Table 1). The loss estimates by operation were: harvesting, 1.81%; piling, 0.54%; threshing/cleaning, 2.17%; drying, 4.50%; storage, 2.72%; and milling, 3.10%.

In terms of grain loss, the most critical was the drying operation with an average loss of 4.50%, representing 30% of the total loss. Next was the milling operation with an average loss of 3.10%, constituting 21% of the total loss.

Previous postproduction loss measurements were done in 1974 and in 1984 and the results are shown in Table 2. However, it should be emphasised here that the methodologies and even the areas covered from which these results were obtained were not exactly the same. Nevertheless, these results could be used as indicators of the trends of losses for the past two decades. Drying loss, which is the most critical among the operations in the 1995–95 result at values ranging from 0.74–8.70%, only ranged from 1–5% in 1974.



**Figure 1.** Study paradigm of postproduction loss assessment for rice and maize (GPEP = Grains Production Enhancement Program, SCU R&D = State Colleges and Universities research and development).



**Paddy analysis:**

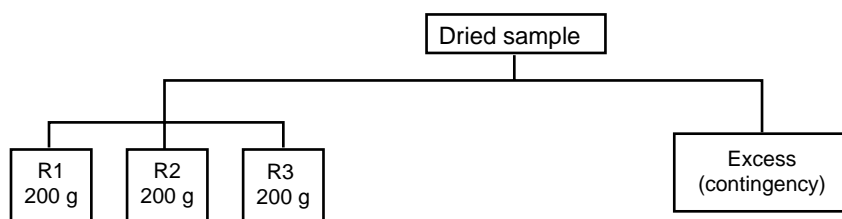
- % purity
- % damaged/ darkened/ discoloured/defective grains
- Germinated grains
- Cracked grains
- Immature/chalky grains

**Milled rice analysis:**

- % milled rice recovery
- % head rice recovery
- % brokens
- % darkened/discoloured/red/damaged grains
- Immature/chalky grains
- Brewers rice

**Figure 2.** Flow diagram of the quality analysis of paddy and milled rice.





Maize quality parameters:

a) % purity

b) % foreign matter

c) % defective grains

1) Discoloured grains

2) Germinated grains

3) Cracked/broken grains

4) Immature grains

5) Mechanically-damaged grains

6) Insect-damaged grains

7) Mouldy grains

8) Mixed variety

**Figure 3.** Flow diagram of the quality analysis of maize.

**Table 1.** Postproduction losses for paddy by region, Philippines, 1994–95 (% average values).

Region	Potential yield (kg/ha)	Harvesting loss	Piling loss	Threshing/cleaning loss	Drying loss	Storage loss	Milling loss	Total post-production loss
1	2 695	2.98	0.01	0.04	4.61	4.55	3.10	15.29
2	3 478	trace	trace	0.08	3.84	4.55	3.10	11.57
3	5 446	0.84	1.07	4.03	2.14	0.35	4.95	13.38
4	4 301	3.78	0.30	2.36	3.49	1.69	1.40	13.02
5 <sup>a</sup>	5 492	0.78	0.21	1.64	7.25	1.29	6.33	17.50
6	3 358	trace	0.08	0.99	4.54	2.38	2.44	10.43
7	4 007	trace	0.05	1.47	2.60	5.20	trace	9.32
8	4 307	1.55	1.45	2.65	5.37	1.06	1.91	13.99
9	4 952	1.60	0.10	1.20	8.70	3.40	4.70	19.70
10	5 925	3.18	0.36	1.50	3.80	2.72	3.10	14.66
11	6 263	0.86	0.56	2.75	4.50	2.72	3.10	14.49
12 <sup>b</sup>	5 388	4.85	1.77	4.37	6.86	2.72	3.10	23.67
ARMM <sup>c</sup>	5 760	3.10	1.06	5.09	0.74	2.72	3.10	15.81
Average (% share of total losses)								
	4 721	1.81	0.54	2.17	4.50	2.72	3.10	14.84
		(12)	(4)	(15)	(30)	(18)	(21)	(100)
Range (average)		trace–4.85	trace–1.77	0.04–5.09	0.74–8.70	0.35–5.20	trace–6.33	1.13–31.94

Note: some operations with no data were replaced with the overall average values.

<sup>a</sup> Combined results from Bicol University College of Agriculture and Forestry (BUCAF) and Camarines Sur State Agricultural College (CSSAC).

<sup>b</sup> Average of Sultan Kudarat Polytechnic State College (SKPSC) and University of Southern Mindanao (USM) results.

<sup>c</sup> ARMM = Autonomous Region of Muslim Mindanao.

This could be partly attributed to the deterioration of the drying facilities being used by farmers and traders/millers, and also to a reversion to sun-drying methods due to high cost of mechanical drying facilities, and carelessness of the drying labour, among other factors. Overall, however, total losses have gradually decreased since 1974 (Table 2).

Qualitative analysis of representative paddy samples obtained from all the regions covered in the study showed a steady decline in quality as the grains passed through each operation. The quality reduction was in terms of milled rice recovery, head rice recovery and percentage broken rice (Table 3).

## Maize losses

For maize, the total losses ranged from 5.5%–16.8% with an average of 12.7% (Table 4). By operation, the losses obtained were as follows: harvesting, 1.3%; piling, 1.0%; shelling/cleaning, 2.7%; drying, 4.6%; and storage, 3.1%.

As with paddy, the drying operation was the most critical among the maize postproduction operations. The drying loss was 4.6%, constituting 37% of the total loss. Storage came next at 3.1%, representing 24% of the total loss (Table 4).

In terms of qualitative loss, there was an increasing trend in the amount of discoloured grains, germinated grains, cracked/broken grains, immature grains, mechanically damaged grains and moldy grains after each postproduction operation (Table 5).

## Postproduction practices

The field survey provided information on the postproduction practices and the level of technology applied by the rice and maize farmers and traders/millers. Harvesting is still predominantly manual. Threshing and cleaning operations (for paddy) varied from traditional (manual) to semi-traditional (i.e. use of pedal threshers and manual and/or mechanised blowers), to axial flow threshers with built-in cleaners. For maize, shelling and cleaning varied from manual (using a simple tool made of wood and a piece of metal) to a mechanised sheller. Hauling of harvested maize to the drying and shelling area utilises various means of transport from manual to carabao-pulled sled or cart to motorised means, such as tractor-trailer, jeeps, trucks etc.

Sun-drying was the method generally used by farmers for both paddy and maize, because of the low volume handled, while many traders/millers utilised

mechanical drying to complement their sun-drying operations in order to cope with larger volume of grain handled. Rice mills used were of the single-pass type, in addition to the multi-pass units owned by medium and big millers. Many rice mills were found to be old and inefficient. Grain storage was usually in bags. Farmers generally practiced household storage, while traders/millers used semi-concrete and concrete warehouses. In general, proper maintenance and sanitation practices were not followed in these warehouses.

## Causes of postproduction losses

Postproduction grain losses occurred due to several reasons as mentioned by the farmers and traders/millers interviewed and as observed by the collaborating research teams. These were mainly related to operational, technical, socioeconomic, cultural, political, and environmental factors.

### *Operational factors*

- Inefficient postproduction practices due to: improper handling of paddy or maize by hired labour; ignorance or lack of awareness of the importance of using underlay during piling, threshing, cleaning, and drying; poor warehouse keeping and sanitation during storage; lack of effective pest control; and carelessness during stacking or piling resulting in tearing of sacks and grain spillage.
- Size, shape and type of piling of harvested paddy stalks for threshing. Smaller sized piles means more piles and therefore more spillage incurred. The shape of the pile depends on the method of threshing and the type of thresher used.
- Type of postproduction facilities.
- Lack of efficient postproduction facilities in the area.
- Inefficient stacking and lack of inventory procedures.

### *Technical factors*

- Inappropriate size and type of facilities used.
- Inefficiency of facilities used due to age (wear and tear), outdated models, or even lack of proper design, testing and proper spare parts, especially for locally fabricated, copied versions of the machines.
- Lack of regular repair and maintenance of facilities.
- Over-drying due to lack of moisture meters.
- Limited experience and lack of training and technical skills of operators.

**Table 2.** Comparative loss ranges by postproduction operation for paddy, Philippines, 1974, 1984 and 1994–95 (% values).

Postproduction operations	1994–95 <sup>a</sup>	1984 <sup>a</sup>	1974 <sup>b</sup>
Harvesting loss	trace–4.85	trace–4.8	1–3
Piling loss	trace–1.77	trace–1.0	2–7
Threshing/cleaning loss	0.04–5.09	0.1–5.4	2–6
Drying loss	0.74–8.70	trace–0.7	1–5
Storage loss	0.35–5.20	2.6–5.0	2–6
Milling loss	trace–6.33	6.3–8.3	2–10
Total loss <sup>c</sup>	1.13–31.94	9–23	10–37
Average	14.84	16	23.5

<sup>a</sup> Data from the National Post-Harvest Institute for Research and Extension (NAPHIRE; now the Bureau of Postharvest Research and Extension—BPRE).

<sup>b</sup> Data from the International Rice Research Institute (IRRI).

<sup>c</sup> Average total loss for region with data on complete postproduction operations from the 1994–1995 NAPHIRE data.

**Table 3.** Quality analysis of paddy and milled rice samples after each postproduction operation, Philippines, 1994–1995 (% values).

Parameters	Operations					
	Harvesting	Threshing	Drying	Storage	Milling	Average
<b>Paddy</b>						
Purity	95.05	97.07	96.50	96.71	96.73	96.41
Damaged/discoloured/darkened grains	5.05	5.94	6.10	11.49	6.23	6.96
Germinated grains	0.40	0.19	0.25	0.10	0.04	0.20
Cracked grains	6.25	6.54	6.24	0.41	0.16	3.92
Immature grains	3.02	2.47	3.16	3.31	3.99	3.19
<b>Milled rice</b>						
Milled rice recovery	67.08	66.37	66.10	65.18	64.51	65.85
Head rice recovery	82.31	79.71	79.10	76.76	66.68	76.91
Brokens	16.38	15.87	15.20	27.80	29.07	20.86
Yellow kernels	1.26	1.91	1.82	1.85	1.27	1.62
Darkened/discoloured/damaged/red	1.60	1.72	1.60	1.51	1.56	1.60
Immature/chalky	2.76	2.63	2.70	2.07	3.05	2.64
Brewers rice	4.56	5.11	4.90	2.66	2.81	4.01

- Cross-infestation resulting from multi-commodity stacking.
- Absence of alternative rice mills in the area.
- Inherent genetic characteristics of the grains (chalky, immature, impurities, mixed varieties).
- Structural defects of facilities.

*Socioeconomic, cultural, political and environmental factors*

- Undue haste of the hired labourers to finish their tasks to be able to honour other commitments in order to get the highest wage possible during the peak season.

- Intentionally leaving out some grains for the gleaners who were relatives or family members of the hired labourers.
- Clinging to traditional practices (possibly due to inherent aversion to change usually associated with risk, distance from market sources and information on modern postharvest facilities).
- Non-affordability of modern and more efficient facilities.
- Fear of or hesitation to kill rats due to some old beliefs.
- Strong patron–client relationship which obligates farmers to continually use a given facility despite its poor performance.
- Bad weather conditions during the operation.
- Low salaries and limited incentives given to machine operators (especially for rice mills) resulting in their fast turnover and low productivity.
- Non-discriminating attitude of mill customers to rice quality, especially those who usually give a higher premium to total milled rice recovery than the head rice recovery.

### Project recommendations

Based on the results of the project and the responses of the project cooperators (farmers and traders/millers) as well as the research teams from the various collaborating institutions, the following courses of action were recommended:

- Results of the study should be fed back to the different sectors involved in the project, especially the farmers and the trader/millers, to sustain the interest generated during the project implementation.
- Awareness campaigns should be conducted through various mass media, such as print and radio/television, among others, for a more effective dissemination of the project findings to a greater number of people.
- Demonstration farms/centres should be established in strategic locations to showcase alternative postproduction technologies involving both the traditional and improved systems to exhibit their varied features, potentials, advantages and disadvantages, problems and limitations.
- Grain Service Centers should be set up to cater to the needs of farmers who would like to take advantage of the benefits and other potentials of improved postproduction practices, machines and equipment as well as be updated with new developments in the grain postproduction industry.
- Actual hands-on training should be conducted on the operation, maintenance, trouble-shooting and repair of improved postproduction facilities and equipment with greater emphasis on the technical principles, features and parameters that need to be recognised and understood by the potential users for higher productivity results.
- Linkages with local equipment and machinery manufacturers and distributors should be strengthened to ensure provision of after-sale services, such as repairs and maintenance, and assurance of the availability of spare parts and accessories in the area.
- A regulating body with the mandate to test and certify the technical efficiency of the locally manufactured postharvest facilities prior to commercialisation to protect the potential users should be established.

### Immediate impacts of the project

The actual implementation of the project in the different regions of the country elicited several immediate impacts such as those outlined below.

- The field loss assessment trials created awareness, not only among farmer-cooperators but also farmers of adjacent farms, of the pattern, magnitude and causes of postproduction losses in rice and in maize. This awareness brought about some improvements in their practices such as the following:
  - i. use of additional underlays during piling, threshing, and cleaning/shelling to allow recovery of spilled grains;
  - ii. animals were no longer allowed to feed on threshed straws unless carefully re-threshed and gleaned to recover the remaining grains; and
  - iii. a number of farmers and/or their family members started to closely supervise the harvesting and threshing operations to ensure hired labourers worked efficiently.
- Another immediate impact was the discovery of the use of tampered weighing scales by some unscrupulous paddy/maize traders and manipulation of moisture measurements in their favour to take advantage of the farmers' trust and/or ignorance of the true weight and quality of their crop.
- Knowledge of the magnitude of losses and their causes opened the eyes of the farmer-cooperators to the fact that it would be more cost-effective to prevent loss of the grain already produced than to spend more money and time on capital-intensive inputs to increase farm productivity.

**Table 4.** Postproduction losses for maize by region, Philippines, 1994–95 (% values).

Region	Potential yield(kg/ha)	Harvesting loss	Piling loss	Shelling/cleaning loss	Drying loss	Storage loss	Total losses
1	5 207	1.5	trace	2.8	4.6	3.1	12.0
2	3 913	0.2	0.1	6.7	5.1	3.1	15.3
5 <sup>a</sup>	3 725	0.4	0.1	0.7	9.8	3.3	14.3
9	2 929	1.6	2.5	5.1	0.1	2.8	12.1
10	4 324	0.7	0.4	1.3	Trace	3.1	5.5
11	4 163	2.7	2.2	2.2	4.7	3.1	14.8
12	3 699	2.7	1.8	2.2	7.0	3.1	16.8
ARMM <sup>b</sup>	4 192	0.8	1.0	0.8	5.2	3.1	10.9
Average	4 019	1.3	1.0	2.7	4.6	3.1	12.7
(% share)	(100)	(10)	(8)	(21)	(37)	(24)	(100)
Range (average)	2 929–5 207	0.2–2.7	trace–2.5	0.7–6.7	trace–9.8	2.8–3.3	3.7–25

<sup>a</sup> Combined results from Bicol University College of Agriculture and Forestry (BUCAF) and Camarines Sur State Agricultural College (CSSAC).  
<sup>b</sup> ARMM = Autonomous Region of Muslim Mindanao.

**Table 5.** Quality analysis of maize samples after each postproduction operation, Philippines, 1994–95 (% values).

Parameter	Operations				
	Harvesting	Shelling/cleaning	Drying	Storage	Average
Purity	98.97	99.15	98.20	97.83	98.54
Defectives					
Discoloured grains	1.07	0.10	1.96	3.39	1.63
Germinated grains	0.46	0.44	0.71	2.11	0.93
Cracked/broken grains	0.42	2.00	4.51	6.17	3.28
Immature grains	1.52	1.62	3.11	3.55	2.45
Mechanically damaged grains	0.29	2.68	3.36	–	2.11
Insect damaged grains/bored grains	0.13	–	–	1.18	0.66
Mouldy grains	2.17	2.38	3.06	–	2.54
Mixed variety	0.52	0.92	2.33	–	1.26

### Institutional benefits derived from project collaboration

Professional and personal benefits were derived by some members of the collaborating research teams from their involvement in the project implementation. These benefits included the following:

- Enriched and broadened knowledge of, as well as field exposure to, the research methodology and computational procedures involved in the measurement and assessment of quantitative and qualitative postproduction losses in rice and maize.
- Better understanding of the pattern, magnitude, causes and other important issues regarding rice and

maize postproduction losses, as viewed and analysed from different perspectives. This was made possible by the multi-disciplinary approach employed, and the constant monitoring, field visits, consultative meetings and seminars held by the BPRE staff and their consultants with the research teams from the different collaborating institutions.

- Linkage and networking activities with other academic institutions, government research and extension agencies, and local government units provided the necessary logistics and technical support as well as facilitated the implementation of the project and other related activities. This linkage also provided opportunities for future collaborative activities with them.
- For those institutions that collaborated with BPRE for the first time, the opportunity was considered a big breakthrough that enabled them to get into the mainstream of research, extension and training activities in the postharvest field.
- Involvement in the project provided additional professional growth, recognition, and incentives to some members of the research team. In some instances, partial results from the project were presented during in-house and even regional exhibits and research competitions that reaped

rewards and prizes, while others were even able to utilise the findings for their school term papers, class requirements, teaching and training materials etc.

- The team spirit and collegial relationships established during the implementation of the field trials and data analyses provided a stronger bond between and among the research staff involved in the project.

## **Future plans**

A sequel project is envisaged to evaluate the impact of the Postharvest Component of the Grains Production Enhancement Program (GPEP), in particular, the impact of the postharvest facility assistance and training courses provided to the farmers, manufacturers, and other stakeholders in the grains postproduction sector.

Another plan of action would be nationwide dissemination of the results of the study to farmers and other stakeholders through popular publications and brochures, and through symposia and other public forums, to increase awareness regarding the magnitude of the postharvest losses and how to prevent them.



# Quality Management Systems in Australian Vegetable and Fruit Industries

J.S. Bagshaw and S.N. Ledger\*

## *Abstract*

Quality management (QM) systems have been in use in the Australian vegetable and fruit industries since the late 1980s. These early systems, based on the QM standard ISO 9002, were used mainly to achieve consistent quality products to meet customer requirements.

From 1997, consumer concerns about food safety increased after some major food poisoning outbreaks implicating non-horticultural produce. The major supermarket chains in Australia reacted by requiring their direct suppliers to adopt stringent management practices to ensure provision of safe, acceptable quality products. This applies to the fruit and vegetable industries as well as other food sectors. Externally audited Hazard Analysis and Critical Control Point (HACCP)-based QM systems provide the levels of assurance the supermarkets are requiring.

Indirect suppliers are now also required to implement on-farm practices under an approved supplier program to assure provision of safe, quality produce. Growers are required to provide proof of these practices in the form of records and other documentation. Most growers in Australia are affected by these supermarket requirements. To adopt QM systems, growers must firstly be motivated to implement them, then gain knowledge about the various QM systems and their specific requirements, and finally have the resources to implement them. There is now strong motivation to adopt QM systems in Australia (access to supermarkets) and knowledge is slowly building through training programs and support services. Larger farms have more resources and are better positioned to implement QM systems. Small family farms struggle to find the time and resources to implement QM systems. Documentation of QM systems is a major challenge for vegetable and fruit growers.

In this paper, we discuss the requirements under externally audited HACCP-based QM systems for direct suppliers and approved supplier programs for indirect suppliers, as well as some implications for other countries from the Australian experience with QM systems.

CONSUMERS of vegetables and fruits are becoming increasingly demanding. They want vegetables and fruits to be consistently attractive, fresh, nutritious, tasty and safe to eat. Retailers and wholesalers in Australia have responded to this consumer pressure, particularly for food safety, by asking for assurance from suppliers that their products meet these requirements. They are looking to quality management (QM) systems to provide the level of assurance they require.

## **A Brief History of QM Systems in Australia**

Quality management systems were first used in Australia in the late 1980s, having been introduced from New Zealand. At about the same time, the Australian Quarantine and Inspection Service (AQIS) introduced a QM system focusing on quarantine issues that businesses could use as an alternative to AQIS inspection. The QM systems from New Zealand and the AQIS systems were based on ISO 9002, an international standard for QM systems.

Those Australian businesses that used non-quarantine QM systems initially focused on using them to control product quality, with an emphasis on product

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inspections just before harvest, at harvest, and during handling and packing. Large customers wanted large volumes of consistent quality product, and QM systems were seen as the best way to achieve this, both by high volume businesses and by smaller businesses marketing together under a common brand.

As vegetable and fruit growers became more familiar with QM principles, they started using them for broader business improvement. Growers that implemented QM systems (particularly those employing large numbers of staff) indicated important business benefits, including more control of their production system, better efficiency and improved staff performance (Maltby et al. 1998).

During the early 1990s, larger businesses implemented QM systems to the ISO 9002 standard and sought certification by independent auditors to provide a competitive edge. It was estimated (Anon. 1995) that between 1 and 2% of horticulture producers in Australia had audited QM systems in place.

Since 1997, consumer concerns about food safety have increased after some major food poisoning outbreaks in Australia. These have mainly implicated processed products (e.g. salami and peanut paste), but one recently was traced to contaminated oranges. The major supermarket chains in Australia reacted by requiring their direct suppliers to adopt stringent management practices to ensure provision of safe, acceptable quality products. This applied to all produce, including fruits and vegetables.

## The Current Situation

The supermarkets initially targeted their direct suppliers (businesses supplying directly into the supermarket central distribution systems). Direct suppliers included a relatively small proportion of growers and packers (mainly large volume businesses), and most wholesalers and processors. These direct suppliers are required to have an externally audited, Hazard Analysis and Critical Control Point (HACCP)-based QM standard in place. Acceptable standards are ISO 9002 + HACCP or SQF 2000<sup>cm</sup> (includes HACCP). One supermarket has its own vendor QM standard which includes HACCP. The supermarkets have allowed their direct suppliers some time to implement their QM systems, with deadlines ranging from the end of 1999 to mid-2000.

In Australia, most smaller growers supply to packers, wholesalers and/or processors, who in turn supply directly to retailers (including the supermarkets) and other food service businesses.

Supermarkets now require these indirect suppliers to have practices in place to ensure safety and quality at the farm level. These practices are commonly referred to as 'approved supplier programs' and are a lower level of QM than that required of direct suppliers. Some indirect suppliers deemed to be a high food safety risk may be required to implement HACCP. Examples are products that have a history of food poisoning (e.g. bean sprouts) or where some minimal processing is done on-farm. Supermarkets place the onus of assurance for safety and quality on their direct suppliers. These direct suppliers are audited to verify that their own QM system meets the QM standard, and that their approved supplier programs with indirect suppliers are adequate. Figure 1 summarises these requirements.

The three major supermarkets in Australia handle a large proportion of Australia's fresh vegetables and fruits, so most producers are affected, either directly or indirectly, by their requirements.

## The QM Standards

ISO 9002 (1994) is an international QM standard that can be applied to any type of business. It does not include HACCP, so this must be added to the ISO 9002 standard. SQF 2000<sup>cm</sup> Quality Code (1997) has been developed by AGWEST Trade and Development in Western Australia specifically for food businesses, and includes HACCP. One supermarket has developed its own vendor QM standard for direct suppliers.

## HACCP

HACCP is an internationally recognised method to identify, evaluate and control hazards to food products. It was originally developed to control food safety hazards, but is now being used in Australia to also control product quality hazards. The HACCP process involves seven 'principles' (Codex Alimentarius Commission 1997):

- Conduct a hazard analysis
- Determine the critical control points
- Establish critical limits
- Establish a system to monitor control of the critical control points
- Establish the corrective actions to be taken when monitoring indicates that a particular control point is not under control

- Establish procedures to verify that the HACCP system is working effectively
- Establish documentation concerning all procedures and records appropriate to these principles and their application.

### Approved Supplier Requirements

Ledger et al. (1999) provides a guide to on-farm practices that may be required by customers. This guide also suggests documents needed to provide evidence of practices. The practices listed in this guide are grouped into five categories: product and handling specifications; product identification and traceability; training; controlling quality hazards; and controlling food safety hazards.

The guide emphasises potential food safety hazards and has identified a number of key areas that need addressing:

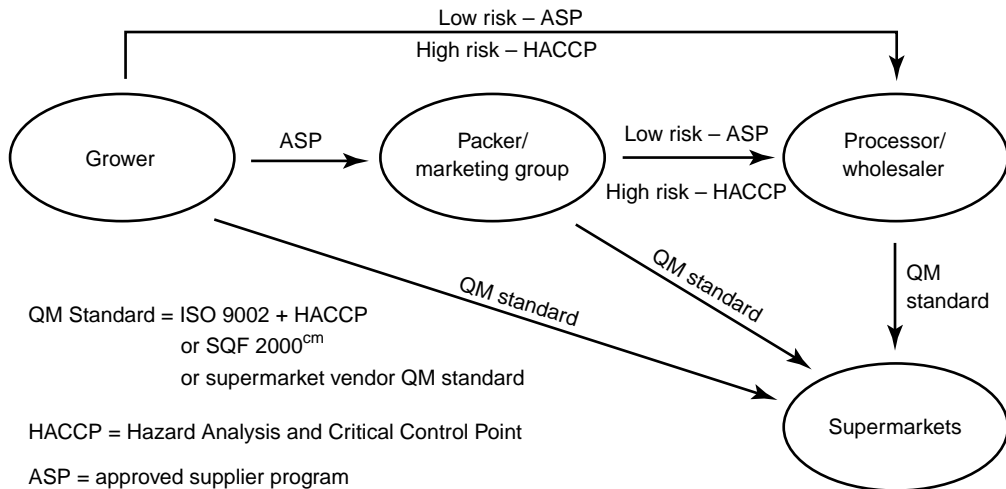
- application of pre- and postharvest chemicals;
- application of fertilisers and soil improvers;
- water quality;
- site (growing area) and premises (handling, packing and storage area);
- equipment and materials (including machinery and other materials that contact produce);
- cleaning programs and pest control (rats, mice, birds etc.);
- personal hygiene of staff; and
- storage and transport of produce.

### Adoption of QM Systems by Australian Vegetable and Fruit Growers

Ledger and Bagshaw (1997) suggest that, like any other technology or practice, the adoption of QM systems by growers is dependent on three things:

- Motivation (the 'want' to).
- Knowledge (the 'how' to).
- Resources (the 'means' to).

Motivation leads to commitment, and commitment is an essential ingredient for adoption of QM systems. In Australia, strong motivation has been provided by the demands of the supermarkets in response to food safety issues, although growers often have difficulty accepting that food safety practices are necessary. For example, they say there has never been a problem in the past, why are the practices needed now? Vegetables and fruits are a low food safety risk compared to meats and dairy products, but there have been food poisonings implicating vegetables and fruits in Europe and North America, and more recently in Australia. Growers also complain about having to implement practices to control food safety hazards when they see little evidence of businesses further down the marketing chain implementing practices to control safety hazards.



**Figure 1.** Quality management (QM) requirements for Australian vegetable and fruit suppliers. (Source: Western Australia, AGWEST Trade and Development.)

Once motivated, growers then need to gain knowledge about QM systems. The wide range of QM standards and guidelines, all with slightly different requirements, are very confusing and growers find it very difficult to determine what they need. They must rely on external sources to gain this information. The messages from these many sources can sometimes be conflicting, so gaining a clear understanding about what is required is not as simple as it sounds. But clear understanding is essential if growers are to progress toward implementing an effective QM system. Anon. (1995) acknowledged these problems and suggested education and training programs with information packages reflecting market requirements, free of QM jargon, horticulture-oriented, consistent and concise. Accredited training programs providing information about QM requirements have been developed and are being conducted for growers.

Once growers are motivated and knowledgeable about QM systems, their ability to implement these systems depends on the resources they have available. The QM standards, ISO 9002 plus HACCP, SQF 2000<sup>cm</sup> and the retailer vendor QM standard, require a significant amount of time to develop, document and maintain. Most growers are not practiced or comfortable with documentation, and find this the most challenging part of a QM standard. Also, the rigour, formatting, and detailed thinking and documentation required for the HACCP component is very challenging for most people, let alone growers who are generally not trained or experienced in office skills.

Some industries have attempted to address this problem by developing generic documents that individual businesses can adapt to their unique business practices. These generic documents go some way to helping growers but do not provide an understanding of the underlying QM principles. Generic documents are best used as part of a broader training program.

In our experience, businesses require skilled people dedicating much of their time to develop and implement the QM standards. Large businesses are better positioned to provide this resource, either by contracting an external consultant or employing staff to coordinate the job. In some instances the owners or managers delegate some of their normal duties to staff, freeing the owners/managers to develop their QM system. Small family businesses often do not have the resources to pay for consultants or staff to implement a QM system, and struggle to find the time over and above normal farming activities to implement QM standards. Some groups of small businesses combine resources and enlist external help, with financial

support from government programs. However, at least one person from each business must learn about the requirements of the QM system, maintain the system and supporting documentation, and perhaps learn new skills, such as computer skills, to aid documentation. Ongoing auditing costs can also be a barrier to small businesses.

The practices under an approved supplier program are simpler to implement and easier to document, and most growers in Australia have many of the practices already in place (e.g. responsible chemical use, spray records, and cleaning programs for harvesting equipment and packing areas). Once again, documenting the approved supplier program is the biggest barrier for small businesses to overcome. Customers require documentation as proof that growers are carrying out the required practices. Some farms enlist the help of family members not directly involved in running the farm to help with documentation and record keeping.

## Implications for Other Countries

Food safety issues will increase, firstly with exports to countries with affluent communities, then with local communities as they become more affluent. Safe food is a basic expectation of all people, and community outrage in the event of major food poisoning can be very damaging to a business, or industry, through loss of markets or litigation. Vegetable and fruit growers need to be aware of what causes food safety problems and the practices to prevent or limit them to acceptable levels.

There are many benefits to be gained from implementing a QM system, particularly for larger farms and other businesses in the marketing chain employing many staff, or for groups of businesses marketing under a common brand. QM principles encourage better planning, clearer objectives and smoother operations, leading to more efficiency and less waste. Sensible application of QM principles will result in more motivated and well-trained staff.

Certification to a particular QM standard may benefit larger businesses whose customers value this level of assurance. This must be balanced against the extra costs associated with certification.

QM standards would be most applicable to large central packinghouses (for operations within the packinghouse) or to businesses sourcing and packing produce for export. These businesses will require grower-suppliers to implement certain farm practices under an approved supplier program.

Industry and government support agencies need to be familiar with domestic and export market QM requirements and communicate them clearly to growers, packers and distributors in appropriate training activities.

## References

- Anon. 1995. Quality management strategies for horticulture. Industry Report No. 8. Canberra, Australia, Horticulture Policy Council.
- Codex Alimentarius Commission 1997. Hazard Analysis and Critical Control Point (HACCP) system and guidelines for its application. Alinorm 97/13A, App 2, Vol 1B Supplement, Rev 3. Rome, Codex Alimentarius Commission.
- ISO 9002 1994. Quality systems—model for quality assurance in production, installation and servicing. Homebush, New South Wales, Standards Australia.
- Ledger, S. and Bagshaw, J. 1997. Reflections on ten years of helping improve horticulture quality management. 2<sup>nd</sup> Australasian Pacific Extension Conference Proceedings, Albury, 1997, Vol. 1, 451–459.
- Ledger, S., Bennett, R., Beattie, B., Ekman, J., White, D., Leamon, K., Premier, R., Darton, M., Hart, R., Lovell, J. and Hill, J. 1999. Developing an approved supplier program for fresh produce—a guide for customers and suppliers. Indooroopilly, Queensland Department Primary Industries.
- Maltby, J., Ledger, S. and Bagshaw, J. 1998. Queensland tomato quality management final report (project VG 429). Sydney, Horticultural Research and Development Corporation.
- SQF 2000<sup>cm</sup> Quality Code 1997. A HACCP quality code for the food industry. Perth, Western Australia, AGWEST Trade and Development.

# Extending the Shelf Life of Broccoli Florets and Pak Choy Leaves

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## Abstract

The shelf life of broccoli (*Brassica oleracea* var. *italica*) florets and detached leaves of pak choy (*Brassica rapa* var. *chinensis*) is severely limited by yellowing. A single initial fumigation using the ethylene action inhibitor 1-methylcyclopropene (1-MCP) delayed yellowing in broccoli and pak choy by 20–45% and 10–20%, respectively, at supermarket retail temperature (10°C). Fumigation with 1-MCP provided protection against contact with exogenous ethylene (1 ppm), a promoter of yellowing. However, multiple applications of 1-MCP did not increase its ability to prolong shelf life. 1-MCP was most effective at concentrations between 1–14 ppm. Lower concentrations were less effective. At concentrations above 25 ppm, 1-MCP induced damage to florets and leaves in the form of brown–red colouring and brown spotting, respectively. When 1-MCP was applied at 20°C or 2°C and the leaves then stored at these respective temperatures, its effect was no different to that observed at 10°C. 1-MCP was effective in extending the shelf life of broccoli florets at all three temperatures. Atmosphere modification (2% O<sub>2</sub>/5% CO<sub>2</sub>) was found to be more effective than 1-MCP, extending the shelf life of pak choy leaves and broccoli florets by 115% and 174% at 10°C, respectively. The research presented highlights differences in the effectiveness of 1-MCP and the modified atmosphere as well as comparing differences between floral and leafy brassica tissues.

PAK CHOY (*Brassica rapa* var. *chinensis*) is an open leafy brassica that is marketed as a shoot (commonly in bunches) or as a component in salad mix or stir-fry. Deterioration is essentially marked by leaf yellowing due to the breakdown of chlorophyll during storage and senescence (Hirata et al. 1987; Wang and Herner 1989; O'Hare et al. 1995). Quality deterioration due to chlorophyll loss also occurs in the high value, seasonal commodity broccoli (*Brassica oleracea* var. *italica*) (Wang 1979).

The presence of ethylene (whether produced by plant tissue or from an external source) has been reported by other authors to enhance postharvest chlorophyll degradation in leafy brassicas such as cabbage (Pratt and Goeschl 1969; Pendergrass et al. 1976) and in broccoli (Aharoni et al. 1985). Potential regulation of this degradation through the application of ethylene inhibitors and atmosphere control has been investigated. Although refrigeration (5°C or lower) is the

ideal for storage, these temperatures are rarely maintained in commercial handling systems with most wholesale/retail outlets displaying produce at approximately 10–15°C. Within this temperature range, atmosphere modification has been found to be effective in retarding chlorophyll loss in pak choy. Reduced oxygen (2% O<sub>2</sub>) (O'Hare et al. 1995) and enhanced carbon dioxide (5% CO<sub>2</sub>) (Wang and Herner 1989) retarded yellowing at 10°C. Atmosphere modification (2–3% O<sub>2</sub>/5–6% CO<sub>2</sub>) has also been shown to increase the storage life of broccoli over a range of temperatures (Isenberg 1979). However, problems do exist with the practicality and the infrastructure required to support the use of controlled atmospheres and modified atmosphere packaging (MAP) for brassicas in some countries. Less expensive post-harvest treatments to extend storage life would be more suitable.

Recently, the gaseous ethylene antagonist 1-methylcyclopropene (1-MCP) has been shown to be an effective inhibitor of ethylene action (Serek et al. 1994, 1995b; Sisler et al. 1995). Pre-treatment fumigation of a range of ornamental species (Porat et al.

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1995; Serek et al. 1995a) and fruits (Sisler et al. 1995) with low levels of 1-MCP has been shown to effectively block ethylene action. This paper highlights differences in the effectiveness of 1-MCP and modified atmosphere as well as differences in response between floral and leafy tissues.

## Methods and Materials

### Plant material

'Shanghai' (green-stemmed) pak choy plants were grown under field conditions in Brisbane (at the Queensland Horticulture Institute—QHI) and harvested when 4 to 5 weeks old. Broccoli ('Maverick' and 'Green Belt') were grown under field conditions at Gatton (Queensland) and heads harvested when approximately 15–25 cm in diameter (market-ready) and transported to QHI laboratories (1 h transit) in polystyrene foam boxes with ice.

In all experiments with pak choy (unless otherwise indicated) the youngest fully expanded leaf was used (cut as close to the abscission zone as possible). With broccoli, the inner branches (with florets and stem) were cut from the broccoli head for use. Prior to use, plant material was surface-sterilised in 2% sodium hypochlorite for 1 min and then air-dried at 10°C (for up to 30 min). All treatments were stored in the dark at 2, 10 or 20°C in lots of 5 in 4 L containers for broccoli and lots of 10 in 2 L containers for pak choy. The containers were flushed with humidified air at a flow rate of 15 L/h. Excess ethylene (produced by the plant material) in control samples was absorbed using Purafil<sup>®</sup>.

### Postharvest treatments

1-methylcyclopropene (1-MCP) was prepared from EthylBloc<sup>®</sup> (Floralife, USA) by dissolving it in 2% KOH buffer in an airtight glass container. The concentration of the gaseous 1-MCP was determined using flame-ionisation gas chromatography with an n-octane/porasil C column, and the peak response was calibrated against 1-butene. 1-MCP was injected to a final concentration of 12 ppm (unless otherwise indicated) into sealed vacuum desiccators containing the plant material to be treated. Plant material was treated with 1-MCP for 16 hours in the dark at the storage temperature. Controls were treated in a similar manner but without the addition of 1-MCP. The optimal 1-MCP concentration was determined over a range of concentrations (0.0875 ppb to 280 ppm). Where multiple

applications of 1-MCP were required, the initial fumigation was performed as detailed previously. Further applications (up to 5 applications in total) were performed daily and for 6 h each.

Ethylene was applied, where required, at concentrations of 0.1 ppm or 1 ppm as part of the airflow system used to flush the containers containing the plant material.

To study the effect of a modified atmosphere, an atmosphere of 2% O<sub>2</sub>/5% CO<sub>2</sub> was maintained at 10°C as per O'Hare et al. 1998.

### Measurements

Hue angle (used as a measure of yellowing) was measured using a Minolta chromoameter and the average of three readings on either leaves or florets was calculated. General appearance (GA) was determined using a scale where 9 was the best condition and 1 was the worst condition. When plant material reached a GA of 5.5, it was considered to be at the end of its shelf life. The degree of yellowing, as observed visually, was monitored using a scale from 1 (no yellowing evident) to 6 (all yellow). Rot and physiological damage were also noted on a scale from 0 (none) to 4 (extreme).

Ethylene was measured using flame-ionisation gas chromatography. Soluble sugars were measured after extraction using a method developed from the enzymatic assay of Boehringer-Roche. Protein was extracted using a sodium dodecyl sulfate (SDS)-based method (Pogson and Morris 1997) and was then assayed using a protein analytical kit (Bio-Rad) based on the Bradford method (Bradford 1976).

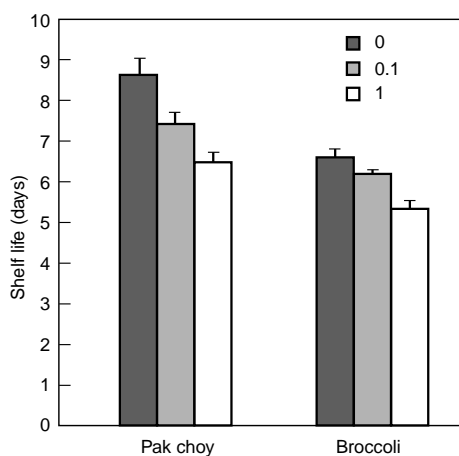
### Results and Discussion

At 10°C, pak choy had a shelf life of approximately 8 days (Figure 1). In the presence of 1 ppm ethylene, the shelf life significantly declined while a lower concentration of 0.1 ppm ethylene failed to have a significant effect (least significant difference—LSD = 1.113) (Figure 1). The shelf life of broccoli florets at 10°C was slightly less than that of pak choy. Ethylene (1 ppm) significantly decreased the shelf life of the florets while 0.1 ppm did not have a significant effect (LSD = 0.5979) (Figure 1). Both florets and leaves, therefore, appear to be sensitive to relatively high levels of ethylene.

When pak choy leaves were treated with 1-MCP, no significant change in shelf life was observed for leaves held in air or under 0.1 ppm ethylene (Figure 2).

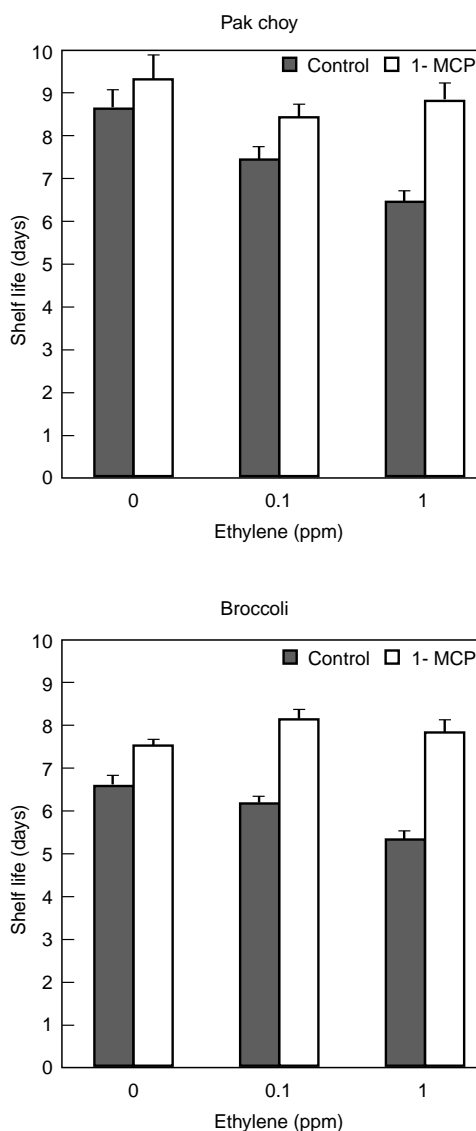
However, in the presence of 1 ppm ethylene—where untreated leaves had a lower shelf life, 1-MCP treatment maintained the shelf life to a level similar to control leaves. As 1-MCP treatment did not alter the shelf life of pak choy leaves in the absence of ethylene, this would suggest that any endogenous ethylene produced by the leaves is not directly involved in decreases in shelf life at 10°C.

When broccoli florets were treated with 1-MCP (Figure 2), their shelf life was significantly increased—both in untreated and ethylene-treated (0.1 ppm or 1 ppm) florets. In comparison to pak choy leaves, therefore, it appears that both endogenously-produced and exogenous (supplied) ethylene promotes loss of marketability of broccoli florets.



**Figure 1.** The effect of exogenous ethylene on the storage life (days) of pak choy leaves and broccoli florets. Plant material was stored at 10°C in the absence of ethylene or in the presence of 0.1 ppm or 1 ppm ethylene. Data represent mean  $\pm$  standard error for  $n = 20$ .

The rate of yellowing (represented as a decline in hue angle) of both pak choy leaves and broccoli florets was accelerated in the presence of 1 ppm ethylene and slowed by 1-MCP (Figure 3). As with shelf life, when ethylene was not applied, 1-MCP slowed yellowing in broccoli florets but had no significant effect on the rate of yellowing in pak choy. This indicates that shelf life is determined by the rate of yellowing in both products, however endogenous ethylene only appears to play a role in yellowing in broccoli florets.



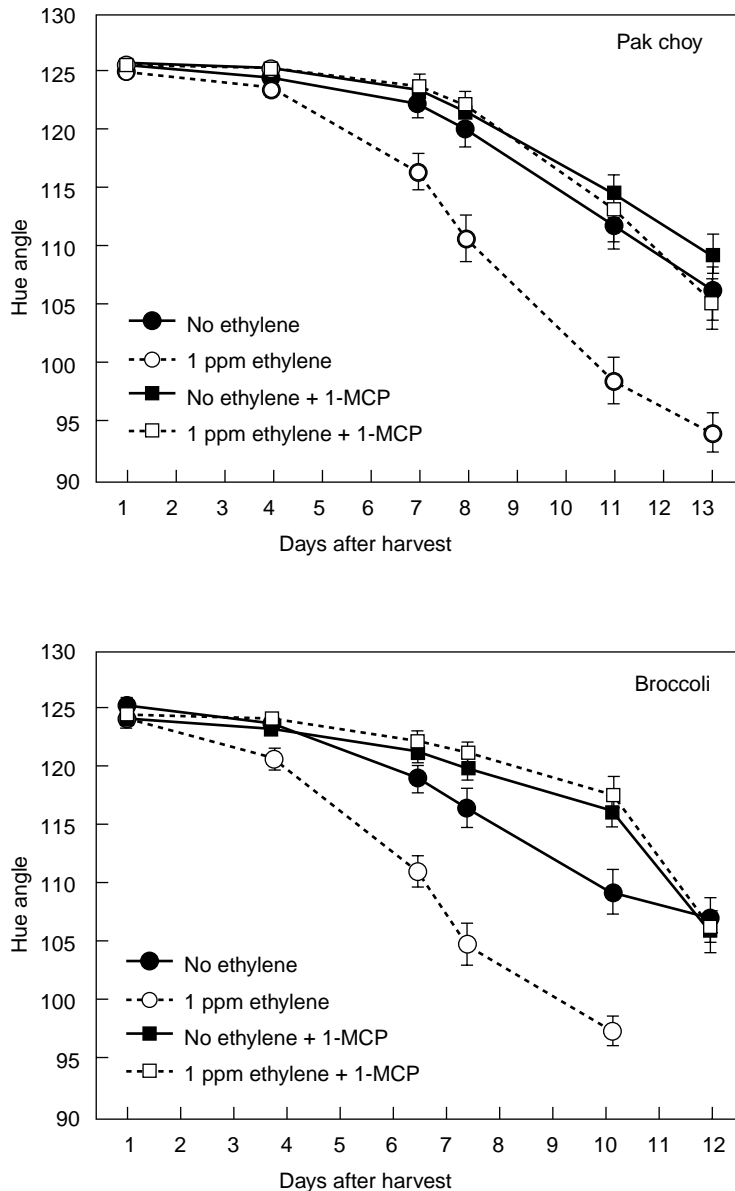
**Figure 2.** The effect of 1-methylcyclopropene (1-MCP) on the shelf life of pak choy leaves and broccoli florets in the absence or presence of ethylene (0.1 or 1 ppm) at 10°C. Data represent mean  $\pm$  standard error for  $n = 20$ .

The concentration of 1-MCP in the above trials was 12 ppm. At a range of concentrations from ~1 ppm to 14 ppm the effect on shelf life and yellowing of pak choy leaves and broccoli florets was not significantly different. No effect was noted in the presence of 1-MCP at concentrations below 1 ppm. However, if con-

centrations of 1-MCP higher than 25 ppm were used, damage was observed in the form of brown spotting on pak choy leaves (due to necrotic cells) and red-brown colouring of broccoli florets.

trialled. However, such treatments did not significantly increase the shelf life in either pak choy or broccoli over that attained by a single fumigation treatment (Figure 4).

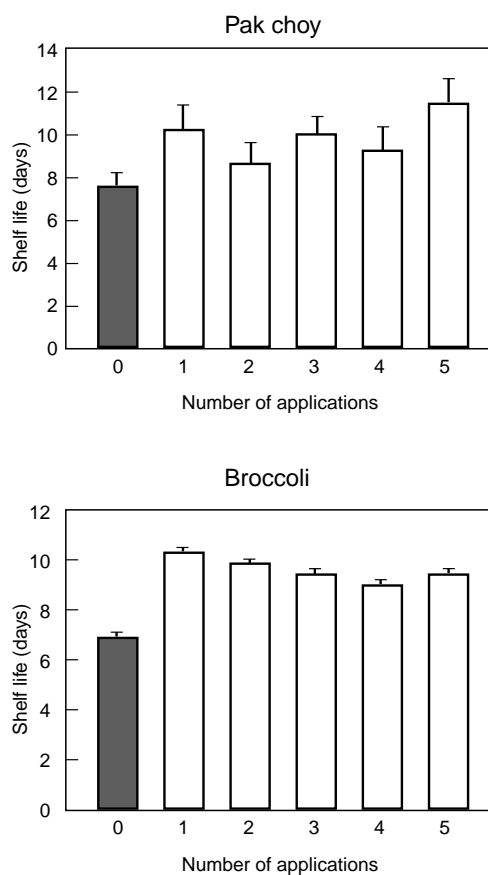
In an attempt to further increase the efficacy of 1-MCP, multiple applications of the fumigant were



**Figure 3.** The effect of 1-methylcyclopropene (1-MCP) on the yellowing (represented as a decline in hue angle) of pak choy leaves and broccoli florets in the absence or presence of ethylene (1 ppm). Data represent mean  $\pm$  standard error for  $n = 20$ .



Treatment with 1-MCP over a range of temperatures (2, 10 and 20°C) followed by storage at those temperatures resulted in an increase in storage life at all temperatures for broccoli but not pak choy (Table 1). 1-MCP fumigation of broccoli florets at 2,10 and 20°C increased shelf life to a greater extent relative to controls at the same temperature. At 10 and 20°C, the increase in shelf life correlated with a decreased rate of yellowing. However, at 2°C, the increase in shelf life appeared to be related to delaying the onset of rots rather than delaying yellowing. Ku and Wills (1999) have reported a similar response to 1-MCP at 5°C.



**Figure 4.** The effect of multiple applications of 1-methylcyclopropene (1-MCP) on the shelf life of pak choy leaves and broccoli florets. Data represent means  $\pm$  standard error for  $n = 20$ .

**Table 1.** Shelf life (days) of pak choy leaves and broccoli florets in the presence or absence of 1-methylcyclopropene (1-MCP) at 2, 10 and 20°C. Data represent mean  $\pm$  standard error for  $n = 15$  (pak choy) and  $n = 20$  (broccoli).

Treatment	2°C	10°C	20°C
<b>Pak choy</b>			
Nil	17.82	5.44	3.11
1-MCP	18.48	6.21	3.76
% increase	3.7	14.15	20.9
<b>Broccoli</b>			
Nil	53.59	6.84	2.21
1-MCP	64.15	9.94	2.86
% increase	19.71 <sup>a</sup>	45.32 <sup>a</sup>	29.41 <sup>a</sup>

<sup>a</sup> the increase in shelf life is significant ( $P < 0.05$ )

1-MCP significantly increased endogenous ethylene production in both pak choy leaves and broccoli (Figure 5). Silver thio-sulfate (STS), a known blocker of ethylene action (Atta et al. 1987), also increases ethylene production (Able et al. 1999). 1-MCP acts by binding to the sites (receptors) where ethylene normally binds (Serek et al. 1994). It is possible that if all, or the majority, of ethylene receptor sites are bound by 1-MCP, ethylene would not be able to bind and would therefore accumulate. The later decline in ethylene may be linked to a feedback mechanism whereby new ethylene receptor sites are created or otherwise may be a result of a lack of living tissue. Alternatively, the 1-MCP may not remain bound to the receptor sites and sensitivity to ethylene is regained (Sisler et al. 1995) or the ethylene simply dissipates out of the tissue by diffusion.

In comparison to 1-MCP, modified atmospheres yielded considerably greater increases in shelf life in both broccoli and pak choy leaves. Pak choy leaves stored in a modified atmosphere of 2% O<sub>2</sub>/5% CO<sub>2</sub> at 10°C had a 115% increase in shelf life in comparison with the marginal increase of 13% after treatment with 1-MCP (Table 2). The shelf life of broccoli increased by 175% when the atmosphere was modified for storage.

In a comparison between 1-MCP and modified atmosphere, as a means of extending the shelf life of broccoli florets or pak choy leaves, our results indicate that 1-MCP is not as effective as the use of a modified atmosphere at 10°C for either pak choy or broccoli. However, in the case of broccoli florets, Ku and Wills (1999) have reported 100 to 200% increases in shelf

life when 1-MCP is used. These increases in shelf life are similar to those observed when the atmosphere is modified. It should be noted, however, that these increases were in broccoli florets treated with 0.1 ppm ethylene, in comparison with our trials where ethylene was not present.

**Table 2.** The effect of 1-methylcyclopropene (1-MCP) and modified air packaging (MAP) on the percentage (%) increase in the shelf life of broccoli florets and pak choy leaves at 10°C. Data represent mean ± standard error for *n* = 20 (pak choy) and *n* = 25 (broccoli).

	1-MCP	MAP
Broccoli	26	174
Pak choy	13	115

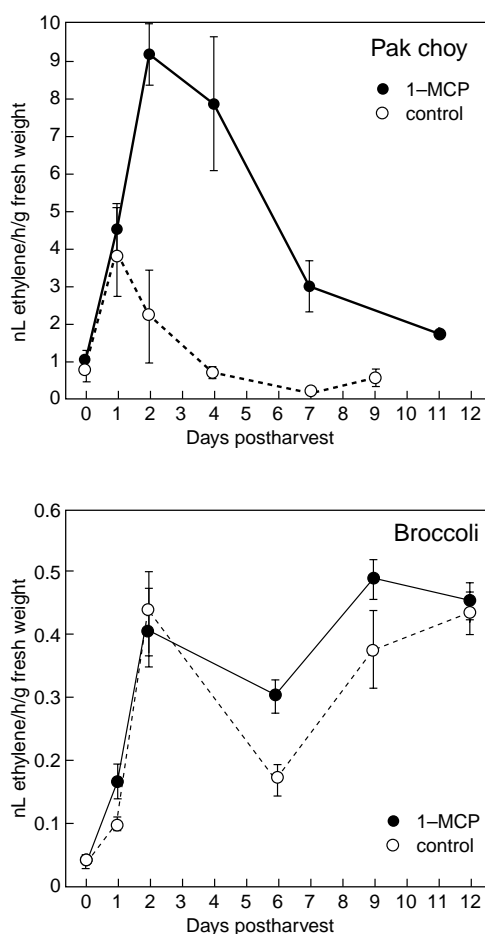
1-MCP was more effective at increasing shelf life of the broccoli florets than the pak choy leaves. This may be related to a number of fundamental differences between floral parts and leaves. Firstly, the broccoli florets are picked when immature and are highly perishable due to extremely high respiration rates. In comparison, the pak choy leaves are physiologically mature and have very low rates of respiration (O'Hare et al. 1995, 1998). Secondly, endogenous ethylene appears to play a major role in colour change of stored broccoli (King and Morris 1994; Kasai et al. 1996; Able et al., unpublished results) but does not in pak choy leaves (Able et al. 1999) suggesting differences in ethylene sensitivity between florets and leaves. Lastly, the efficacy of 1-MCP may be reliant upon its ability to reach receptors or upon the type of receptors available in the two different types of tissue. Sisler et al. (1995) have suggested that 1-MCP may not be as active in seedlings or leaves in comparison with fruit due to the possibility of a modified receptor which is not inactivated by 1-MCP.

## Conclusions

Our current trials indicate that the use of 1-MCP to extend the shelf life of broccoli florets would be of marginal benefit and of little benefit for pak choy leaves. Certainly, 1-MCP provided a protective effect against external sources of ethylene that reduced the shelf life of both vegetable tissues. In this regard, 1-MCP may be of practical value in the common situations where co-storage or co-retail with ethylene-producing fruits is practised. Presently, however, 1-

MCP remains unregistered for use with edible produce.

The use of atmosphere modification (either controlled atmosphere or modified atmosphere packaging—MAP) is still more effective than 1-MCP in extending shelf life, although practical implementation is still largely limited by the requirement for good temperature control throughout the postharvest handling system. Higher temperatures than those MAP is designed for can lead to anaerobic conditions developing and subsequent product spoilage. However, new packaging materials are currently available which actively respond to temperature fluctuations (using Interlimer<sup>®</sup> technology), but are currently more expensive than traditional plastic films.



**Figure 5.** The effect of 1-methylcyclopropene (1-MCP) on ethylene production at 10°C in pak choy leaves and broccoli florets. Data represent mean ± standard error for *n* = 20)

## Acknowledgments

The authors wish to acknowledge help from Andrew Macnish with 1-MCP preparation and Mary Valley Plantation, Australia, for supplying pak choy seed. The research presented is supported by the Australian Centre for International Agricultural Research (ACIAR) Project 9416 and the Rural Industries Research and Development Corporation (RIRDC) project DAQ213A/DAQ239A.

## References

- Able, A.J., Wong, L.S., Prasad, A. and O'Hare, T.J. 1999. Postharvest physiology of pak choy (*Brassica rapa* var. *chinensis*). Proceedings of the Australasian Postharvest Horticulture Conference, Waitangi, New Zealand, 3–7 October 1999, 33.
- Aharoni, N., Philosoph-Hadas, S. and Barkai-Golan, R. 1985. Modified atmospheres to delay senescence and decay of broccoli. In: Blankenship, S.M., ed., Controlled atmospheres for storage and transport of perishable agricultural commodities. NCSU Department of Horticultural Science, 169–177.
- Atta, A.M.A., Saltveit, M.E. Jr and Hobson, G.E. 1987. Effect of silver ions on ethylene biosynthesis by tomato fruit tissue. *Plant Physiology*, 83, 44–48.
- Bradford, M.M. 1976. Quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry*, 72, 248–254.
- Hirata, K., Chachin, K. and Iwata, T. 1987. Quality changes of some vegetables used in tropical and subtropical areas during storage at various temperatures. *Journal of the Japanese Society of Food Science and Technology*, 34, 566–573.
- Isenberg, F.M.R. 1979. Controlled atmosphere storage of vegetables. *Horticultural Reviews*, 1, 337.
- Kasai, Y., Kato, M. and Hyodo, H. 1996. Ethylene biosynthesis and its involvement in senescence of broccoli florets. *Journal of the Japanese Society of Horticultural Science*, 65, 185–191.
- King, G.A. and Morris, S.C. 1994. Physiological changes during early postharvest senescence and through the preharvest–postharvest continuum. *Journal of the American Society of Horticultural Science*, 119, 270–275.
- Ku, V.V.V. and Wills, R.B.H. 1999. Effect of 1-methylcyclopropene on the storage life of broccoli. *Postharvest Biology and Technology*, 17, 127–132.
- O'Hare, T.J., Smith, L.G., Wong, L.S. and Meiburg, G.F. 1995. Low-oxygen storage of whole and minimally-processed pak choy. Proceedings of the Australasian Postharvest Conference, Waitangi, New Zealand, 3–7 October 1999, 459–462.
- O'Hare, T.J., Wong, L.S. and Prasad, A. 1998. Extending the shelf-life of leafy Asian vegetables—a report for the Rural Industries Research and Development Corporation. Final Report DAQ213A.
- Pendergrass, A., Isenberg, F.M.R., Howell, L.L. and Carroll, J.E. 1976. Ethylene-induced changes in appearance and hormone content of Florida grown cabbage. *Canadian Journal of Plant Science*, 56, 319.
- Pogson, B.J. and Morris, S.C. 1997. Consequences of cool storage of broccoli on physiological and biochemical changes and subsequent senescence at 20°C. *Journal of the American Society of Horticultural Science*, 122, 553–558.
- Porat, R., Shlomo, E., Serek, M., Sisler, C.L. and Borochoy, A. 1995. 1-methylcyclopropene inhibits ethylene action in cut phlox flowers. *Postharvest Biology and Technology*, 6, 313–319.
- Pratt, H.K. and Goeschl, J.D. 1969. Physiological roles of ethylene in plants. *Annual Review of Plant Physiology*, 20, 541.
- Serek, M., Sisler, E.C. and Reid, M.S. 1994. Novel gaseous ethylene binding inhibitor prevents ethylene effects in potted flowering plants. *Journal of the American Society of Horticultural Science*, 119, 1230–1233.
- Serek, M., Sisler, E.C., Torsh, T. and Mayak, S. 1995a. 1-Methylcyclopropene prevents bud, flower and leaf abscission of Geraldton waxflower. *HortScience*, 30, 1310–1311.
- Serek, M., Tamari, G., Sisler, E.C. and Borochoy, A. 1995b. Inhibition of ethylene-induced cellular senescence symptoms by 1-methylcyclopropene, a new inhibitor of ethylene action. *Physiologia Plantarum*, 94, 229–232.
- Sisler, E.C., Serek, M. and Dupille, E. 1995. Comparison of cyclopropene, 1-methylcyclopropene and 3,3-dimethylcyclopropene as ethylene antagonists in plants. *Plant Growth Regulation*, 17, 1–6.
- Wang, C.Y. 1979. Effect of short-term carbon dioxide treatment on the market quality of stored broccoli. *Journal of Food Science*, 44, 1478–1482.
- Wang, H. and Herner, R.C. 1989. Effect of CA storage on the ultrastructure of chloroplasts and chlorophyll content of Chinese mustard. Proceedings of the 5<sup>th</sup> International Controlled Atmosphere Research Conference, 2, 9–17.

# Assessment of Postharvest Handling Systems of Vegetable Crops in the Beijing Area

Shufang Zheng, Li Wu, Lipu Gao and Ping Wu\*

## *Abstract*

The postharvest handling systems of four crops (cabbage, Chinese cabbage, broccoli and Oriental bunching onion) in the Beijing area were assessed. Data were collected on: the time of harvest; types, timing and availability of transport; grading; pre-cooling; packaging; and storage of produce. The main factors responsible for postharvest losses were a lack of proper packaging, no pre-cooling, no proper transportation and lack of good storage techniques. It was estimated that postharvest losses of Chinese cabbage and Oriental bunching onions after storage were 20% and 50%, respectively.

WITH the improvement of life in China, vegetable production has increased enormously in its volume and varieties. Correct postharvest handling techniques are essential to prevent damage to produce. However, the use of correct postharvest techniques may be limited by market price, cost and grower skills. Fifteen years ago, there were almost no postharvest handling techniques such as grading, washing, packaging and pre-cooling. Vegetables were often packed in willow or bamboo baskets from field to market. Sometimes produce was delivered directly to the market in no container at all. The vegetable weight loss and quality loss was therefore very high, generally 30–50%. Although some postharvest handling methods have been introduced into vegetable production systems, these are difficult to apply in a general manner as the handling system employed is dependent both upon the crop, season and market. In China at the present time, potential profit decides what kind of handling methods are to be used. In order to obtain information about the handling systems of vegetable crops with an aim to improve grower skills, we conducted an assessment of systems in the Beijing area, using cabbage, Chinese cabbage, Oriental bunching onion and broccoli as assessment crops.

## **Assessment Methodology**

The assessment was made following the steps displayed in Figure 1. Distribution of vegetable crops, technique application, postharvest losses, environmental conditions, quality, tools and materials were recorded.

## **Results**

### **Distribution of vegetables after harvest**

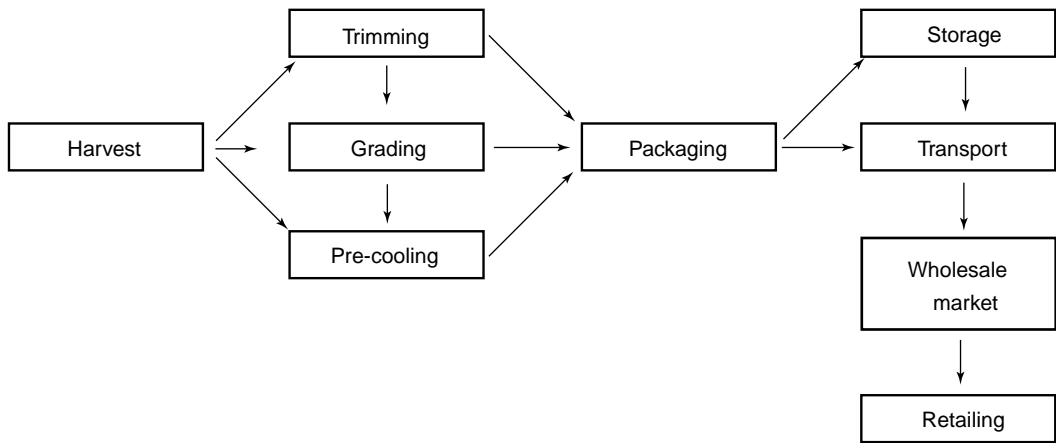
Three kinds of farm contribute to vegetable production in the Beijing area: individual farmers, corporate farms and company farms (see Figure 2). Production by individual farmers amounts to 90%, corporate farms 7%, and company farms 3%. Vegetables produced by individual farmers are delivered to wholesale markets through crop-collectors who buy vegetables from the farmer and then transport them to the wholesale market in Beijing city. For the crops under study, 60% of vegetables were produced in the Beijing area when 'in season', and almost 80% supplied by southern China when out of season.

### **Harvest**

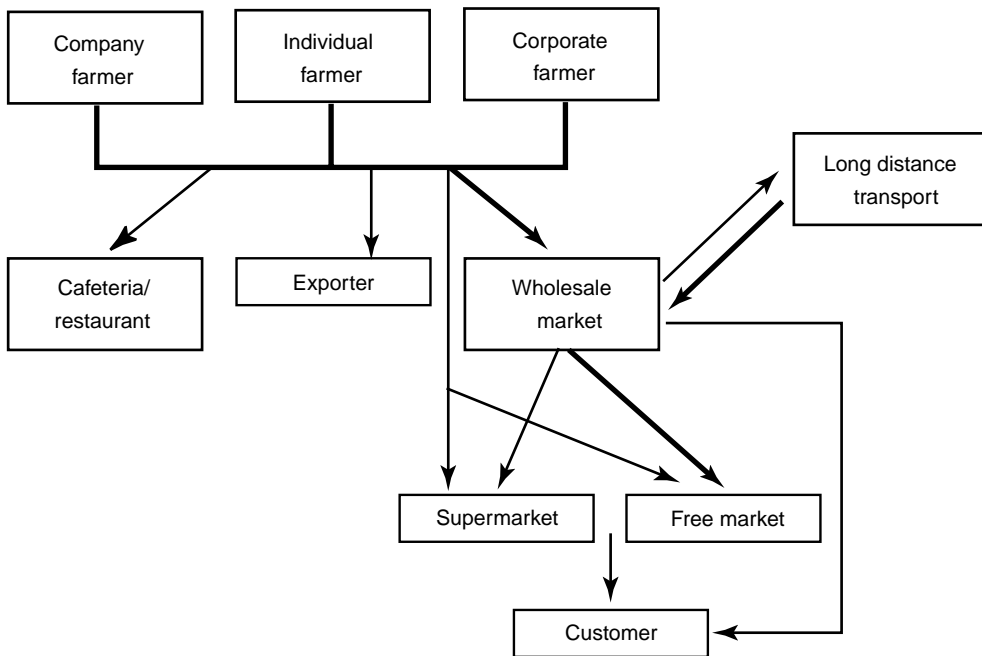
Chinese cabbage, broccoli and Oriental bunching onion were all harvested by hand, knife or spade.

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**Figure 1.** Flow chart of the vegetable handling system used in the assessment.



**Figure 2.** Flow chart of vegetable distribution.

There was no mechanical loss caused by machinery. Chinese cabbage and Oriental bunching onions were only harvested once, depending on the season and their growth period. Broccoli was harvested several times depending on size and growth period. Trimming loss at harvest was dependent upon whether it was destined for the domestic or overseas market (Table 1). For the overseas market, more outer leaves and stem were removed from cabbage and broccoli, respectively. In

1998, winter Chinese cabbage was seriously infested with disease. The production of some cultivars was almost nil, with only two cultivars not heavily infested.

Carts or tractors were used to carry vegetables to the collection site, where broccoli was packed into willow baskets, and Chinese cabbage and Oriental bunching onions packed into tractors.

**Table 1.** Vegetable loss after harvest from grower to crop-collector.

	Chinese cabbage	Broccoli	Oriental bunching onions
Domestic market	7%	4%	1%
Overseas market	50%	25%	–

### Pre-cooling

The pre-cooling operation was conducted according to destination, season and variety. If exported, vegetables were pre-cooled in a coldroom. However, no special cooling equipment was used for pre-cooling. Vegetables were spread on the ground of the coldroom for between 24 and 30 hours. This initial cooling was therefore not very effective. For the domestic market, a simple cooling method for broccoli was used. The

broccoli was dipped in ice-water for about 3 minutes, decreasing the temperature from 35°C to 26°C. For comparison, we conducted a pre-cooling trial on Chinese cabbage using a forced-air cooler (designed by the Beijing Vegetable Research Center and Qinghua University). It took 5 hours to cool cabbage from 28°C to 3°C. For cabbages and Oriental bunching onions destined for the domestic market, no pre-cooling was carried out (Table 2).

**Table 2.** The pre-cooling operation for Chinese cabbage, cabbage, broccoli and Oriental bunching onions.

Produce type	Pre-cooling	Initial temperature (°C)	Final temperature (°C)	Cooling period	Operation
Broccoli (domestic)	Yes	35	26	5 min	Dip in ice-water
Broccoli (overseas)	Yes	35	12	24 h	Spread on ground
Cabbage (domestic)	No	29	29	–	–
Cabbage (overseas)	Yes	29	17	30 h	Spread on ground
Bunching onions	No	15	15	–	–
Chinese cabbage	Yes	28	3	5 h	Forced-air cooling

### Grading

There was no grading operation conducted at the time of our assessment.

bags and placed into cartons (one bag weighing approximately 20 kg). Chinese cabbage was put into polymer net bags, with one bag weighing about 25 kg. For domestic purposes, only willow baskets and net bags were used for packaging (no tissue paper or cartons). Oriental bunching onions were tied into bundles using wheat straw, regardless of market. Bundles averaged around 25 kg (Table 3).

### Packaging

For export, Chinese cabbage and broccoli were well packed. Firstly, they were individually wrapped in tissue paper. Broccoli was then packed in large film

**Table 3.** Packaging and price of Chinese cabbage, broccoli and Oriental bunching onions.

Produce type	Packaging	Volume (kg)	Package material	Cost (yuan/pg)	Price (yuan/kg)
Broccoli (domestic)	Yes	25	Willow basket	1.0	3.0
Broccoli (overseas)	Yes	20	Paper, film bag, carton	5.0	20
Chinese cabbage (domestic)	No			0	1.6
Chinese cabbage (overseas)	Yes	25	Paper, net bag	2.0	10.0
Bunching onions	Yes	25	Straw	0	0.8

## Storage

Oriental bunching onions and Chinese cabbage were stored during winter. Bunching onions were stored in the farmer's yard. During storage, the leaves became dry and covered the onion stem. Storage occurred from November to March, with a loss of about 50%. Chinese cabbage was stored in storage pits on-farm from November to March, with losses of up to 33% by the end of the storage period. For export, they were stored in a coldroom at 0°C. During storage, some outer leaves continuously detached. By the end of March, loss was about 25%. After packaging, vegetables destined for export were stored in the coldroom for 2 to 3 days (to meet the required volume for shipment) with almost no loss.

## Wholesale market

Vegetables were transported to the wholesale market from the field or collection site by truck. Chinese cabbage and Oriental bunching onions were stacked into trucks without packaging or a cover, while broccoli was packed into tractors or trucks with ice (during summer), and then covered to maintain a low temperature. No coldroom exists at the wholesale market to store vegetables, so losses are very high. Losses were estimated at 10–20% for Oriental bunching onions after 1 day at the wholesale market and 5–15% for Chinese cabbage. However, broccoli that was stored in a coldroom (far from the wholesale market) had only a small loss of about 3%. Deals are made freely between seller and buyer with only an administration fee to be paid to the wholesale market. The market is not responsible for buying, storing or selling, but only provides a place to organise deals.

## Export

From harvest to wholesale market, vegetables destined for export were kept at low temperatures all

the time. Vegetables were pre-cooled, packed and stored in a coldroom, and transported by refrigerated container. There was no loss during the time from pre-cooling to the wholesale market. A period of 3–4 days occurred between collection and arrival at the overseas market. The quality for and profit from export were higher than for the domestic market (Table 4).

## Conclusion

Because of low prices and profit in the domestic market, the farmers' access to postharvest techniques has been limited. Growers have had no knowledge of how to maintain vegetable quality and upgrade their product. Many factors have contributed to significant losses within the postharvest handling system.

## Pre-cooling

Although many coldrooms were built at the production field, there was no pre-cooling for most vegetables after harvest, and growers were not aware of the importance of pre-cooling. Until now, only vacuum pre-cooling equipment was available and it was too expensive for vegetables. Consequently, our centre (the Beijing Vegetable Research Center) and Qinghua University cooperated to design and produce forced-air pre-cooling equipment which is cheap and portable, with a pre-cooling rate 5–6 times faster than natural cooling in the coldroom.

## Packaging

Because growers wanted to reduce costs, they preferred not to invest in packaging. Packing vegetables in bamboo baskets or stacking them directly into trucks resulted in high mechanical injury and exposure to sunlight leading to high water loss. The produce was consequently of low quality when delivered to market.

**Table 4.** Vegetable losses at different steps from harvest to wholesale market.

Produce type	Harvest loss	Transport loss	Wholesale loss	Total loss	Price (yuan/kg)
Chinese cabbage (domestic)	10%	8%	10%	28%	1.0–1.6
Chinese cabbage (export)	50%	0%	0%	50%	10–12
Broccoli (domestic)	1%	5%	3%	9%	3.0–6.0
Broccoli (export)	20%	0%	0%	20%	12–16
Oriental bunching onions	1%	5%	15%	21%	0.8–1.4

## **Transport**

In summer, when produce was directly exposed to high temperatures and sunlight without covering and cooling, water loss was high for Chinese cabbage and broccoli. Refrigerated container trucks were not used unless the vegetables were destined for export.

## **Wholesale market**

Wholesale markets could not provide coldrooms for sellers, and vegetables could remain there for up to 3 days. During this time, produce remained packed in the truck in a condensed manner, with respiration and temperature in the produce stack being very high.

In summary, growers must learn techniques necessary for pre-cooling, packaging and transport of vegetable produce if vegetable quality is to be improved.

## **Acknowledgments**

This work is part of the Australian Centre for International Agricultural Research project 9416 'Extension of shelf-life of Asian leafy vegetables'. The authors would like to extend their thanks to Dr Tim O'Hare, Mr John Bagshaw and Mr Lung Wong from the Queensland Department of Primary Industries (QDPI) who gave much advice and help during this research.



# Postharvest Handling of 'Asian' Vegetables in the Northern Territory

M.J. Gosbee\* and T.K. Lim†

## Abstract

In the Northern Territory (NT) of Australia a significant proportion of vegetable production is based on 'Asian' type vegetables. These are mainly grown in the dry season (April–October) and are sold locally and interstate. Interstate markets are 4,000 km away from the place of production. Most vegetables are transported south by refrigerated road freight, which takes up to 4 days. This has necessitated careful handling and cooling of the vegetables to ensure they reach the market in an acceptable condition.

The most popular vegetables grown in the NT are bitter melon (*Momordica charantia*), snake bean (*Vigna unguiculata* cv. Group Sesquipedalis), okra (*Abelmoschus esculentus*), angled luffa or sinqua (*Luffa acutangula*), long, hairy and winter melon (all types of *Benincasa hispida*), kang kong (*Ipomoea aquatica*), and basil (*Ocimum basilicum*). These vegetables have different postharvest storage requirements.

Storage experiments testing the shelf life of some of these vegetables have been carried out over several years. Boxes of vegetables stored in several types of packaging at 5, 10, 15, and 20°C were evaluated for overall quality, chilling injury, water loss, and decay. Bitter melon and sinqua were best stored at 5°C in paper wrapping or a perforated plastic bag. Okra and snake bean developed chilling injury at 5°C, and were best stored at 10°C in plastic bags. Kang kong maintained its quality for longest when stored at 5°C. Generally, vegetables need to be cooled to less than 12°C before packaging. A more difficult issue has been educating the growers to thoroughly cool produce before packing to ensure the vegetables remain cool during transport.

TEMPERATURE control is the single most important factor in maintaining the shelf life and quality of vegetables after harvest (Kader 1992). In the Northern Territory (NT) of Australia, ambient daytime temperatures during the main vegetable production season (May to October) are hot and dry: temperature 19.3–33.1°C and relative humidity 38–78% (Bureau of Meteorology 1999). Vegetables of both 'European' and 'Asian' origin are grown in the NT. The 'Asian' vegetables are mainly tropical cucurbits, along with others requiring similar tropical climates. Interstate markets for these commodities are 4,000 km away. Produce is generally transported by refrigerated road freight which takes up to 4 days. Information on the medium-term storage of these vegetables is limited.

This paper describes several storage experiments conducted to determine the optimum temperature for transporting these vegetables, and some of the problems encountered with their postharvest handling.

## Materials and Methods

Five types of Asian vegetables were chosen for this study. Bitter melon (*Momordica charantia*) and snake beans (*Vigna unguiculata* cv. Group Sesquipedalis) are the most commonly grown vegetables (H. Ngo, NT Department of Primary Industry and Fisheries Economist, 1999, pers. comm.) and frequently have deterioration problems. Okra (*Abelmoschus esculentus*) also tends to have similar problems, presumably because of its high respiration rate (Kader 1992). Sinqua, or angled luffa, (*Luffa acutangula*) was chosen to be representative of several types of melon which are considered by growers to be less sensitive to temperature. Kang kong (*Ipomoea aquatica*) was chosen as a representative of common leafy vegetables.

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Vegetables were packed into boxes containing 3–10 kg of produce. Pack sizes were chosen to simulate current industry practices. They were either commercial size (for bitter melon and sinqua) or scaled down but still a representative size (snake bean, okra, and kang kong). Vegetables were sourced from local growers and repacked into the packaging treatments. Produce packed in paper wrapping had a double thickness placed at the top and bottom of the carton. Plastic bags were made of low-density polyethylene. Perforated bags had large holes (10 mm diameter) 20 mm apart over most of the area, while Peakfresh® bags are microperforated plastic bags with gas exchange properties. Again, specific treatments were chosen depending on the type of vegetable and the types of packaging used by growers (Table 1). They were then placed in a coolroom at 5, 10, 15, or 20°C.

Vegetables were assessed twice a week for quality, and once a week for weight loss. Quality was scored on a 1 to 5 subjective scale of 1 = excellent, 2 = good, 3 = saleable, 4 = poor and 5 = very poor. Shelf life was determined as the number of days a product took from harvest to reach a score of less than 3. Ratings were continued until produce reach a score of less than 2. Weight loss is expressed as the percentage of initial fresh weight remaining. This was determined in a slightly different manner in each experiment (Table 1).

Two boxes of each packaging × temperature treatment were used. Unfortunately the effect of temperature could not be statistically analysed as only one coolroom was available at each temperature. The effect of packaging on quality score was analysed using general linear models. Weight loss was significantly affected by packaging, and data were analysed by analysis of deviance.

## Results and Discussion

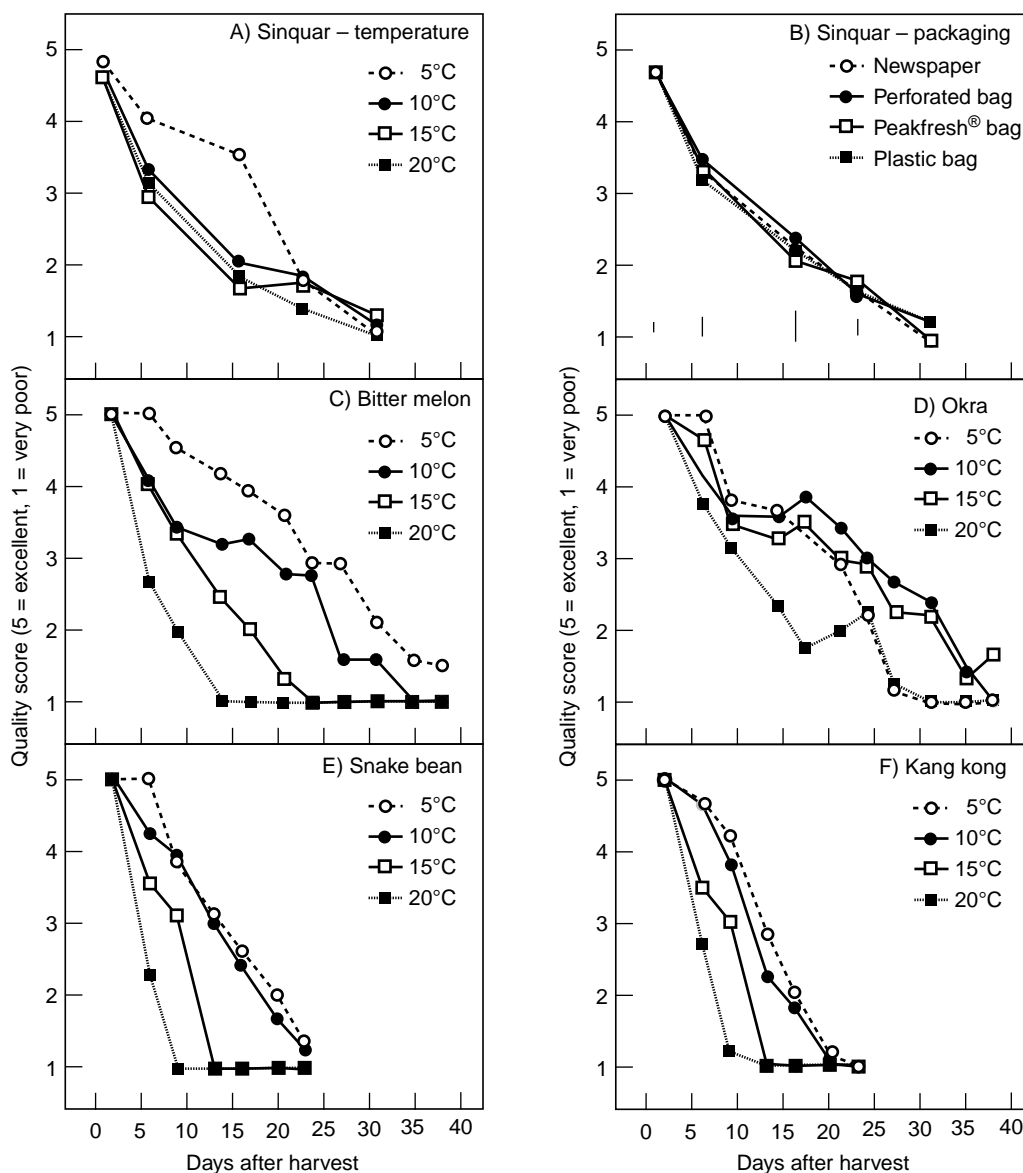
Temperature had a greater effect than packaging on quality and shelf life. Differences in the quality score of vegetables stored at different temperatures (Figure 1A, C–F) were greater than those observed between vegetables stored in different types of packaging (Figure 1B).

At any particular temperature, however, packaging had a distinct effect on the rate of water loss. Vegetables stored in plastic lost significantly less water than product stored without any plastic covering. Perforated bags were intermediate (Table 2). The rates for okra, <2% for produce in bags and 8.2% for okra in paper wrapping, were similar to those reported by Perkins-Veazie and Collins (1992). The use of Peakfresh® bags did not significantly increase the storage life of any of these products over the use of plastic bags.

The simple conclusion that every vegetable is best stored at 5°C in a plastic bag was not the case (Table 3). The use of plastic bags to reduce water loss is recommended only when the temperature can be accurately controlled. Warm produce packaged in plastic bags is difficult to cool because of reduced ventilation. If the temperature is not well controlled during transport, vegetables packaged in plastic bags are more likely to ‘cook’ because of the heat produced by their own respiration. For products such as snake bean which have a very high respiration rate (Zong et al. 1992), we currently recommend the use of perforated plastic bags as these have greater airflow capacity when the product is being cooled. This also highlights the importance of completely cooling produce before packaging.

**Table 1.** Packaging and pack size used in the assessment of optimum storage life and temperature of five ‘Asian’ vegetables.

	Bitter melon	Okra	Sinqua	Snake bean	Kang kong
Packaging					
Paper wrapping	M	M	M	M	M
Perforated bag	M		M	M	M
Peakfresh® bag		M	M	M	M
Plastic bag	M	M	M	M	M
Pack size	10 kg	5 kg	10 kg	5 kg	3 kg
Weight loss	Combined weight of 5 fruit	Combined weight of 10 fruit	Individual weight of 5 fruit	Total weight of 5 kg box	Total weight of 3 kg box



**Figure 1.** Effect of temperature (A, C–F) and packaging (B) on the quality of various ‘Asian’ vegetables during storage. Vertical bars (B) represent the least significant difference ( $P < 0.05$ ).

The use of plastic bags for bitter melon poses a different problem. These fruit are close to maturity at harvest. They produce, and are sensitive to, ethylene (Zong et al. 1992). The optimum stage of harvest is difficult to determine, and is clouded by the desire of growers to harvest heavier and therefore more profitable vegetables. As a bitter melon ripens, its flesh rapidly turns a brilliant yellow and splits open. This

may induce the rest of the melons in the box to likewise ripen. Since bitter melon is consumed immature, ripe fruit are unmarketable. Reducing the temperature reduces the rate of ripening and loss of quality (Figure 1C), but packing bitter melon in paper wrapping increases ventilation within the box and reduces the possibility of ethylene triggering the fruit to ripen.

**Table 2.** Weight loss (% initial fresh weight) after approximately 2 weeks in storage. Results are averaged across the four temperatures. Values followed by different letters within columns are significantly different ( $P < 0.05$ ).

	Bitter melon	Okra	Sinqua	Snake bean	Kang kong
Days after harvest	14	14	16	13	13
Packaging					
Paper wrapping	97.61 a	91.76 a	93.97 a	89.59 a	85.39 a
Perforated bag	97.81 a		95.03 a	94.14 b	93.27 b
Peakfresh <sup>®</sup> bag		98.54 b	97.90 b	99.56 c	99.91 c
Plastic bag	99.12 b	98.20 b	98.71 b	99.59 c	100.44 c

**Table 3.** Optimum storage temperatures and packaging combinations for maximising the shelf life of the five selected vegetables.

	Temperature (°C)	Packaging	Shelf life (weeks)
Bitter melon	5	Paper wrapping	3
Okra	10	Plastic bag	3
Sinqua	5	Any	2.5
Snake bean	5–10	Plastic bag	2.5
Kang kong	5	Plastic bag	2

In this trial, okra stored in paper wrapping succumbed to fungal decay more readily than that stored in plastic bags. It may be that the paper wrapping was a source of inoculum, or that water loss from the okra predisposed them to decay. These results indicate that plastic packaging is better than paper wrapping for this vegetable (Table 3).

The shelf life of sinqua stored at 20°C was not much different to that at 15° or 10°C, reflecting why sinqua and other melons have a reputation among growers for longer shelf life. Nevertheless, sinqua stored at 5°C had a significantly longer shelf life than sinqua stored at any other temperature (Figure 1A).

Kang kong is a leafy vegetable with a very short shelf life. Low temperatures of 5–10°C were beneficial in prolonging shelf life (Figure 1F). Water loss was significantly greater in paper wrapping and perforated bags from day 6, and the use of plastic bags is strongly recommended. At 15 and 20°C, breakdown in kang kong was seen as wilting and yellowing of the lower leaves, and fungal decay. At lower temperatures, colour and turgor were maintained for longer.

Chilling injury was observed in bitter melon and okra after 3 weeks at 5°C. Dark watery pits first appeared on the bitter melon at this time and increased with time in storage. Zong et al. (1992) suggested that none of these vegetables should be stored at less than

10°C for more than 2 weeks, due to chilling injury. The discrepancy in our results may be due to the time over which chilling injury was recorded. In the experiment of Zong et al. (1992), the vegetables were removed to 20°C and chilling injury recorded after 2–3 days. Symptoms of chilling injury may have been detected earlier had we held the vegetables at 20°C after removal from cooler temperatures.

At present, most growers cool their produce to 8–10°C, and temperatures of 4–6°C are used in road freight for short periods. While these temperatures may seem too low, they reduce the possibility of the vegetables heating within packaging. The transit time of 4 days to southern markets is short enough to minimise the risk of developing chilling injury. When vegetables are properly pre-cooled, vegetable quality is maintained and produce reaches markets in good condition.

Temperature control and packaging technologies exist for a range of vegetables. It is, however, important to match these not only to the physiology of each vegetable, but also to the capability of the growers and available transport options. Our recommendations may well change as the skill of the growers in postharvest handling and managing the cool chain increases.

## Acknowledgments

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## References

- Bureau of Meteorology, Commonwealth of Australia 1999. <<http://www.bom.gov.au/climate/averages/tables>>.
- Kader, A.A. 1992. Postharvest biology and technology: an overview. In: Kader, A.A., ed., Postharvest technology of horticultural crops. University of California (Division of Agriculture and Natural Resources), USA, Special Publication No. 3311, 15–20.
- Perkins-Veazie, P. and Collins, J.K. 1992. Cultivar, packaging, and storage temperature differences in postharvest shelf life of okra. *HortTechnology*, 2, 350–352.
- Zong, R.J., Cantwell, M., Morris, L. and Rubatzky, V. 1992. Postharvest studies on four fruit-type Chinese vegetables. *Acta Horticulturae*, 318, 345–354.

# Field Evaluation of Pesticides

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## *Abstract*

A field evaluation was conducted on three new pesticides alongside the two pesticides currently used in National Food Authority (NFA) warehouses. The evaluation was undertaken to source alternative pesticides for possible inclusion into the agency's pest control program.

The three NFA pest control methods—protective spraying, residual spraying, and fogging—were used to test cyfluthrin, deltamethrin, and permethrin-s-biol-piperonyl butoxide as the new pesticides, and permethrin and pirimiphos-methyl as controls.

Technical findings revealed that the new pesticides were comparable to the existing pesticides used by the NFA. Furthermore, all pesticides gave similar results in the control of stored product pests.

INFESTATION is one of the factors principally responsible for the deterioration of stored grains. Insects, mites etc. develop and reproduce rapidly in stored grains stored under ambient conditions, and have the ability to adapt to their environment. Insects usually affect stored product through feeding, subsequent heat damage caused by insect respiration, and microbiological activity on the infested stock.

Continuous use of same pesticide in a storage facility can trigger the evolution of resistant strains and eventually lead to the development of some levels of tolerance or resistance to pesticides. Even the use of lethal fumigants, such as phosphine gas, has failed to arrest the development of resistant strains. As new and more resistant strains of insect species develop, new pesticides need to be evaluated in order to discover alternative chemicals that could effectively eradicate insects. Promising candidates are include the pyrethroids. These are synthetic compounds that have chemical structures modelled on pyrethrin (or rethrin), a potent insecticide extracted from chrysanthemum flowers. The advantage of these chemicals is that they

have high biological activity against insects while being relatively safe for mammals (Magallona 1980).

This study, therefore, aimed to pursue improved and cost-effective pest control measures suitable for National Food Authority (NFA) stock management operations.

## **Objectives**

### **General**

To determine the effectiveness of cyfluthrin, deltamethrin, permethrin-s-biol-piperonyl butoxide, permethrin, and pirimiphos-methyl pesticides against stored product insects under field conditions.

### **Specific**

1. To determine the percentage insect mortality, and analyse pesticide residues and persistency of these five pesticides used as surface, stack, and space sprays under field conditions.
2. To compare the efficacy of cyfluthrin, deltamethrin, and permethrin-s-biol-piperonyl butoxide with existing chemicals used by NFA in their warehouses.
3. To determine the cost of application of the different pesticides tested.

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## Materials and Methods

The materials and equipment used in this study were stored bags of paddy and milled rice, nine warehouses and piles, test chemicals of cyfluthrin, deltamethrin, permethrin-s-biol-piperonyl butoxide, permthrin, and pirimiphos-methyl insecticides, backpack sprayers (10 L capacity), fogging machines, high-powered sprayers (200 L capacity), fumigating sheets, phosphine tablets, phosphine trays, plastic petri dishes, insect brush, magnifying lamp, microscope, forceps, masking tape, label forms, sample bags, grain probes, flashlights, extendable ladders, chalk, sampling frame, record books, bottom and sieve pans, sampling probe, sampling frame, and light traps.

### Experimental warehouses and piles

Identification of experimental warehouses and piles was conducted in NFA warehouses. Warehouse design and the materials used in construction, as well as the provision for prevention of insect infestation, were considered. The condition and volume of the stocks were also determined and pile size was based on what existed inside the warehouses.

### Preliminary survey of insect occurrence

Identification and assessment of insect occurrence per species was determined in all designated experimental warehouses. Insects were collected in these warehouses every other day (3 pm–8 am). The survey was conducted to provide baseline data on the presence of different insect species found in each warehouse before the application of the test chemical, and was followed by a 3-day break before the pest control treatments were applied, in order to stabilise the situation inside the warehouse with respect to insect activity.

### Data gathering

The different chemicals applied using the various pest control methods were evaluated using data gathered on the follow factors: percentage insect mortality and/or knockdown, persistency, development of inner infestation, and pesticide residue analysis.

## Pest control experimental treatments

The following treatments were applied, using three replications per treatment.

### *Protective spraying*

This treatment involves the application of contact pesticides (wettable powder) to piles of commodities, and aims to kill insects on the surface of the bags as well as to provide protection against reinfestation. The chemicals tested were cyfluthrin, deltamethrin, and permethrin (control).

Before chemical application, all experimental piles were fumigated and aerated for 7 days, to ensure that all piles began the trial in the same condition, i.e. free from outside and inner infestation. The three test chemicals are all synthetic pyrethroid insecticides which act mainly as contact poisons for the control of crawling and flying insects. The wettable powder form is odourless, off-white in colour, and does not stain. Protective spraying was applied with the aid of a backpack sprayer. A single application was made, following the mixing instructions and rate of application recommended by the manufacturer. All four sides and the top portion of the piles were sprayed. There were 23 identified sampling points per pile (peripheries and top portion of the pile) and on the floor base of the piles. Each sampling point measured 0.3 m × 0.3 m and a customised styropor was used as a sampling frame. The development of inner infestation inside the bags was monitored through the sampling of milled rice after fumigation on the initial, 7<sup>th</sup>, 14<sup>th</sup>, 21<sup>st</sup>, and 30<sup>th</sup> days of the observation period. Sampled bags were marked 'X' in order to have a uniform sample size and source for the initial and final sampling schedules. Similarly, samples from the same bags taken on the initial and 21<sup>st</sup> day (NFA standard operational procedure on protective spraying is every 21 days) were submitted immediately for pesticide residue analysis using gas–liquid chromatography at the Bureau of Plant Industry (BPI), National Pesticide Residue Analytical Laboratory. Insects were collected each morning from all experimental piles and submitted to the laboratory for insect counting and identification. Observations and sampling for persistency assessment of the pesticides took place from the 2<sup>nd</sup> day until the 30<sup>th</sup> day.

### *Fogging*

Fogging is a type of space-spraying intended to kill flying and crawling insects. It is also a necessary supplement to protective spraying. Smoke is generated

inside the warehouse by vaporising the insecticide in an oil solution or water emulsion. To maximise the effect, it is conducted at dawn or dusk, when insects are usually active.

There were nine experimental piles used in this segment of the project. Monitoring inside the warehouses was conducted for 28 days. Test chemicals used were cyfluthrin and permethrin-s-biol-piperonyl butoxide, while the control chemical was pirimiphos-methyl. Cyfluthrin and permethrin-s-biol-piperonyl butoxide are space-spray concentrates that are suitable for dilution in light oil or water and applied as an ultra-low volume aerosol, thermal fog or mist. They control a broad spectrum of flying insects and aid in the control of crawling insects such as cockroaches. They are pyrethroid-based chemicals with the principal active ingredient of cyfluthrin and permethrin, respectively. The latter has the addition of a synergist (piperonyl butoxide) and s-biol for knockdown effect. These were mixed and applied as per the manufacturer's recommendation. Pirimiphos-methyl, on the other hand, belongs to the organo-phosphate group of insecticides, also for use with stored products. It is in the form of an emulsifiable concentrate that eliminates both crawling and flying insects. Mixing and application of the chemical was followed as per the label recommendation. Cleaning of the warehouses was implemented prior to the application of treatments. All pesticides were applied in the late afternoon starting at 3:30 pm. 20 predetermined sampling points were designated in each of the 9 experimental warehouses, again using the sampling frame. Before the application of the chemicals, all sampling points were cleared of dead insects. Sampling was conducted on a daily basis. Initial samples were gathered after approximately 3–4 hours, or after the fog had cleared considerably or permitted sampling inside the warehouse, to observe the knockdown effect of the chemical.

#### *Residual spraying*

This treatment is a preventive pest control measure applied in storage buildings or warehouses. It aims to kill insects on all the surfaces in the building and provides protection against infestation. Only insects that come into contact with the insecticide are killed. Cyfluthrin, deltamethrin, and permethrin were again utilised in this phase of the project. All insecticides were tested in three NFA warehouses. Treatments were applied once and monitored for 30 days. The treatment chemical was applied to all walls, floors, posts, postharvest facilities and other structures as well as on the piles of paddy stored inside the warehouse. A

high-power sprayer that has the ability to reach higher parts of the warehouse structure—up to 15 metres—was used in this segment of the project. The mixing ratio for this phase was doubled for cyfluthrin (as per the manufacturer's suggested mixing ratio) while the mixing ratios for deltamethrin and permethrin were kept at the levels used previously. As in previous parts of this study, cleaning of the warehouse was conducted before treatment application. There were 25 identified sampling points scattered inside the warehouse floors. Initial samples to determine the insect mortality and knockdown effect of the pesticides were gathered a day after treatment. Pesticide persistency was measured through daily sampling from the 2<sup>nd</sup> day until the end of the monitoring period.

## Results and Discussion

### Protective spraying

#### *Insect mortality and/or knockdown*

The mortality/knockdown effect of the test chemical cyfluthrin indicated complete mortality, achieving a 100% mean on all major and minor pests after treatment, as shown in Table 1. Meanwhile, both deltamethrin and permethrin produced very similar results, with a mean mortality range value of 98–100% on all major and minor pests.

#### *Development of inner infestation*

Analysis of the inner infestation in bags showed that, directly after fumigation and aeration, all kinds of insect species collected were dead. As the monitoring period progressed, Psocopteran species reappeared after a week in all treatments. Towards the start of the third week, rust-red flour beetle, rusty grain beetle, psocids, and larvae were observed on the pile applied with cyfluthrin. On the other hand, using deltamethrin, psocids reappeared within 7 days and rusty grain beetle or *Cryptolestes* spp. on the 14<sup>th</sup> day and were observed throughout the rest of the 30-day monitoring period. Another minor pest, *Oryzaephilus surinamensis*, reappeared only on the 21<sup>st</sup> day, while the re-emergence of larvae started at the beginning of the third week of monitoring. For permethrin, only live psocids and larvae were observed, the latter emerging towards the fourth week of monitoring.

#### *Persistence of chemicals*

The persistence of all three chemicals was quite high, as indicated by mean mortality rates above 81% throughout the 30-day monitoring period. Live larvae



**Table 1.** Results of the protective spraying treatment.

Performance indicators	Cyfluthrin	Deltamethrin	Permethrin
Percentage insect mortality/ knockdown effect on major and minor pests	Effective 100% mean mortality	Effective 98–100% mean mortality	Effective 99–100% mean mortality
Development of inner infestation (bags)—emergent species	<i>Tribolium castaneum</i> <i>Cryptolestes</i> spp. <i>Liposcellis</i> spp. Larvae	<i>Liposcellis</i> spp. <i>Cryptolestes</i> spp. <i>Oryzaephilus surinamensis</i> Larvae	<i>Liposcellis</i> spp. Larvae
Persistency effect of chemicals on major and minor pests over 30-day monitoring period	86–100% mean mortality Psocids recurred after a week Live larvae on the 21 <sup>st</sup> day	81–99% mean mortality Psocids recurred after a week Live larvae on the 19 <sup>th</sup> day	84–100% mean mortality Psocids recurred after a week Live larvae by the 4 <sup>th</sup> week
Pesticide residue analysis	None detected	None detected	None detected
Flushing effect	Cockroaches	Cockroaches and lesser mealworms ( <i>Alphitobius diaperinus</i> )	Cockroaches
Cost analysis	PhP <sup>a</sup> 27.80/t	PhP 19.60/t	PhP 18.40/t

<sup>a</sup> PhP = Philippine Peso

were found on all piles, floors and peripheries treated with cyfluthrin, deltamethrin, and permethrin on the 21<sup>st</sup> day, 19<sup>th</sup> day, and by the beginning of the fourth week, respectively.

#### *Pesticide residue analysis*

There were no pesticide residues found on any of the piles, as determined by multi-residue analysis of rice samples.

#### *Flushing effect*

Cockroaches were flushed out by all the pesticides tested, with lesser mealworms also flushed out by deltamethrin.

#### *Pesticide cost analysis*

The existing pesticide (permethrin) had a cost of Philippine Peso (PhP) at PhP 18.40/t compared with deltamethrin and cyfluthrin costing PhP 19.60/t and PhP 27.80/t, respectively.

## **Fogging**

#### *Insect mortality and/or knockdown*

All the major and minor pests were affected, with the control pirimiphos-methyl registering the highest mean mortality rate of 95–100% (Table 2), followed by cyfluthrin at 88–100% and permethrin-s-biol-piperonyl butoxide at 78–100%.

#### *Persistence of chemicals and diluent requirement*

Persistence of the three chemicals was evident until the 28<sup>th</sup> day with a 90–100% mean mortality on all major and minor insects under observation. It is also important to mention here that applied cyfluthrin left a more lingering smell of the diesel inside the warehouse compared to the other two chemicals tested. This is probably because the ratio of diesel (6 L) to cyfluthrin (0.04 L of the product) is greater than the 0.45 L diluent per 0.1 L of pirimiphos-methyl, and 1 L of diluent for every 0.2 L of permethrin-s-biol-piperonyl butoxide.

#### *Pesticide cost analysis*

Permethrin-s-biol-piperonyl butoxide had a lower cost of application at PhP 0.058/m<sup>3</sup>, followed by pirimiphos-methyl at PhP 0.064/m<sup>3</sup> and cyfluthrin at PhP 0.071/m<sup>3</sup>.

## **Residual spraying**

#### *Insect mortality and/or knockdown*

Both cyfluthrin and the control permethrin exhibited 100% mean mortality, while deltamethrin registered a mean mortality range of 96–100% (Table 3).

**Table 2.** Results of fogging treatment.

Performance indicators	Cyfluthrin	Permethrin-s-biol-piperonyl butoxide	Pirimiphos-methyl
Percentage insect mortality/ knockdown effect on major and minor pests	Effective 88–100% mean mortality	Effective 78–100% mean mortality	Effective 95–100% mean mortality
Persistency effect of chemicals on major and minor pests over 28-day monitoring period	95–100% mean mortality	90–100% mean mortality	94–100% mean mortality
Diluent requirement	Higher consumption per application (6 L:0.04 L product) Lingering smell	Lower consumption per application (1 L:0.02 L product)	Least consumption per application (0.45 L:0.1 L product)
Cost analysis	PhP <sup>a</sup> 0.071/m <sup>3</sup>	PhP 0.058/m <sup>3</sup>	PhP 0.064/m <sup>3</sup>

<sup>a</sup> PhP = Philippine Peso

**Table 3.** Results of residual spraying treatment.

Performance indicators	Cyfluthrin	Deltamethrin	Permethrin
Percentage insect mortality/ knockdown effect on major and minor pests	Effective 100% mean mortality	Effective 96–100% mean mortality	Effective 100% mean mortality
Persistency effect of chemicals on major and minor pests over 30-day monitoring period	97–100% mean mortality	95–100% mean mortality	96–100% mean mortality
Cost analysis	PhP <sup>a</sup> 2.49/m <sup>2</sup>	PhP 1.77/m <sup>2</sup>	PhP 1.67/m <sup>2</sup>

<sup>a</sup> PhP = Philippine Peso

### *Persistence and cost of chemicals*

The three pesticides showed similar persistence behaviour with 95–100% mean mortality of major and minor pests throughout the 30-day monitoring period. Meanwhile, on a per square metre cost basis, the existing pesticide, permethrin, again showed the lowest application cost at PhP 1.67/m<sup>2</sup>, while the cost of cyfluthrin application is PhP 2.49/m<sup>2</sup> and deltamethrin is PhP 1.77/m<sup>2</sup>.

## Conclusions

### Protective and residual spraying

- Cyfluthrin, deltamethrin, and permethrin (control) showed a similar insect mortality/knockdown effect on all major and minor insect pests. Regarding persistence, all the pesticides tested had the same effect on all major and minor pests over the monitoring period.

- Protective spraying as a pest control method is safe, as far as consumer safety is concerned, as revealed by the negative result of the pesticide residue analysis conducted on all three pesticides.
- The existing pesticide being used by the agency (permethrin) remained the cheapest option compared to the two new pesticides tested for this type of control.

### Fogging

- Mortality and persistence of the pesticides tested revealed a high performance level in the control of major and minor insect pests. Meanwhile, cyfluthrin consumed a higher amount of diesel (diluent) when mixed with the test product compared with permethrin-s-biol-piperonyl butoxide and pirimiphos-methyl. A lingering smell of the diesel inside the warehouse was more pronounced using cyfluthrin compared to the other two chemicals tested. Further, in terms of cost per

application, permethrin-s-biol-piperonyl butoxide was found to be cheaper than cyfluthrin and pirimiphos-methyl.

In summary, all chemicals evaluated in these trials behaved similarly in the control of stored product pests.

### **Recommendations**

1. Based on their technical performance, it is recommended that cyfluthrin, deltamethrin and permethrin-s-biol-piperonyl butoxide be included in the approved list of pesticides to be used by the NFA in its Pest Management Program. This will provide users with a wider choice of pesticides to be used with the most appropriate pest control method for

warehouse application. Furthermore, rotation in the use of different pesticides can be adopted to aid in the reduction of build-up of resistance in insect pests to a single chemical.

2. Based on the findings, NFA could continue to use the existing pesticides (permethrin and pirimiphos-methyl) provided that the correct mixing ratio, dosage, and application methods are strictly followed.
3. Lastly, there is no substitute for the application of the basic principles of hygiene and sanitation to minimise, if not completely eradicate, infestation in the warehouse.

### **Reference**

- Magallona, E.D. 1980. Pesticide management. Philippines, Fertilizer and Pesticide Authority, 45–46.

# Trial on Storing of Maize Seed in Airtight Storage

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## Abstract

Trials on the preservation of maize seed quality under airtight storage conditions were carried out in the Nakornrachasima Province of Thailand during 1996–7. Sacks of maize for seed purposes ('Suwan #1') were stored in sealed polyvinyl chloride (PVC) sheeting, 0.8 mm thick and tailored to a shape known as the Volcani cube, with a volume of 15 m<sup>3</sup> and a storage capacity of approximately 10 t. Two cubes were loaded with grain and placed outdoors for 3 and 9 months, respectively, and observations were made at 2-week intervals to monitor temperature, relative humidity and seed moisture content inside the cubes. At the end of the respective storage periods, the cubes were opened to enable evaluation of numbers of insects, grain damage by insects, mould infection, percentage germination, and moisture content of the maize seed. The results of both trials indicated that the cubes could preserve maize seed quality. At the end of the trials, insect damage and live insects were not observed. Also, the levels of mould infection had only slightly increased and a low level of aflatoxin was revealed only in the second trial. Seed moisture content, germination percentage, temperature and relative humidity within the cubes before and after treatment showed only slightly differences and the seed was still in good condition.

MAIZE, when shelled, lacks its outer protective sheath, making it more susceptible to insect infestation. In Thailand, infestation may start in the field or in storage when sanitation is poor, and moulds may develop if the grain is not properly dried. It has been observed that severe damage to maize usually occurs within a few months of storage. Sukprakarn and Visarathanonth (1989) reported seven species of insect attacking maize during storage, with the maize weevil (*Sitophilus zeamais* Motsch.) being the most destructive pest. This insect caused damage of up to 50% damaged grains within six months of storage.

To reduce losses, grain protectants and fumigants are widely employed in spite of the fact that they leave pesticide residues that are detrimental to health and are environmentally hazardous. Safety concerns include both acute and chronic toxicity to pesticide operators

in particular, and to humans and animal life in general. Methyl bromide, for example, as an ozone-depleting substance, has been subjected to international restrictions in its use through the Montreal Protocol. (In some countries, pollution of surface and ground water by methyl bromide is also a concern.) Continuous and incorrect use of the fumigant phosphine has been shown to lead to insect resistance problems (Sukprakarn 1996).

The present trend in many countries is to use alternatives to these chemicals such as controlled or modified atmospheres by flushing with carbon dioxide (CO<sub>2</sub>) to control the insect pests. Furthermore, airtight or hermetic storage inside structures tailored from flexible polyvinyl chloride (PVC) liners (termed the Volcani cube) has been shown to provide an excellent grain storage solution where permanent structures are not available or affordable (e.g. Alvindia et al. 1994; Donahaye and Navarro 1990; Donahaye et al. 1991; Navarro and Donahaye 1993; Navarro et al. 1994, 1997). Such storage structures have also been adapted for the application of modified atmospheres, particularly for the prolonged storage of high value commodities.

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These studies were conducted to evaluate the performance of the Volcani cube, and to determine its suitability for the hermetic storage of maize seed under Thai conditions.

## Materials and Methods

Two trials using Volcani cubes were carried out at Nakhon in the Rachasima Province of Thailand, from October to December 1996, and December 1996 to September 1997. In each trial, 10 t of maize seed ('Suwan #1') in 100 kg bags were used with an average moisture content (MC) of 12.4% in trial 1 and 12.2% in trial 2, and an initial germination level that ranged from 94 to 100%.

The Volcani cubes, made of tailored, white PVC liner, 0.8 mm thick, consisted of a lower and the upper section which could be sealed together by a gas-proof zipper to completely enclose the grain stack. Dimensions of a '10 t cube' are 3.0 × 3.3 × 1.5 m (width × length × height) with a volume of 15 m<sup>3</sup>. Each cube was provided with a port-hole in the lower section to allow for removal of grain samples, and temperature and humidity measurements. The cubes were placed outdoors on the ground and the stacks of maize seed were stored in the cubes for 3 months in trial 1, and 9 months in trial 2. A stack of seed stored indoors at room temperature without any protection served as the control.

During the investigations, 1 kg samples of seed were removed from each cube every 2 weeks to determine insect and mould damage, seed moisture content, and germination percentage, and temperature and humidity were measured within the cubes. At the end of the trial, 14 marked sacks from different levels of the stack were sampled and compared with seed samples taken before treatment from the same sacks, and with the control sack.

**Table 1.** Total numbers of adult insects recorded in 1 × 1 kg sample taken before storage, and 14 × 1 kg samples at the end of storage in trial 1 and trial 2.

Species	Trial 1				Trial 2			
	Storage		Control		Storage		Control	
	Before	After	Before	After	Before	After	Before	After
<i>Sitophilus zeamais</i>	0	0	0	24	0	0	24	79
<i>Tribolium castaneum</i>	2	0	0	3	0	0	3	7
<i>Rhyzopertha dominica</i>					0	0	0	11
<i>Cryptolestes pusillus</i>					0	0	0	3

## Results

### Insect infestation

In trial 1, two live red flour beetle adults (*Tribolium castaneum*) were recorded before treatment, whereas after 3 months of storage, no live or dead insects were found in any sample (Table 1). However, in the control stack, the number of *Sitophilus oryzae* adults had increased considerably after 3 months of storage and the percentage of damaged grains was 7.85%.

In trial 2, there were no live or dead insects on the seed at the end of the sealed storage period, whereas in the control, numbers of *S. zeamais* and *T. castaneum* had increased, and the lesser grain borer (*Rhyzopertha dominica*) and the flat grain beetle (*Cryptolestes pusillus*) were also recorded (Table 1), and grain damage had reached 100%.

### Fungal infection

In trial 1, before storage, two fungal species were identified as infecting the maize seed, namely, *Fusarium moniliforme* (with 11% infected seeds) and *Aspergillus flavus* (9%). At the end of storage in the cube, infection levels of 1% by *Penicillium citrinum* and 2–4% by *Chaetomium* sp. were also recorded, while percentage infection by *F. moniliforme* (4–13%) and *A. flavus* (1–9%) revealed little change. Similarly, in the control stack, 9% infection by *F. moniliforme* and 1% by *P. citrinum* were recorded at the end of storage (Table 2). There were no differences in mould damage of the marked sacks inside the cube and aflatoxin was not detected.

In trial 2, five fungal species—*Aspergillus niger*, *A. flavus*, *F. moniliforme*, *Emericella nidulans* and *Chaetomium* sp.—were found contaminating the seed at the end of the 9-month storage period, although in

small numbers (Table 2). The only marked increase in infection at the end of the trial was in the control, where a 28% infection by *A. flavus* and 12% by *A. niger* were recorded (Table 2). Aflatoxin was recorded in the samples from all the marked bags in the cube, ranging from 0.29–1.44 parts per billion (ppb), with an average of 0.62 ppb, whereas in the control stack the aflatoxin level averaged 4.53 ppb.

## Seed moisture content and germination

The moisture content and germination level of the seeds in both trials are summarised in Table 3. Before storage, the average seed moisture content (MC) recorded in trial 1 was 12.4%, while at the end of the trial it was 12.2% in the cube, and 11.5% in the control. In trial 2, there was a slight increase to 13.6% MC during the 9 months of storage, with very little difference in MC between the 14 samples taken.

In trial 1, the initial germination averaged 97.2% (94–100%) and after 3-months storage it averaged 98.2% (97–100%), while germination in the control sack was 95%. In trial 2, germination averaged 81.2% (75–87%) after 9 months, whereas in the control all the seed had been damaged by insects, and a germination test could not be performed (Table 3).

## Temperature

The temperatures recorded once every two weeks inside the cube closely followed the average daily ambient temperatures in both trials (Figures 1 and 2).

## Relative humidity

Figures 3 and 4 show the percentage relative humidity within the cubes throughout the trials. There were no marked changes in relative humidity within the stacks in either trial, indicating that the moisture content of the seed also remained relatively stable throughout the stacks.

## Discussion and Conclusion

The trials undertaken to preserve maize seed quality using airtight storage resulted in complete control of insect infestation, with no live insects or insect-damaged kernels observed. Mould infection increased slightly in a few samples, though aflatoxin was observed only in trial 2, with a maximum concentration of 1.44 ppb as compared to control which reached up to 4.53 ppb. However, there was no indication that the stack had any effect on mould infection

percentage and aflatoxin contamination. Furthermore, seed moisture content and germination was scarcely affected by storage in the cube. Temperatures and humidity levels inside were similar to the ambient conditions even though the cubes were placed outdoors. These results indicate that airtight storage provided significant advantages for the long-term storage of maize seed in order to maintain quality.

The trials on the long-term storage of maize seed by storing in airtight storage for 3 and 9 months gave satisfactory results in controlling insect and mould infestation, although aflatoxin was detected in small amounts after 9 months of storage. Temperature and humidity conditions inside the cubes remained stable. Seed moisture content and germination percentages before and after storage revealed only slightly differences, and the seed was still in good condition

## Acknowledgments

We should like to thank the Uniseeds Co., Nakhon, Thailand, for providing the facilities that enabled these trials to be carried out, and Dr Jonathan Donahaye for helpful comments. We also thank the Australian Centre for International Agricultural Research (ACIAR) for funding us to contribute this paper in the poster session of the 19<sup>th</sup> Association of South-East Asian Nations (ASEAN)/1st Asia–Pacific Economic Cooperation (APEC) Seminar on Postharvest Technology.

## References

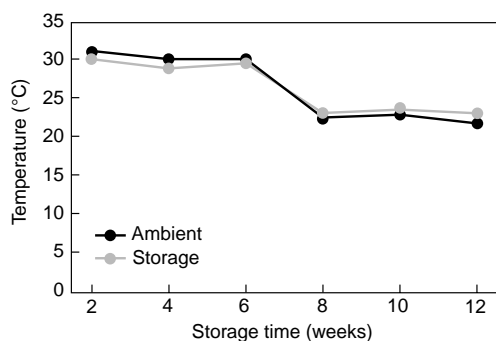
- Alvandia, D.G., Caliboso, F.M., Sabio G.C. and Regpara, A.R. 1994. Modified atmosphere storage of bagged maize outdoors using flexible liners: a preliminary report. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., Stored product protection. Proceedings of the 6<sup>th</sup> international working conference on stored-product protection, 17–23 April 1994, Canberra, Australia, Volume 1. Wallingford, CAB International, 22–29.
- Donahaye, E., Ziv, A., Blauschild, Y., Navarro, S. and Weerasinghe, D. 1991. Storage of paddy in hermetically sealed plastic liners in Sri Lanka. *Tropical Science*, 31, 109–121.
- Donahaye, E. and Navarro, S. 1990. Flexible PVC liners for hermetic or modified atmospheric storage of stacked commodities. In: Champ, B.R., Highley, E. and Banks, H.J., ed., Fumigation and controlled atmosphere storage of grain. Proceedings of an international conference held at Singapore, 14–18 February 1989. ACIAR Proceedings No. 25. Canberra, Australian Centre for International Agricultural Research, 271.

**Table 2.** Fungal infection (%) in maize samples taken before and after storage in trial 1 and trial 2.

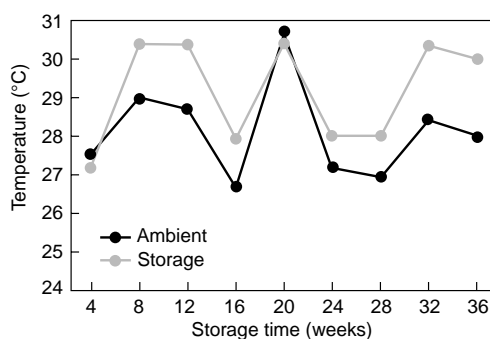
Species	Trial 1				Trial 2			
	Storage		Control		Storage		Control	
	Before	After	Before	After	Before	After	Before	After
<i>Fusarium moniliforme</i>	11	4–13	11	9	4–13	1	9	0
<i>Aspergillus flavus</i>	9	1–9	9	0	1–9	1–11	0	28
<i>Aspergillus niger</i>	0	0	0	0	0	2	0	12
<i>Penicillium citrinum</i>	0	1	0	1	1	0	1	0
<i>Emericella nidulans</i>	0	0	0	0	0	1	0	0
<i>Chaetomium</i> sp.	0	2–4	0	0	2–4	1	0	0

**Table 3.** Moisture content (%) and germination (%) of maize seed taken before (1 sample) and after storage (14 samples) in trial 1 and trial 2.

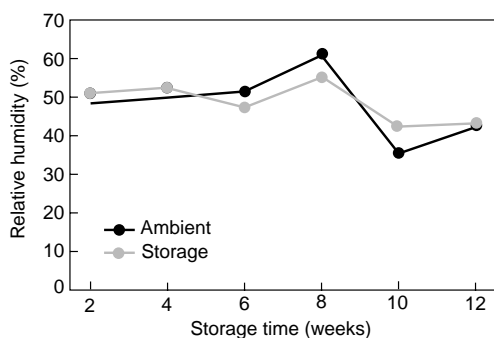
Sack no.	Trial 1		Trial 2	
	Moisture content	Germination	Moisture content	Germination
1	12.7	97.0	13.0	87.0
2	12.5	98.0	13.5	80.0
3	11.8	97.0	13.7	84.0
4	11.2	100.0	13.6	86.0
5	12.7	98.0	13.4	82.0
6	11.8	99.0	13.8	79.0
7	11.6	97.0	13.6	81.0
8	12.5	99.0	13.6	80.0
9	11.9	99.0	13.9	81.0
10	12.4	98.0	13.7	85.0
11	12.5	99.0	13.9	75.0
12	13.0	98.0	13.7	82.0
13	11.6	99.0	13.5	76.0
14	12.1	97.0	13.6	79.0
Mean after treatment	12.2	98.2	13.6	81.2
Control	11.5	95.0	13.6	0.0
Before treatment	12.4	97.2	12.2	98.2



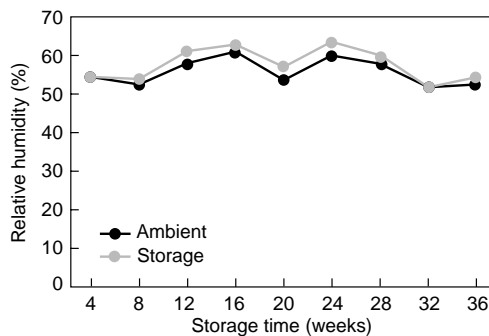
**Figure 1.** Temperatures recorded at different times throughout the 3 month storage period of trial 1.



**Figure 2.** Temperatures recorded at different times throughout the 9 month storage period of trial 2.



**Figure 3.** The relative humidity recorded at different times throughout the 3 month storage period of trial 1.



**Figure 4.** The relative humidity recorded at different times throughout the 9 month storage period of trial 2.

Navarro, S. and Donahaye, E. 1993. Preservation of grain in airtight storages. In: 5th international congress on mechanization and energy in agriculture, 11–14 October 1993, Kusadasi, Turkey, 425–434.

Navarro, S., Donahaye, E.J. and Fishman, S. 1994. The future of hermetic storage of dry grains in tropical and subtropical climates. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., Stored product protection. Proceedings of the 6<sup>th</sup> international working conference on stored-product protection, 17–23 April 1994, Canberra, Australia, Volume 1. Wallingford, CAB International, 130–138.

Navarro, S., Caliboso, F.M., Sabio, G.C. and Donahaye, E.J. 1997. Quality conservation of paddy stored under gas-

tight seal outdoors in the Philippines. In: Proceedings of an international conference on controlled atmosphere and fumigation in grain storages, 21–26 April 1996, Nicosia, Cyprus, 159–168.

Sukprakarn, C. 1996. Alternative chemicals for replacing methyl bromide. *Journal of Entomology and Zoology*, 18, 66–68 (in Thai).

Sukprakarn, C. and Visarathanonth, P. 1989. Insecticide control for stored maize. In: Naewbanij, ed., Grain postharvest research and development: priorities for the nineties: proceedings of the twelfth ASEAN seminar on grain postharvest technology, Surabaya, Indonesia, 68–74.



# Airtight Storage of Maize: Its Effect on Fungal Infection and Aflatoxin Production

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## Abstract

The effects of airtight storage on fungal infection and aflatoxin production of maize were investigated. Maize 'CPI-2' was placed in polyethylene bags (2 kg/bag) under airtight conditions (initial O<sub>2</sub> content was 1.4 ± 0.1%). The maize was stored for six months under warehouse conditions. Three replicates were used for each treatment. The initial moisture contents (MCs) of maize in the bags were 14 ± 0.3%, 17 ± 0.2% and 20 ± 0.2%. As controls, maize samples with the same initial MCs were placed in polyethylene bags under normal conditions (air) with O<sub>2</sub> content of 21%. Each bag was arranged horizontally and randomly on a wooden table.

The *Aspergillus flavus* population was determined through isolation using a dilution method followed by plating on *Aspergillus flavus* and *parasiticus* agar (AFPA), while dichloran 18% glycerol agar (DG18) was used for isolation of other storage fungi. Aflatoxin content was determined using thin layer chromatography (TLC).

The results showed that the total fungal population, population of *A. flavus*, and total aflatoxin B<sub>1</sub> content in maize with the three initial MCs packed under normal conditions were higher than under airtight conditions. The total fungal population in maize with initial MCs of 14 and 17% increased with the increase of storage duration, while the population in maize with initial MC of 20% fluctuated. The population of *A. flavus* on maize fluctuated during storage in all treatments. Total aflatoxin B<sub>1</sub> content increased with the increase of storage duration.

DURING STORAGE, maize can be infested with insects, mites, microorganisms and rodents. Among the microorganisms, fungi are the most important cause of deterioration of stored products (Sauer et al. 1992). Storage fungi can cause discoloration, decreases in nutritional content and seed germination, and produce heat, mustiness and mycotoxins.

The most notorious toxin is aflatoxin, as it is an extremely potent carcinogen affecting several domestic animals and humans. It is produced by *Aspergillus flavus* and *A. parasiticus*. Most feedstuffs are contaminated by aflatoxin (Dutton and Westlake 1985). Among the raw materials of feedstuffs, maize is a common source of aflatoxin.

Surveys conducted by a BIOTROP team in 1993/1994 revealed that 108 maize samples collected from farmers in two maize-growing areas (Central Lampung and Kediri Regencies) contained 5–291 parts per billion (ppb) of aflatoxin B<sub>1</sub>. 87 samples contained more than 30 ppb aflatoxin B<sub>1</sub> (Dharmaputra et al. 1996). The Food and Agriculture Organization of the United Nations/World Health Organization/United Nations International Children's Emergency Fund (FAO/WHO/UNICEF) Protein Advisory Group have recommended a tolerable aflatoxin limit of 30 ppb for human foods (Bainton et al. 1980). In all member states of the European Union, the maximum permitted levels for aflatoxin B<sub>1</sub> and total aflatoxins in cereals are 2 and 4 ppb, respectively (Visconti 1998).

Control of aflatoxin is attained, among others ways, by preventing fungal growth. In stored grain, fungal growth can be inhibited through airtight storage (low O<sub>2</sub>). The moisture content (MC) of grains also plays an

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important role in enhancing fungal growth. High MC encourages the incidence of fungi, while airtight storage reduces it. Nevertheless, the sporulation of yeast is not inhibited when levels of available O<sub>2</sub> are low.

In tropical countries like Indonesia, at the farm level, grain is often stored at high MC as harvesting time often occurs during the rainy season.

The objective of this study was to obtain information on the effects of airtight storage on fungal infection and aflatoxin production of maize with different initial MCs.

## Materials and Methods

### Maize storage

Maize 'CPI-2' was packed in polyethylene bags (2 kg/bag) under airtight conditions (initial O<sub>2</sub> content at the beginning of storage was 1.4 ± 0.1%) for 6 months in a warehouse. The daily range of temperatures and relative humidity of the storage were 23–28°C and 67–93%, respectively. Three replications (three bags) were used for each treatment. The initial MCs of the maize samples were 14 ± 0.3%, 17 ± 0.2% and 20 ± 0.2%, respectively. Each bag was arranged horizontally and randomly on a wooden table. As controls, maize samples with the same initial MCs were packed in polyethylene bags under normal conditions (air) with O<sub>2</sub> content of 21%. During storage, the temperature and relative humidity of the storage were recorded using a thermohygrograph.

### Obtaining samples for different analyses

Samples were obtained from each bag at the beginning of storage, and subsequently at 1, 2, 3, 4, 5 and 6 months of storage. Subsamples were then used to analyse MC, fungal populations and aflatoxin content.

### Moisture content and fungal and aflatoxin analyses

Moisture content was determined using an oven method (AOAC 1984). The *Aspergillus flavus* population was determined by isolation using a dilution method followed by pour-plating on *Aspergillus flavus* and *parasiticus* agar (AFPA), while dichloran 18% glycerol agar (DG18) (Pitt and Hocking 1997) was used for isolation of other storage fungi. Aflatoxin

levels were determined using a thin layer chromatography (TLC) method (Blaney et al. 1984).

### Statistical analysis

The data were analysed using a completely randomised factorial design with two factors. The 1<sup>st</sup> and 2<sup>nd</sup> factors were oxygen content and duration of storage, respectively.

## Results and Discussion

### Fungal species and population

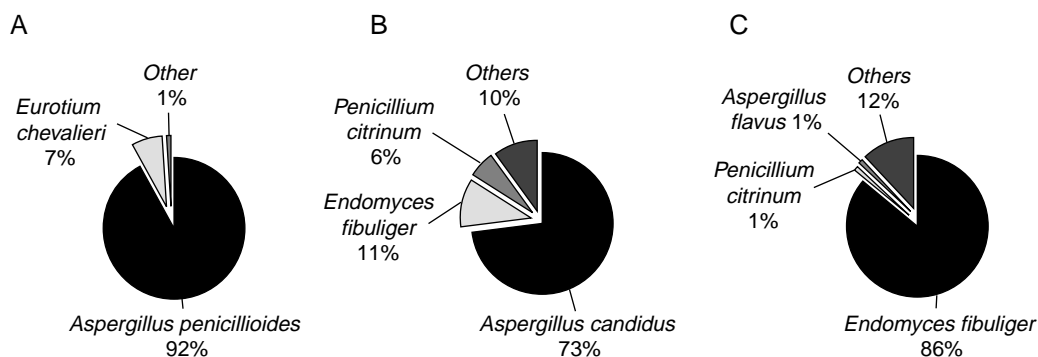
Nineteen species of fungi were isolated from the maize samples under all conditions after six months of storage. They were *Acremonium strictum*, *Aspergillus candidus*, *A. flavus*, *A. niger*, *A. ochraceus*, *A. penicillioides*, *A. tamarii*, *A. versicolor*, *A. wentii*, *Cladosporium cladosporioides*, *Endomyces fibuliger*, *Eurotium chevalieri*, *E. repens*, *E. rubrum*, *Fusarium moniliforme*, *F. semitectum*, *Paecilomyces variotii*, *Penicillium citrinum* and *Syncephalastrum racemosum*. The predominant fungi in maize of 14, 17 and 20% MC were *A. penicillioides* (92%), *A. candidus* (73%) and *Endomyces fibuliger* (86%), respectively (Figure 1).

A summary of the total fungal population, population of *A. flavus* and total aflatoxin B<sub>1</sub> of maize at the different initial MCs stored for a 6-month period is shown in Table 1.

Statistically, the effect of O<sub>2</sub> concentration on the total fungal population of maize of initial MCs of 17 and 20% was very significant. The effect of storage duration on total fungal populations was also very significant for all three initial MCs.

The total fungal populations of maize with initial MCs of 14, 17 and 20%, stored under airtight conditions, were lower than those of samples stored under normal conditions, although, statistically, the difference in total fungal population of maize with initial MC of 14% between these two conditions was not significant.

According to Clarke and Hill (1981), there was no fungal growth on wheat stored under airtight conditions. Richard-Molard et al. (1986) reported that the growth of most storage fungi (including *Penicillium* and *Aspergillus*) on milled rice stored under airtight conditions (less than 1% O<sub>2</sub>) was inhibited and they could not grow without oxygen. In general, storage fungi such as *Penicillium* and *Aspergillus* are more sensitive to low O<sub>2</sub> concentrations than field fungi.



**Figure 1.** Predominant and other fungal species on maize with moisture contents of (A) 14%, (B) 17% and (C) 20%.

**Table 1.** Mean of total fungal population, population of *Aspergillus flavus* and total aflatoxin B<sub>1</sub> content of maize with different initial moisture contents and stored for 6 months.

Moisture content (%)	Total fungal population (colonies/g)	Population of <i>A. flavus</i> (colonies/g)	Total aflatoxin B <sub>1</sub> content (ppb)
14	$8.1 \times 10^4$	$1.5 \times 10^2$	65
17	$2.1 \times 10^6$	$1.6 \times 10^4$	95
20	$1.3 \times 10^6$	$7.4 \times 10^2$	79

Except for *P. roqueforti*, the growth of most *Penicillium* species was reduced by more than 50% in atmospheres with 1% O<sub>2</sub> or less. *A. candidus* and some *Eurotium* species are the most tolerant to low O<sub>2</sub> conditions (Magan and Lacey 1984). According to Richard-Molard et al. (1986) the growth of most storage fungi on milled rice stored for 2–4 months was inhibited under conditions of less than 1% O<sub>2</sub>.

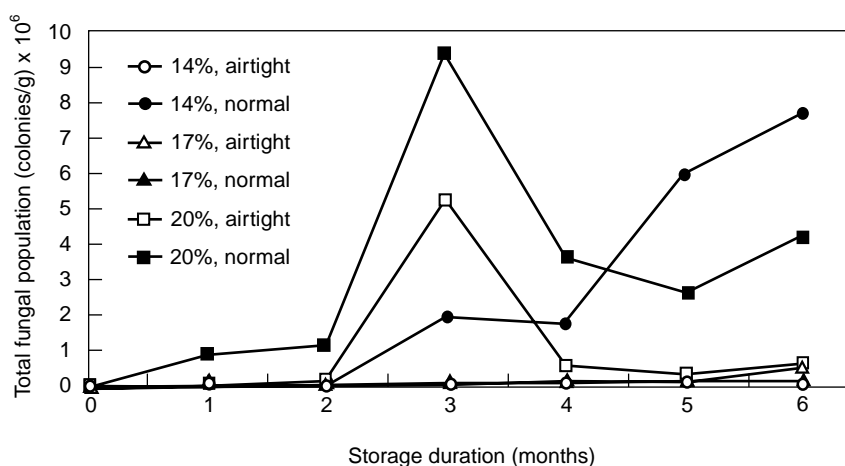
During storage, the mean total fungal populations on maize with initial MC of 14% stored under normal and airtight conditions were  $8.5 \times 10^4$  and  $7.7 \times 10^4$  colonies/g, respectively; at 17% MC were  $2.5 \times 10^6$  and  $1.8 \times 10^5$  colonies/g, respectively; and at 20% MC were  $3.1 \times 10^6$  and  $1.0 \times 10^6$  colonies/g, respectively (Tables 2, 3 and 4). The highest total fungal population was on maize with an initial MC of 20% ( $2.1 \times 10^6$  colonies/g) and the lowest was on maize with initial MC of 14% ( $8.1 \times 10^4$  colonies/g), while on maize with initial MC of 17% it was  $1.3 \times 10^6$  colonies/g (Table 1). This was due to the high population of *Endomyces fibuliger* on maize with initial MC of 20%. According to Pitt and Hocking (1997), yeast such as *E. fibuliger* grow well at high MCs.

The average total fungal population on maize with initial MCs of 14 and 17% stored under airtight and normal conditions increased as the storage duration increased, while on maize with initial MC of 20% the population fluctuated (Figure 2). The fluctuation was due to drastic changes in the *E. fibuliger* population.

### *Aspergillus flavus*

Based on the statistical analysis, O<sub>2</sub> concentration and storage duration gave very significant differences in the populations of *A. flavus* on maize with initial MCs of 17 and 20%.

The populations of *A. flavus* on maize with initial MCs of 14, 17 and 20% and stored under airtight conditions were lower than those stored under normal conditions, although based on statistical analysis the population of maize with initial MC of 14% was not significantly different for the two conditions. Landers et al. (1967) revealed that *A. flavus* growth on peanuts was much reduced in atmospheres of less than 5% O<sub>2</sub>, and almost completely inhibited at less than 1% O<sub>2</sub>.



**Figure 2.** Total fungal population on maize with initial moisture contents of 14, 17 and 20%, stored under airtight and normal conditions.

**Table 2.** Total fungal population (colonies/g) of maize with initial moisture content of 14%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	$7.8 \times 10^2$	$5.9 \times 10^2$	$5.8 \times 10^3$	$6.0 \times 10^4$	$1.1 \times 10^5$	$2.2 \times 10^5$	$2.0 \times 10^5$	$8.5 \times 10^4$
Airtight	$2.4 \times 10^2$	$4.5 \times 10^2$	$4.8 \times 10^3$	$4.4 \times 10^4$	$1.1 \times 10^5$	$1.8 \times 10^5$	$2.0 \times 10^5$	$7.7 \times 10^4$
Average	$5.1 \times 10^2$ a	$5.2 \times 10^2$ a	$5.3 \times 10^3$ b	$5.2 \times 10^4$ c	$1.1 \times 10^5$ d	$2.0 \times 10^5$ e	$2.0 \times 10^5$ e	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.

**Table 3.** Total fungal population (colonies/g) of maize with initial moisture content of 17%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	$1.7 \times 10^2$ h	$5.4 \times 10^4$ i	$9.3 \times 10^4$ i	$2.0 \times 10^6$ jk	$1.8 \times 10^6$ jk	$5.9 \times 10^6$ jk	$7.6 \times 10^6$ k	$2.5 \times 10^6$ a
Airtight	$1.7 \times 10^2$ h	$6.7 \times 10^4$ i	$7.7 \times 10^4$ i	$1.2 \times 10^5$ i	$2.2 \times 10^5$ ij	$1.3 \times 10^5$ i	$6.1 \times 10^5$ ij	$1.8 \times 10^5$ b
Average	$1.7 \times 10^2$ c	$6.1 \times 10^4$ d	$8.5 \times 10^4$ de	$1.0 \times 10^6$ fg	$1.0 \times 10^6$ fg	$3.0 \times 10^6$ ef	$4.1 \times 10^6$ g	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.

During storage, populations of *A. flavus* on maize with an initial MC of 14%, stored under normal and airtight conditions were  $2.0 \times 10^2$  and  $1.1 \times 10^2$  colonies/g, respectively; at initial MC of 17% were  $3.1 \times 10^4$  and  $1.6 \times 10^3$  colonies/g, respectively; and at initial MC of 20% were  $1.2 \times 10^3$  and  $2.5 \times 10^2$  colonies/g, respectively (Tables 5, 6 and 7). The highest population of *A. flavus* was on maize with initial MC of 17% ( $1.6 \times 10^4$  colonies/g) and the lowest was on maize with initial MC of 14% ( $1.5 \times 10^2$  colonies/g), while on maize with initial MC of 20% it was  $7.4 \times 10^2$  colonies/g (Table 1). Brockington et al. (1949) considered the optimal MC for *A. flavus* growth

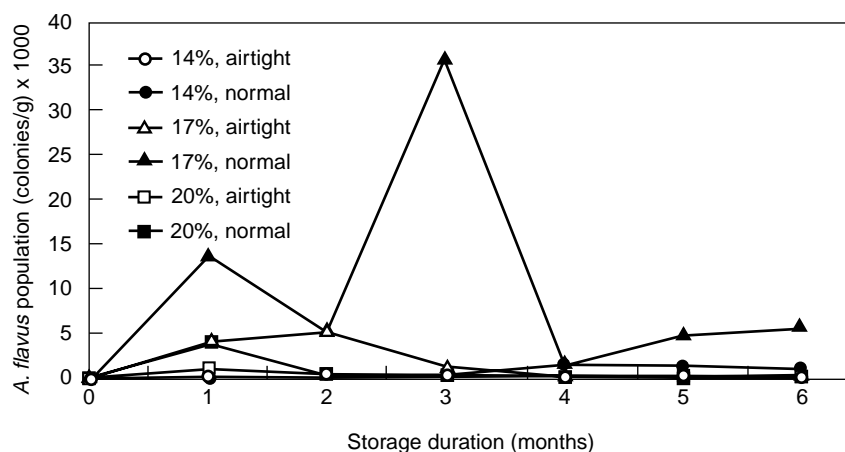
to be 17.0–17.4%, while Christensen and Kaufmann (1974) reported that it was 18.0–18.5%.

During storage, populations of *A. flavus* on maize with initial MCs of 14, 17 and 20%, stored under airtight and normal conditions, fluctuated (Figure 3). The fluctuation was due to the presence of fungi antagonistic to *A. flavus*. According to Zummo and Scott (1992), *F. moniliforme* inhibited *A. flavus* infection on maize. Choudhary and Sinha (1993) reported that the predominant fungi competing with *A. flavus* were *A. glaucus*, *A. niger*, *Fusarium* spp. and *Penicillium* spp. Dharmaputra and Putri (1996) revealed that *Eurotium chevalieri* and *F. moniliforme* were antagonistic to *A. flavus*.

**Table 4.** Total fungal population (colonies/g) of maize with initial moisture content of 20%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	$5.6 \times 10^2$	$8.8 \times 10^5$	$1.2 \times 10^6$	$9.2 \times 10^6$	$3.6 \times 10^6$	$2.6 \times 10^6$	$4.2 \times 10^6$	$3.1 \times 10^6$ a
Airtight	$1.4 \times 10^2$	$1.4 \times 10^5$	$1.5 \times 10^5$	$5.3 \times 10^6$	$6.0 \times 10^5$	$3.6 \times 10^5$	$5.9 \times 10^5$	$1.0 \times 10^6$ b
Average	$3.5 \times 10^2$ c	$5.1 \times 10^5$ d	$6.8 \times 10^5$ d	$7.2 \times 10^6$ e	$2.1 \times 10^6$ d	$1.5 \times 10^6$ d	$2.4 \times 10^6$ d	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.



**Figure 3.** Population of *Aspergillus flavus* on maize with initial moisture contents of 14, 17 and 20%, stored under airtight and normal conditions.

**Table 5.** Population of *Aspergillus flavus* (colonies/g) of maize with initial moisture content of 14%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	$1.8 \times 10^2$	$4.8 \times 10^2$	$3.2 \times 10^2$	$2.3 \times 10^2$	$5.3 \times 10$	$4.3 \times 10$	$8.9 \times 10$	$2.0 \times 10^2$
Airtight	$9.2 \times 10$	$1.6 \times 10^2$	$1.9 \times 10^2$	$9.8 \times 10$	$7.6 \times 10$	$7.3 \times 10$	$6.2 \times 10$	$1.1 \times 10^2$
Average	$1.3 \times 10^2$	$3.2 \times 10^2$	$2.5 \times 10^2$	$1.7 \times 10^2$	$6.5 \times 10$	$5.8 \times 10$	$7.6 \times 10$	

**Table 6.** Population of *Aspergillus flavus* (colonies/g) of maize with initial moisture content of 17%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	$5.6 \times 10^f$	$1.4 \times 10^4$ hi	$5.0 \times 10^3$ hi	$3.6 \times 10^4$ i	$1.5 \times 10^5$ j	$4.6 \times 10^3$ hi	$5.7 \times 10^3$ hi	$3.1 \times 10^4$ a
Airtight	$1.9 \times 10^f$	$3.8 \times 10^3$ h	$5.7 \times 10^3$ hi	$1.0 \times 10^3$ g	$3.2 \times 10^2$ g	$4.5 \times 10^f$	$3.2 \times 10^f$	$1.6 \times 10^3$ b
Average	$3.7 \times 10^c$	$9.0 \times 10^3$ e	$5.4 \times 10^3$ e	$1.9 \times 10^4$ e	$7.4 \times 10^4$ e	$2.3 \times 10^3$ d	$2.9 \times 10^3$ f	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.

**Table 7.** Population of *Aspergillus flavus* (colonies/g) of maize with initial moisture content of 20%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	$7.5 \times 10$	$3.9 \times 10^3$	$6.6 \times 10^2$	$1.6 \times 10^2$	$1.3 \times 10^3$	$1.4 \times 10^3$	$1.1 \times 10^3$	$1.2 \times 10^3$ a
Airtight	$3.9 \times 10$	$9.5 \times 10^2$	$9.9 \times 10$	$3.9 \times 10^2$	$1.6 \times 10^2$	$1.0 \times 10^2$	$2.0 \times 10$	$2.5 \times 10^2$ b
Average	$5.7 \times 10$ cd	$2.4 \times 10^3$ e	$3.8 \times 10^2$ cde	$2.8 \times 10^2$ cd	$7.5 \times 10^2$ de	$7.3 \times 10^2$ cd	$5.4 \times 10^2$ c	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.

## Total aflatoxin B<sub>1</sub> content

In this study, two kinds of aflatoxin were obtained, i.e. aflatoxin B<sub>1</sub> and B<sub>2</sub>. Aflatoxin B<sub>2</sub> was converted into aflatoxin B<sub>1</sub>, and calculated as total B<sub>1</sub>. According to Heathcote and Hibbert (1978), aflatoxin B<sub>1</sub> was the most acutely toxic of the first four aflatoxins to be recognised.

Based on the statistical analysis, O<sub>2</sub> concentration and storage duration gave very significant differences in the total aflatoxin B<sub>1</sub> content of maize with initial MCs of 14, 17 and 20%. Their interaction regarding maize with initial MCs of 14 and 20% were significantly different, but did not give significant differences in maize with an initial MC of 17%.

During storage, the total aflatoxin B<sub>1</sub> content on maize with initial MCs of 14, 17 and 20%, stored under airtight conditions was lower than that stored under normal conditions. Wilson and Jay (1976) observed that aflatoxin accumulation was controlled effectively under atmospheres of less than 1% O<sub>2</sub>. Furthermore, Wilson et al. (1977) reported that no aflatoxin was detected on maize with a MC of 18.8% stored under conditions of 14–15% CO<sub>2</sub> and 0.5–1.0% O<sub>2</sub> for 35 and 109 days, respectively, whereas a control sample stored in the air contained 472 ppb total aflatoxin. The aflatoxin content of wheat stored in an atmosphere of 0.03% O<sub>2</sub> was less than 1 ppb, while for the control (air) it was more than 1,000 ppb (Fabbri et al. 1980). Landers et al. (1967) revealed that aflatoxin produced by *A. flavus* on peanuts stored under airtight

conditions decreased greatly compared to the control (air).

During storage, the total aflatoxin B<sub>1</sub> contents of maize with an initial MC of 14%, stored under normal and airtight conditions were 71 and 59 ppb, respectively; at an initial MC of 17% were 101 and 87 ppb, respectively; and at an initial MC of 20% were 95 and 62 ppb, respectively (Tables 8, 9 and 10). Viquez et al. (1994) reported that three main factors (biological, chemical and environmental) greatly influenced aflatoxin production, where O<sub>2</sub> concentration was one of the environmental factors. The highest total aflatoxin B<sub>1</sub> content was on maize with an initial MC of 17% (95 ppb) and the lowest was on maize with initial MC of 14% (65 ppb), while on maize with initial MC of 20% it was 79 ppb (Table 1). During storage, the highest population of *A. flavus* was also on maize with an initial MC of 17% and the lowest was on maize with an initial MC of 14% (Table 1). WHO (1979) reported that the lower limit of MC for aflatoxin production in maize was 18.3–18.5%.

During storage, the total aflatoxin B<sub>1</sub> content of maize with initial MCs of 14, 17 and 20%, stored under airtight and normal conditions increased (Figure 4). This increase was due to aflatoxin accumulation on the substrate. According to Sinha (1993), detoxification of mycotoxin on substrate stored under normal conditions is difficult to carry out.

## Conclusions

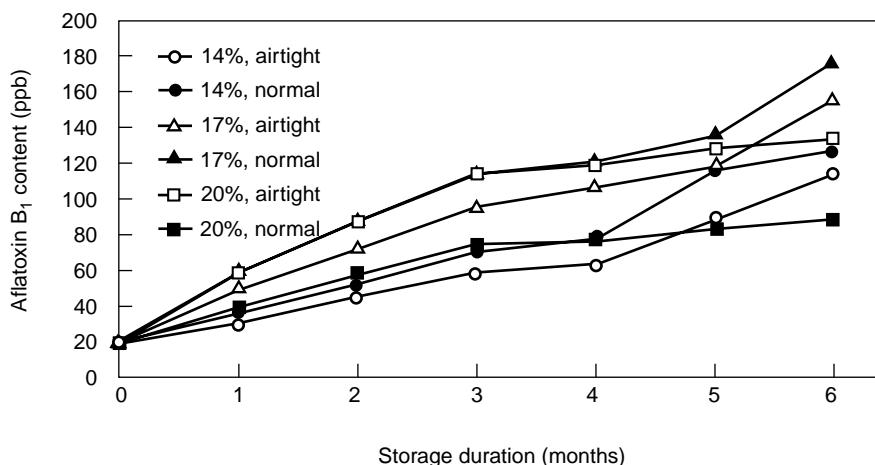
The total fungal population, population of *A. flavus*, and total aflatoxin B<sub>1</sub> content on maize stored under airtight conditions were lower than under normal conditions.

Maize with initial an MC of 14%, kept under airtight conditions, had the lowest total fungal population, *A. flavus* population, and aflatoxin B<sub>1</sub> content during six months of storage.

During storage, the total fungal population on maize with initial MCs of 14 and 17% increased, while initial 20% MC fluctuated. The population of *A. flavus* fluctuated during storage. Total aflatoxin B<sub>1</sub> content increased with the increase of storage duration.

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**Figure 4.** Aflatoxin B<sub>1</sub> content on maize with initial moisture contents of 14, 17 and 20%, stored under airtight and normal conditions.

**Table 8.** Total aflatoxin B<sub>1</sub> content (ppb) of maize with initial moisture content of 14%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	18 j	35 l	53 n	70 p	78 q	116 s	128 t	71 a
Airtight	18 j	29 k	44 m	58 nq	63 o	87 r	114 s	59 b
Average	18 c	32 d	48 e	64 f	71 g	102 h	121 i	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.

**Table 9.** Total aflatoxin B<sub>1</sub> content (ppb) of maize with initial moisture content of 17%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	18	58	87	113	121	135	177	101 a
Airtight	18	48	72	96	108	119	157	87 b
Average	18 c	53 d	80 e	105 f	115 f	127 g	167 h	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.

**Table 10.** Total aflatoxin B<sub>1</sub> content (ppb) of maize with initial moisture content of 20%, stored under normal and airtight conditions.

Treatment	Duration of storage (months)							Mean
	0	1	2	3	4	5	6	
Normal	19 j	58 l	87 o	116 p	121 p	129 q	133 q	95 a
Airtight	19 j	37 k	56 l	74 m	78 mn	83 no	89 o	62 b
Average	19 c	48 d	71 e	95 f	100 g	106 h	111 i	

Note: Numbers followed by the same letter do not differ significantly according to Duncan's multiple range test at 95% confidence level.

## References

- AOAC (Association of Official Analytical Chemists) 1984. Official methods of analysis of the Association of Official Analytical Chemists. Arlington, Virginia, AOAC.
- Bainton, S.J., Coker, R.D., Jones, B.D., Morley E.M., Nagler, M.J. and Turner, R.L. 1980. Mycotoxin training manual. London, Tropical Products Institute.
- Blaney, B.J., Moore, C.J. and Tyler, A.L. 1984. Mycotoxin and fungal damage in maize harvested during 1982 in far north Queensland. Australian Journal of Agricultural Research, 35, 463–471.



- Brockington, S.F., Dorin, H.C. and Howerton, H.K. 1949. Hygroscopic equilibria of whole kernel corn. *Cereal Chemistry*, 16, 166–173.
- Choudhary, A.K. and Sinha, K.K. 1993. Competition between a toxigenic *Aspergillus flavus* strain and other fungi on stored maize kernels. *Journal of Stored Product Research*, 29, 75–80.
- Christensen, C.M. and Kaufmann, H.H. 1974. Microflora. In: Christensen, C.M., ed., *Storage of cereal grains and their products*. American Association of Cereal Chemists, 158–191.
- Clarke, J.H. and Hill, S.T. 1981. Microfloras of moist barley during sealed storage in farm and laboratory silos. *Transactions of the British Mycology Society*, 77, 557–565.
- Dharmaputra, O.S., Retnowati, I. and Ambarwati, S. 1996. *Aspergillus flavus* and aflatoxin in maize and peanut collected from different parts of the postharvest handling chain. In: Nakase T. and Takeo, K., ed., *Proceedings of Asian International Mycological Congress '96*, Chiba, Japan, 3–5 July 1996, 150 (Abstract).
- Dharmaputra, O.S. and Putri, A.S.R. 1996. Antagonistic effect of *Eurotium chevalieri* and *Fusarium moniliforme* to *Aspergillus flavus* in vitro. Internal report. Bogor, SEAMEO BIOTROP (in Indonesian).
- Dutton, M.F. and Westlake, K. 1985. Occurrence of mycotoxin in cereals and animal feedstuffs in Natal, South Africa. *Journal of Association of Official Analytical Chemists*, 68, 839–842.
- Fabbri, A.A., Fanelli, C., Serafini, M., Di Magio, D. and Pirazzi, R. 1980. Aflatoxin production on wheat seed stored in air and nitrogen. *Transactions of the British Mycology Society*, 74, 197–198.
- Heathcote, J.G. and Hibbert, J.R. 1978. *Aflatoxin: chemical and biological aspects*. New York, Elsevier Scientific.
- Landers, K.E., Davis, N.D. and Diener, U.L. 1967. Influence of atmospheric gases on aflatoxin production by *Aspergillus flavus* in peanuts. *Phytopathology*, 57, 1086–1090.
- Magan, N. and Lacey, J. 1984. The effect of gas composition and water activity on field and storage fungi and their interactions. *Transactions of the British Mycology Society*, 82, 305–314.
- Pitt, J.I. and Hocking A.D. 1997. *Fungi and food spoilage*. London, Blackie Academic and Professional.
- Richard-Molard, D., Diawara, B. and Cahagnier, B. 1986. Susceptibility of cereal microflora to oxygen deficiency and carbon dioxide concentration. In: Donahaye, E. and Navarro, S., ed., *Proceedings of the 4<sup>th</sup> international working conference on stored-product protection*, Tel Aviv. Israel, Agricultural Research Organization, 85–92.
- Sauer, D.B., Meronuck, R.A. and Christensen, C.M. 1992. Microflora. In: Sauer, D.B., ed., *Storage of cereal grains and their products*. St. Paul, Minnesota, American Association of Cereal Chemists, 313–340.
- Sinha, K.K. 1993. Mycotoxins. *Association of South-East Asian Nations (ASEAN) Food Journal*, 8, 87–93.
- Viquez, O.M., Castell-Perez, M.E., Shelby, R.A. and Brown, G. 1994. Aflatoxin contamination in corn samples due to environmental conditions, aflatoxin-producing strain and nutrient in grain grown in Costa Rica. *Journal of Agricultural Food Chemistry*, 42, 2552–2555.
- Visconti, A. (ed.) 1998. *New European Union regulation for aflatoxins in foodstuffs*. *Mycotoxicology Newsletter*, 4(2), 1.
- WHO (World Health Organization) 1979. *Mycotoxins*. Geneva, World Health Organization, 126p.
- Wilson, D.M. and Jay, E.G. 1976. Effect of controlled atmosphere storage on aflatoxin production in high moisture peanuts. *Journal of Stored Products Research*, 12, 97–100.
- Wilson, D.M., Jay E.G., Hale, O.M. and Huang, L.H. 1977. Controlled atmosphere storage of high-moisture corn and peanuts to control aflatoxin production. *Annals de Technologie Agricole*, 26, 339–342.
- Zummo, N. and Scott, G.E. 1992. Interaction of *Fusarium moniliforme* and *Aspergillus flavus* on kernel infection and aflatoxin contamination in maize ears. *Plant Disease*, 76, 771–773.

# Bacterial Antagonism Against *Aspergillus* Growth and Aflatoxin Production in Maize Feedstuff

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## Abstract

Maize, having high nutritional value, comprises 40–60% of the material cost of feed ration in the swine and poultry industries. But aflatoxin contamination in maize is a serious problem, as aflatoxin is an extremely potent carcinogen, teratogen and mutagen affecting man and animals. Thus, it is imperative that aflatoxin formation be prevented or at least minimised.

The use of fungicides is one immediately available method to control the major and most abundant aflatoxin producers, *Aspergillus flavus* and *A. parasiticus*. However, through the constant and increasing use of fungicides, serious problems arise: development of genetic resistance; side-effects on non-target organisms; environmental pollution; and other deleterious effects of residues on man and animals. In this context, bacterial antagonism was conducted as an alternative control and detoxifying agent against *Aspergillus* species and aflatoxin, respectively.

A strain of *Bacillus megaterium* was the most promising among the 32 antagonistic bacterial isolates tested in vitro. In vivo testing focused on the evaluation of this *B. megaterium* strain against *Aspergillus* growth in maize. Over two months of storage, the *B. megaterium* population increased continuously with a simultaneous decrease in *Aspergillus* propagule counts and aflatoxin content giving better effect when applied therapeutically. Assuming that the bacteria detoxified aflatoxin present, its detoxification metabolites may, however, also be toxic.

An experiment was conducted to test the toxicity to animals of the said metabolites, using 32 chicks fed on *A. flavus* and/or *B. megaterium*-treated diets. Chicks fed with *B. megaterium* and *A. flavus* diets registered the best feed efficiency, while those fed with *B. megaterium* alone had the lowest body weight gain after 3 weeks.

Despite the potential of *B. megaterium* as an *Aspergillus* antagonist, its mechanism of action needs to be determined, and the active antagonistic metabolites of the bacteria need to be characterised, prior to its application as control agent.

MAIZE IS the most important feedstuff of the swine and poultry industries, comprising 40–60% of the material cost of feed and 50–70% of the total cost of production, because of its high nutritional value and relatively low cost of production. In the Philippines, aflatoxin contamination in maize has gained the most

attention among the mycotoxins discovered, since it is a common contaminant of many stored agricultural commodities and, under natural conditions, maize contains highly toxic levels of aflatoxins (Garcia and Ilag 1986). The National Postharvest Institute for Research and Extension (NAPHIRE), now the Bureau of Postharvest Research and Extension (BPRE), estimates that about 70% of all stocks of maize are contaminated with aflatoxins. Research conducted at the Food and Nutrition Research Institute (FNRI) has shown a possible relationship between the consumption of aflatoxin-contaminated maize by Filipinos and the development of primary liver cancer (Jayme et al. 1976, 1982). Since 1991, malignant neoplasm has become the fifth-leading cause of death

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in the Philippines. There could be a link between the high incidence of cancer cases and the presence of mycotoxins, particularly aflatoxins, in the diet.

Aflatoxin is an extremely potent carcinogen, teratogen and mutagen affecting man and animals. In livestock and poultry production, aflatoxin-associated problems are manifested in poor performance, such as decreased efficiency in nutrient absorption and utilisation, and immune system impairment that increases the susceptibility of the animals to various diseases. In a pioneering extrapolation and mathematical modelling paper published by Lubulwa and Davis (1994), it was reported that aflatoxin contamination in maize and peanuts incurred animal health losses of A\$78 million which were associated with loss of efficiency in animals, and death in some cases.

In this context, bacterial antagonism against aflatoxin-forming fungi was explored as an alternative preventive control agent. Bacterial application may prove useful because, aside from their mycostatic potential, they may have nutritive value in the feedstuff and likewise thrive under normal conditions of warehousing and storage. Hence, isolation, screening and identification of bacterial isolates capable of inhibiting *Aspergillus* growth and detoxifying aflatoxin were conducted. To test the toxicity of most promising strain of *Bacillus megaterium*, an experiment using broiler chicks fed with *B. megaterium*-treated diets was carried out.

Various preventive and control measures that will inhibit the growth of *A. flavus* and destroy/detoxify the aflatoxin from contaminated products have been tested by some investigators in different countries. However, acceptable control measures/methods should meet the following criteria: wide-scale application; economically advantageous; effective; no adverse effects on the nutritive and aesthetic quality of the commodity; and no new toxic products formed.

Microbial degradation of toxin can be a means of controlling aflatoxin in some food products. Ciegler (1975) reported that one bacterium, *Flavobacterium auranticum* (NRRLB-184), can completely remove aflatoxin in contaminated milk, maize oil, peanut butter and maize, and partially detoxify contaminated soybeans. Duckling tests showed that detoxification of aflatoxin solutions by this organism was complete and no new toxic products were found. The same line of studies (e.g. Chintana et al. 1988; Lauzon 1992) using other microorganisms followed, which further underscores the possibility of employing this method.

Even if a particular microbial control approach has been explored as a potential means to control

*Aspergillus* infection and aflatoxin formation, questions regarding its effectiveness and safeness in application remain to be resolved.

## Materials and Methods

### Isolation, purification and screening of the bacterial isolates

Different feeds and maize samples were serially diluted and surface-plated on potato dextrose agar (PDA) plates. After 3–5 days of incubation at room temperature (29–33°C), bacterial colonies were isolated and transferred to nutrient agar slants, using a standard purification procedure. The desired colonies were picked and re-isolated on suitable agar slants. The inhibitory/antagonistic activity of bacterial isolates against *A. flavus* and *A. parasiticus* was determined using filter paper disc assay (in vitro test). Bacterial isolates which exhibited a minimum zone of inhibition of 70–80% compared to the positive (+ Benlate) control plate were considered promising and maintained/preserved for further study.

### In vivo test of the most promising *B. megaterium* isolate

Of the promising antagonists selected in vitro, *B. megaterium* was further investigated for practical application on small-scale storage of maize (in vivo). Only grain previously tested and found to be least infected with *Aspergillus* and negative for aflatoxin content were used in this study. To test the protective effect of the antagonist, the maize was treated with *B. megaterium* two days before *A. flavus* or *A. parasiticus* inoculation. In the therapeutic treatment, the maize was treated with *B. megaterium* two days after *A. flavus* or *A. parasiticus* inoculation. Controls consisted of non-inoculated maize with no *B. megaterium*. The population levels of *Aspergillus* were determined by plating.

The aflatoxin content of the variously treated maize samples was determined following the Wilson et al. (1976) extraction method and thin-layer chromatography (TLC) analysis set by the Association of Official Analytical Chemists (AOAC). All treatments were completely randomised. Three replicates per treatment were made.

## Tests using chicks

Whole maize samples which were found to be minimally infected with *Aspergillus* and negative for aflatoxin content were used in the test. The samples were ground and assigned to one of four treatments, each using 500 g samples of the ground maize. In each treatment the maize was sprayed 10 times with sterile potato dextrose peptone broth (PDPB) containing: treatment 1, nothing else (i.e. control); treatment 2, a suspension of approximately  $10^8$  *B. megaterium* cells/mL PDPB; treatment 3, a suspension of approximately  $10^8$  *Aspergillus* spores +  $10^8$  *B. megaterium* cells/mL PDPB; and treatment 4, a suspension of  $10^8$  *Aspergillus* spores/mL PDPB. After spraying, all the treatments were air-dried for 20–30 min, then mixed with the other ingredients of each diet. All inoculations were done therapeutically before feeding the diets to the chicks.

The four dietary treatments were randomly assigned to eight cages of 4-day-old broiler chicks, following a completely randomised design. Each treatment was replicated two times with a cage of four chicks each. They were fed with their respective diets for 3 weeks. The following parameters were observed and recorded weekly: 1) body weight; 2) feed consumption; and 3) feed efficiency.

## Results and Discussion

A total of 150 feed/maize isolated microbial isolates were screened for their antagonistic effect against *A. flavus* and *A. parasiticus*. 32 bacterial isolates gave positive results, and were maintained and subjected to further screening.

After several screening trials, *Bacillus megaterium* was determined to be most promising. It exhibited, on average, a 70–80% zone of inhibition against *A. flavus* and *A. parasiticus*. Furthermore, considering that *B. megaterium* is a spore-forming bacterium, it would be more resistant to adverse conditions present in maize storage than non-spore forming isolates. *B. megaterium*, therefore, was selected and prioritised for the in vivo, small-scale storage test using maize.

Preliminary results showed that *B. megaterium* had an apparently therapeutic effect compared with the protective treatment (Figures 1 and 2). The *B. megaterium* used in this study seemed to be at its spore-forming age (3–5 days). After its inoculation into the maize samples, it re-entered a whole new growth curve. The typical growth curve of a bacterium has four principal phases: lag phase, log or exponential growth curve, maximum

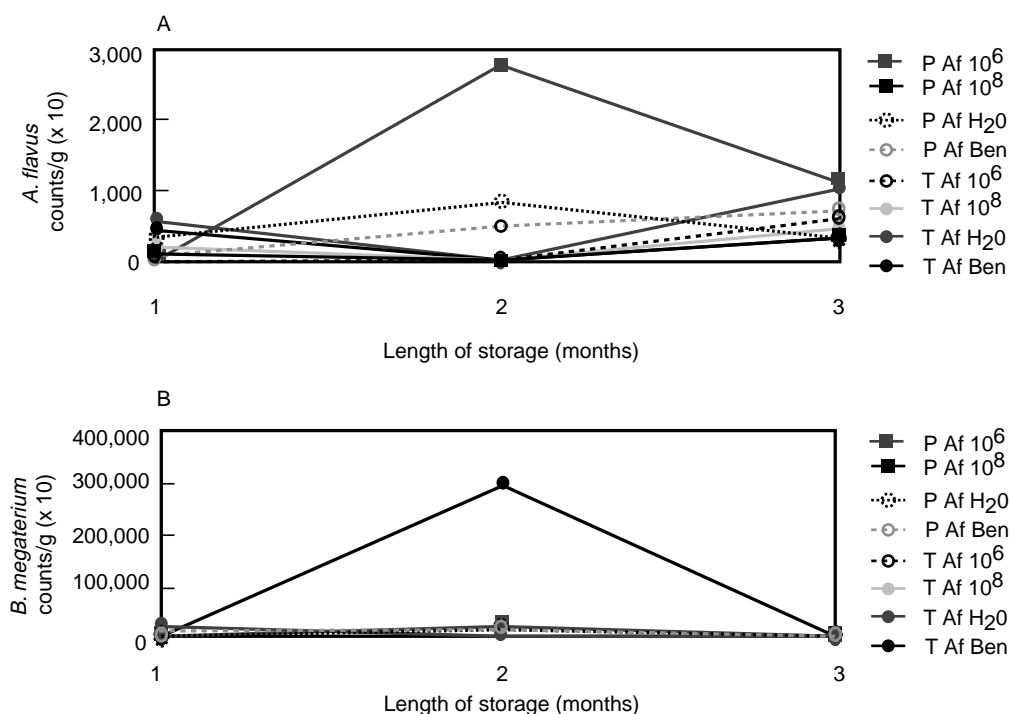
stationary phase, and death phase (Stainer et al. 1963). Based on the results, *B. megaterium* controls *Aspergillus* at its peak exponential and maximum stationary phases which implies that it is the metabolically active vegetative cell that can antagonise *Aspergillus*. During the one-month sampling, *B. megaterium* showed very little or no inhibitory effect on *Aspergillus*. This implies that the spore form or sporulated form of *B. megaterium* has no participation in the antagonism. It appears that it is actually during the metabolism of the vegetative cell that *Aspergillus* growth can be inhibited. Another possibility is that during the two-month sampling, the cells have already undergone autolysis, releasing their toxins into the feedstuff and consequently affecting *Aspergillus*.

Table 1 shows the results of the chick trials—weekly performance of chicks fed with the control diet, or diets with *B. megaterium*, *B. megaterium* + *A. flavus*, or *A. flavus*. Chicks fed with the *B. megaterium* -treated diet and those fed with *A. flavus*-treated diet showed a depression in weekly body weight and feed consumption compared to the control chicks. In contrast, chicks fed with the *B. megaterium* + *A. flavus*-treated diet had a similar body weight and feed consumption as the control chicks. The dietary treatment showed no specific trend in the feed efficiency of the chicks during the 3-week period. However, it is noticeable that, except during the first week, chicks fed with *B. megaterium* + *A. flavus* diet registered the best efficiency (g feed/g gain) during the second and third week, while those fed with diets treated with *B. megaterium* alone had the poorest feed efficiency during the first and second week of feeding.

The above observations indicate that *B. megaterium* had a depressing effect on the growth, feed consumption and feed efficiency of the chicks when used in the absence of *A. flavus*. However, when *A. flavus* was present, *B. megaterium* reduced the adverse effect of *A. flavus* on the performance of the chicks to some extent.

## Conclusions

1. Thirty-two bacterial isolates showed an inhibitory/antagonistic effect on *Aspergillus* growth, with *B. megaterium* being the most promising antagonist.
2. It is quite difficult to draw a concrete conclusion from in vivo test results, since only one trial with three replicates per treatment was conducted. However, it is interesting to note that generally *B. megaterium* had a better therapeutic than protective effect on *A. flavus* and *A. parasiticus* growth.



**Figure 1.** (A) Protective and therapeutic effects of *Bacillus megaterium* on *Aspergillus flavus* propagule counts on maize feedstuff stored for three months at room temperature (29–33°C). (B) shows the *B. megaterium* counts during the same period (P = protective; T = therapeutic; Af = *A. flavus*; 10<sup>6</sup> and 10<sup>8</sup> = number of fungal spores/mL; H<sub>2</sub>O and Ben = controls). See text for treatment details.

**Table 1.** Summary of the weekly body weight, feed consumption and feed efficiency of broiler chicks fed with the control diet or diets with *Bacillus megaterium* (Bm), *B. megaterium* + *Aspergillus flavus* (Af), or *A. flavus*.

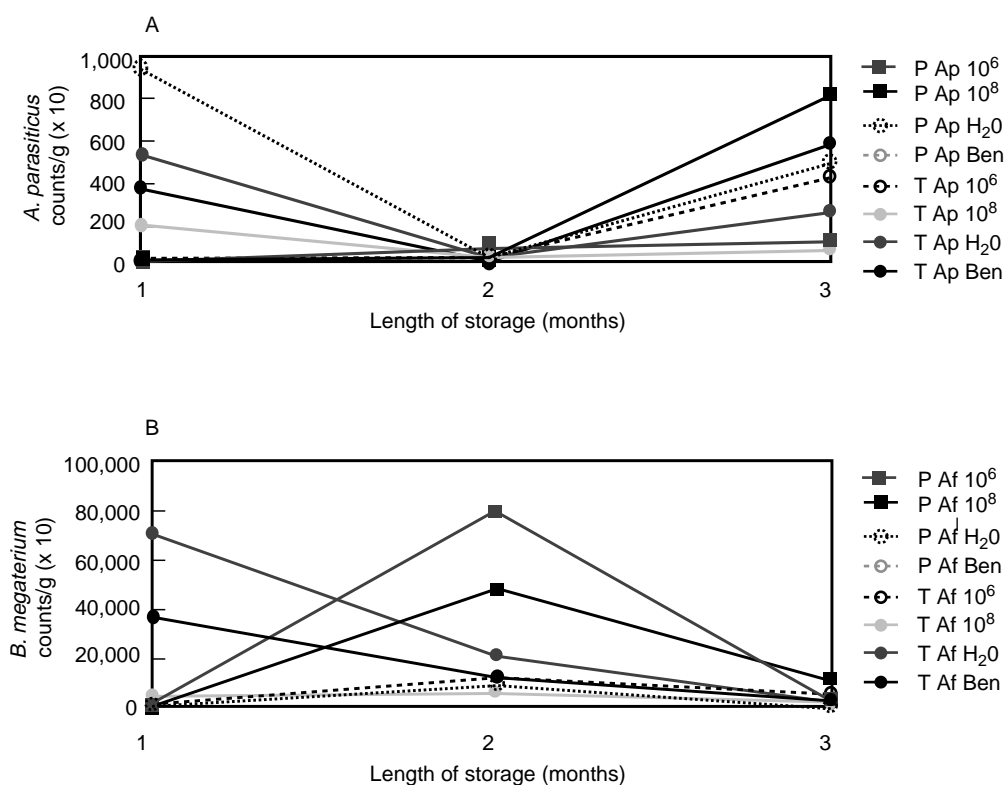
Dietary treatment	Chick age (weeks)			
	0	1	2	3
Average body weight (g)				
Control	49.00	115.63	260.00 b	421.43
Bm	49.00	97.15	219.29 c	407.15
Bm + Af	49.50	118.33	274.84 a	458.33
Af	50.50	110.00	258.33 b	429.17
Average cumulative feed consumption (g)				
Control		120.75	451.61 a	792.56
Bm		114.29	370.71 b	716.07
Bm + Af		134.17	384.42 b	794.42
Af		125.00	337.50 c	745.00

Note: means followed by different letters within columns are significantly different at the 5% level of probability.

**Table 1.** (Cont'd) Summary of the weekly body weight, feed consumption and feed efficiency of broiler chicks fed with the control diet or diets with *Bacillus megaterium* (Bm), *B. megaterium* + *Aspergillus flavus* (Af), or *A. flavus*.

Dietary treatment	Chick age (weeks)			
	0	1	2	3
Average cumulative feed efficiency				
Control		1.81	2.15	2.14
Bm		2.41	2.18	2.01
Bm + Af		1.97	1.72	1.94
Af		2.12	1.79	1.97

Note: means followed by different letters within columns are significantly different at the 5% level of probability.



**Figure 2.** (A) Protective and therapeutic effects of *Bacillus megaterium* on *Aspergillus parasiticus* propagule counts on maize feedstuff stored for three months at room temperature (29–33°C). (B) shows the *B. megaterium* counts during the same period (P = protective; T = therapeutic; Ap = *A. parasiticus*; 10<sup>6</sup> and 10<sup>8</sup> = number of fungal spores/mL; H<sub>2</sub>O and Ben = controls). See text for treatment details.

3. The active components of *B. megaterium* that are antagonistic to *Aspergillus* growth need to be fractionated, isolated and characterised to identify

the bacterium's antifungal properties. Identifying its active components will facilitate its synthesis.

4. Bioassay tests are indispensable in biological control agent evaluation. It is recommended that usefulness and safeness of the most promising antagonists should pass bioassay tests prior to use as control agents.

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## References

- Chintana, C., Somsiri, S. and Unnop, O. 1988. Progress report on: mycotoxins and their control in corn and in other cereals. Research report of the 19<sup>th</sup> Conference on Thai National Corn and Sorghum. Bangkok, Department of Agricultural Extension, 88–89.
- Ciegler, A. 1975. Mycotoxins: occurrence, chemistry, biological activity. *Lloydia*, 38, 21.
- Garcia, R.P. and Ilag, L.L. 1986. Aflatoxins in the Philippines. Proceedings of the United States Agency for International Development–United National Development Programme –International Maize and Wheat Improvement Centre (USAID – UNDP – CIMMYT) Aflatoxin Workshop, Mexico City, Mexico April 6–11.
- Jayme, J.B., Almero, E.M. and Salamat, L.A. 1976. Epidemiology of primary liver cancer in the Philippines with special considerations of a possible aflatoxin factor. *Journal of the Philippines Medical Association*, 52, 129–150.
- Jayme, J.B., Almero, J.E.M., Castro, M.C.A., Jardaleza, M.T.R. and Salamat, L.A. 1982. A case control dietary study of primary liver cancer risk from aflatoxin exposure. *International Journal of Epidemiology*, 11, 112–119.
- Lauzon, R.D. 1992. Control of *Aspergillus parasiticus* by *Cladosporium fulvum* in rice and corn. PhD dissertation, Food Science, University of the Philippines at Los Baños.
- Lubulwa, A.S.G. and Davis, J.S. 1994. Estimating the social costs of the impacts of fungi and aflatoxins in maize and peanuts. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., *Stored product protection. Proceedings of the 6<sup>th</sup> international working conference in stored-product protection, Volume 2.* Wallingford, CAB International, 1017–1042.
- Stainer, R.V., Doudoroff, M. and Adelberg, E.A. 1963. *General microbiology.* London, MacMillan and Company Limited.
- Wilson, D.M., Tabor, W.H. and Trucksess, M.W. 1976. Screening method for the detection of aflatoxins, ochratoxin, zearalenone, penicillic acid, and citrinin. *Journal of the Association of Official Analytical Chemists (AOAC)*, 59, 125–127.

# Sustaining the Development of the Grains Industry through Standardisation: the Philippine Experience

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## *Abstract*

The effective implementation of national grains standards, notably for the major staples of rice and maize, is the key factor in the evolution of a dynamic, progressive and globally competitive grains industry, particularly among developing countries. Standardisation efforts in the grains industry, along with similar efforts in all other sectors of the economy, gain critical significance in modernising the industry and agriculture sectors as the Philippines gears up for the challenges and opportunities of globalisation in the 21<sup>st</sup> century.

This paper presents the Philippine experience in pursuing its national grains standardisation program. It highlights the strategies and significant achievements, as well as constraints and prospects of the program, nearly three years after its launch. It also underscores the prospects of promoting harmonisation of the national grains standards with prevailing international standards toward enhancing trade and economic cooperation among countries in the Association of South-East Asian Nations (ASEAN) and Asia-Pacific regions.

STANDARDISATION plays a vital role in the socio-economic, cultural and technological development of countries and peoples worldwide. Advances in the production, trade and utilisation of various products and services, in agriculture and industry, and in practically all sectors of the economy and society, have been made possible over the years by the extensive application of certain sets of national or international standards on quality, quantity and safety, among others. As the level of standardisation varies among countries, it provides an indication of the development status and potential of a given country.

The extensive application of national standards as a development tool has enabled developed and advanced economies to attain their status. But as countries worldwide gear up for globalisation, where attaining international competitiveness is the bottom line, it has become crucial for developing countries like the Philippines and the rest of the countries in the Association of South-East Asian Nations (ASEAN) and Asia-Pacific regions to pursue standardisation in all sectors of the economy. Participation in international markets requires relatively sophisticated marketing, information and transport networks. Suc-

cessful competition requires quality control and product standardisation. National standards are integral components of the country's food control system which safeguards the integrity of domestic and international trade. The development of the Philippine agriculture sector, as in many less-developed countries, has been hampered (among other factors) by the lack or limited application of standards and codes of practice in the production-consumption continuum of agricultural products.

Thus, the effective implementation of national grains standards, notably for the major staples of rice and maize, is the key factor in the evolution of the dynamic, progressive and globally competitive grains industry, in the Philippines and other developing countries. Standardisation efforts in the grains industry, along with similar efforts in all other sectors of the economy, are critical to the success of the agricultural modernisation agenda of the government in response to the challenges and opportunities of globalisation in the 21<sup>st</sup> century. The National Food Authority (NFA), in line with its mandate to promote the integrated growth and development of the grains industry, initiated the national grains standardisation program in 1996. The implementation of the program has been given further impetus by the recent enactment of the

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Agriculture and Fisheries Modernization Act (AFMA) which provided for (among other issues) the creation of an agency to oversee the standardisation of agricultural and fisheries products in coordination with other concerned agencies and institutions.

This paper presents an overview of the Philippine experience in pursuing its national grains standardisation program, highlighting, among other aspects, the strategies and significant achievements, as well as constraints and prospects of the program, nearly three years after its launch. It also underscores the prospects of pursuing standards harmonisation as one of the possible areas for collaboration towards enhancing global trade and economic cooperation among countries in the ASEAN and Asia-Pacific regions.

## The Grains Industry Situation and Standardisation

The Philippine rice and maize industry, more commonly known as the grains industry, is a vital sector of the economy, accounting for about 3.4% of the gross national product and providing livelihood, directly or indirectly, to about 70% of the population, about 4.1 million of which are rice and maize farmers. As rice is a staple food to about 85% of the population, it constitutes 23.2% of the food basket while maize, eaten by 15% of the population, constitutes about 2.4% of the food basket. Per capita consumption of rice ranges from 92 kg to 103 kg per year, while daily national consumption was estimated at 22,000 t in 1998.

Aside from the farmers and the consumers, the grains industry is also composed of some 120,000 grains businessmen engaged mainly in the processing, storage, wholesaling and retailing of rice and maize, and other related business activities. These economic activities are under the regulatory function of the NFA through registration and licensing, as well as enforcement of pertinent rules and regulation on grains business.

Typical of any developing economy which has to contend with ensuring the supply and affordability of grain food for its increasing population, regardless of whether the products strictly conform with the national standards, serious efforts to introduce and promote standardisation in the grains industry began only in recent years. Notions of 'standards' on rice quality and local terminology used among producers, traders and consumers were quite diverse, parochial and simple. Rice quality preferences are influenced or

dictated to a varying extent by regional cultural differences, personal idiosyncrasies and the socioeconomic status of the people. For instance, white or well-milled rice (*maputi*) with desirable cooking qualities (i.e. *mabango*) is generally preferred to the more nutritious regular milled or under-milled rice. Among low income groups, aged rice (*laon*) is preferred, and in some remote rural areas, bahai or rice with a high proportion of discoloured or yellow kernels is also acceptable. Premium or export quality rice with a high head rice to brokens ratio, along with fancy or aromatic rice types, are preferred by the upscale markets. Despite the official adoption of the metric system, the volumetric method of selling rice using the ganta (*salop*) and chupas is still practiced in some rural areas.

In the absence of a concerted effort to introduce standardisation, the basis for the supply or sale of rice by the producers, processors and traders, and the acceptance of same by the buyers or consumers is largely arbitrary, has depended on the demand or special preference for a given product. This situation often perpetuates confusion and misinformation among market-players, including regulatory authorities, that results in unfair trade practices such as mislabelling, short-selling, and price manipulation, specially in time of shortages. On the part of the producers, this state of affairs has not provided them with enough motivation to modernise or invest in modern grain processing and marketing facilities, despite the lifting of price control in recent years, as a result of the deregulation and economic liberalisation policies of the government.

## Introducing innovations in the grains industry

Given the scenario described above, the progress of standardisation in the grains industry and the agriculture sector at large has been rather slow compared to other sectors of the economy, such as the electronic and manufacturing industries. But with the increasing national focus on agricultural modernisation in recent years as the key to achieving and sustaining food security and national development in the 21<sup>st</sup> century, the need to intensify national grains standardisation efforts has become more prominent.

Initial efforts to introduce standardisation in the local rice markets began in the mid-1990s, when a group of NFA middle-level executives conducted a pilot advocacy project among millers, retailers, consumers and students on the adoption of rice grades

and standards in selected Davao markets in Mindanao. The activity was part of their productivity improvement plan as participants in a seminar-workshop on the Productivity Management and Development Program. The promising results of this activity in terms of generating enthusiastic support from targeted stakeholders and the prospects of instituting reforms and innovations in the grains market led to the nationwide implementation of a grains standardisation program starting in the latter part of 1996, in support of the grains production enhancement programs of the government.

## **Philippine Grains Standardization Program**

The Philippine Grains Standardization Program is a multi-sectoral effort spearheaded by the NFA that aims to effectively implement or institutionalise the national standards in the grains industry through continuing advocacy, enforcement and monitoring activities among grains farmers, millers, traders or retailers and the general consuming public. The NFA, by virtue of Presidential Decree No. 4 and Republic Act 7394 (Consumers Act of the Philippines) is mandated to establish and enforce the national grains standards in collaboration with various sectors.

The program consists of two major project components, namely: Grains Standards Implementation and Grains Standards Revision. The grains standards implementation project involves the implementation of existing national standards for paddy, milled rice, maize and maize grits. These standards are set of official rules prescribing standard specifications on the quality (grade), packaging, and labelling, as well as tests and analysis for a given commodity. The features of these national standards are summarised in Table 1. On the other hand, the grains standards revision project is concerned with the review and update of the existing standards to conform with recent developments in technology and marketing, through an inter-agency, national technical committee organised and led by the NFA.

### **Program strategies and activities**

In implementing the program, the NFA pursued the following strategies and activities.

#### *Creation of program management structures*

Project management committees were organised at the national, regional and provincial offices of the NFA nationwide. This ensured proper coordination in the planning and execution of the various projects and activities between the NFA and its cooperators from the public and private sectors.

#### *Forging of public and private sector partnership*

Memorandums of agreement (MOAs) between the NFA and various program cooperators were executed at the national and local levels to ensure broad, multi-sectoral support in institutionalising the program. Public and private sector cooperators who are signatories of the MOAs include: grains industry stakeholders associations (farmers, millers/processors, retailers); national government agencies (NGAs), such as those in the agriculture education, and trade sectors; local government units (LGUs); and other private organisations such as the media, consumers, and agri-machinery and sack manufacturers.

#### *Continuing advocacy, enforcement and monitoring activities*

These ensure broad support and cooperation from all concerned sectors, especially the stakeholders. The conduct of briefings, workshops and media advocacy have been made part of the regular program activities, including the establishment of Philippine Grains Standardization Program showcase markets in all provinces and municipalities.

#### *Annual celebration of National Grains Industry Week (September 20–26)*

Presidential Proclamation 1058 mandates this annual celebration which coincides with the founding anniversary of NFA, and serves as the occasion for highlighting the significance of standardisation and the grains industry in national development, and giving recognition to outstanding achievers among program implementers and cooperators through the Philippine Grains Standardisation Achievement Award. The award has been institutionalised to be able to build up and sustain broad sectoral support for the program.

#### *Program review and evaluation*

The progress of program implementation is reviewed and evaluated annually, based on the approved medium-term strategic action plan.

**Table 1.** Standard packaging and labelling for milled rice, shelled maize and grits for sale (NRA 1998).

Commodity classification and grade	Packaging			Labelling			
	Package size (kg)	Type of material	Colour of packaging material <sup>a</sup>	Colour of print on packaging material	Required information <sup>b</sup>	Suitable tag <sup>c</sup>	
						Size	Information
A. Big package	10, 15, 20, 25, 30, 35, 40, 45, 50 (multiples of 5)	Woven polypropylene			<ul style="list-style-type: none"> <li>• Classification</li> <li>• Variety</li> <li>• Grade</li> <li>• Net weight in kilograms (kg)</li> <li>• Name and address of miller/packer</li> <li>• Crop year</li> <li>• Date of milling<sup>c</sup></li> <li>• Moisture content</li> </ul>	8 cm x 15 cm	<ul style="list-style-type: none"> <li>• Name and address of miller/packer</li> <li>• Crop year</li> <li>• Date of milling<sup>c</sup></li> <li>• Moisture content</li> </ul>
Fancy rice			Sky blue	Emerald green			
Premium grade rice			Light yellow	Emerald green			
Well milled rice (WMR) Grade No. 1, 2 or 3			White	Emerald green			
Regular milled rice (RMR) Grade No. 1, 2 or 3			White	Emerald green			
Shelled maize and maize grits (all grades and grits sizes)			Light green	Chrome yellow	Aflatoxin content in parts per billion <sup>d</sup>		

**Table 1.** (Cont'd) Standard packaging and labelling for milled rice, shelled maize and grits for sale (NRA 1998).

Commodity classification and grade	Packaging			Labelling		
	Package size (kg)	Type of material	Colour of packaging material <sup>a</sup>	Colour of print on packaging material	Required information <sup>b</sup>	
					Size	Suitable tag <sup>c</sup>
B. Small package	1, 2, 5, 10	Polyethylene, paper or carton				
<ul style="list-style-type: none"> <li>• Fancy rice</li> <li>• Premium grade rice</li> <li>• Well milled rice (WMR) Grade No. 1, 2 or 3</li> <li>• Regular milled rice (RMR) Grade No. 1, 2 or 3</li> <li>• Shelled maize and maize grits (all grades and grits sizes)</li> </ul>			Sky blue Light yellow White White Light green			

<sup>a</sup> In small packages, the colour code is reflected in the colour of print on the packaging.

<sup>b</sup> In small packages, all required information must be printed on either side of the container

<sup>c</sup> Not required in packed shelled maize

<sup>d</sup> Required in packed shelled maize and maize grits

<sup>e</sup> Suitable tag to be used when not all required information can printed on material of big packages (e.g. 50 kg sack)

Note: unpacked milled rice, shelled maize, and maize grits for retail must be displayed in white painted boxes/containers.

## **Impact of Standardisation on the Industry**

As a result of the continuing multi-sectoral efforts to implement the program nationwide, the stage has been set for the long-envisioned modernisation of the grains industry. While the implementation has already covered all the provinces and cities, it is gradually spreading to the surrounding rural areas of the provinces and urban centres. The grains sections of major urban and suburban markets—particularly showcase markets in these areas—are now marked by order, transparency and improved observance of basic sanitation and hygiene. Colour-coded price tags and containers/sacks for various grades of rice and maize products—complete with the prescribed product information, along with signboards and boxes, have become common features of these markets. This is a clear indication that standardisation effectively serves as a catalyst for instituting reforms and infusing dynamism in the industry. There is also a gradual transformation in orientation and values of the industry and its key players from being traditional and parochial to more socially-responsive, competitive and forward-looking economic entities.

As the prime-mover of the grains industry that should thrive under a free-market environment, the NFA for its part, was able to harness standardisation as a strategic tool for modernising the industry, particularly in the pursuit of developmental regulation. It has enabled the NFA to rationalise its domestic and international marketing policies and operations, including the integration of ‘clean and green’ concepts in quality assurance systems for maintaining the country’s buffer-stocks. The agency also initiated other innovative programs, such as those on electronic grains marketing and facility modernisation, as part of its indirect market intervention activities on grains industry development.

### **Consumers**

The implementation of the national grains standards ensured the protection of consumers against unfair trade practices such as short-weighing, mislabelling and price manipulation, among others. It helped minimise confusion brought about by numerous local rice and maize varieties classified or labelled at random, and retailed under an equally confusing pricing system in the market. More importantly, this provided them with opportunities to exercise their power of choice and enjoy real value for their money

that helps advance the cause of consumerism worldwide.

### **Retailers**

The implementation of the program in the retailing subsector served as the ‘show-window’ for the initial modest gains of the program, providing the needed impact on the grains industry and public at large. The support and cooperation extended by the retailers greatly complemented the enforcement activities of NFA. The strict adherence and compliance of the retailers to the set standards on quality, labelling and packaging compelled millers and processors to likewise comply with the same prescribed standards. The ultimate result was a relatively stable supply and multi-tiered pricing of rice and maize that enabled retailers to optimise their profit while providing consumers with a wide array of affordable, competitively priced products.

### **Millers/Processors**

Grains standardisation opened a wide door of opportunity for higher returns on the processing and trading activities of the grain milling/processing subsector. The same premium grade paddy procured and graded in highly efficient milling facilities produces higher-priced rice intended for the upscale markets. The cost of upgrading facilities is eventually compensated by higher returns. Essentially, standardisation provided the grain-processing sector with the incentive to invest in modern, highly efficient processing facilities and equipment that will enable them to offer quality, but affordable, rice due to an eventual reduction in operating costs. The adoption of International Standards Organisation (ISO) standards by more advanced processing enterprises will enable them to develop a market niche for their premium products in both the local and export markets.

### **Farmer-producers**

Although the immediate impact of the program may not be actually felt or enjoyed by the farmer-producers, they could ultimately benefit from standardisation. The increasing demand for higher priced, premium-grade paddy could motivate them to adopt improved production and postproduction technologies. Farmer-cooperatives with capability to mill and trade their paddy produce would also be able to optimise their returns.

## Constraints and Prospects for Standardisation Efforts

Although the local grains marketing landscape has considerably improved through the initial gains of standardisation efforts, there are still underlying constraints that must be addressed so that the success of the program can be sustained. The implementation of the strategic action plan is constrained by a lack of financial and logistical resources for: undertaking massive advocacy activities; upgrading or expanding existing grain postharvest and laboratory facilities, such as those for grain quality and mycotoxin analysis; and drying and milling facilities of the private sector. There is also a need to further strengthen institutional capabilities and collaboration in the conduct of research and development (R&D), advocacy/extension, and enforcement activities in the entire grains production and postproduction system. There are also technical, policy and operational issues, such as the attainability and practicality of the standards to ensure acceptance in both the domestic and international markets.

Existing mechanisms and institutional arrangements for addressing the foregoing constraints are being actively pursued by the NFA. Program management is being strengthened and more focus is being given to advocacy and enforcement activities among the millers and processors whose active cooperation is critical to the success and sustainability of the program. Institutional linkages with program cooperators are being strengthened at the national and local levels so that, with the complementation and sharing of physical and human resources, the effective implementation of various program activities is ensured. The establishment of the Philippine Corn Mycotoxin Network and the Philippine Rice Postproduction Consortium, for instance, provides the NFA with opportunities for pursuing collaboration and networking with local and international R&D institutions and funding agencies to support the program and other grains industry initiatives of the NFA.

### Prospects of standards harmonisation

With the anticipated globalisation of trade in rice and maize in the 21<sup>st</sup> century, as World Trade Organ-

ization member countries open up their economies, the prospect of eventually harmonising national standards, along with other agriculture and industrial products, has become inevitable. In fact, this is one of the principal considerations in the continuing process of updating or revising existing national standards. However, given that the peculiarities and uniqueness of the national standards of a given country (e.g. in the ASEAN region) make full harmonisation difficult, if not impossible, the equivalency of standards within the region could be explored. This would help minimise trade disputes and enhance trade and economic cooperation among countries in the ASEAN and Asia-Pacific regions. The adoption of ISO standards series in local integrated rice processing and marketing would also be a strategic step towards enhancing the competitiveness of the local grains industry and its integration in the global economy.

## Conclusion and Recommendation

Standardisation, as demonstrated by the Philippine experience, is a strategic development tool for modernising the grains industry as developing countries gear up for globalisation. The success of pursuing similar efforts in other countries would depend largely on socio-cultural considerations, receptivity to change of industry players, and strong public and private sector partnership. As an integral part of the food control system of countries worldwide, the harmonisation of national standards for grains, as in other products and services, would be a great opportunity for strengthening trade and economic cooperation among countries in the ASEAN and Asia-Pacific regions under an emerging free-market global economy in the 21<sup>st</sup> century. It is recommended that harmonisation of national standards for grains be actively pursued as a component of the trade and economic agenda in future ASEAN and Asia-Pacific Economic Cooperation (APEC) forums.

## Reference

NFA (National Food Authority) 1998. Primer on Philippine grains standardization program. Quezon City, National Food Authority, 40p.

# Monitoring Mycotoxins and Pesticides in Grain and Food Production Systems for Risk Management in Vietnam and Australia

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## *Abstract*

Contamination of agricultural produce with mycotoxins and pesticides can present serious problems, both for human health and the economic value of crops. Mycotoxins may develop either in crop production, or in storage, where drying technology may be preventative. Pesticide contamination occurs either by direct application to food commodities or as a result of environmental transport as drift, volatilisation, or in run-off. Contamination can be reduced or prevented by correct practices, both while farming and postharvest. However, the development of effective practices demands a rigorous monitoring program to ensure contaminated produce is detected and not consumed by humans or livestock.

A collaborative research project (PHT/1996/004) funded by the Australian Centre for International Agricultural Research (ACIAR) to monitor mycotoxins and pesticides in grain and food production systems for risk management in Vietnam and Australia has commenced. This project involves six research organisations—three in Vietnam and three in Australia. These are the Post-Harvest Technology Institute (PHTI), the Pasteur Institute, and Vietnam National University College of Agriculture and Forestry (UAF) in Ho Chi Minh City, University of Sydney, Commonwealth Scientific and Industrial Research Organisation (CSIRO) Plant Industry and AWB Research Pty Ltd (Agrifood Technology). The objectives of the project are listed below:

- to develop immunochemical methods for major mycotoxins and pesticides for detection of contamination in grain, vegetables, dried fruits and peanuts;
- to train Vietnamese project scientists both in the methodology for the development of immunoassays and related simple tests and in protocols for their application;
- to strengthen the monitoring network in Vietnam to ensure ongoing monitoring of mycotoxin and pesticide contamination;
- to monitor the incidence and quantify the severity of contamination by mycotoxins and pesticides in both Vietnam and Australia; and
- to review methods to limit production of mycotoxins and to reduce sources of pesticide contamination through traceback and other appropriate methods.

This paper will illustrate these different aspects of the project and its role in quality assurance for agricultural produce.

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## Background

CONTAMINATION of agricultural produce with mycotoxins and pesticides affects the economical and trade values of the produce, and also presents serious human health and environmental problems. These problems are becoming more critical for developing countries such as Vietnam, where the tropical climate favours the growth of fungi with mycotoxins and invasion by insects requiring the use of insecticides. Mycotoxins are toxic fungal metabolites that occur naturally when crop produce is infested with moulds. Contamination is more common when the harvest is stored in an inadequate drying facility, however it can occur during crop production, processing and transport. It is estimated that 25% of the world's food crops are affected by mycotoxins each year (Mannon and Johnson 1985). Mycotoxins can directly affect the health of both humans and livestock and are potential carcinogens. Human mycotoxicosis caused by intake of a high dose of mycotoxin-contaminated food in developing countries has been documented. However, little or no convincing scientific data relating human diseases to dietary intake of mycotoxins at low levels are available.

In Vietnam, many of the higher-yielding maize and rice cultivars are harvested during the wet season, increasing the risk of fungal/mycotoxin contamination. The problem of contamination of produce has significantly increased as food production has increased in regions such as the Mekong Delta, outstripping available food storage facilities. Maize is a major export product and also represents a major feed source for domestic livestock production. Contaminated maize presents a major problem with pigs and, to a lesser extent, poultry—together forming a major part of the meat component of the Vietnamese diet. These species cannot detoxify aflatoxins, which may then be passed to humans. Also, coffee, another major export commodity grown in the highlands of central Vietnam, is a candidate for ochratoxin contamination. A major concern is that less is known about toxins other than aflatoxins, or feedstuffs other than maize, rice or peanuts. As well, current aflatoxin-monitoring methods are neither sufficiently quantitative, nor suitable for use in poorly equipped field-testing facilities. Additionally, imported enzyme-linked immunosorbent assay (ELISA) test kits are too expensive.

Studies show that 40% of crop and fibre production can be lost through ineffective pest (insect, disease and weed) management (O'Brien 1992). As far as seeking more economical agricultural production, the benefits

of agrochemicals for effective control of pests during the crop production and postharvest outweigh the problems caused by agrochemicals, when properly used. Unlike mycotoxins which occur naturally, pesticide contamination occurs either by direct application to food commodities or by environmental transport such as drift, volatilisation, or in run-off. Pesticides may also be very toxic to humans when misused at concentrations higher than recommended, but are more likely to affect the commercial value of produce or have impacts on the environment.

In recent years, there has been a number of life-threatening cases of pesticide contamination in food in Vietnam (Nguyen et al. 1998). Acute pesticide poisoning in developing countries is often attributed to either misuse or abuse of pesticides by uneducated farmers using low-quality pesticides. Contamination can be reduced or prevented by correct practices, both while farming and postharvest. Thus, direct education of farmers seems to be urgently needed. Also, stringent regulations enforced by national regulatory authorities require attention. For these to be successful, simple but effective monitoring technology needs to be developed and employed. In view of all these issues, a collaborative research project, PHT/1996/004, has been funded by the Australian Centre for International Agricultural Research (ACIAR). This project sets the objectives to develop simple ELISA tests for problem pesticides and mycotoxins, and to monitor mycotoxins and pesticides in grain and food production systems for risk management in Vietnam and Australia.

## Baseline Survey

A baseline survey will be conducted in Vietnam during the course of this project, intending to study the occurrence of mycotoxins and the level of contamination in food and feedstuffs by mycotoxins and pesticides. The primary objective of this study in Vietnam is to select the contaminants associated with the production of these products presenting the greatest risks, for which monitoring technology (ELISAs) will be required. This baseline study will be divided into two parts. The first part, which will be conducted at the beginning of the project, will target aflatoxins, ochratoxin, cyclodiene insecticides (endosulfan dieldrin, aldrin and heptachlor) and dichlorodiphenyltrichloroethane (DDT). A range of crops, including maize, rice, wheat and soybean, will be monitored for aflatoxin using commercial ELISA kits. For ochratoxin, coffee will be the target commodity. For pesti-



cides, leafy vegetables, coffee and tea will be tested using in-house ELISA kits (Lee et al. 1995; Beasley et al. 1998). The second part of baseline study will be conducted during the project as the need and resources (e.g. ELISA kits for alternaria toxins) become available. This study will aim to monitor the occurrence of fumonisins and alternaria toxins in grain, and carbofuran in leafy vegetables.

## Immunochemical Methods for Residue Monitoring

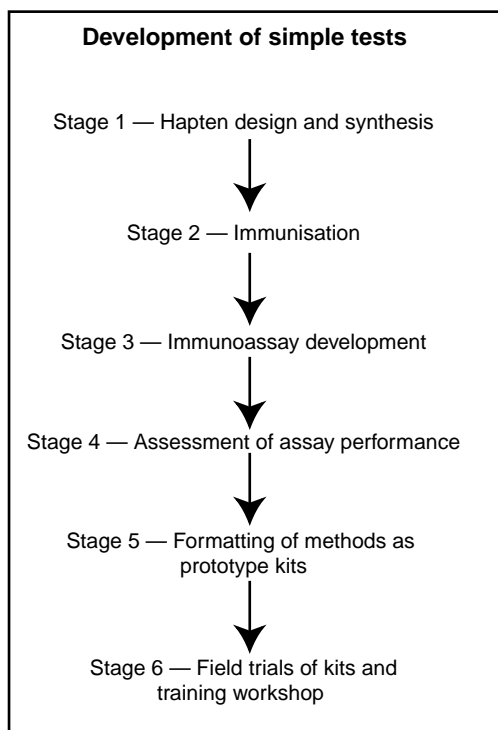
ELISA offers added advantages over the conventional analytical methods when used for pre-screening for contamination. Samples identified positive by ELISA would undergo more quantitative analysis using instruments. Together with the instrumental methods, ELISA can form a powerful and valuable analytical tool to reduce an overall cost of a monitoring program (Lee et al. 1997). Additionally, ELISA can provide a high sample throughput for a more thorough monitoring at a significantly reduced cost when compared with instrumental analyses. Increasingly more monitoring programs in developed countries utilise ELISA as an analytical/screening tool simply because of the reasons mentioned above.

At present, the commercial ELISA kits are out of reach of developing countries because of their cost. Even in Australia, where research funds are not so limited, commercial ELISA kits are not easily affordable. For Vietnam, this project provides a means of escaping this financial trap by allowing the local development (using published and new methods) of test kits to be costed according to Vietnamese economic factors of infrastructure and salaries. The project will establish local Vietnamese expertise in these methods, potentially enabling them to continue to manufacture kits for local or regional use after the project is completed. Thus, two critical objectives of this project, as indicated below, have been set out to meet these requirements:

- to develop immunochemical methods for the target mycotoxins and pesticides for detection of contamination in grain, vegetables, dried fruits and peanuts; and
- to train Vietnamese project scientists, both in the methodology for the development of immunoassays and related simple tests, and in protocols for their application.

There are several stages involved in the development of an immunoassay for any organic molecule

such as a mycotoxin or a pesticide, as shown in the Figure 1 (Hammock et al. 1986; Stanker et al. 1988). The development of an ELISA test requires the synthesis of haptens (stage 1, Figure 1)—molecules that mimic the ecotoxin in structure—that can be used when bound to a macromolecule to raise antibodies in animal species such as rabbits or poultry (stage 2, Figure 1). A similar hapten is required to be linked to an enzyme (e.g. peroxidase, phosphatase) used in the ELISA test, acting as a competitor for the toxin itself for a binding reaction to the specific antibodies (stage 3, Figure 1). In most tests, the more ecotoxin present in extracts from agricultural produce or environmental samples such as soil or water, the less hapten-linked enzyme will bind to the antibodies and the less colour that will develop in the subsequent enzyme reaction. Thus, the presence of the ecotoxin in a test is negatively correlated with colour development. Obtaining a test of the correct sensitivity is currently a challenging process, mainly with respect to hapten design, although experience shortens the time taken to develop an appropriate kit.



**Figure 1.** A flow chart showing development of an immunoassay.

## Monitoring Network for Risk Assessment

The importance of proper monitoring for pesticide and mycotoxin contamination in produce for general public welfare and for international trade cannot be overemphasised. Risk management by monitoring networks, in the longer term, will bring about a cost-effective solution to the current trade problem relating to quality assurance issues. There is already a large scope for monitoring of both pesticide and mycotoxins in Vietnam, as well as in Australia for risk management (Kennedy et al. 1998). Currently, monitoring in Vietnam is conducted centrally at a small number of locations. It is desirable from a logistical viewpoint that such monitoring takes place in regional laboratories, preferably near the sites of primary production. Already a limited monitoring network has been established in Vietnam. This project will help extend that network from local laboratories to provincial laboratories by application of the ELISA technique, so that contamination can be detected at the earliest possible time to avoid unnecessary costs involved in transport of produce. This project provides technical aid for prototype ELISA kit manufacture and protocols for their application in Vietnam (stage 5, Figure 1). Possible users of these ELISA kits, such as regulatory authorities, university personnel and even farmers will be trained in workshops conducted by both local and collaborating partners (stage 6, Figure 1).

When ELISA development (stages 1–6, Figure 1) is completed, implementing this technology will allow work to commence on the following three objectives:

- to strengthen the monitoring network in Vietnam to ensure ongoing monitoring of mycotoxin and pesticide contamination;
- to monitor the incidence and quantify the severity of contamination by mycotoxins and pesticides in both Vietnam and Australia; and
- to examine methods to limit production of mycotoxins and reduce sources of pesticide contamination through traceback and other appropriate methods.

## Conclusion

The main goal of the ACIAR project, PHT/1996/004, can be simply summed up as risk management of pesticides and mycotoxins using ELISA technology. This project can be considered as having three phases. The first phase involves a baseline survey of suspected pesticides and mycotoxins, during which time the

suspected problem contaminants will be confirmed. The second phase involves the development of immunochemical methods for the target mycotoxins and pesticides for detection of contamination in grain, vegetables, dried fruits and peanuts. This phase also involves the training of the Vietnamese collaborators in the methodology for the development of immunoassays and related simple tests and in protocols for their application. A number of prototype ELISA kits will be developed and tested for their performance. Workshops will be conducted to train local farmers and potential users in the use of ELISA kits for monitoring of contaminants. The final phase of the project involves strengthening the existing monitoring network in Vietnam to ensure ongoing monitoring of mycotoxin and pesticide contamination. The expected outcomes of this project are thus:

- Higher quality produce for national consumption. In addition, the knowledge that food and feedstuffs are of high quality will act to encourage industry and stimulate national and international interaction in the countries involved.
- Higher quality produce for export will command higher prices. In addition, penalties are likely to be imposed and losses suffered where produce is contaminated.
- Better health in humans and livestock. The prospects for improved health of both Vietnamese and Australians has direct economic benefits by reducing costs for medical treatment and infrastructure for maintaining human health and national productivity.
- These outcomes would result in sustainable agricultural production in Vietnam, thus enhancing the economic benefits arising from improved trade between Australia and Vietnam.

## References

- Beasley, H.L., Phongkham, T., Daunt, M.H., Guihot, S.L. and Skerritt, J.H. 1998. Development of a panel of immunoassays for monitoring DDT, its metabolites and analogs in food and environmental matrices. *Journal of Agricultural and Food Chemistry*, 46, 3339–3352.
- Hammock, B.D., Gee, S.J., Cheng, P.Y.K., Miyamoto, T., Goodrow, M.H. and Seiber, J.N. 1986. Utility of immunoassay in pesticide trace analysis. In: *The Sixth International Congress of Pesticide Chemistry Proceedings*, Ottawa, Canada, 11–15 August, 309–316.
- Kennedy, I.R., Skerritt, J.H., Johnson, G.I. and Highley, E. (ed.) 1998. Seeking agricultural produce free of pesticide residues. ACIAR Proceedings No. 85. Canberra,

- Australian Centre for International Agricultural Research, 406p.
- Lee, N., Beasley, H.L., Kimber, S.W.L., Silburn, M., Woods, N., Skerritt, J.H. and Kennedy, I.R. 1997. Application of immunoassays to studies of the environmental fate of endosulfan. *Journal of Agricultural and Food Chemistry*, 45, 4147–4155.
- Lee, N., Skerritt, J.H. and McAdam, D.P. 1995. Hapten synthesis and development of ELISAs for detection of endosulfan in water and soil. *Journal of Agricultural and Food Chemistry*, 43, 1730–1739.
- Mannon, J. and Johnson, E. 1985. Fungi down on the farm. *New Scientist*, 1446, 12–16.
- Nguyen, T., Bui, V.T. and Nguyen, D.D. 1998. Reduction of pesticide residue contamination on vegetables by agro-extension work. In: Kennedy, I.R., Skerritt, J.H., Johnson, G.I. and Highley, E., ed., *Seeking agricultural produce free of pesticide residues*. ACIAR Proceedings No. 85. Canberra, Australian Centre for International Agricultural Research, 318–322.
- O'Brien, R.J. 1992. Pesticides and world food supply. In: Pimentel, D. and Dinnette, D.A., ed., *The science of global change: the impact of human activities on the environment*. American Chemical Society Symposium Series, 483, 309–323.
- Stanker, L.H., Watkins, B.E. and Vanderlaan, M. 1988. Environmental monitoring by immunoassay. *Environmental Science and Technology*, 22, 387–407.

# Use of the Flat-bed Dryer SHG-4 for Coffee Drying

Nguyen Hung Tam and Phan Hieu Hien\*

## Abstract

Coffee growing has increased in recent years in the Dak-Lak and Lam-Dong Provinces of Vietnam's Central Highland. Difficulties in drying are encountered during the annual coffee harvest from October to December because of the high rainfall conditions. Such weather causes a delay in natural sun-drying which results in blackening of the beans and a reduction in quality. Improper mechanical drying as currently practiced by most farmers—such as overheating or prolonged piling—also turns the beans black or brown. The value of losses due to delayed sun-drying or improper drying range from 12 to 50%.

Since 1996, the SHG dryer—originally designed for paddy at the University of Agriculture and Forestry, Ho Chi Minh City—has been modified and adapted to dry coffee beans. From test results, a batch of 4 t of beans at a depth of 0.3 m, at 65–70°C drying temperature could be dried down to 20–18% moisture content (MC) in 12 h with wet-husked coffee, or 16 h with whole beans. At 18% MC, after final husking and cleaning, coffee is further dried at a temperature not exceeding 50°C down to 13% MC. This assures moisture uniformity and meets quality criteria for storage and export.

Data for calculating drying cost: 1.2 L of diesel per hour, 50 kg/h woodwaste or maizecob, 5 persons for operating, loading/unloading, and mixing twice. The investment for the equipment, including the shed, is 32 million VND (~US\$2,300). The drying cost for 1 kg of dried beans is 426VND (~US\$30/t) or about 3.5% of the coffee value. Six SHG dryers, which were sold to farmers and used in the past three years, proved their technical and economic performance in keeping the coffee quality for the export market.

COFFEE IS a popular beverage in Vietnam and elsewhere. Coffee drying is an important step in the processing technology. In recent years, coffee production has increased greatly in the provinces of Dak-Lak and Lam-Dong in Vietnam. Difficulties in drying are encountered during the annual coffee harvest from October to December because of high rainfall conditions. Presently, either natural sun-drying or mechanical drying is practiced.

Sun-drying does not require any investment for equipment, only a large yard—either cemented or on earth with trays. Sun-drying needs labour for mixing, and the drying time depends primarily on the weather. This is unpredictable and risky. With bad weather and prolonged drying, coffee beans turn black, become infested with moulds, and deteriorate in quality.

Drying with some high-capacity, high-investment dryers like the fluidised-bed dryer, the tower dryer, the rotary dryer etc. is not suitable for small-scale pro-

duction of 2.5 ha (over 80% of coffee growing involves farm households). Drying with home-made, flat-bed dryers which do not meet technical requirements usually leads to overheated beans and reduced quality.

It is estimated that losses caused by delayed drying are high—15–50% of beans are blackened due to prolonged piling, or turn brown due to overheated drying.

From 1996, the Faculty of Agricultural Engineering of the University of Agriculture and Forestry (UAF), Ho Chi Minh City, began studies on the application of the SHG-4 dryer for drying coffee. This shows much promise as it fits the small and medium scales of production.

The objectives were:

- to check the design specifications of the SHG-4 dryer for drying coffee;
- to determine the resistance to airflow; and
- to determine the moisture reduction curve and the drying process.

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Following are descriptions of the study and some research results.

## Materials and Methods

Experiments were conducted at two places.

- Drying tests of whole coffee and pulped coffee were conducted in the Dak-Min District of Dak-Lak Province in the Central Highlands of Vietnam.
- Tests on airflow resistance of coffee beans were conducted at UAF, Ho Chi Minh City.

### SHG-4 dryer

The SHG-4 dryer tested at Dak-Min was a flat-bed dryer originally designed at UAF for paddy and maize. The dryer used for coffee had the following specifications:

- rectangular drying bin, with a floor area of 24 m<sup>2</sup> (3 m × 8m) (Figure 1);
- axial-flow fan, 750 mm diameter, 1,650–1,750 rpm, 7.5 kW motor. The fan had been checked and tested according to Japanese Standards JIS-8003.B; and
- inverted-draft furnace (Figure 2) using woodwaste, maizecob, coffee husk etc. as fuel, with a consumption of 50 kg/h. The drying temperature of 50–70°C, read with a thermometer, could be adjusted.

### Laboratory dryer

The laboratory dryer was constructed according to the published design of Sutherland and Macmillan (1992) and consisted of three components:

- centrifugal fan, 1 kW, provided the drying air—the airflow could be adjusted by the distribution louvre;
- drying bin was a galvanised cylinder with a diameter of 320 mm and a height of 500 mm; and
- electric resistors provided heat.

### Measuring equipment

- For determining the moisture content of the coffee, the oven method with electronic balance and 0.01 g accuracy was used.
- The airflow resistance and the superficial velocity were measured with a digital manometer (1–1,000 Pa) and a floating disk airflow meter (8–14 m/min), respectively.

## Results and Discussion

The following results were obtained from experiments with coffee planted in the Dak-Min District of Dak-Lak Province.

### Airflow resistance of coffee beans

The airflow resistance of pulped coffee beans of thickness layers of 10, 20, 30, 40 and 50 cm, and with different superficial velocity from 8–14 m/min is shown in Figure 3. Results show that the resistance is rather small, in the range of 20–100 Pa.

### Moisture reduction

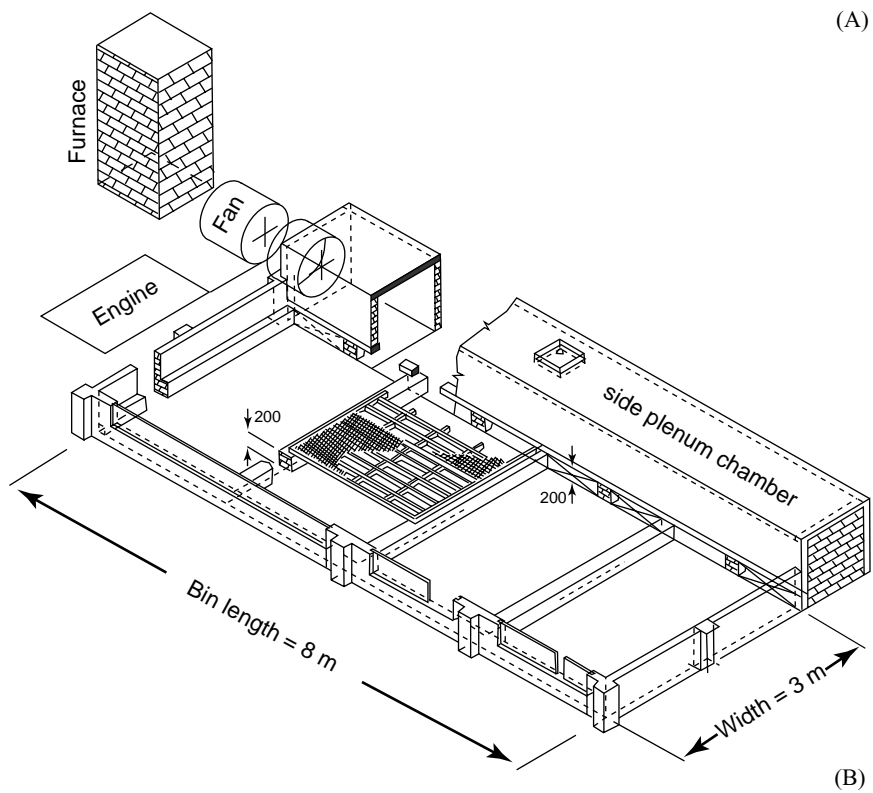
Since 1996, six dryers have been installed for coffee drying. Depending on the process, either whole coffee or dry-pulped coffee was dried at 60–70°C, in order to reduce the moisture content (MC) from fresh to 18–20%. Next, coffee was further dried down to 12–13% so that the MC was uniform for storage or export. Whole coffee could be dry-pulped and cleaned before re-drying in order to reduce the drying time; the required temperature at this stage was below 50°C. The fan of the SHG-4 dryer provided sufficient airflow that only two mixings were required.

Data from drying batches of pulped coffee and whole coffee are graphed in Figures 4 and 5, respectively.

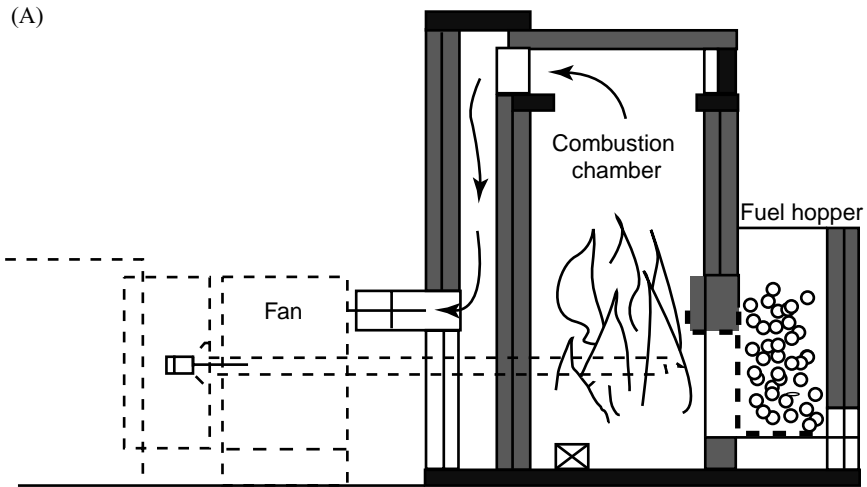
### Drying cost

Data (US\$1 ≡ VND 13,800):

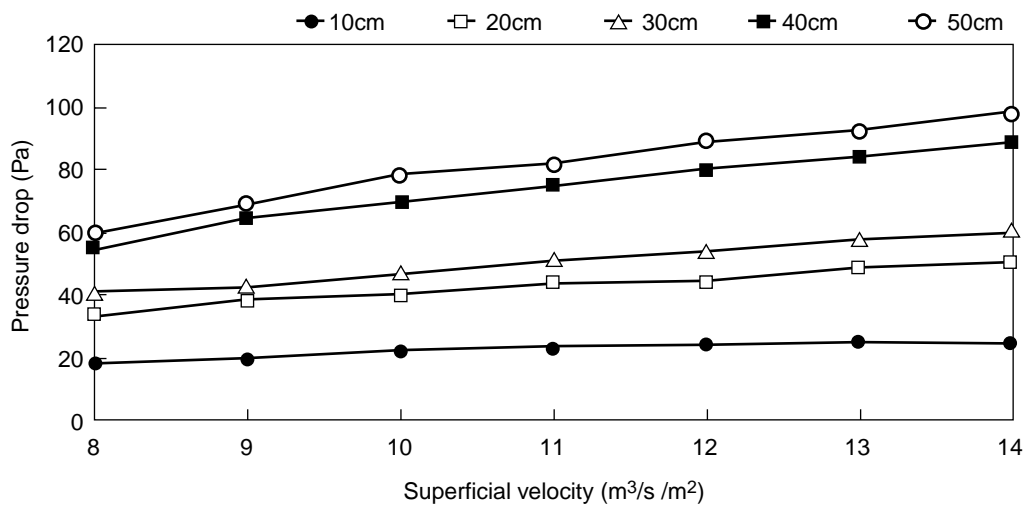
- Dryer price, including engine VND 24,000,000
- Total investment (including shed) VND 32,000,000
- Engine price VND 5,000,000
- Diesel fuel consumption for fan 1.2 L/h
- Fuel for furnace (woodwaste) ≡ 50 kg/h.
- Labour (operation, mixing, loading/unloading) 5 persons
- Days of use per year 40 days
- Drying capacity per batch 900 kg (dried coffee)
- Drying quantity per year 130 t
- Operator's wage VND 35,000/day
- Diesel price VND 3,600/L
- Woodwaste price VND 200/kg



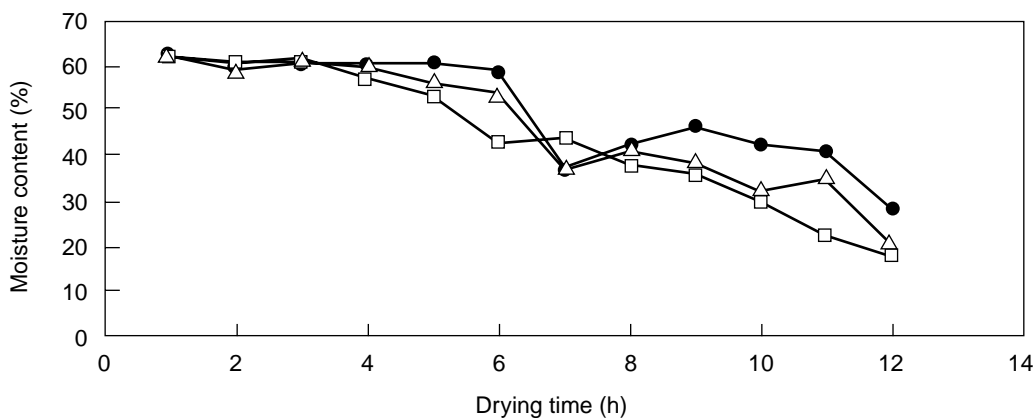
**Figure 1.** Schematic diagram of the SHG-4 dryer (A) and photograph of coffee drying in the dryer (B).



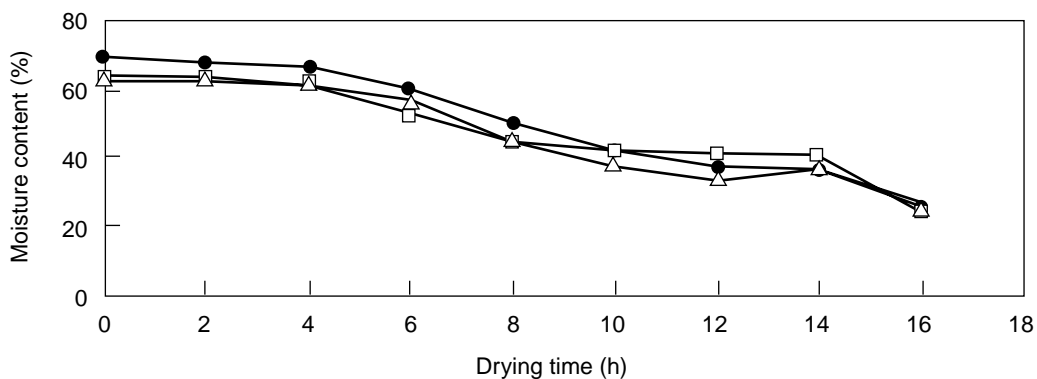
**Figure 2.** Schematic diagram (A) and photograph (B) of the inverted-draft furnace.



**Figure 3.** Airflow resistance to pulped coffee beans with increasing thickness of the coffee layer.



**Figure 4.** Drying curves of pulped coffee at three points in the drying bin; 1 December 1998, 70°C.



**Figure 5.** Drying curves of whole coffee at three points in the drying bin; 2 December 1998, 80°C.



The calculated drying cost is VND 426/kg of dried coffee (≡ US\$30/t). The cost components are: labour, 19%; fuel, 30%; diesel, 13%; depreciation and repairs, 30%; and interest and land rent, 8%. This drying cost is about 3.5% of the coffee value.

### **Conclusion**

The tests and use of the SHG-4 dryer with inverted-draft furnace for drying both whole and pulped coffee show good results: high quality, low investment, and low drying cost. These results demonstrate the possi-

bility of promoting this type of dryer under the present conditions of small and medium production.

### **Reference**

Sutherland, J.W. and Macmillan, R.H. 1992. Grain drying rig. Manual No. 7.1. Equipment for teaching and research in agricultural engineering and development techniques. Melbourne, Australia, Department of Civil and Agricultural Engineering, University of Melbourne.

# The Study of Aflatoxin-producing Strains, Fumonisin-producing Strains, and Non-producing Strains and their Application in Mycotoxin Prevention in Agricultural Products

Nguyen Thuy Chau, Nguyen Thi Huong Tra, Nguyen Thi Hong Ha\*

## Abstract

The aflatoxin-producing ability of 17 strains of *Aspergillus flavus* and *A. parasiticus* isolated from maize sampled in some provinces in northern Vietnam was studied. 8 of the 17 strains produced aflatoxin. Inoculation using a mixture of a strain of *A. flavus* producing 331 parts per billion (ppb) aflatoxin with each of 8 strains of non-aflatoxin producing *A. flavus* showed a reduction in aflatoxin production which varied between strains. Non-producing strain VN<sub>2</sub> gave the best results, reducing the aflatoxin yield in the inoculation mixture by 98.5%. Use of the VN<sub>2</sub> strain reduced aflatoxin contamination in maize from 3,000 ppb before treatment to 253 ppb after treatment.

The fumonisin-producing ability of *Fusarium* species isolated from maize sampled in northern Vietnam was also studied. 6 of strains produced fumonisin B<sub>1</sub> (FB<sub>1</sub>) and fumonisin B<sub>2</sub> (FB<sub>2</sub>), namely, *F. moniliforme*-strain 1, *F. moniliforme*-strain 2, *F. fusarioides*-strain 1, *F. fusarioides*-strain 2, *F. oxysporum*, and *F. proliferatum*. The yield of FB<sub>1</sub> was highest in the strain of *F. proliferatum* (5,800,000 ppb). Inoculation using a mixture of non-fumonisin producing strain *F. moniliforme* var. *subglutinans* with the strain of *F. proliferatum* producing 5,800,000 ppb reduced the fumonisin yield considerably—the yield of FB<sub>1</sub> and FB<sub>2</sub> in the inoculation mixture was 13,700 ppb and 800 ppb, respectively.

These results indicate that the non-producing fungi we isolated are potential candidates for application to prevent aflatoxin and fumonisin contamination in agricultural products in both the preharvest and postharvest stages. Experiments to clarify the mechanism of the reduction of aflatoxin and fumonisin yields of toxin-producing strains as well as contaminated maize samples by non-producing strains will be carried out in the future.

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# Research on the Down-draft Rice Husk Furnace

Nguyen Van Xuan and Phan Hieu Hien\*

## *Abstract*

Rice husk has been widely used as a heat source for dryer furnaces in the Mekong Delta of Vietnam. It has taken advantage of using local by-product bulk as well as principally reducing the cost of dried products. The concern is to optimise the effective usage of this biomass material as the energy demand increases gradually, along with requirements on environment protection.

Due to its highly volatile nature, rice husk burning by the traditional methods is smoky. This reduces the dried product's quality, pollutes the environment and lowers the efficiency.

Rice husk gasification, although attractive, requires high investment, leading to high drying costs. Additionally, the design of a low-cost, continuous rice husk gasification system is still a challenge to researchers worldwide.

Burning rice husk directly and completely is considered more appropriate. Thus, a down-draft rice husk furnace for use with the low-cost SRR-1 dryer has been designed and built at the University of Agriculture and Forestry Ho Chi Minh City. It consists of a cylindrical container with a concentric inner grate and combustion chamber. The key feature of this furnace is that the pyrolysis gases have to pass through the char combustion area, and reach the high temperatures needed for good combustion. In addition, heat of the char combustion is transferred by radiation to sustain a high temperature inside the gas combustion area, which results in an almost complete combustion of the volatile matter.

Experimental results showed that the average rice husk consumption rate was about 2.6 kg/h, and the gas-air mixture was clean and stable. The CO content in flue gases is 0.3–0.7% which was lower than the permissible limits of the permitted limitations in environmental standards of Vietnam and other countries. The good combustion efficiency of 90% and furnace efficiency of 80–82% was obtained.

RICE HUSK has been widely used as a heat source for dryer furnaces in the Mekong Delta of Vietnam. It has taken advantage of using local by-product bulk as well as principally reduced the cost of dried products. The concern is to optimise the effective usage of this biomass material as energy demands increase and environmental protection becomes an increasing concern.

Due to its high volatile matter, rice husk burning by the traditional methods is smoky. This reduces the dried product's quality, pollutes the environment and lowers the efficiency.

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tionally, the design of a low-cost, continuous rice husk gasification system is still a challenge to researchers worldwide.

Burning rice husk directly and completely is considered more appropriate. Thus, a study on a down-draft rice husk furnace for use with the low-cost SRR-1 dryer has been carried out. The furnace was designed and built at the University of Agriculture and Forestry, Ho Chi Minh City.

## **Objective of the Study**

To develop a rice husk furnace which is smokeless and highly efficient so that the flue gases can be used directly as drying air without the need for a heat exchanger.

\* University of Agriculture and Forestry, Thu Doc, Ho Chi Minh City, Vietnam.

## Construction of the Furnace

The following design criteria were set out:

- clean flue gases;
- high thermal efficiency;
- stable drying temperature;
- simple construction, fabricated with basic workshop tools, using standard materials; and
- cost-competitive to other available heating systems for dryers.

The furnace construction is shown in Figure 1 and 2. The four-wall column contains rice husk. The perforated central tube collects and burns volatile gases which exit to the dryer fan. The grate separates the ash from the burning rice husk. The primary air is supplied from the top. Ash removal and fuel feeding are done manually.

## Experimental Set-up

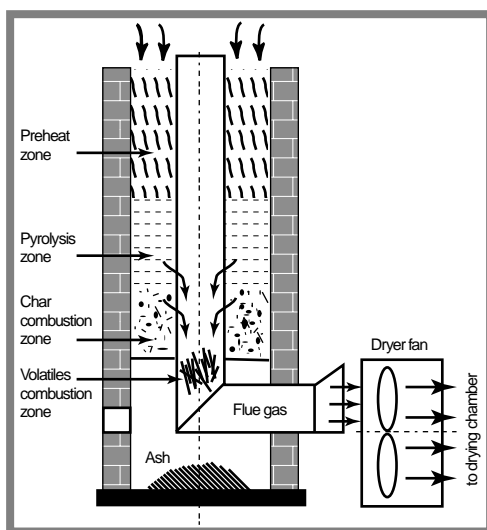
A 2-hour test was carried out to measure the following variables with their respective instruments:

- drying air temperature and combustion zone temperature, with the data logger;
- CO content in flue gases, with the Baccharah gas analyser; and
- average rice husk consumption rate.

The combustion efficiency and the drying air efficiency were computed as in a previous paper (Nguyen Van Xuan et al. 1995).

## Results (Preliminary)

- The drying air temperature rise could be maintained at 9–12°C above ambient, the gas-air mixture was clean and stable. The temperature in different zones of the furnace are shown in Figure 3.
- The CO content in flue gases is low, 0.3–0.7%, which is indicative of the high combustion efficiency of furnace (see Figure 4).
- Average rice husk consumption rate = 2.6 kg/h.
- Combustion efficiency = 90%.
- Drying air efficiency = 80–82%.



**Figure 1.** Schematic diagram of the down-draft rice husk furnace.



**Figure 2.** Photograph of the down-draft rice husk furnace.

## Conclusion

The down-draft rice husk furnace showed promising results as to combustion and drying air efficiency. The flue gases are clean, and it can thus be fitted as a direct heat source to the dryer. The rice husk consumption rate fits with the popular low-cost dryer SRR-1 in Vietnam. Further tests are planned to optimise the operation of the furnace.

## Reference

Nguyen Van Xuan, Truong Vinh, Pham Tuan Anh and Phan Hieu Hien 1995. Development of rice husk furnaces for grain drying. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., Grain drying in Asia. ACIAR Proceedings No. 71. Canberra, Australian Centre for International Agricultural Research, 336–341.

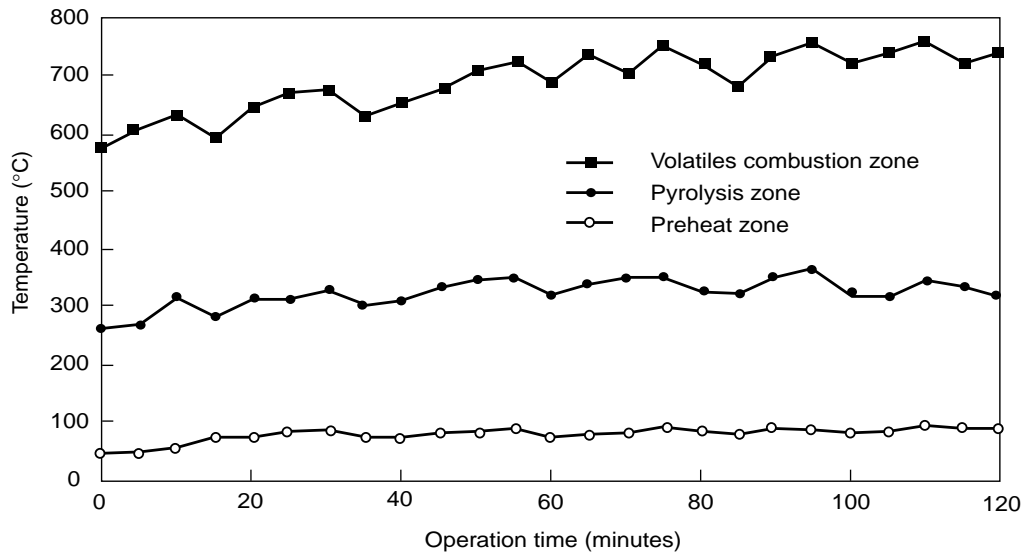


Figure 3. Variation in temperature at different combustion zones during testing of the furnace.

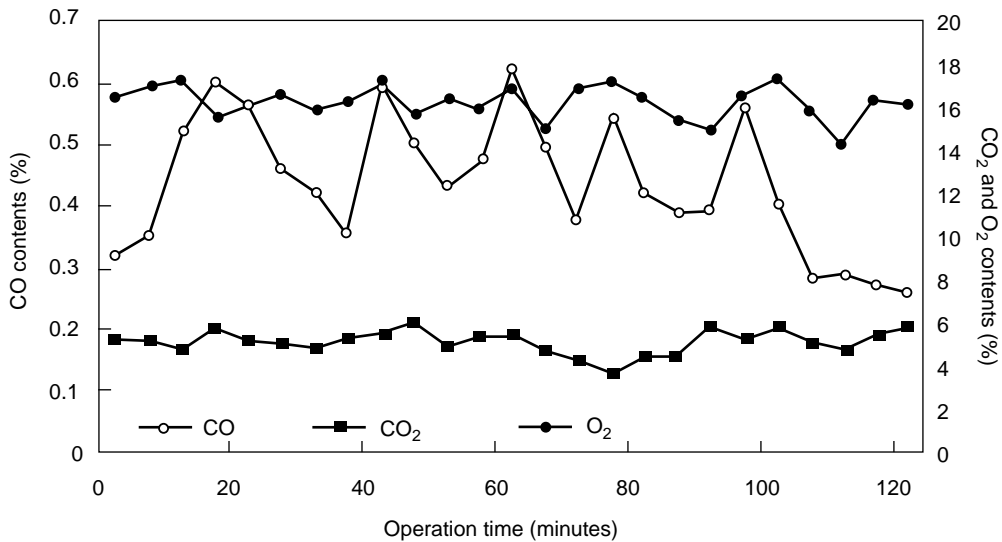


Figure 4. Variation in flue gas contents during testing of the furnace.

# Techniques for Grain Dryer Performance Assessment and Effects of Drying on Maize Grain Quality

L.U. Opara\*, P. Meas† and A. Hardacre§

## Abstract

Removal of excessive moisture after harvest is important for prolonging the storage life and maintaining the quality of grains. In many developing countries, mechanical drying is often applied where sun-drying alone cannot cope with large crop volumes and/or inclement weather. Mechanical dryers must be designed and operated such that the adverse effects of drying on product quality are minimal. The objectives of this paper are to review the techniques for assessing the performance of grain dryers, and to discuss the effects of drying conditions on grain quality attributes of 'hard' ('Clint') and 'soft' ('Raissa') maize hybrids.

INCREASING GLOBAL emphasis on grain quality and energy conservation has created a need to develop drying systems that will deliver a better quality product with lower energy consumption for drying (Gustafson et al. 1978). In the design and utilisation of grain dryers it is important to understand the effects of drying parameters—such as drying air temperature, drying time, airflow rate, tempering time and temperature—on the quality of the dried grain (Abe et al. 1992).

Postharvest grain losses due to delayed or improper drying or lack of drying facilities are still high, especially when harvesting coincides with a rainy season, and particularly in developing countries. However, where mechanical drying is possible, the operation must not be considered as merely the removal of moisture, since many grain quality attributes can be adversely affected by incorrect selection of drying conditions and equipment (Trim and Robinson 1994). Performance evaluation of existing or new dryers is

therefore critical to facilitate the selection of drying parameters to ensure optimum grain quality.

Poor or defective drying facilities or incorrect drying procedures may result in very fast drying rates, incomplete drying, and uneven moisture re-absorption within the grain mass. Improper drying can result in high costs, low efficiencies, high milling losses, poor quality of the grain or reduced germination capacity of the dried seeds (ESCAP 1995).

Evaluation of the performance of grain dryers and understanding the effects of drying on grain properties are, therefore, very important to satisfy the needs of grain producers, grain traders, grain processors and grain users. The objectives of this paper are: (1) to review the criteria for assessing the overall performance of grain dryers, and (2) to examine the effects of drying conditions on quality attributes of 'hard' ('Clint') and 'soft' ('Raissa') maize hybrids.

## Criteria for Evaluating Grain Dryers—a Review

Both new and existing dryers must be designed and operated to satisfy the often conflicting demands to reduce operational costs (such as energy and labour) as well as to minimise adverse effects on product quality (such as breakage and hardness). To meet these requirements, two broad criteria, namely, operational

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performance and economic performance, can be identified for evaluating grain dryer performance, in addition to the effects of drying on dried grain quality. These will be briefly reviewed in the following sections.

## Operational performance

Several factors contribute to the operational performance of a dryer including drying efficiency, drying capacity, energy efficiency, and labour aspects.

### *Drying efficiency*

The drying efficiency of the drying operation is an important factor in the assessment and selection of the optimal dryer. There are three groups of factors affecting drying efficiency: (i) those related to the environment, in particular, ambient air conditions; (ii) those specific to the crop; and (iii) those specific to the design and operation of the dryer (Trim and Robinson 1994).

There are several different ways of expressing the efficiency of drying. Adeyemo (1993) noted that drying efficiency (expressed also in terms of fuel efficiency and sensible heat utilisation efficiency) are very important considerations in dryer selection. Drying efficiency (DE) is based on how well a drying system converts sensible heat to latent heat, which can be expressed as:

$$DE = \frac{HU}{HA} \times 100\% = \frac{WWE \times LHV}{WF \times HVF} \times 100\% \quad (1)$$

where:

HU = heat utilised for moisture removal (kJ)

HA = heat available for moisture removal (kJ)

WWE = weight of water evaporated (kg)

LHV = latent heat of vapourisation (kJ/kg)

WF = weight of fuel utilised (kg)

HVF = heat value of fuel (kJ/kg)

### *Drying capacity*

Arinze et al. (1996) defined the drying capacity (DC) of a dryer as the rate at which the wet product can be dried to specified moisture content (MC) while the dryer is operated at specified drying conditions. DC is one of the most important factors in the design and utilisation of grain dryers. Decision making by purchasers or operators of grain dryers would be simplified if manufacturers or designers used common criteria to describe the performance of their products (McLean 1989), e.g. the weight of maize at 25% MC that can be dried to 14% when the drying air temper-

ature is 58°C. If the capacity of the dryer is inadequate, in practice it is possible that the following extreme possibilities may be encountered: (i) harvesting will be delayed to the extent that grain will be overripe and shattered; (ii) its MC may rise in the field and thus additional fuel or energy will be required to dry it when it is eventually harvested; (iii) the grain that has been harvested will be deteriorated when drying has to be delayed; or (iv) the amount of grain to be dried may be very small compared to the high capacity of dryers.

### *Specific total energy consumption*

ESCAP (1995) defined the specific total energy consumption as the total energy used per kilogram of water evaporated. The utilisation of the world's reserves of fossil fuel is a controversial subject which makes it appropriate that the energy requirements of grain drying systems are considered when new installations are planned (McLean 1989).

### *Labour requirements, ease and safety of operation*

A well-designed grain dryer should not be very complicated to operate nor require many workers or operators. It is also necessary for the design and operation of grain dryer to be carried out safely by those who operate it, or have reason to visit grain drying facilities (McLean 1989). ESCAP (1995) listed the ease of use and safety features and hazards, related to the operational performance of grain dryers, including the following:

- fire and electrical hazards;
- unguarded power transmission shafts, belts, pulleys etc.;
- noise level;
- unusual vibration;
- dust emission control;
- ease or difficulty of loading and unloading grain;
- ease or difficulty of making adjustments;
- ease or difficulty of cleaning and repairing parts; and
- other significant operational, safety and hazardous features of the dryer.

## Economic performance

It is beneficial to design and operate mechanical dryers to minimise their capital and drying costs. The widespread introduction and adoption of grain dryers will be inevitable in the near future in many developing countries. However, to be successful, the dryers will have to be economical in terms of capital and running (or drying) costs (Ofoche et al. 1991). To

achieve this goal, dryers should be designed taking into full consideration the costs, local environmental conditions, and technical skill and construction material available.

Variations in the capital cost of grain dryers and their specific energy consumption do exist. In addition, most grain dryers are utilised only a few weeks per year. It may be necessary to compare the relative merits of purchasing an expensive dryer with low fuel or energy consumption with a less expensive one (McLean 1989). In India, for instance, an important reason for not using dryers is their high initial cost. Most of the commercially available dryers are designed to suit the needs of the processing industry and their output capacity is therefore far above the needs of individual farmers, or even of farmer groups (Shukla and Patil 1988).

The major components and sources of grain dryer expenditure include fan(s), motor(s) and air heating system (Hall 1980). The cost of fuel and/or power for drying grain is greatly dependent on weather conditions. The cost of drying grain with unheated or heated forced air varies greatly with atmospheric temperature, humidity, and grain MC. Overall, the economic performance of a new or existing drying system is an important factor affecting the adoption and continued use by farmers (Rodriguez 1999).

## Effects of postharvest drying on grain quality attributes

The drying process has been known to affect the quality of the dried grain, resulting in cracking, increase in breakage susceptibility, and opportunistic microbial infection. Damage to grain may be caused by either drying it too slowly or too rapidly. If grain is dried too slowly and for too long a period, undesirable deterioration occurs, such as mould growth. Other damage occurs when grain is dried too rapidly. Reducing grain damage and maintaining post-drying quality is therefore important in evaluating the performance of a drying system.

Previous studies have shown that maize grain dried from a higher initial MC cracked and broke more easily than that dried from a lower initial MC (Weller et al. 1990). Ross and White (1972) concluded that the MC prior to drying affected stress crack formation in dried maize. Higher grain initial MC increased the incidence of cracking in dried grain.

Fast drying—high drying rate and capacity—is normally obtained using air of high temperature and flow rate. Rapid drying, however, makes the grain

more brittle and more subject to damage when handled. Extremely rapid drying results in grain of reduced bulk density with kernels that are enlarged or puffed. If grain is dried at high temperatures, discoloration and other kinds of heat damage may occur (Foster 1973).

Thompson and Foster (1963) found that internal damage was frequently the consequence of a high-temperature drying process and as the number of stress cracks in the maize grain increased the susceptibility to breakage increased. When handled and transported, kernels with stress cracks broke more readily than sound kernels, leading to considerable amounts of broken grain and fine material. The authors also reported that shelled maize dried with heated air at 60–115°C was two to three times more susceptible to breakage than the same maize dried with unheated air.

Peplinski et al. (1994) reported that as the air-drying temperature increased from 25 to 100°C, maize kernel test weight and germination decreased, kernel breakage susceptibility and percentage of floating kernels increased, and 100-kernel weight and stress-cracked kernels were unchanged. Brooker et al. (1992) reported that the feed efficiency (average daily gain, daily maize intake and feed/gain ratio of rats), and thus the nutritive value of the maize, were adversely affected when the grain was dried at 50°C.

For each of the three maize hybrids ('hard', 'intermediate' and 'soft'), Kirleis and Strohshine (1990) found that Stenvert hardness values remained relatively constant when grain was dried at temperatures from 27–60°C. The hardness declined only slightly, but not significantly, at the higher drying temperatures. At drying temperatures of 60–93°C, bulk density was significantly different among the three tested hybrids and decreased in the following order: hard > intermediate > soft. The authors concluded that Stein breakage susceptibility was primarily influenced by hardness. Stein breakage was greatest for the soft hybrid and least for the hard hybrid.

## Summary of the literature

Grains are important direct sources of food for humans and feed for livestock. As they are produced on a seasonal basis, it is essential to store the grains for late consumption for periods varying from one month up to more than a year. Grains are often harvested at MCs that are too high for safe storage. Drying is the most practised grain preservation method that enables grains to attain a MC sufficiently low to ensure good quality grain that is free of fungi and microorganisms



and that has desirable quality characteristics for marketing and final use. It is generally agreed that improper drying is the major cause of high drying costs, low efficiencies, and poor grain quality. Poor or defective drying facilities or incorrect drying procedures may result in a very fast drying rate, incomplete drying and uneven moisture re-absorption within the grain mass.

Very slow drying of high MC grain (as in sun or crib drying in inclement weather or in a deep bed dryer with unheated air) provides conditions for: mould growth; rapid loss of vigour and eventually germination loss; deterioration due to sprouting, weathering and respiration heating; and discoloration. These conditions result in both quantitative and qualitative postharvest losses. Very fast drying accomplished using large volumes of high temperature air, however, is likely to be inefficient in energy use and liable to damage the grain by over-heating and/or over-drying. Fast drying can cause cracking and splitting (including internal cracking), case hardening, discoloration, and loss of germination and vigour.

The design and operation of mechanical dryers which are cost-effective and efficient, and which have minimum detrimental impact on grain quality is a major, continuing challenge for the cereal industry. Mechanical dryers are important for commercial drying of grains and as aids for evaluating new cultivars and postharvest research. Performance evaluation of new and existing dryer designs facilitates the optimisation of dryer parameters, drying conditions and dried grain quality.

## **Experimental Study of the Effects of Grain Initial MC and Drying Air Temperature on Quality Attributes of 'Hard' and 'Soft' Maize Hybrids**

### **Materials and methods**

Two maize hybrids, representing hard ('Clint') and soft ('Raissa') grains were used in the experiments to assess the effects of drying on grain quality attributes. Mature cobs were harvested and shelled manually. Firstly, grains were wetted to achieve the desired initial MC before drying. Grain at three initial MCs (approximately 20, 25 and 30%) were dried at three drying air temperatures (58, 80 and 110°C) in three replications. The flow rate of the drying air was

constant for all the drying treatments (approximately 0.16 m/s). A new prototype flat-bed grain dryer was used, and details of the dryer design and experimental procedure have been documented by Meas (1999).

For each drying run, a 5 kg sample of one hybrid at one initial MC was dried in one of three drying bins. The depth of the drying sample was approximately 5 cm. A 100–150 g subsample of grain from each bin was put into a small, metal-mesh bag and replaced within the grain bulk. During the drying process, the metal-mesh bags containing the grain subsamples were taken out of the drying bins every 10 minutes and weighed, in order to monitor moisture reduction of the drying samples. Drying was stopped when the subsample weight reduced to a predetermined value, which was related to the MC of: 16% at 110°C, 15.4% at 80°C, and 14.6% at 58°C.

In addition to mechanical drying, grain samples of each hybrid, at each of the three initial MCs, were dried at room temperature (approximately 20°C) to serve as the control—a sample of 1 kg was put onto a perforated tray, spread in thin layer (approximately 1.5 cm) and left in the laboratory for about one week until the MC equilibrated. After drying, grain samples were assessed for their mechanical properties, which are often major determinants of grain quality (Liu et al. 1999; Meas 1999).

### **Results and discussion**

#### *Bulk density*

Analysis of variance of the change in bulk density shows that grain bulk density means were significantly affected by the interaction of the grain initial MC and the drying air temperature. However, the density of the two hybrids tended to decrease as the MC and drying temperature increased (Table 1).

Maximum grain bulk density (approximately 78 kg/hL) of the dried 'Clint' maize occurred when the grain was dried at ambient air temperature (20°C). It decreased as the MC increased from 25 to 30% but increased as the MC increased from 20 to 25% MC (Table 1). Black spots observed within the grain samples dried with this air—presumably caused by fungal growth—caused this irregularity. At 58 and 80°C, the density decreased almost linearly as the MC increased (Table 1). At 110°C, the density dropped more sharply when the moisture increased from 20 to 25% than when the moisture increased from 25 to 30%.

The trend of the bulk density for the 'Clint' maize was the same for the 'Raissa' maize dried from all the

three MCs at all the three temperatures produced by the dryer. When dried under ambient air conditions, the density of the latest hybrid decreased almost linearly with increasing MC. The lowest density (approximately 66 kg/hL) resulted in the grain dried at the highest temperature from the highest MC. Under each drying condition, the 'Clint' bulk density was always higher than the 'Raissa' bulk density. The overall difference between the two hybrids (from 74.73 kg/hL for 'Clint' to 71.59 kg/hL for 'Raissa') was statistically significant (Table 1).

### Breakage susceptibility

Breakage susceptibility of both hybrids was also affected by the drying temperature and the MC. As the temperature and/or the MC increased, the dried grain became somewhat more susceptible to breakage (Table 2). The highest damage (above 30%) occurred for grain dried from the highest MC (30%) at the highest air temperature (110°C for 'Clint', and 80 and 110°C for 'Raissa').

The statistical analysis indicates that there were interaction effects between the grain MC and the drying air temperature on the breakage susceptibility. The breakage was almost constantly low (approximately 1.5%) for the two hybrids dried at the ambient temperature from all the three MCs. At the three air temperatures produced by the dryer (58, 80 and 110°C), the breakage increased as the MC increased. When the MC increased from 20 to 25%, drying the grain at these temperatures increased the breakage significantly more than when the MC increased from 25 to 30% (Table 2).

For the 'Clint' hybrid, the 110°C and 20°C drying temperatures significantly caused the highest and the lowest damage, respectively. Drying at 80°C caused about 2% more breakage than at 58°C but this difference was not statistically significant. For the 'Raissa' hybrid, the effects of the 80 and 110°C air temperatures (25.58 and 27.45% breakage susceptibility, respectively) were not statistically significantly different from one another but they were significantly the highest compared with the effects of other temperatures. Drying the grain at 58°C caused significantly more breakage than drying it at the ambient air temperature (20°C). The difference between the drying effects on the two hybrids (approximately 17.61 and 18.38% breakage susceptibility for 'Clint' and 'Raissa', respectively) was not statistically significant (Table 2).

### Stenvert hardness

Stenvert results, shown in Tables 3 and 4, do not show clear effects of the MC of the grain and/or temperature of the air on the hardness properties of the two hybrids. For the 'Raissa' hybrid, the effects on the Stenvert energy consumption were not significantly different. The mean of the resistance time was, however, significantly lower when it was dried from 30% MC than when it was dried from the other two, lower MCs. The resistance time was not significantly affected by the three drying air temperatures produced by the dryer.

For the 'Clint' hybrid, the Stenvert energy consumption and resistance time indicated that drying from 20% MC produced significantly harder grain compared to drying from higher initial MCs. These two attributes were significantly highest when grain initial MC was 20%. Results of the samples dried by the dryer show that the dried grain was somehow harder when it was dried at lower air temperatures. The energy consumption and resistance time were significantly higher for the grain dried at 58°C and 110°C. The energy consumption for the grain dried at 80°C was also significantly different from the grain dried at 110°C, but not significantly different from the grain dried at 58°C. Whereas, the resistance time for the grain dried at 80°C was not significantly different from the grain dried at 110°C or at 58°C. Interaction effects indicated by the statistical analysis confirmed these inconsistencies. However, the overall results indicate that the dried 'Clint' maize was significantly harder than the dried 'Raissa' maize. The Stenvert milling energy and resistance time were approximately 10 kJ and 32 s, respectively, for 'Clint' but they were significantly lower (approximately 7.8 kJ and 18 s, respectively) for the 'Raissa' hybrid (Tables 3 and 4).

### Summary of grain properties as affected by drying parameters

The drying time for both hybrids increased significantly with increasing initial MC of grain, but decreased with increasing drying air temperature. Thus, increasing the drying air temperature is a common strategy adopted when drying grain at high initial MC. The application of an optimum drying air temperature and post-drying treatments are often employed to reduce potential deleterious effects on grain mechanical integrity (Meas 1999).

**Table 1.** Effects of grain initial moisture content and drying air temperature on bulk density of dried grain (kg/hL).

Temperature (°C)	'Clint'				'Raissa'			
	Moisture content (%)				Moisture content (%)			
	20	25	30	Mean	20	25	30	Mean
20	77.58 ± 0.00	77.91 ± 0.00	76.44 ± 0.00	77.31 ± 0.22 a	76.00 ± 0.00	74.57 ± 0.00	72.85 ± 0.00	74.47 ± 0.46 a
58	77.09 ± 0.14	75.31 ± 0.21	72.63 ± 0.12	75.01 ± 0.65 b	74.49 ± 0.04	72.11 ± 0.28	69.60 ± 0.12	72.06 ± 0.71 b
80	76.24 ± 0.23	73.92 ± 0.21	71.46 ± 0.49	73.87 ± 0.71 c	73.41 ± 0.14	70.61 ± 0.19	67.83 ± 0.45	70.62 ± 0.82 c
110	75.74 ± 0.17	72.57 ± 0.50	69.83 ± 0.33	72.71 ± 0.87 d	72.46 ± 0.20	68.90 ± 0.41	66.28 ± 0.68	69.21 ± 0.93 d
Mean	76.66 ± 0.23 a	74.93 ± 0.61 b	72.59 ± 0.75 c	<b>74.73 ± 0.43 A</b>	74.09 ± 0.40 a	71.55 ± 0.64 b	69.14 ± 0.76 c	<b>71.59 ± 0.49 B</b>

Note: Means for each grain moisture content or air temperature with the same letter (within each column or each row) are not significantly different at the 5% level.

**Table 2.** Effects of grain initial moisture content and drying air temperature on breakage susceptibility of dried grain (%).

Temperature (°C)	'Clint'				'Raissa'			
	Moisture content (%)				Moisture content (%)			
	20	25	30	Mean	20	25	30	Mean
20	1.86 ± 0.35	1.24 ± 0.06	1.20 ± 0.18	1.43 ± 0.16 c	1.21 ± 0.18	1.96 ± 0.21	1.24 ± 0.08	1.47 ± 0.15 c
58	13.37 ± 1.53	22.19 ± 1.31	25.21 ± 2.41	20.26 ± 1.99 b	13.18 ± 0.60	20.62 ± 2.97	23.24 ± 1.70	19.02 ± 1.81 b
80	15.68 ± 0.56	23.11 ± 1.87	28.23 ± 0.90	22.34 ± 1.92 b	14.23 ± 3.13	28.57 ± 3.47	33.95 ± 3.12	25.58 ± 3.36 a
110	19.28 ± 1.52	28.83 ± 2.84	31.17 ± 3.17	26.43 ± 2.24 a	18.29 ± 2.53	30.14 ± 3.31	33.94 ± 0.35	27.45 ± 2.65 a
Mean	12.55 ± 2.02 b	18.84 ± 3.25 a	21.45 ± 3.69 a	<b>17.61 ± 1.83 A</b>	11.73 ± 2.11 b	20.32 ± 3.58 a	23.10 ± 4.10 a	<b>18.38 ± 2.06 A</b>

Note: Means for each grain moisture content or air temperature with the same letter (within each column or each row) are not significantly different at the 5% level.

**Table 3.** Effects of grain initial moisture content and drying air temperature on Stenvert energy consumption (kJ).

Temperature (°C)	'Clint'				'Raissa'			
	Moisture content (%)				Moisture content (%)			
	20	25	30	Mean	20	25	30	Mean
20	9.34 ± 0.12	9.26 ± 0.12	9.68 ± 0.21	9.43 ± 0.10 b	7.51 ± 0.07	7.99 ± 0.24	7.81 ± 0.48	7.77 ± 0.17 a
58	10.50 ± 0.24	10.05 ± 0.12	10.40 ± 0.26	10.32 ± 0.13 a	7.96 ± 0.22	7.77 ± 0.22	7.59 ± 0.27	7.77 ± 0.13 a
80	10.43 ± 0.06	10.20 ± 0.32	10.27 ± 0.22	10.30 ± 0.12 a	7.74 ± 0.12	7.53 ± 0.13	7.63 ± 0.31	7.63 ± 0.11 a
110	10.76 ± 0.09	9.19 ± 0.21	9.18 ± 0.22	9.71 ± 0.28 b	8.15 ± 0.19	7.81 ± 0.16	7.38 ± 0.09	7.78 ± 0.14 a
Mean	10.26 ± 0.18 a	9.68 ± 0.16 b	9.88 ± 0.18 b	<b>9.94 ± 0.10 A</b>	7.84 ± 0.10 a	7.78 ± 0.10 a	7.60 ± 0.14 a	<b>7.74 ± 0.07 B</b>

Note: Means for each grain moisture content or air temperature with the same letter (within each column or each row) are not significantly different at the 5% level.

**Table 4.** Effects of grain initial moisture content and drying air temperature on Stenvert resistance time (s).

Temperature (°C)	'Clint'				'Raissa'			
	Moisture content (%)				Moisture content (%)			
	20	25	30	Mean	20	25	30	Mean
20	29.80 ± 0.67	28.67 ± 0.52	28.83 ± 1.36	29.10 ± 0.50 c	18.87 ± 0.23	20.30 ± 0.85	18.40 ± 1.30	19.19 ± 0.54 a
58	34.83 ± 0.62	33.30 ± 0.61	33.07 ± 0.76	33.73 ± 0.43 a	19.17 ± 0.38	17.20 ± 1.30	16.87 ± 0.87	17.74 ± 0.59 ab
80	33.73 ± 0.47	32.33 ± 0.81	31.47 ± 0.95	32.51 ± 0.51 ab	19.07 ± 0.74	16.43 ± 0.90	15.43 ± 1.01	16.98 ± 0.70 b
110	36.07 ± 1.09	29.47 ± 0.57	27.43 ± 1.05	30.99 ± 1.38 b	19.37 ± 0.17	17.07 ± 0.38	14.43 ± 0.39	16.96 ± 0.73 b
Mean	33.61 ± 0.78 a	30.94 ± 0.64 b	30.20 ± 0.80 b	<b>31.58 ± 0.48 A</b>	19.12 ± 0.20 a	17.75 ± 0.60 a	16.28 ± 0.61 b	<b>17.72 ± 0.34 B</b>

Note: Means for each grain moisture content or air temperature with the same letter (within each column or each row) are not significantly different at the 5% level.

The hard hybrid ('Clint') had lower, but statistically insignificant, breakage susceptibility than the soft hybrid ('Raissa'). However, 'Clint' had significantly higher bulk density and hardness characteristics than 'Raissa'. The low breakage susceptibility and high bulk density of 'Clint' could help explain the high preference for 'hard' hybrids by maize processors. The bulk density and the breakage susceptibility of the two hybrids tended to decrease and increase, respectively, as the initial MC increased, and as the drying air temperature increased. These results agree with those previously reported by Gunasekaran and Paulsen (1985) and other researchers. Kirleis and Stroshine (1990) had also found that for each of their tested hybrids, Stenvert hardness test values remained relatively constant for maize dried at temperatures up to 60°C and then declined only slightly, but not significantly, at higher drying temperatures (93.3°C). The level of the damage was very small for both hybrids when dried at the ambient air temperature, but the drying took a longer time and the dried samples developed pathological problems such as mould or fungal infection.

## Conclusions

Postharvest drying is important for removing excess grain moisture. Mechanical dryers must be designed and operated efficiently to reduce operating costs and minimise adverse effects on grain quality. The parameters and techniques used to evaluate the overall performance of grain dryers have been reviewed based on literature evidence. Experimental studies using 'hard' and 'soft' maize hybrids showed that both the initial MC of grain and drying air temperature affected grain quality attributes. The breakage and bulk density of the dried grain were most adversely affected at high drying air temperatures and high initial grain MC. The hardness characteristics of the dried grain decreased at higher initial MC and/or at higher drying air temperature. Grains of 'Clint' hybrid were consistently harder and had lower breakage susceptibility than 'Raissa' hybrid grains.

## References

- Abe T., Otoche, C.E., Hikida, Y. and Yamashita, J. 1992. Effects of drying parameters on the quality of artificially dried rough rice. *Journal of Agricultural Mechanisation in Asia, Africa and Latin America*, 23(4), 42–46.
- Adeyemo, L.T. 1993. Modification of a natural air convection dryer. *Journal of Agricultural Mechanisation in Asia, Africa and Latin America*, 24(2), 33–36.
- Arinze, E.A., Sokhansanj, S., Schoenau, G.J. and Trauttmansdorff, F.G. 1996. Experimental evaluation, simulation and optimisation of a commercial heated-air batch hay drier: part 1, drier functional performance, product quality, and economic analysis of drying. *Journal of Agricultural Engineering Research*, 63, 301–314.
- Brooker, B.D., Bakker-Arkema, W.F. and Hall, W.C. 1992. *Drying and storage of grains and oilseeds*. New York, Van Nostrand Reinhold.
- ESCAP (Economic and Social Commission for Asia and the Pacific) 1995. *Regional Network for Agricultural Machinery (RNAM) test codes and procedures for farm machinery*. Technical Series No. 12.
- Foster, H.G. 1973. Dryerage: heated air drying and corn quality. *Annales de Technologie Agricole*, 22, 233–244.
- Gunasekaran, S. and Paulsen, M.R. 1985. Breakage resistance of corn as a function of drying rates. *Transactions of the American Society of Agricultural Engineers*, 28, 2071.
- Gustafson, R.J., Morey, R.V., Christensen, C.M. and Meronuck, R.A. 1978. Quality changes during high–low temperature drying. *American Society of Agricultural Engineers (ASAE) Paper No. 76-3523*. St Paul, Minnesota, Scientific Journal Series No. 9747 of the Minnesota Agricultural Experiment Station.
- Hall, C.W. 1980. *Drying and storage of agricultural crops*. Westport, Connecticut, AVI Publishing Company.
- Kirleis, A.W. and Stroshine, R.L. 1990. Effects of hardness and drying air temperature on breakage susceptibility and dry-milling characteristics of yellow dent corn. *Cereal Chemistry*, 67, 523–528.
- Liu, Q., Cao, C.W. and Bakker-Arkema, F.W. 1999. Grain drying. In: *CIGR (International Commission on Agricultural Engineering) Agricultural Engineering Hand Book*, volume IV. St. Joseph, Michigan, USA, American Society of Agricultural Engineers.
- Meas, P. 1999. Performance evaluation of a prototype flat-bed grain dryer. MAppSc thesis, Massey University, Palmerston North, New Zealand.
- McLean, A.K. 1989. *Drying and storing combinable crops*, 2<sup>nd</sup> edition. Ipswich, United Kingdom, Farming Press.
- Ofoche, E.C., Abe, T. and Hikida, Y. 1991. Accelerating design and performance test evaluation of cross-flow tempering drier using computer simulation model. *Agricultural Mechanisation in Asia, Africa and Latin America*, 22(4), 54–60.
- Peplinski, J.A., Paulis, W.J., Bietz, A.J. and Pratt, C.R. 1994. Drying of high-moisture corn: changes in properties and physical quality. *Cereal Chemistry*, 71, 129–133.

- Rodriguez, A. 1999. Factors affecting the adoption and continued use of mechanical dryers in the Philippines. MAppSc thesis, Massey University, Palmerston North, New Zealand.
- Ross, I.J. and White, G.M. 1972. Thin layer drying characteristics of white corn. *Transactions of the American Society of Agricultural Engineers*, 15, 175–176 + 179.
- Shukla, D.B. and Patil, T.R. 1988. Overview of grain drying and storage problems in India. In: *Research and development issues in grain postharvest problems in Asia*. GASGA (Group for Assistance on Systems relating to Grain After harvest) Executive Seminar Series No. 2. Eschborn, Germany, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.
- Trim, D.S. and Robinson, A.P. 1994. Drying methods. In: Proctor, L.D., ed., *Grain storage techniques, evolution and trends in developing countries*. Food and Agriculture Organization of the United Nations. *Agricultural Services Bulletin* 1994, No. 109.
- Thompson, R.A. and Foster, G.H. 1963. Stress cracks and breakage in artificially dried corn. United States Department of Agriculture. *Marketing Research Report* No. 631, 24p.
- Weller, C.L., Paulsen, M.R. and Steinberg, M.P. 1990. Stress cracking and breakage susceptibility as affected by moisture content at harvest for four Yellow Dent corn hybrids. *Transactions of the American Society of Agricultural Engineers*, 33, 863–869.

# Rice Milling in Cambodia

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## *Abstract*

Rice milling in Cambodia can be broadly classified as village or commercial milling. The white rice and head rice yield from these rice mills is low and highly variable. The value of paddy milled by village mills is significantly lower than that milled in modern commercial mills. There are opportunities to increase both the quantity and quality of white rice recovered if farmers and millers dried, stored and milled rice at the correct moisture level and maintained their milling equipment regularly.

## **Background**

THE white rice and head rice yield (whole kernels) of mills in Cambodia is low and highly variable. Rice milling can be broadly classified as village or commercial milling. Village milling is normally undertaken on a part-time basis for village families. Commercial milling is done in larger mills using more modern equipment for larger urban populations or export.

### **Village milling**

Village households store their rice as paddy rice. They take small quantities, normally about 20 kg, to the mill several times a week for processing. The village miller usually operates the mill on a part-time basis, milling for 2–3 h/day. Depending on the locality, payment is made through the retention of the meal and husk by the miller or cash payment on a white rice basis. A single mill usually services 45–60 families.

There are two types of mill used in villages. The first is a steel huller and polisher that removes the husk and polishes the paddy in one operation. The second type uses rubber rollers to remove the husk, and steel polishers to remove the bran and polish the rice. These small mills have a relatively high power requirement (10–15 kW) and subject the paddy to high pressure and friction, which results in heating, low mill recovery

and high breakage of grain. The milling recovery, which is the percentage of white rice obtained from the paddy, is relatively low. These mills are capable of processing 150–300 kg of paddy/h and are very well known and accepted in villages. They are fairly cheap to operate and easy to repair, and produce one mixed grade of white rice, one grade of meal and the rice husk. The by-products of milling are used in pig, fish and poultry production.

### **Commercial milling**

The modern commercial mills are capable of milling 0.5–2.5 t/h. While they do some local milling, they prefer to buy paddy and mill it for a larger urban or export market. The modern mills in Cambodia are common in most provinces, especially in or near large towns or transport routes. Much of the equipment in these mills came from China and is very old. Most new equipment is imported from Vietnam. These mills incorporate a rubber roller system for removing the husk from the grain and use stone polishing wheels to remove the bran to produce white rice. When properly adjusted, they give the highest white and head rice yields. Milling outputs are graded into head rice, 1 or 2 grades of cracked rice, 1 to 3 grades of meal, and the rice husk.

We examined the cost and efficiency of milling operations in 25 village and modern mills in 4 provinces in Cambodia. Mills were performance tested under normal working conditions. Head rice

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samples were tested for the percentage of cracked grain.

## Results and Discussion

### Milling recovery

The recovery of white rice from village mills is very low. On average, only 53% of the white rice is recovered for human consumption and 17% is left in the bran and husk (Table 1).

In village mills, the sieves are changed every 5–15 days and rubber rollers once a month. Millers often felt that white rice yields began to decrease after 2–3 days of using a new sieve. Very few millers attempted to retrieve white rice mixed in with bran and husk. As the millers often receive the bran and husk as payment for milling, there is little incentive for them to improve milling efficiency.

In modern mills, both the quantity and quality of white rice recovered is much higher than from the village mill. There is a potential to increase white rice yields by 5% and head rice by 8% based on local experience and yield figures from other countries. In a well set up and managed modern mill, it is possible to recover 70% of white rice, and up to 48% of this could be head rice which contained no cracked kernels.

In many mills, the rubber rollers, which are used to remove the husk from the paddy or rough rice, are

being used well beyond their design life. Examples were found where rollers rated at 80 t throughput were used for more than 120 t throughput. Milling stones were often not refaced on a regular basis. In some instances, millers refaced the stones only once or twice per year, irrespective of throughputs. Other millers refaced or checked stones every 250 t of throughput. Grain moisture is not measured before milling and only one miller owned a moisture meter and that did not work properly. If grain is dried and milled below 14% moisture, cracking during milling will increase.

Before testing the mill, the miller was asked to estimate the head rice yield. In all tests, the millers overestimated the head rice yields by at least 5%, and in some instances by 10%.

### Potential value

The value of 1 t of paddy rice presently being milled by a village mill is worth significantly less than that milled by a modern mill (Table 2).

The value of 1 t of paddy milled at a village mill is \$122.25 compared to \$162.75 if milled in a modern mill. In both systems, there appears to be the potential to increase the value by more than \$20/t if an improved maintenance program were adopted. This increase would be achieved in village mills by decreasing the losses of white rice in the husk, and in modern commercial mills by improving the yield of head rice.

**Table 1.** Milling yields measured in Cambodian rice mills.

	Village mill	Commercial mill	Potential
Yearly throughput (t)	150–560	500–5 000	
Capacity (t paddy/h)	0.20 (0.14–0.32) <sup>a</sup>	1.35 (0.56–2.45)	
Fuel consumption (L/t)	6	9	
Head rice, no cracks (%)		40 (30–48)	48
Large cracks (%)		22 (1–35)	19
Fine cracks (%)		3 (1–5)	3
Total white rice (%)	53 (50–55)	65	70
Bran/meal (%)	16 (15–23)	11 (8–14)	8
Husk (%)	31 (23–36)	24 (21–27)	22

<sup>a</sup> Figures in brackets are the ranges.



**Table 2.** The value of 1 t of paddy rice processed in different mills.

	Village mill	Commercial mill	Potential mill yield
	(\$)	(\$)	(\$)
Purchase price	550	8 550	
Fuel cost (\$/t)	1.75	2.50	
Repairs/maintenance (\$/t)	1.00	1.00	
Labour (\$/t)	1.00	1.00	
Milling charges			
As cash(\$/t)	5–7.5	5–7.5	
As meal/husk (\$/t)	10.00	6.75	
Head rice		120.00	144.00
Large cracks		33.00	28.50
Fine cracks		3.00	3.00
Total white rice	112.75	156.00	175.50
Bran/meal	8.00	5.50	4.00
Husk	1.50	1.25	4.10
Total value (1 t paddy)	\$122.25	\$162.75	\$183.60

## Conclusions

The quantity and value of white rice recovered in the milling process in Cambodia could be significantly increased if:

- millers measured the output from the mills and maintained their milling equipment regularly; and
- farmers paid for milling on a cash payment basis, rather than the village miller retaining fine cracks and meal as payment for the service.

# Strategies to Replace the Use of Methyl Bromide for the Fumigation of Bagged or Bulk Export Shipments of Rice

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## Abstract

For many years, exports of rice have been fumigated with methyl bromide either prior to loading on board the vessel, or after loading but before sailing. This remains normal practice in most of the rice-exporting countries, and in some situations this type of fumigation is believed to be a mandatory requirement of the exporting country.

Methyl bromide is being phased out of production under the United Nations Montreal Protocol Agreement as it has been identified as depleting the ozone layer. Although it may be some years before production completely ceases, the reduction in availability will inevitably lead to an increase in cost. In addition, buyers of rice are likely to give preference to rice that has not been fumigated with methyl bromide. Therefore, there is an urgent requirement to introduce alternative, cost-effective measures.

This paper sets out the specific methodology that has been developed to meet this requirement by a group of organisations based in different parts of the world. It describes the development work, tests, and resulting procedures that have been evolved to allow phosphine fumigation of rice in bags and bulk to be carried out in ships economically, safely and more efficiently than fumigation with methyl bromide.

METHYL BROMIDE has been used for the fumigation of rice shipments for many years. It has proved to be effective, rapid and economical, whether used for fumigation in ships or in warehouses before loading or after discharge.

In 1991, methyl bromide was identified as affecting the ozone layer. It was subsequently assessed by the Technical Experts of the United Nations Environment Programme (UNEP) and, following recommendations to the Montreal Protocol Treaty on ozone-depleting substances, it was agreed that a phase-out or ban on its production and use would be introduced.

The phase-out schedule currently agreed on is as follows:

- developed countries (Article 2)—25% reduction on 1 January 1999, 50% reduction on 1 January 2001, 70% reduction on 1 January 2003, and phase-out on 1 January 2005; and
- developing countries (Article 5)—20% reduction in 2005, and phase-out on 1 January 2015.

Quarantine and pre-shipment uses are currently exempt from controls. After phase-out there will be exemptions for 'critical uses' which are still to be defined, but they are likely to be almost impractical.

The European Union Commission has agreed to a more rigorous schedule of controls in the European Union which are as follows: 60% reduction on 1 January 2001, 75% reduction on 1 January 2003, and phase-out on 1 January 2005.

It is expected that the time of the Montreal Protocol phase-out schedule for Article 5 countries will be reduced considerably following negotiations due to take place during the next 12 months. In addition, the

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exemptions for pre-shipment and quarantine received a critical analysis from UNEP experts and the resulting recommendations mean that the current control measures are likely to be significantly tightened in the future.

In addition to the restrictions that will be introduced by the Montreal Protocol, there will also be significant pressure from buyers, on suppliers of rice to guarantee that their produce is supplied without methyl bromide having been used on it. The demands of the consumers in Article 2 countries where methyl bromide is banned are likely to enforce this. Therefore, it is necessary to consider alternatives to methyl bromide for the treatment of rice.

The paper sets out to show that the fumigant gas phosphine can be used safely, effectively and economically to replace the use of methyl bromide in many shipment situations.

### **Estimates of Tonnages of Rice and Other Commodity Shipments Currently Fumigated with Methyl Bromide Per Annum**

India	2 million tonnes of rice; 1 million tonnes of other commodities.
Thailand	4 million tonnes of rice; 1 million tonnes of tapioca; 1 million tonnes of other commodities.
Vietnam	4 million tonnes of rice; 1 million tonnes of other commodities.
Korea	2 million tonnes of imported cargoes that are fumigated in vessels prior to discharge.
Japan	Large quantities of imported cargo are believed to be fumigated in vessels prior to discharge and immediately following discharge.
Africa	Imported cargoes are regularly fumigated at ports in the south, east, west, and north, usually in the vessel prior to discharge because cargoes arrive with easily detectable infestation.
Article 2 countries	Imported cargoes are regularly fumigated in many countries, usually immediately following discharge, due to imported infestation.

### **What does the Receiver or End User of the Cargo Want?**

The receiver does not want to receive live infestation at any time, but especially not from imported cargoes. This is because imported cargoes may contain species or strains that are not present in the receiving country (DSV 1996). For example, with resistance to phosphine becoming more widespread in some Asian and African countries, it is especially important that phosphine-resistant strains not be allowed to enter countries where resistance is not present.

In addition, in many countries the food processors will not accept commodities that show any signs of live infestation. In the United Kingdom, for example, most food production companies, including flour millers, have a zero insect tolerance policy.

### **Is it Possible to Achieve Fully-effective, In-transit Fumigation of Goods?**

In 1994, a group of independent fumigation companies located in different parts of the world drew up a protocol to work together to address this issue. It was recognised that methyl bromide and phosphine are very different fumigants (see Figures 1 and 2). The objectives were also set to take into account the many variables which existed worldwide with reference to phosphine in-transit fumigation, but the common factors were:

1. A ship's hold can be an excellent fumigation chamber if it can be made gastight.
2. A lot of research has been carried out by well-respected government laboratories throughout the world on the movement and distribution of fumigants and on the concentrations necessary to eradicate a wide range of pests at different temperatures (Hole et al. 1976). Most of the research is ignored by exporters when specifying fumigation.
3. In some countries, systems which provide an excellent distribution of the fumigant are already available (e.g. Degesch recirculation J System in Europe, Africa and the United States: J.T. Rogerson and P. Winspear, 1996, pers. comm.), while in other countries (e.g. India) they are not.
4. Control of the fumigation once it leaves the load port is largely ignored. The responsibility for the completion of the fumigation and the ventilation

at the discharge port is generally left to the master of the vessel (Watson et al. 1999).

5. Safety—in some countries (e.g. Canada), the safety recommendations and regulations set out by the United Nations International Maritime Organization (Anon. 1996) are strictly adhered to. In others countries, such as Spain and India, they are often ignored.

The objective of the group was therefore to provide the receiver or the end user with the opportunity to choose to specify that their cargo be treated so that all live infestation was eradicated, with little or no detectable residues remaining, and using methods and procedures which ensured the safety of the vessel's crew and of all those involved in discharging the vessel.

## Development Work

It was decided that various methods of fumigation were needed to address different situations and therefore the following schedule of development work was followed.

## Verification of the Degesch J System

A request was received to arrange for a cargo of bagged rice to be fumigated which had been loaded in Southeast Asia and had then been fumigated with methyl bromide before sailing for Cuba. The vessel, which had already set sail, was redirected to Durban, Republic of South Africa. The request for fumigation was that the cargo must be fully guaranteed to have no live infestation of any type of insect at any stage of the life cycle on arrival in Havana.

It was decided to use the Degesch J System which is normally fitted before loading (Figure 3), but because of the way the rice had been stowed could be fitted after loading. Pestmaster of South Africa met the vessel in Durban and carried out the fumigation as specified and directed by Igrox Ltd in the United Kingdom. It was decided to use this opportunity to test the efficacy of the Degesch J System under these most difficult conditions.

### Method

The Degesch J System was fitted to the 'MV Asian Progress' as shown in Figure 4. There was sufficient access down the side of the hold and below the tween deck to allow the Pestmaster technicians to fit the pipes in each hold. Gas sample lines were also fitted in

three places in each hold. Live infestation (*Tribolium* spp.) was detected throughout the cargo.

Aluminium phosphide in retrievable sachets was placed on top of the cargo and the fans switched on. The holds and all access points were sealed and tests carried out for leakage. When all requirements as per United Nations International Maritime Organization Recommendations on the Safe Use of Pesticides in Ships had been met, the vessel was allowed to sail on 27 February 1996 with strict instructions to ensure all seals remained intact and the fans switched on until arrival in Cuba.

### Findings: Havana, Cuba, 27 March 1996

The inspection of the fumigation commenced on board the vessel at approximately 10:30 am with representatives of Cuba Plant Quarantine, Igrox Ltd and the shipper in attendance.

The fans were switched off (No. 2 was already not running as it stopped 10 days after the vessel left Durban), then the access manholes to each hold were opened in turn. The three gas sampling lines positioned in each hold were retrieved. The lines were labelled as B (bottom), M (middle), H (near to the top). Samples were drawn using an Agridox Phosphine Meter. Low levels of approximately 1 parts per million (ppm) were recorded on all lines in the first hold checked (No. 5). Further samples were then drawn using a Drager pump and phosphine tube 0.1/a (meaning the lowest concentration it can reliably measure is 0.1 ppm). This confirmed that the concentrations were between approximately 0.7 and 1.00 ppm. The remaining four holds were tested in a similar way and all lines indicated concentrations between 0.6 and 1.00 ppm.

On completion of these measurements the ventilators were opened and the ship's ventilation system was switched on. Phosphine was immediately detected by smell on the deck. The hatch covers were opened and the polythene sheets used to seal the holds were removed and ventilation continued. Gas concentration checks carried out indicated it was safe to work in the holds and initial checks were made by Cuba Plant Quarantine inspectors in each hold to ensure all fumigation ducts and fans had been located correctly, which was confirmed. Ducts to the lower holds could be clearly seen.

The sachets containing the aluminium phosphide residues were collected and taken away for disposal by Plant Quarantine.

Further gas-measuring checks with the Drager equipment were carried out in the air-space below the

surface, and zero or only traces of phosphine were recorded. A Clearance Certificate was issued at 4:00 pm.

#### Observations

- The Plant Quarantine (PQ) inspectors were very keen to see all aspects of the fumigation system and obviously knew what they were talking about and what to look for. This especially applied to Mr Jacinto Dominguez Luis, the head of the port inspectors, and to Mr Omar Amaro Rodriguez. They wanted to see that the fumigation ducts actually went to the bottom of each hold and that they were all connected correctly, and that the holds had been sealed effectively.
- During the detailed examination of the cargo on 28 March, widespread evidence of infestation was found with dead insects (all *Tribolium* spp.) in almost all the bags.
- Despite the fact that no ventilation was carried out during the voyage from Durban, there was no evidence of moisture damage.
- Samples were taken by the PQ inspectors for incubation. No evidence of live infestation was reported.
- Discharge commenced on 31 March and continued for 3 weeks. All cargo remaining on the vessel was inspected each day by the PQ inspectors.

#### Conclusions

- The concentrations of gas found to be present in Havana, although low, indicate that it is very likely that the total concentration time product (CTP) that had been achieved during the fumigation at the sample points had been well in excess of that needed to effect total eradication.
- During the 29-day fumigation the gas would have slowly leaked out, broken down, and been sorbed by the commodity. Because of the recirculation system being used, the low levels of gas remaining were found to be evenly distributed, and it is likely that any residues that remain from the phosphine gas in the product would have been very low.
- As the system could not be fully fitted as normal in Durban because the cargo was already loaded, did the gas reach all parts of the cargo? Because of the way the cargo was stowed with gaps between the bags at regular intervals, and the way the fumigation ducts were positioned in the lower holds, it was concluded that the gas would almost certainly have reached everywhere evenly. This was apparent because despite thorough and continuous checking

of the cargo throughout the 3-week discharge, including incubation of samples, no live insects were found.

- Ventilation in future could commence 10 days or so after application of fumigant. The recirculation system, correctly fitted, will result in high CTPs in 10 days in all parts of the cargo. These CTPs will result in the fully-efficient eradication of any infestation, and by commencing ventilation after a 10-day fumigation period, it will be likely to eliminate any possibility of condensation damage which could occur under certain weather conditions.

### Development of a passive system

In India, where no powered recirculation systems (e.g. Degesch J System) are available, a request was received from buyers to provide a fumigation system which had, as far as possible, similar benefits to the recirculation system, and could ensure good distribution and removal of all residues.

This led International Maritime Fumigation Organisation (IMFO) members Pest Control (M. Walshe) of Bombay, with assistance from Igrox Ltd of the United Kingdom, to develop a system specifically for this requirement (Figure 5). The system used was an adaptation of the passive system developed by Bob Davis of the United States Department of Agriculture in the 1980s.

Two fumigations took place in western India at the ports of Bedi and Navlakhhi. Both ports are anchorage ports. The vessels which loaded the wheat in bulk were both bulk carriers and tween deckers.

Aluminium phosphide in pre-packed sachets in chains of 50 and 10 was used for fumigation. Each sachet weighed 34 g. The rate of application was 3 g phosphine/t.

100 mm diameter reinforced polyvinyl chloride (PVC) pipes were purchased and drilled with holes of about 5 mm. The drilling was done as evenly as possible. Care was taken to ensure that the reinforcements were not damaged. The pipes chosen were rigid and reinforced so that they would not be crushed by either the wheat, or when they were passed through the manholes and laid in the lower holds. To assist adequate dispersion and penetration of gas in the tween decks, the perforated pipes were inserted into the grain cargo vertically. A cotton string was run end-to-end into the pipes laid in the lower holds. The concept was that the sachets would be lowered in from

the top and the string would pull the sachets into the pipes to their full depth.

As a further experiment, 1.13 and 0.45 kg (2.5 and 1.0 pound) weights were specially made to be used to pull the sachets deep into the pipes. Tests were run to see how deep the weights would go. The results showed that this was likely to work satisfactorily.

After completion of loading, when tests were carried out to determine whether it was possible to pull the strings laid through the pipes, this system proved unreliable. However, the alternative plan of using the weights was used successfully.

For treatment in the tween decks, sachet chains of 10 sachets were let down using the 0.45 kg weights into the pipes which were laid vertically in the grain. For the lower holds, sachet chains of 50 sachets were lowered using the 1.13 kg weights. Also, chains were secured by ropes so that they would be easily retrieved on arrival at the discharge port.

Fumigation was carried out as per International Maritime Organization procedures regarding safe working practices. The Masters of the vessels were given comprehensive sets of paperwork giving all details pertaining to the type of fumigant, safety recommendations, first aid, ventilation/discharge instructions, use of gas monitoring equipment etc., together with all required safety equipment and training of the crew in its use.

The vessels sailed for Turkey where they were met on arrival by IMFO agents. All residues were satisfactorily removed and tests throughout discharge showed no evidence of any live infestation anywhere in the cargo. The vessels used for these tests were:

- 'MV Oscar Jupiter', fumigated at Bedi on 9 January 1996 and discharged at Turkish Port on 24 January 1996; and
- 'MV Andreas V', fumigated at Navlakhi on 9 February 1996 and discharged at Turkish Port on 26 February 1996.

The conclusion reached by Pest Control (M. Walshe) and Igrox Ltd was that this method, although relatively labour intensive, can provide a satisfactory option (where the journey time is at least 10 days) for a thorough fumigation of bulk or bagged cargoes, when it is required that residues must be removed and where it is not possible to use a powered recirculation system.

## Development of the deep probe

The deep probing method was developed by Denis Bureau and his team at Adalia Ltd in Canada (Figure

6). The system consists of a platform and probe pipe with pneumatic or mechanical propulsion. There are two types of probe pipe. The first type is made of aluminium, is 0.62 mm in diameter and is used for very deep applications. It can be used to depths of 25 m or more. The second type of probe is made of plastic and is 100 mm in diameter and is specifically designed for recirculation and for passive application with dust-retaining materials. It can be used to depths of up to 20 m. Both types of probe have a patented head to maximise performance, and the probes are driven in using a vacuum system, or by mechanical force.

For very high volumes of over 20,000 tonnes, such as large silos and ships, the most efficient method is likely to involve the 100 mm probes connected to a recirculation system. Several 100 mm probes are inserted into the grain with the system, then they are connected to a recirculation system with hoses. The fumigant is placed on top of the grain.

The combined benefit of new fumigant production technologies—the Horne generator, the united phosphorus/CSIRO generator; Ecofume; and Frisin—and the deep-probing system, will be a major asset for food protection. The combined system will diffuse the fumigant through the grain very rapidly. The advantage the technology offers is that it can be used at any time, e.g. when an infestation is identified in a cargo during loading, the deep-probing method will enable these new phosphine production technologies to be used with excellent results. Development work continues so that it can be used elsewhere in the world.

## Comparative costs of methyl bromide fumigation and phosphine in-transit fumigations of shipments

Studies on shipments of rice and other grains from Spain to the United Kingdom (UK) were carried out by Roca Defisan of Spain and Igrox Limited of UK.

### *Methodology compared*

- (a) Methyl bromide fumigation of cargo in the ship on arrival in UK and prior to discharge, including ventilation to ensure safe levels throughout the cargo prior to discharge.
- (b) Phosphine fumigation in-transit by application of tablets/pellets into the cargo and ventilation prior to discharge carried out to ensure safe levels.
- (c) As (b), but with all the tablets/pellets in retrievable sachets/sleeves enabling residues to be removed prior to discharge.

- (d) As (c), but with the Degesch J Systems fitted to enable more rapid fumigation and ventilation.

The cost per hour of delays and cost of fumigation depends on the size of the vessel. The average size shipment in this study was 3,000 t, with average cost of port charges of US\$0.30 per gross registered tonne (GRT) per day, and demurrage of US\$3,000/day. The average cost of fumigation and ventilation was US\$2/t. The costs of delay times (Table 1) includes demurrage and port charges and are based on the average calculated for UK and Spanish ports. (Port charges vary in different parts of the world, e.g. in India the average cost is US\$0.15 GRT/day, but demurrage costs remain similar.) Costs per hour of delay times increase with the size of the vessel, but the number of hours required for fumigation and ventilation remain approximately the same regardless of vessel size. The cost of fumigation is much lower with larger cargoes. Therefore, the larger the vessel the more relevant it is to use a method which results in minimum overall delay time to minimise potential costs.

### Appraisal of Phosphine Application Methodology that can be Considered for Fumigating Rice in the Ship during Transit (In-transit Fumigation)

1. *Application of tablets or pellets to the grain surface (or into the top half metre) (Figure 1)*

High concentrations of gas build up in the head space, potentially resulting in a lot of leakage through the hatch covers unless they are very well sealed. Very little penetration down into the cargo. Powdery residues cannot be removed. Good kill of insects in the top part of cargo but negligible effect on eggs or juveniles, or even adults in the lower part of the cargo.

2. *Application of tablets or pellets by probing into the cargo a few metres (Figure 1)*

Less loss of gas through hatch covers than in method 1. Better penetration of gas than when applied on the surface only, but unlikely to be fully effective unless holds are relatively shallow and the voyage time is relatively long. Powdery residues cannot be removed.

3. *Application of tablets or pellets by deep probing into the full depth of the cargo*

This is difficult to achieve and currently practically impossible if the cargo is more than 10 m deep. Effective fumigation can be achieved provided the voyage time is relatively long to allow the gas to distribute. Powdery residues cannot be removed.

4. *Application of aluminium phosphide in blankets, sachets, or sleeves placed on the surface of the cargo (or into the top half metre) (Figure 1)*

All points the same as method 1, except that with this method powdery residues can be removed.

5. *Application of tablets or pellets by probing into the cargo a few metres in retrievable sleeves (Figure 1)*

All points as for method 2, except that with this method powdery residues can be removed.

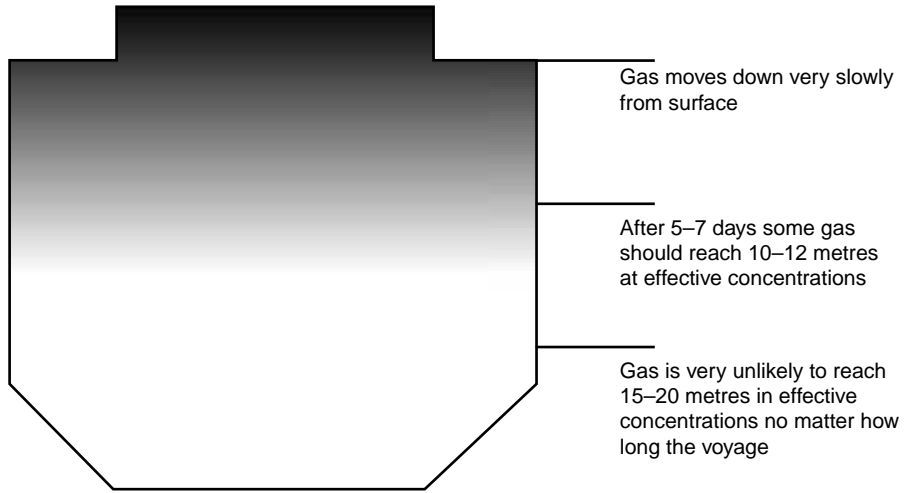
6. *Fitting of an enclosed, powered recirculation system to the hold and application of aluminium phosphide tablets or pellets to the surface (Figure 3)*

This method will ensure that the gas is distributed throughout the cargo evenly and rapidly, making maximum use of the fumigant in the shortest possible time. Powdery residues cannot be removed.

**Table 1.** The average delay times and costs of delay for the shipments from Spain to the United Kingdom (UK) (for details of fumigation methodologies a–d, see text).

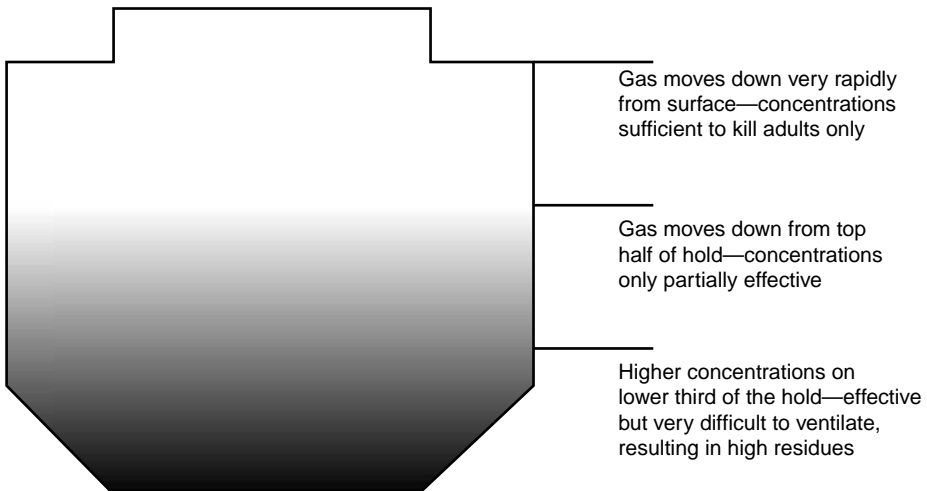
Methodology	Average delay in Spain	Average delay for fumigation in UK	Average delay for ventilation in UK	Total cost of delay
a	–	24 h	20 h	US\$6 380
b	2 h	–	30 h	US\$4 640
c	3 h	–	15 h	US\$2 560
d	4 h	–	6 h	US\$1 450

Phosphine applied on surface or probed a few metres into cargo



**Figure 1.** Traditional fumigation of cargo in a ship's hold using phosphine.

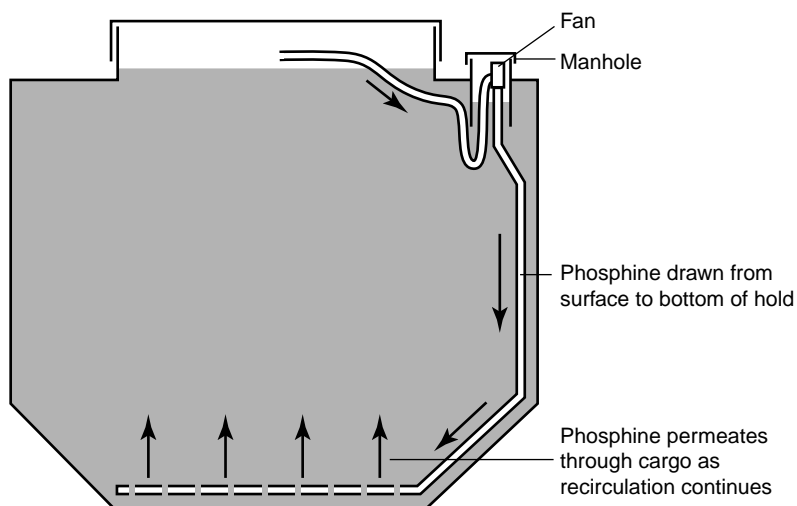
Methyl bromide applied on surface



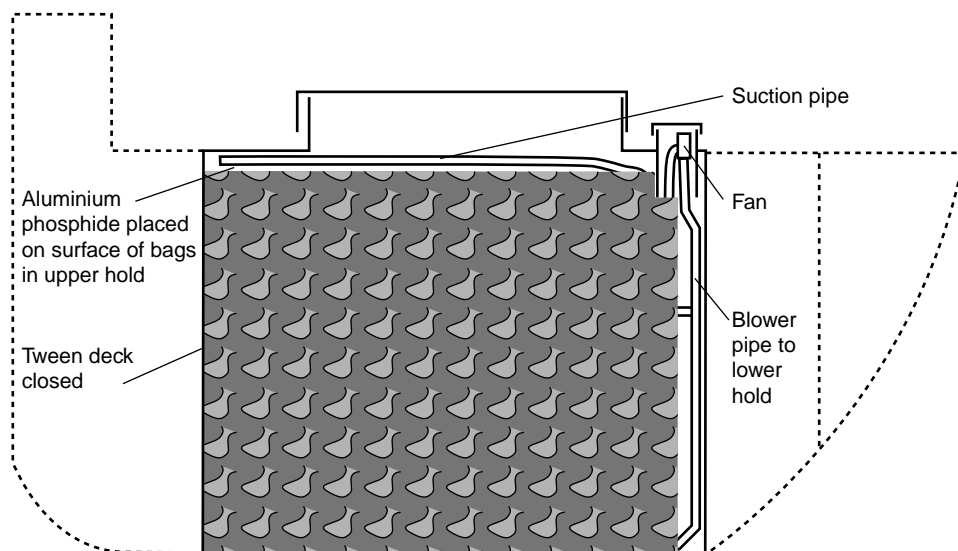
**Figure 2.** Traditional fumigation of cargo in a ship's hold using methyl bromide.



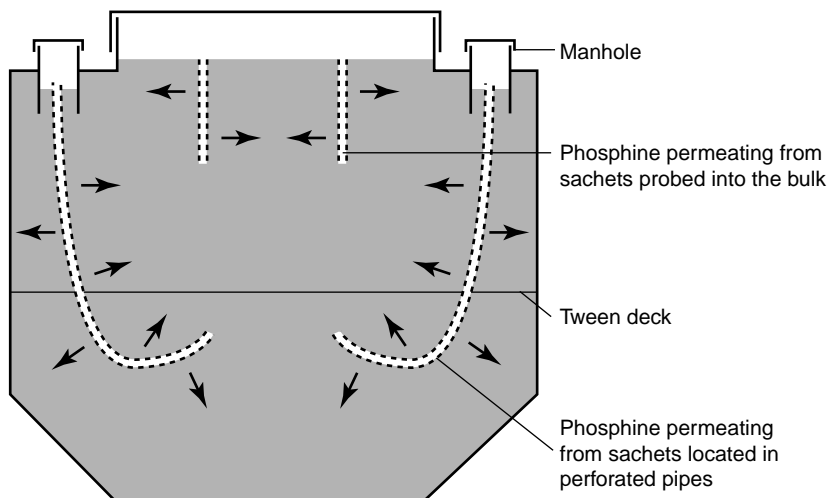
Phosphine applied on surface



**Figure 3.** Fumigation of cargo in a ship's hold using phosphine and the Degesch J System.



**Figure 4.** Installation of the Degesch J System into loaded, bagged cargo on the ship 'MV Asian Progress'.



**Figure 5.** Fumigation of cargo in the ship's hold in bulk carriers/tween deckers with phosphine using a passive system.

7. *Fitting of an enclosed, powered recirculation system to the hold and application of aluminium phosphide in blankets, sachets or sleeves on the surface or probed into the top 1–2 m (Figure 3)*

As for method 6, except that powdery residues can be removed. Also gaseous residues can be removed more easily than with other methods, as once the powdery residues have been removed, the recirculation system can be used to rapidly assist this process.

8. *Deep probing into the full depth of the cargo (however deep) with tablets or pellets (in retrievable sleeves when required). This is being developed in Canada but is not yet available (Figure 6). Also, deep probing using pre-inserted pipes (Figure 5)*

These methods enable good distribution of gas to be achieved without the requirement for a powered recirculation system, provided the voyage is long enough.

9. *Use of a powered recirculation system with phosphine from cylinders*

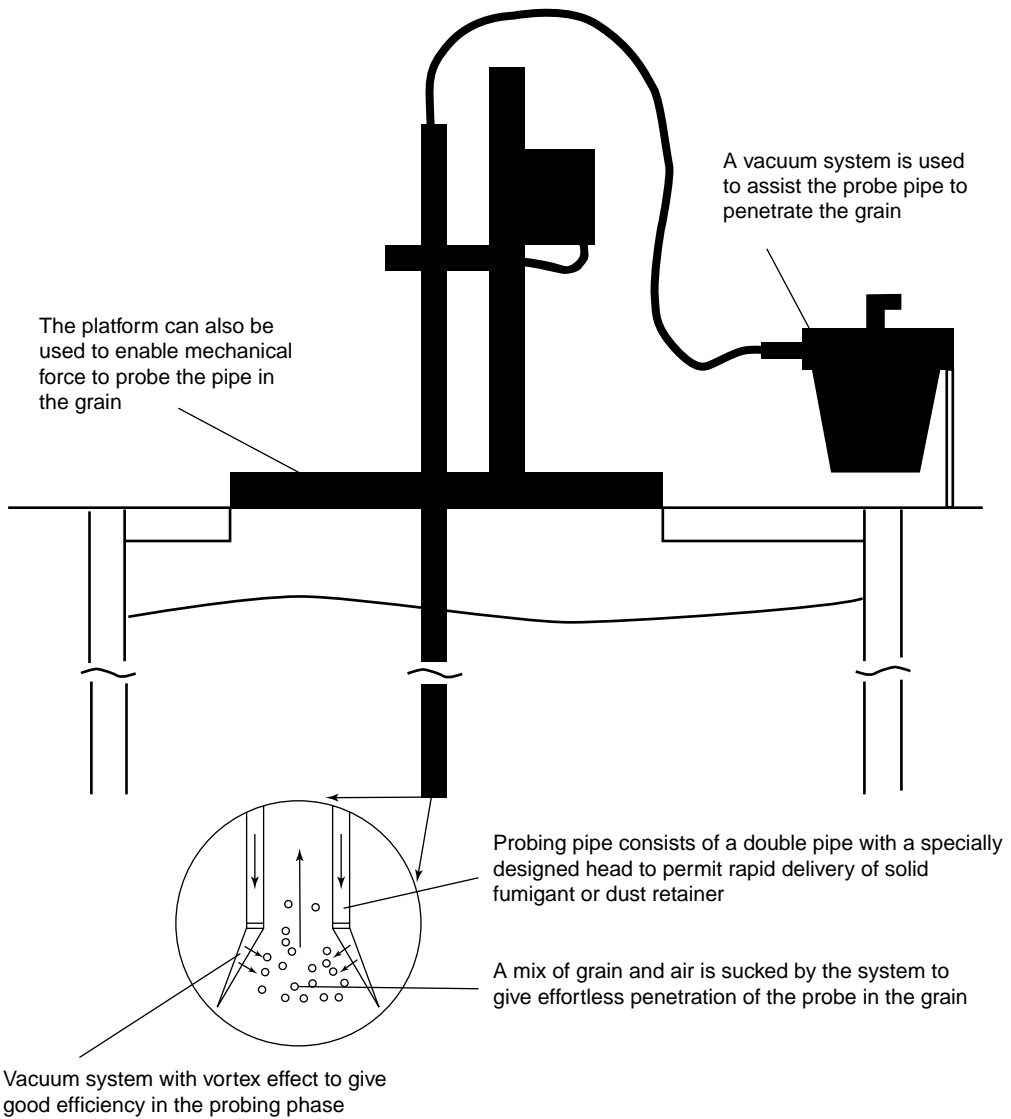
This is not yet available but could be in the future and would enable phosphine fumigation to be carried out without using aluminium phosphide. This would mean no powdery residues to deal with, and therefore

residue and safety problems at discharge ports would be minimised. A powered recirculation system would be needed to enable this system to work with maximum efficacy.

## Conclusions

Phosphine could both technically and economically replace the use of methyl bromide for the fumigation of both bulk and bagged rice and other cargoes. To satisfy the phytosanitary authorities of exporting countries, and the phytosanitary and quarantine authorities of importing countries, it is likely to be necessary to convince them of the efficacy of phosphine compared to methyl bromide.

The fact is that phosphine is just as efficient at killing insects as methyl bromide, provided the correct application methodology and time period are specified and adhered to. Comparatively, it is technically easier to reach an efficient kill with methyl bromide because the required time period is shorter. However, by making use of the time available during the journey it is relatively simple to guarantee a fully effective kill using phosphine provided the application methodology and the time period for fumigation are both specified.



**Figure 6.** Fumigation using the deep probing system.

The key to the more widespread use of phosphine in replacing methyl bromide is that the phytosanitary or quarantine authority or the purchaser of the cargo must specify in writing a precise specification requirement that can then be monitored to ensure it is adhered to.

## References

- Anon. 1996. Recommendations for the safe use of pesticides on ships. London, International Maritime Organization.
- DSV (Departamento De Sanidade Vegetal) 1996. Quarantine requirements relating to import/trasit of maize grain from countries where larger grain borer (*Prosterphanus truncatus*) is present. Maputo, Mozambique, DSV.
- Hole, B.D., Bell, C.H., Mills, K.A. and Goodship, G. 1976. The toxicity of phosphine to all developmental stages of thirteen species of stored product beetles. *Journal of Stored Products Research*, 12, 235–244.
- Watson, C.R., Pruthi, N., Bureau, D., Macdonald, C. and Roca, J. 1999. Intransit disinfection of bulk and bagged commodities: a new approach to safety and efficacy. In: Jin Zuxun, Liang Quan, Liang Yongsheng, Tan Xianchang and Guan Lianghua, ed., *Stored product protection. Proceedings of the 7<sup>th</sup> international working conference on stored-product protection, 14–19 October 1998, Beijing, P.R. China., volume 1.* Chengdu, Sichuan Province, Sichuan Publishing House of Science and Technology, 462–476.

# Ergosterol in Paddy as an Indicator of Quality

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## *Abstract*

Ergosterol is the predominant sterol component in fungi and can be used as an indicator of the extent of fungal infection in grain. One of the analytical methods available to extract ergosterol from grain is solid-phase extraction (SPE). SPE is a simpler and faster method than the conventional liquid extraction methods. Different analytical steps have been determined for the use of SPE in paddy samples. Storage studies in conjunction with different drying treatments have been conducted in which levels of ergosterol have been monitored. The results of these observations have been related to the ambient conditions during storage. An attempt has been made to use ergosterol determination by SPE for quality control purposes in stored paddy.

CEREAL CROPS, such as maize, rice and wheat, are among the major food crops for both humans and animals throughout the world. Due to the progress in production techniques, farmers are encouraged to grow high-yielding crop varieties in order to increase production as well as to achieve a marketable surplus (Boxall and Calverley 1985). In a number of countries, irrigation is used and then two or more crops of rice are grown per year (Kent and Evers 1994). As a result, grain producers and handlers are faced with a new problem, which is to dry a larger amount of grain at the same time. Failing to solve this problem may result in grain quality deterioration from insect pests, moulds and biochemical processes occurring within the grain itself (Boxall and Calverley 1985).

Rice, especially the wet season crop, is often harvested at very high moisture contents (MCs) which are well above those suitable for safe storage. Post-harvest treatments, such as sealed storage, chemical treatment, chilling and drying are available to ensure short- and long-term preservation of grains. In practice, drying of grain is the most widely used grain-preservation method (Brooker et al. 1992).

The aim of grain drying is to reduce the MC in the grain from 22–30% to 12–14% in order to prevent the crop from deteriorating during storage (Bakker-Arkema and Salleh 1985). Grains can be dried in

various ways, such as traditional sun-drying or mechanical drying (e.g. high temperature continuous or batch drying, near ambient air drying or a combination of both). For paddy, once the moisture is reduced below 18%, high temperature drying becomes inefficient and tends to cause fissuring. Consequently, a two-stage drying system has been developed in order to solve this problem. The basic principle is to use high temperatures for removing initial moisture down to 18% and to use low temperatures in the second stage of drying (Driscoll and Srzednicki 1995). The advantage of in-store drying is to maximise the drying capacity of the grain dryer at minimum consumption of energy, without affecting the quality of the rice. In order to determine the optimum air temperature and drying time for the second stage of drying, the quality of grain after drying should be investigated. As fungal invasion is one of major causes of grain deterioration, determination of the amount of fungal activity is one of the most important methods available for examining the quality of grain (Brooker et al. 1992).

Fungi can be detected in various ways, such as microbiological methods, reduction of seed germination, discoloration, and chitin content measurement. However, these methods are quite ineffective in determining the grain quality. Some of them require a long period of time in determining fungal biomass, while others require sophisticated laboratory equipment, e.g. for chitin content measurement (Nurjanah 1996).

Seitz et al. (1977) proposed the determination of ergosterol, which is the predominant sterol in most

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fungi, as an indicator of fungal invasion in grain. Ergosterol analysis offers the potential to measure live fungal biomass, because of its localisation in membranes and oxidation upon cell death. Moreover, this method appears to be capable of quantifying fungal biomass as well as growth rate. Thus, it allows a true appreciation of the dynamics of fungal growth in nature (Gessner and Schmitt 1996). The methodology that is widely used to detect ergosterol content in grain involves total lipid extraction and saponification, followed by unsaponifiable matter extraction using solvents and ergosterol assay (Seitz et al. 1977, 1979).

In general, liquid–liquid extraction has been used as an effective and reliable method to extract ergosterol from grain. However, this extraction requires large amounts of solvent and is time-consuming (Gessner and Schmitt 1996). Hence, alternative, effective methods of ergosterol extraction have been investigated.

In recent years, solid-phase extraction (SPE) has replaced liquid–liquid extraction in many applications because it reduces the time of sample preparation, and most highly toxic and inflammable solvents such as petroleum ether, which are commonly used in liquid–liquid extraction, can be avoided (Gessner and Schmitt 1996). The authors of the paper had worked on extraction of ergosterol by using an SPE technique. The research showed that SPE could produce satisfactory results in the isolation of ergosterol. Taking advantage of the SPE extraction technique, followed by high performance liquid chromatography (HPLC) analysis results in a simple, quick and accurate method for quantifying ergosterol which serves as an indicator of fungal invasion in grain (Gessner and Schmitt 1996; Wattananon 1997).

Given these considerations, the objective of this study was to optimise the operating parameters (temperature and time) of in-store drying on paddy rice and use the recently developed ergosterol determination techniques (Gessner and Schmitt 1996; Wattananon 1997; Mantais 1998) to assess paddy rice quality after drying.

## Materials and Methods

Two Australian paddy rice varieties were used, namely a medium-grain variety ‘Amaroo’ and long-grain variety ‘Langi’, supplied by the Rice Growers Cooperative at Leeton, New South Wales.

Ergosterol for standard solutions, supplied by Sigma (>90% purity) or Fluka (>98% purity), was stored in tightly capped bottles, covered with

aluminium foil and kept in the refrigerator. All solvents and reagents used were of either analytical or HPLC-grade. SPE maxi-clean cartridges (C18, 900 mg of sorbent, 3 mL column volume) were from Alltech Associates, Inc.

The HPLC system consisted of a Bio-Rad model 1330 pump, Waters U6K injector, and Waters 486 tunable absorbance detector, set at 282 nm, and was connected to a personal computer operating as the system controller. The column used was a Supelcosil LC-8 column (15 cm length × 4.6 mm diameter × 5 µm particle size) from Supelco.

A laboratory-scale fluidised bed dryer (Figure 1) and in-store dryer (Figure 2) were used in the experiments.

## Ergosterol assays

### *Lipid extraction and saponification*

According to the method of Gessner and Schmitt (1996), a 100–200 mg sample of ground paddy rice were refluxed in 25 mL of 0.14 M KOH in pure methanol for 30 min. The extract was allowed to cool down and then transferred to a 50 mL beaker. The extraction flask was rinsed with 5 mL of methanol and added to the beaker.

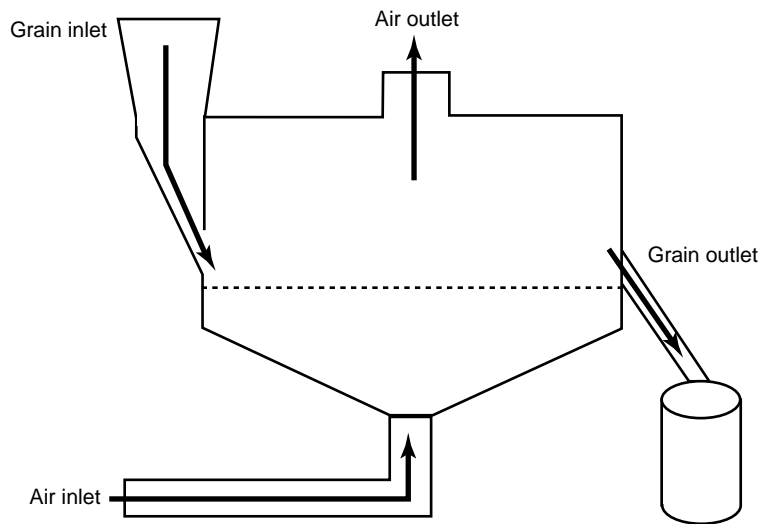
### *Acidification*

The pH of the total extract was adjusted to 4–6 by adding 0.75 M HCl (X mL), and then Y mL of distilled water to make up a total of 10 mL. For example, if 3 mL of 0.75 M HCl were used, 7 mL of distilled water were added.

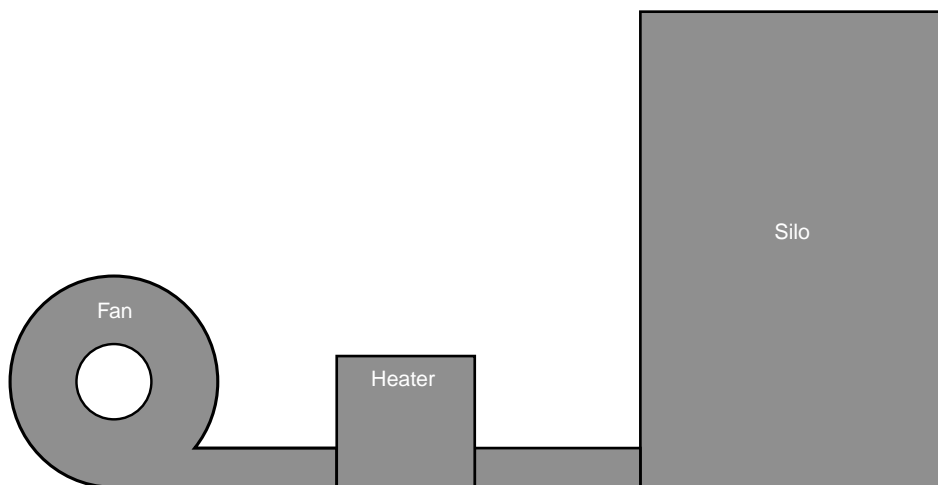
### *Solid-phase extraction (SPE)*

A SPE cartridge was fitted into a 20 mL syringe and held by the clamp holder. The cartridge was then conditioned with 7.5 mL methanol, followed by 7.5 mL of conditioning solvent (6 volumes of 0.12 M KOH dissolved in pure methanol plus 1 volume of 0.75 M HCl) at a flow rate of 2–5 mL/min.

The supernatant liquid of the extract was loaded into the cartridge at a flow rate of 1 mL/min. After loading, the cartridge was washed with 2.5 mL 0.4 M KOH in 60% methanol. Then, ergosterol was eluted with 5 mL 0.1 M KOH in pure isopropanol, into a small, brown bottle containing 0.3 mL 1 M KOH in pure methanol.



**Figure 1.** Schematic diagram of a laboratory-scale fluidised bed dryer.



**Figure 2.** Schematic diagram of a laboratory-scale in-store dryer.

### Quantitation by HPLC

The ergosterol eluate was analysed by HPLC. The system was run isocratically with mixture of isopropanol, acetonitrile and deionised water (45:30:25 by volume) at a flow rate of 1 mL/min. 25 µL of sample was injected and ergosterol was detected at 10–12 min. Ergosterol was quantified by measuring the peak area obtained from the chromatogram.

### Calculation

The ergosterol content was determined as shown in Equation 1:

$$\text{Ergosterol (g/g dry matter)} = (C \times V)/D \quad (1)$$

where:

C=Concentration of ergosterol reading from standard curve (mg/mL)

V=Volume of final separation of ergosterol (5 mL)

D=Dry matter of grain (g)

### Standard curve

A 1.25 mg/mL stock solution was prepared by accurately weighing 0.125 g of ergosterol using a four decimal place, digital analytical balance, and dissolving the ergosterol in 100 mL methanol. The stock solution was then diluted with methanol to obtain concentrations of 0.125, 0.1, 0.05, 0.025, 0.01, 0.005, 0.002 and 0.001 mg/mL. Each standard solution (except the 1.25 mg/mL stock solution) was injected into the HPLC apparatus six times in random order. A standard curve was constructed from the relationship between concentration of ergosterol and average peak area obtained from the chromatograms.

### Recovery of ergosterol after SPE in the absence of paddy sample

5 mL each of 0.125 mg/mL and 0.05 mg/mL standard solutions were subjected to lipid extraction, acidification, SPE and injected for HPLC four times in random order. A standard curve was constructed in the same way as for the pure standard.

### Recovery of ergosterol after SPE in the presence of paddy sample

The same method was used, but in the presence of a paddy sample (both long and medium grain with 14% MC).

## Grain drying

### Grain preparation

10 batches (11 kg per batch) of long-grain paddy rice ('Langi') were rewetted from 14% to 26% MC, closed tightly and stored in a cold room (5°C) for

several weeks (until the MC of all grain in the batch was uniform).

### Treatments

Two batches of wetted grain were dried in a fluidised bed dryer at 90°C with an airflow rate of 66 m<sup>3</sup>/min for 11 min to reduce the MC of the grain from 26% to 18%. This was followed by drying in an in-store dryer at ambient temperature with an airflow rate of 25.5 m<sup>3</sup>/min (treatment 1) or 51 m<sup>3</sup>/min (treatment 2) to reduce the MC of grain from 18% to 14%. Another three batches were dried directly in an in-store dryer at ambient temperature with an airflow rate of 25.5, 83, or 117 m<sup>3</sup>/min (treatments 3, 4, and 5) to reduce the MC of grain from 26% to 14% in the surface layer of grain. Each treatment was carried out in duplicate.

### Grain analysis

Grain samples were taken from three depths: 0 cm (surface), 12 cm (middle) and 24 cm (bottom) from the paddy rice surface. MC was determined using an infrared dryer (3 g of ground paddy rice, dried for 13 min). Ergosterol content determination was carried out by SPE and HPLC (see above).

## Results

### Standard curve

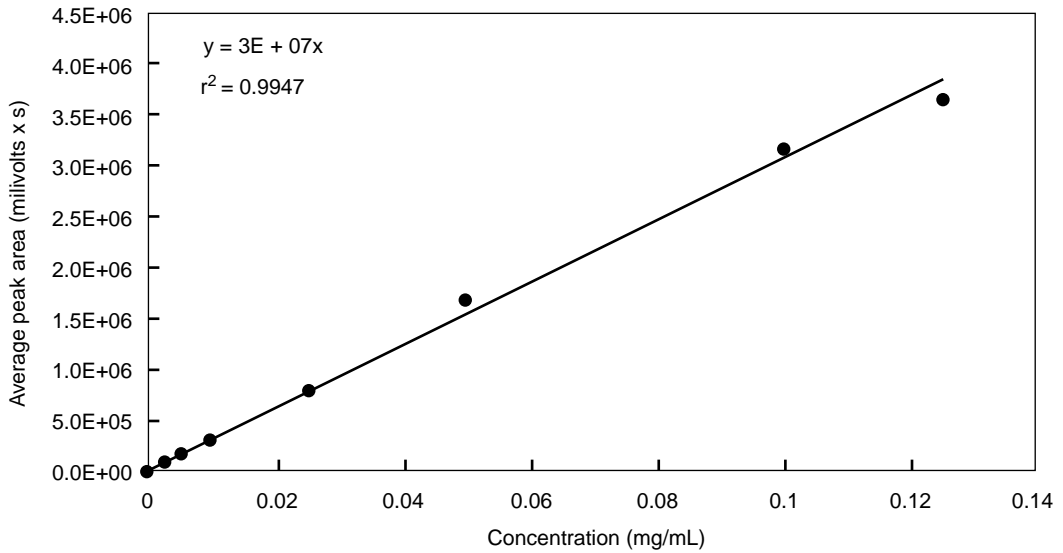
The standard curve was linear with a R<sup>2</sup> value of 0.9947 as shown in Figure 3.

### Recovery of ergosterol after SPE work up in the presence of paddy sample

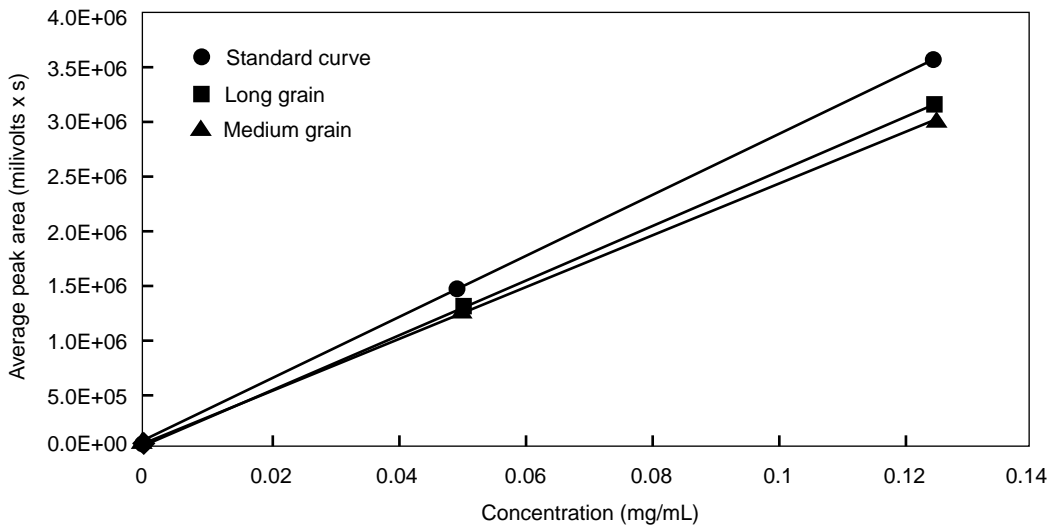
The recovery studies of ergosterol through the SPE procedures were carried out in long-grain and medium-grain paddy. However, only 0.125 mg/mL and 0.05 mg/mL stock solutions were used, which was enough to study the ergosterol recovery in the presence of paddy rice. The results obtained are shown in Figure 4.

The ergosterol recovery was reduced by 14% in the presence of both varieties of grains when compared with the standard curve. The recovery varied very slightly between the two grain types. Furthermore, the ergosterol recovery in the presence of both grains tended to decrease as the concentration of stock solution increased. The result obtained was quite similar to that found by Mantais (1998).





**Figure 3.** Standard curve of ergosterol (Sigma >90% purity) in methanol.



**Figure 4.** Comparison of ergosterol recovery in the presence of medium and long-grain paddy rice after solid-phase extraction (SPE) work up with standard curve.

### Recovery of ergosterol after SPE in the presence and absence of paddy sample

In order to assess the effects of paddy on the recovery of ergosterol the same procedure was carried out with both concentrations of stock solutions (0.125

mg/mL and 0.05 mg/mL), this time in the presence and absence of paddy rice. As the varieties of grains did not show any difference in ergosterol recovery, only long-grain paddy rice was selected for the recovery studies. Both ergosterol contents of stock solutions in the presence and in the absence of paddy rice after SPE

work up decreased slightly when compared with the standard curve. However, there was no significant difference in the ergosterol recovery of stock solution between the presence and the absence of paddy rice (see Figure 5). Hence, it could be concluded that the loss of ergosterol did not result from the presence of paddy rice. The loss of ergosterol might be due to the several steps of the extraction process used. For example, some of the ergosterol might be lost during saponification (thermal reaction), pH adjustment, transfer from one container to another etc.—all steps being possible sources of unavoidable errors.

In addition, as the initial ergosterol present in rice was very low, this then could not have affected any difference in ergosterol recovery from both treatments. As a result, it was not surprising to observe similar ergosterol recoveries in the presence or absence of paddy rice.

As in earlier experiments, the ergosterol recovery in both treatments tended to decrease as the concentration of stock solution increased. The ergosterol recovery was between 85% and 90% for 0.125 mg/mL and 0.05 mg/mL, respectively. Hence, it appears that the level of ergosterol recovery depends on the concentration of ergosterol present. Since the maximum level of ergosterol found in spoiled paddy rice in this experiment was around 60.5  $\mu\text{g/g}$  dry matter (equivalent to 0.002 mg/mL), about 90% of it could be recovered. As, in general, the levels of ergosterol in

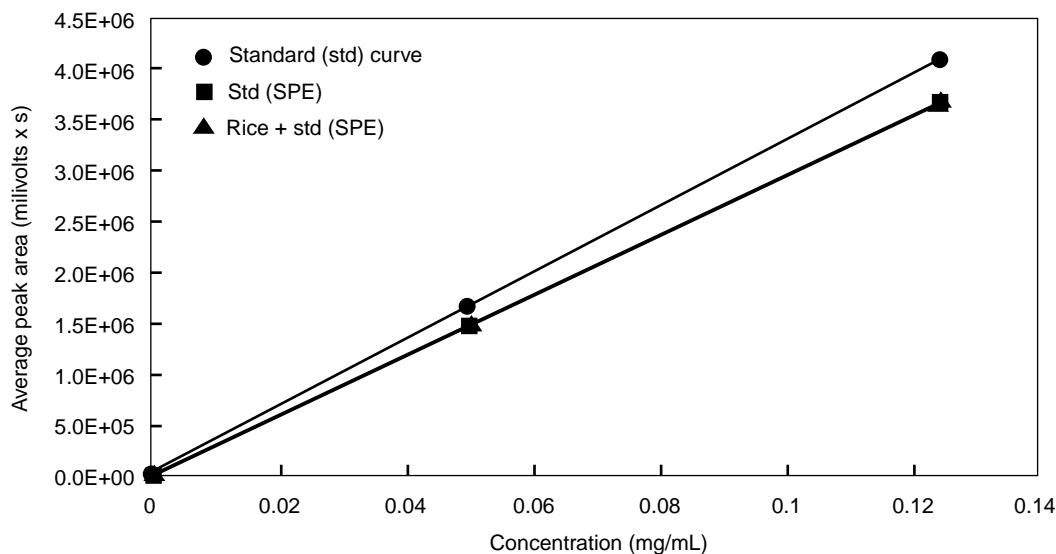
mouldy grain are in the range 8–15  $\mu\text{g/g}$  dry matter, we can assume that 90% of ergosterol can be determined (Schnurer and Jonsson 1992).

## Optimisation of grain drying

The optimisation of paddy drying was based on ergosterol content determination using the SPE technique. High moisture paddy rice (26%) was dried and analysed for moisture and ergosterol content as described earlier. The results obtained are shown in Figures 6–10.

In the drying experiments, the Fluka standard (>98% purity) was used to prepare the standard curve. The reason for doing so was that a higher purity standard was more likely to lead to more accurate results with regard to the ergosterol content in paddy.

In the first treatment, paddy was dried by using a fluidised bed dryer until the MC of paddy rice dropped from 26% to 18%. Then, paddy was dried slowly in an in-store dryer with a low airflow rate (25.5  $\text{m}^3/\text{m}^3/\text{min}$ ) until the MC at the surface was 14%. As can be seen in Figure 6A, the MC of paddy rice in all three layers was quite uniform. In addition, using a slow airflow rate resulted in high drying efficiency and low energy consumption. As air passed through each layer of grain slowly, this allowed more time for the air to pick up moisture from the paddy rice. The air leaving the surface of grain become nearly saturated. The



**Figure 5.** Comparison of ergosterol recovery in the presence and the absence of long-grain rice after solid-phase extraction (SPE) work up with standard curve.

ergosterol content from each layer was lower than that initially. Furthermore, the ergosterol content from the bottom layer was the lowest, while the surface was the highest. This was because air first flowed through the bottom layer, followed by middle and surface layers, respectively. The outlet air of the bottom layer became the inlet air of the middle layer and so on. This resulted in a time delay for the next layers to reach the same condition as the first layer. As a result, the bottom layer had dried first and thus showed the lowest ergosterol content. A similar result was obtained from the second sample subjected to this treatment (Figure 6B).

In the second treatment, the same procedure was carried out as in the first treatment, but this time with a doubled airflow rate ( $51 \text{ m}^3/\text{m}^3/\text{min}$ ) in the in-store dryer (see Figure 7). The MCs in each layer were less uniform than those in treatment 1. As the airflow rate was increased, grain was dried quicker, since the time that it was exposed to air had decreased. As a result, this led to a higher moisture gradient in the same bin. The ergosterol content from each layer was also lower than the initial ergosterol content. Furthermore, the ergosterol content in the bottom layer was the lowest while the ergosterol at the surface layer was the highest for the same reason as in treatment 1. The second batch (Figure 7B) showed very similar results.

In the third treatment, paddy rice was dried using only an in-store dryer with a low airflow rate ( $25.5 \text{ m}^3/\text{m}^3/\text{min}$ ). The MC from each layer of dried paddy rice was quite uniform (Figure 8A), which was similar to the results obtained in treatment 1. However, the ergosterol content from each layer of dried paddy rice was higher than the initial ergosterol content. This was because paddy rice was dried from the high MC (26%) to 14% with ambient air temperature at a slow airflow rate, which had taken a considerable time (nearly 2 weeks). Consequently, there was a possibility that fungi could germinate during the initial period of drying, resulting in a higher ergosterol content in the dried paddy. The same result was obtained in the duplicate batch (Figure 8B).

The fourth treatment was carried out in the same way as in treatment 3, but with a doubled air flow rate ( $83 \text{ m}^3/\text{m}^3/\text{min}$ ) and reduced depth. The results obtained from this treatment are shown in Figure 9. The MC from each layer of dried paddy was quite uniform which was quite different from the results obtained in treatment 2 with the same air speed. This could be attributed to the fact that the depth of grain in this treatment was reduced. Similarly, the ergosterol content in each layer of dried paddy was higher as

compared with the initial ergosterol content. Both batches showed similar results.

The fifth treatment was carried out in the same way as treatment 3, but with a very high air flow rate ( $117 \text{ m}^3/\text{m}^3/\text{min}$ ). A high moisture gradient was observed in spite of the reduction in the depth of grain (Figure 10). Similarly, the ergosterol content in each layer of dried paddy was increased as compared to the initial ergosterol content. However, the increase of ergosterol content in absolute terms was lower than in treatments 3 and 4. This was because using a higher airflow rate resulted in faster drying. Hence, the probability that fungi germinated during the initial period of paddy rice drying was decreased with a higher airflow rate. The duplicate batch showed similar results.

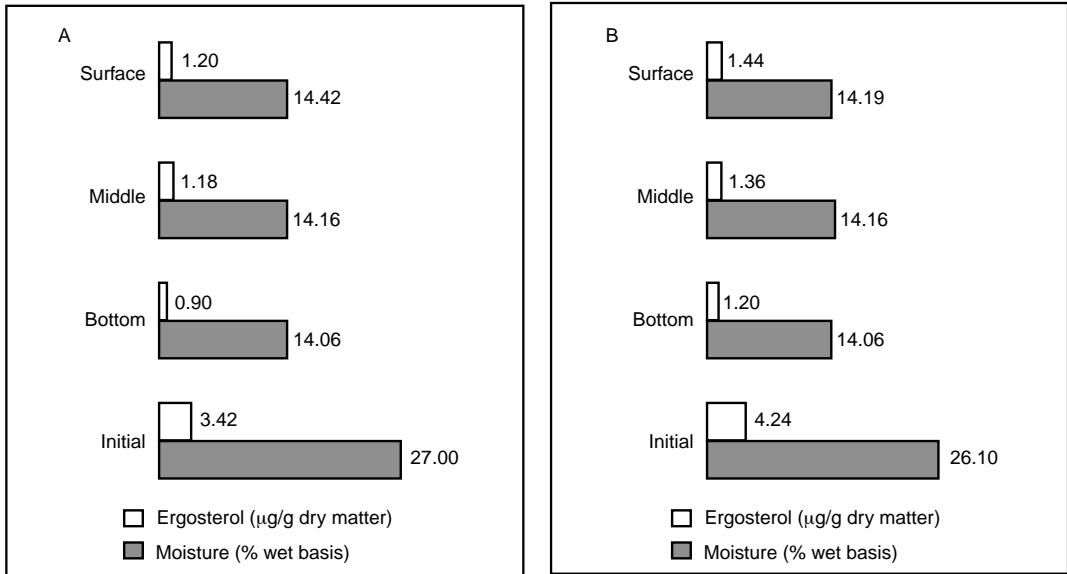
Considering the change in ergosterol content in each treatment (Figure 11), it was found that a two-stage drying system, which was used in treatments 1 and 2, tended to decrease the ergosterol content in dried paddy rice around 60% and 30%, respectively. In contrast, using only an in-store dryer was not an effective way to dry paddy with respect to the drying time, especially for low airflow rates, or the preservation of quality. It can be seen in Figure 11 that the ergosterol content of paddy rice dried with in-store dryer alone increased around 20–30% when compared to the initial ergosterol content.

As a result, the SPE method was accepted on account of its simplicity, high ergosterol recovery (>85%), high consistency and reliability in determining ergosterol in paddy.

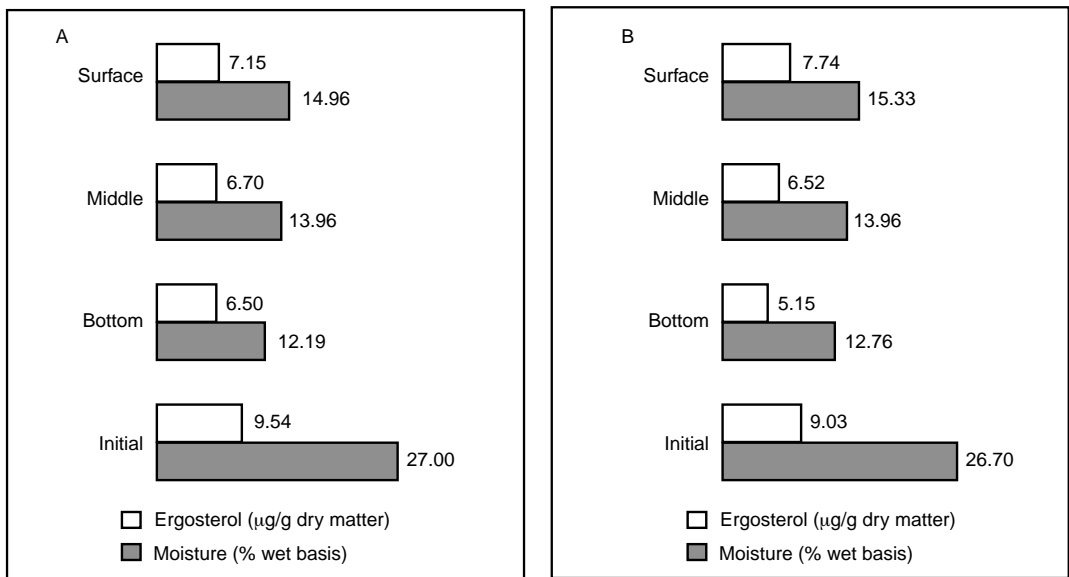
However, it remains unclear which mechanism is involved in the reduction of ergosterol content when using a fluidised bed dryer. As high temperature was used in fluidised bed drying, the reduction of ergosterol might have resulted from a thermal breakdown. This issue is currently being explored, including chemical analysis of products of decomposition of ergosterol following exposure of paddy to high temperature. This appears to be a necessary step before recommendations can be issued with regard to the use of ergosterol as a quality indicator on a commercial scale.

## Conclusions

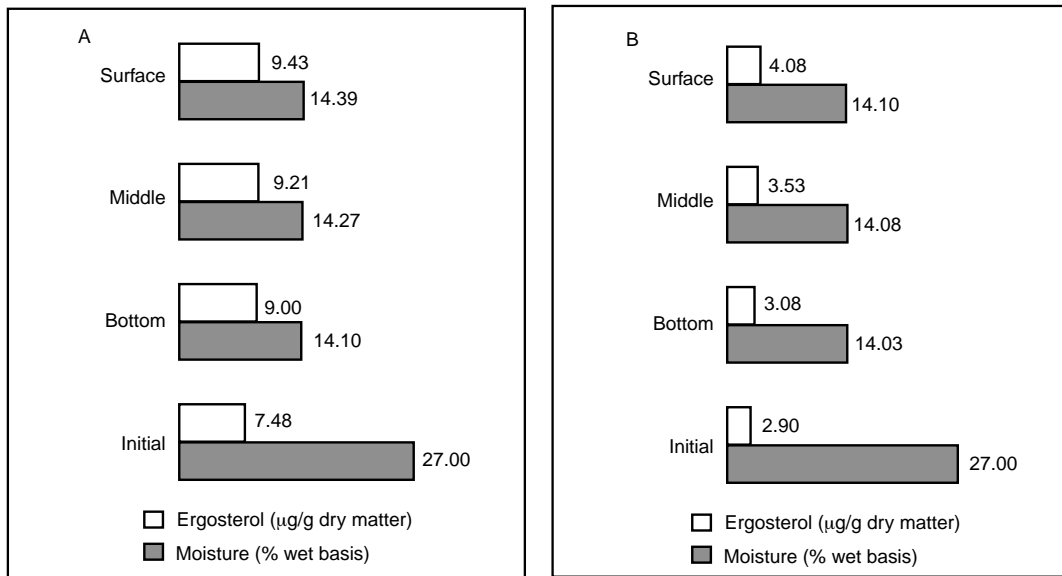
The present study has shown that the SPE method was acceptable on the grounds of its simplicity, high ergosterol recovery (>85%), high consistency and reliability in determining ergosterol in paddy. It appears that the efficiency of ergosterol recovery depends on the concentration of ergosterol present. The recovery of



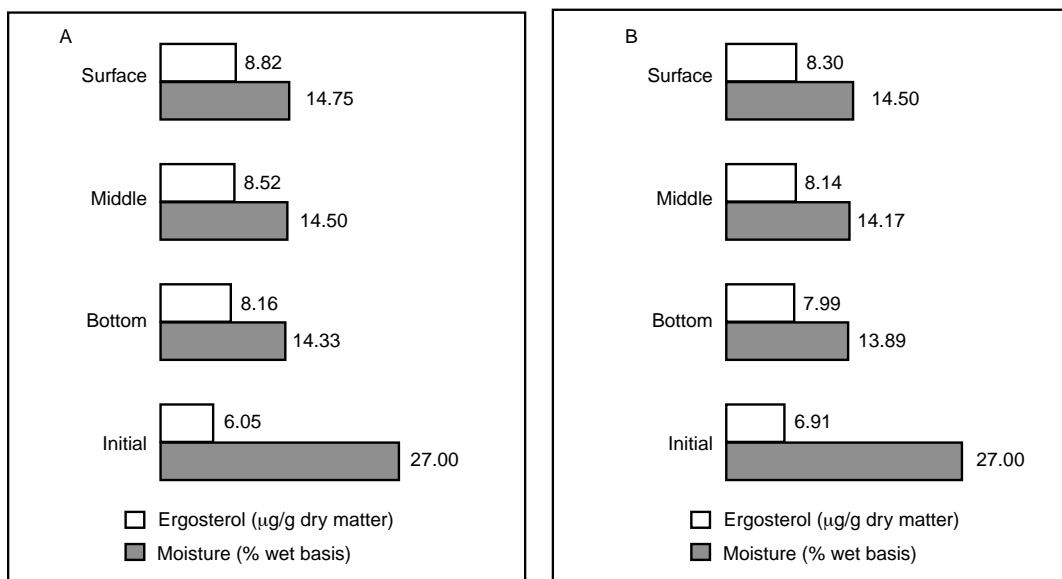
**Figure 6.** Moisture and ergosterol content of dried paddy rice. Treatment 1: fluidised bed drying + in-store drying (airflow rate 25.5 m<sup>3</sup>/m<sup>3</sup>/min). (A) and (B) are replicates.



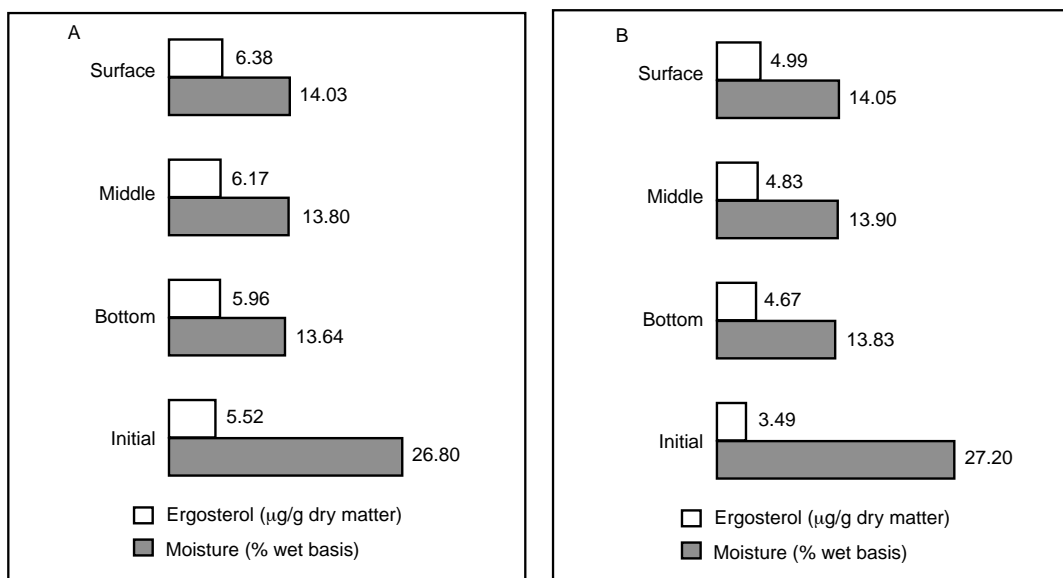
**Figure 7.** Moisture and ergosterol content of dried paddy rice. Treatment 2: fluidised bed drying + in-store drying (airflow rate 51 m<sup>3</sup>/m<sup>3</sup>/min). (A) and (B) are replicates.



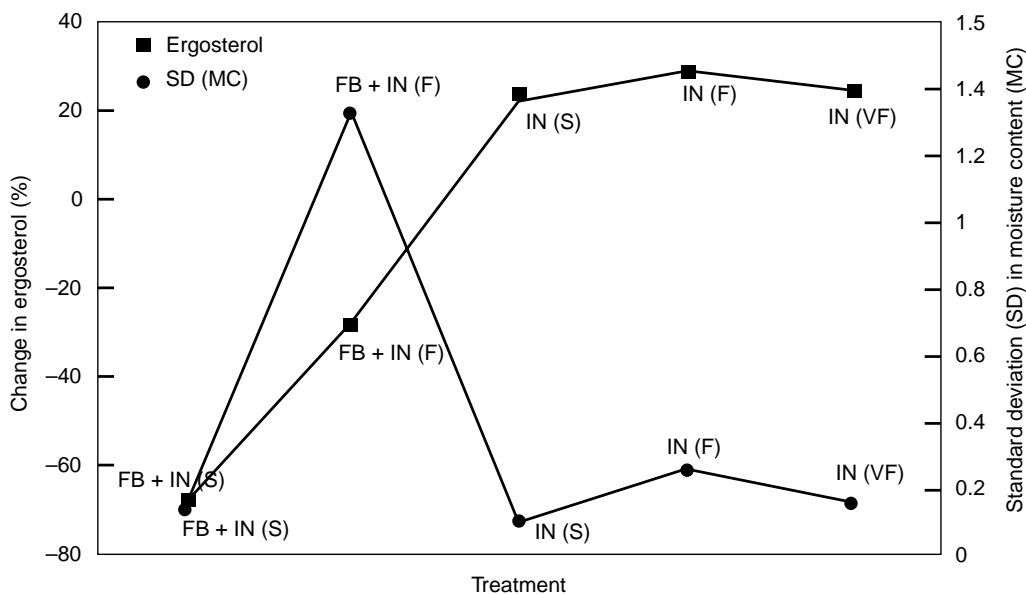
**Figure 8.** Moisture and ergosterol content of dried paddy rice. Treatment 3: in-store drying (airflow rate 25.5 m<sup>3</sup>/m<sup>3</sup>/min). (A) and (B) are replicates.



**Figure 9.** Moisture and ergosterol content of dried paddy rice. Treatment 4: in-store drying (airflow rate 83 m<sup>3</sup>/m<sup>3</sup>/min). (A) and (B) are replicates.



**Figure 10.** Moisture and ergosterol content of dried paddy rice. Treatment 5: in-store drying (airflow rate 117 m<sup>3</sup>/m<sup>3</sup>/min). (A) and (B) are replicates.



**Figure 11.** Comparison between treatments with regard to moisture contents and ergosterol changes, where: FB = fluidised bed drying; IN = in-store drying; S = slow airflow rate; F = fast airflow rate; and VF = very fast airflow rate.

ergosterol is inversely proportional to its concentration in the grain. As the maximum level of ergosterol found in spoiled paddy rice in the recovery experiment was around 60.5 µg/g dry matter (equivalent to 0.002 mg/mL) the ergosterol recovery was still above 90%.

By using ergosterol techniques as quality assessment, it was found that a two-stage drying system (fluidised bed drying + in-store drying with slow airflow rate) was the best drying method for paddy. This drying strategy resulted in a uniform MC of paddy at all depths of the grain bed. Furthermore, it contributed to the preservation of the quality of paddy by lowering the ergosterol content.

However, the effects of fluidised bed drying on the reduction of ergosterol content still remain to be explained. Since high temperature was used in fluidised bed dryer, the reduction of ergosterol might have resulted from thermal breakdown. Further studies are being conducted on the ergosterol content in paddy after drying at high temperature in the fluidised bed dryer and on the products of decomposition resulting from this treatment. The conclusions of the remaining investigations should lead to recommendations on the use of ergosterol as a quality indicator for paddy on a commercial scale.

## Acknowledgment

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## References

- Bakker-Arkema, F.W. and Salleh, H.M. 1985. In-store drying of grain: the state of the art. In: Highley, E. and Champ B.R., ed., *Preserving grain quality by aeration and in-store drying*. Proceedings of an international seminar held at Kuala Lumpur, Malaysia, 9–11 October 1985. ACIAR Proceedings, No. 15. Canberra, Australian Centre for International Agricultural Research, 24–30.
- Boxall, R.A. and Calverley, D.J.B. 1985. Grain quality considerations in relation to aeration and in-store drying. In: Highley, E. and Champ B.R., ed., *Preserving grain quality by aeration and in-store drying*. Proceedings of an international seminar held at Kuala Lumpur, Malaysia, 9–11 October 1985. ACIAR Proceedings, No. 15. Canberra, Australian Centre for International Agricultural Research, 17–23.
- Brooker D.B., Bakker-Arkema, F.W. and Hall, C.W. 1992. *Drying and storage of grains and oilseeds*. New York, The AVI Publishing Company.
- Driscoll, R. and Szrednicki, G. 1995. In-bin grain drying systems. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Grain drying in Asia*. Proceedings of an international conference held at the FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, 17–20 October 1995. ACIAR Proceedings, No. 71. Canberra, Australian Centre for International Agricultural Research, 210–214.
- Gessner, M.O. and Schmitt, A.L. 1996. Use of solid phase extraction to determine ergosterol concentrations in plant tissue colonised by fungi. *Applied and Environmental Microbiology*, 62, 415–419.
- Kent, N.L. and Evers, A.D. 1994. *Technology of cereals*. New York, Pergamon Press.
- Mantais, R.G. 1998. Determination of ergosterol as paddy rice quality indicator using solid phase extraction. Unpublished BSc thesis, University of New South Wales, Australia.
- Nurjanah, S. 1996. Determination of ergosterol as an indicator of fungal growth in paddy rice.
- Schnurer, J. and Jonsson, A. 1992. Ergosterol levels and mould colony forming units in Swedish grains of food and feed grade. *Plant Science*, 42, 240–245.
- Seitz, L.M., Mohr, H.E., Burroughs, R. and Sauer, D.B. 1977. Ergosterol as an indicator of fungal invasion in grains. *Cereal Chemistry*, 54, 1207–1217.
- Seitz, L.M., Sauer, D.B., Burroughs, R., Mohr, H.E. and Hubbard, J.D. 1979. Ergosterol as a measure of fungal growth. *Phytopathology*, 69, 1201–1203.
- Wattananon, S. 1997. Development of a simplified analytical method for ergosterol determination in paddy rice. Unpublished MAppSc thesis, University of New South Wales, Australia.

# Milling, Pasting, and Texture Changes in Rice as Affected by Aging

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## Abstract

This study was conducted to verify the effect of aging on rice grain quality, and to determine the minimum period wherein rice properties become stable. Four varieties (PSBRc10, PSBRc14, IR64, and IR74) of freshly harvested rice differing in amylose content and gelatinisation temperature, and stored at room temperature for 90 days, were assessed every 15 days for their milling quality, pasting characteristics, and texture properties. As the storage period increased, a decreasing trend in total milled rice recovery was observed for all the rice varieties. Percentage brown rice of PSBRc10 and head rice recovery of IR64, however, were not affected by storage. Aging of the four varieties also resulted in changes in their characteristics. Peak and cooked paste viscosity and breakdown values increased with prolonged storage. Changes in cooked rice hardness occurred within 15 days of storage, but the texture of aged IR64 remained unaffected up to the end of the 90-day storage period. A minimum of 60 days of storage was required for stabilisation of the grain characteristics.

THE quality of rice is one of the major considerations in the breeding program of the Philippine Rice Research Institute (PhilRice). As such, promising selections entered under the National Rice Cooperative Testing Project are constantly being evaluated for rice grain quality.

In the evaluation of grain quality, significant differences in the milling potential of rice have been observed from season to season. Since samples are aged for different periods prior to evaluation, discrepancies have been attributed to these differences in length of storage. Rice samples are also aged for at least three months prior to the conduct of sensory evaluation. This lengthy storage period often causes delays in the processing and evaluation of rice grain quality data.

Some physico-chemical properties of rice which have been reported to be affected by storage include swelling fragility, shape of the rice grain, and the volume of cooked rice (Chrastil 1990). Cooking and processing qualities of freshly harvested rice have also been shown to differ from those of stored or aged rice

(Normand et al. 1964). Changes in texture and pasting characteristics of rice during storage have likewise been reported (Perez and Juliano 1981). Hence, this study was conducted to verify the effect of storage on the milling potential, pasting, and texture properties of rice. It also aimed to determine the critical period in which changes occur and the optimum period wherein grain quality stabilises.

## Materials and Methods

### Sample preparation

Four varieties (PSBRc10, PSBRc14, IR64, and IR74) of freshly harvested rice differing in amylose content and gelatinisation temperature were used. Samples of each variety were procured from the Seed Production and Health Division of the Philippine Rice Research Institute after harvest. The samples were immediately dried to a moisture content of approximately 12%, cleaned, placed in paper bags, and stored at room temperature. Samples were withdrawn at 15-day intervals starting from the beginning of the trial up to 90 days of storage, and analysed for moisture content, milling potential, gelatinisation properties, and cooked rice texture.

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## Milling potential

The milling quality of rice was evaluated by determining percentage brown rice, total milled rice and head rice recoveries. The percentage of brown rice was measured by dehulling a 125 g sample of rough rice using the SATAKE dehuller. The brown rice was whitened using the McGill #2 polisher to obtain total milled rice. The head rice recovery was then measured by separating the whole grains and broken grains from milled rice using a SATAKE rice grader. Percentage brown rice and total milled rice were based on the weight of rough rice (125 g). Head rice recovery was based on the weight of total milled rice.

## Gelatinisation properties

The pasting characteristics of the rice varieties were measured using the Rapid Visco Analyzer (RVA) (Newport Scientific Model 3CR). The test was conducted using the standard AACC Method 61–02 of the American Association of Cereal Chemists.

A 3.0 g sample of rice flour was weighed and placed in the RVA canister. 25 mL of distilled water was added and the RVA paddle was inserted into the canister. The whole assembly was then lowered into the instrument for measurements. The test proceeded and terminated automatically. The peak, minimum and final viscosity at 50°C was recorded. Viscosity was measured in rapid visco units (RVU). Breakdown values (peak–minimum) are indicative of the fragility of the starch granules and are good indices of the susceptibility of starch to disintegration (Juliano 1985). Setback viscosity (final–minimum), on the other hand, is a measure of the degree of retrogradation or hardening of starch upon cooling.

## Cooked rice texture

Milled rice samples from the different rice varieties were cleaned with cheese cloth to remove adhering bran. A 5 g sample was weighed and placed in an aluminum canister. 8 mL of distilled water was added to obtain a rice to water ratio of 1:1.6. The rice–water mixture was allowed to stand for 30 min. The canister containing the sample was placed inside a rice cooker containing 75 mL of distilled water. The sample was cooked and kept inside the rice cooker for an additional 15 min after the rice cooker automatically shut off. The cooked sample was removed from the rice cooker and allowed to cool for 1 hour. Texture measurements were then immediately taken using a

tensipresser (My Boy System Analyzer and Controller, Japan).

Duplicate samples of cooked rice were evaluated and the texture profiles of 10 single grains were taken. An average of 10 measurements was reported.

## Results and Discussion

### Storage changes

#### *Milling quality*

The effects of storage on the milling quality of four different rice varieties differing in amylose content and gelatinisation temperature are shown in Tables 1 and 2. Storage of up to 75 days did not cause any significant changes to percentage brown rice of IR64 harvested during the wet and dry seasons. A slight decrease, however, was observed at the end of the 90-day storage period. Percentage brown rice of the wet-season harvest of IR74 and PSBRc14 was not affected by the length of storage, but the dry-season harvest of the same varieties decreased upon storage. Percentage brown rice of PSBRc10 for both the wet and the dry season decreased as the storage period increased.

A decreasing trend in total milled rice recovery with increasing storage period was observed for all the rice varieties when planted during the dry season (Table 2). IR64 and PSBRc10 also exhibited the same trend when planted during the wet season. Total milled rice of IR74 and PSBRc14 remained unaffected throughout the 90-day storage period during the wet season.

The percentage head rice recovery of IR64 was stable across the seasons. Head rice recovery of IR74 harvested during the wet and dry seasons, however, decreased as the storage period increased. The opposite trend was noted for PSBRc10. PSBRc14 showed an increase in head rice recovery as the storage period increased during the wet season. Dry-season harvest of the same variety was also noted to have lower head rice recovery when aged.

#### *Pasting characteristics*

Significant changes in the viscosity of the four different rice varieties were observed upon storage of freshly harvested rice, as shown in Tables 3 and 4. An increase in peak viscosity of high amylose rice varieties (IR74 and PSBRc10) sampled during the wet season was observed after 90 days of storage. Wet-season harvest of rice varieties with intermediate amylose content (PSBRc14 and IR64) likewise showed an increase in peak viscosity during storage.

**Table 1.** Effect of storage period on the milling potential of different rice varieties harvested during the 1997 wet season (BR = brown rice, MR = total milled rice recovery, HR = head rice recovery, MC = moisture content).

Variety/Milling potential	Storage period (days)						
	0	15	30	45	60	75	90
IR64	0	15	30	45	60	75	90
BR (%)	80.01 a	79.76 ab	79.92 a	79.88 a	79.89 a	79.80 a	79.59 b
MR (%)	71.44 ab	70.91 bc	70.94 bc	70.92 bc	71.61 a	71.49 a	70.50 c
HR (%)	74.21 ab	72.60 b	74.89 a	73.51 ab	74.27 ab	74.26 ab	74.82 a
MC (%)	10.67 c	10.83 b	10.79 b	11.30 a	10.06 d	9.99 d	9.84 e
IR74	0	15	30	45	60	75	90
BR (%)	78.50 a	78.55 a	78.81 a	78.71 a	78.58 a	77.89 a	78.56 a
MR (%)	63.31 a	63.59 a	63.52 a	64.00 a	62.46 b	61.92 b	63.38 a
HR (%)	21.57 bc	21.31 bc	24.83 a	19.96 cd	26.38 a	23.81 b	17.51 d
MC (%)	11.09 b	11.68 a	10.43 c	10.43 c	10.10 d	10.29 c	11.10 b
IR64	0	15	30	45	60	75	90
BR (%)	80.04 a	79.93 a	79.86 ab	80.04 a	80.13 a	79.57 b	78.88 c
MR (%)	70.89 a	70.64 a	71.34 a	71.32 a	71.08 a	71.10 a	69.89 b
HR (%)	63.05 b	61.17 c	63.91 ab	65.60 a	63.07 b	65.23 b	65.09 b
MC (%)	10.92 c	10.93 c	11.57 a	11.31 b	10.15 d	10.07 e	9.99 e
IR64	0	15	30	45	60	75	90
BR (%)	79.20 b	79.09 b	79.08 b	79.28 b	79.39 ab	79.68 a	79.17 b
MR (%)	70.36 b	69.92 b	70.33 b	70.32 b	70.67 b	71.59 a	70.14 b
HR (%)	75.95 bc	75.35 c	77.24 ab	77.11 ab	77.72 a	76.08 bc	78.04 a
MC (%)	10.32 d	10.57 c	11.21 a	11.00 b	9.78 ef	9.66 f	9.87 e

Note: in a row, means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test (DMRT).

**Table 2.** Effect of storage period on the milling potential of different rice varieties harvested during the 1998 dry season (BR = brown rice, MR = total milled rice recovery, HR = head rice recovery, MC = moisture content).

Variety/Milling potential	Storage period (days)						
	0	15	30	45	60	75	90
IR64	0	15	30	45	60	75	90
BR (%)	77.97 a	78.02 a	77.86 ab	78.01 a	77.77 ab	77.95 ab	77.22 b
MR (%)	68.56 ab	68.69 ab	69.12 a	68.77 b	68.09 bc	67.82 bc	67.35 c
HR (%)	57.19 a	57.78 a	58.82 a	58.33 a	57.78 a	59.25 a	57.43 a
MC (%)	10.65 b	10.12 e	10.30 d	10.94 a	10.95 a	9.92 f	10.49 c

**Table 2.** (Cont'd) Effect of storage period on the milling potential of different rice varieties harvested during the 1998 dry season (BR = brown rice, MR = total milled rice recovery, HR = head rice recovery, MC = moisture content).

Variety/Milling potential	Storage period (days)						
	0	15	30	45	60	75	90
IR74							
BR (%)	79.29 a	78.66 bc	78.42 c	78.92 b	78.50 a	78.71 bc	78.10 d
MR (%)	69.79 a	69.96 a	69.74 a	69.61 a	69.23 ab	69.59 a	68.40 b
HR (%)	65.53 b	64.76 b	67.03 a	64.45 b	65.05 b	62.76 c	61.19 d
MC (%)	11.32 b	10.57 d	10.01 e	11.32 b	11.71 a	10.65 d	11.08 c
PSBRc10							
BR (%)	77.84 ab	78.08 a	77.86 ab	78.00 ab	77.75 ab	76.76 bc	76.33 c
MR (%)	64.90 bc	65.73 ab	66.35 a	65.16 bc	64.84 bc	64.11 dc	63.52 d
HR (%)	43.00 c	48.15 a	45.88 b	44.77 bc	47.59 c	44.25 bc	46.20 b
MC (%)	11.38 b	10.47 d	10.33 d	11.59 ab	11.72 a	10.48 d	10.96 d
PSBRc14							
BR (%)	79.56 a	79.50 a	79.24 b	79.63 a	79.17 b	79.08 b	78.70 c
MR (%)	71.01 ab	71.61 a	71.35 ab	71.38 ab	70.85 b	70.17 c	69.86 c
HR (%)	85.06 bc	86.64 a	86.29 ab	85.61 ab	84.18 c	80.43 d	78.09 e
MC (%)	11.01 b	10.11 c	10.23 c	11.36 a	11.34 a	10.28 c	11.07 b

Note: in a row, means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test (DMRT).

**Table 3.** Effect of storage on the pasting characteristics of different rice varieties harvested during the 1997 wet season. All viscosity measurements are expressed in rapid visco units (RVU).

Variety/ Pasting characteristics	Storage period (days)						
	0	15	30	45	60	75	90
IR64							
Peak viscosity	214.67 e	222.67 d	235.67 c	238.33 c	262.67 a	261.33 a	250.67 b
Setback	9.67 a	10.00 a	2.33 ab	3.00 ab	-4.33 bc	-6.33 c	-0.33 bc
Breakdown	90.00 c	89.67 c	100.67 b	102.00 b	114.00 a	117.68 a	114.00 a
Consistency	99.67 d	99.67 d	103.00 c	105.00 c	109.67 b	111.33 ab	113.00 a
Moisture content (%)	9.21 e	10.86 a	10.17 b	9.53 d	10.72 a	9.84 c	10.90 a
IR74							
Peak viscosity	266.00 dc	263.00 d	301.00 a	294.67 ab	275.33 c	290.00 b	292.33 ab
Setback	134.67 d	130.67 d	139.67 dc	152.00 ab	158.00 a	146.00 bc	149.33abc
Breakdown	34.00 bc	31.00 c	39.67 a	37.67 ab	31.33 c	34.00 bc	34.67 bc
Consistency	168.67 bc	165.67 c	179.33 ab	189.67 a	189.33 a	180.00 ab	184.00 a
Moisture content (%)	10.80 b	9.97 d	11.06 a	10.29 c	10.78 b	11.08 a	10.85 ab

**Table 3.** (Cont'd) Effect of storage on the pasting characteristics of different rice varieties harvested during the 1997 wet season. All viscosity measurements are expressed in rapid visco units (RVU).

Variety/ Pasting characteristics	Storage period (days)						
	0	15	30	45	60	75	90
PSBRc10	0	15	30	45	60	75	90
Peak viscosity	210.33 d	228.67 c	237.00 bc	238.00 bc	255.33 a	258.33 a	244.67 ab
Setback	83.33 d	87.33 cd	97.67 c	96.67 bc	92.67 bcd	99.67 b	110.67 a
Breakdown	31.67 c	42.33 ab	40.67 b	46.67 ab	49.67 a	49.33 a	44.67 ab
Consistency	115.00 d	129.67 c	138.33 bc	143.33 ab	142.33 b	149.00 ab	155.33 a
Moisture content (%)	10.14 cd	10.27 bc	10.46 b	9.75 e	10.97 a	9.99 de	11.06 a
PSBRc14	0	15	30	45	60	75	90
Peak viscosity	235.67 e	244.33 d	254.00 bc	250.67 cd	272.00 a	271.33 a	260.67 b
Setback	2.67 a	-6.33 ab	-9.67 b	-3.33 ab	-14.33 b	-13.00 b	-3.33 ab
Breakdown	100.33 c	111.33 b	116.33 b	113.33 b	128.00 a	127.33 a	121.33 ab
Consistency	103.00 e	105.00 de	106.67 d	110.00 c	113.67 b	114.33 b	118.00 a
Moisture content (%)	9.36 d	10.46 ab	10.07 bc	9.93 c	10.83 a	9.87 c	10.71 a

Note: in a row, means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test (DMRT).

**Table 4.** Effect of storage period on the pasting characteristics of different rice varieties harvested during the 1998 dry season. All viscosity measurements are expressed in rapid visco units (RVU).

Variety/ Pasting characteristics	Storage period (days)						
	0	15	30	45	60	75	90
IR64	0	15	30	45	60	75	90
Peak viscosity	260.00 a	260.67 a	244.00 b	242.67 b	235.33 bc	232.00 c	222.67 d
Setback	12.67 d	15.33 d	21.67 c	27.00 cd	30.00 b	32.33 ab	36.67 a
Breakdown	105.33 a	105.67 a	94.33 b	94.33 b	91.00 bc	86.67 cd	83.67 d
Consistency	118.00 bc	121.00 a	116.00 c	121.33 a	121.00 a	119.00 ab	120.33 ab
Moisture content (%)	10.95 a	9.66 d	10.20 c	10.56 ab	11.03 a	9.95 cd	10.01 cd
IR74	0	15	30	45	60	75	90
Peak viscosity	213.33 d	237.67 c	244.00 c	261.00 b	265.33 ab	265.33 ab	272.67 a
Setback	70.00 d	82.00 c	81.00 c	97.33 b	102.00 b	106.00 b	117.00 a
Breakdown	26.00 e	36.00 d	33.67 d	41.33 c	45.33 bc	48.67 b	54.00 a
Consistency	96.00 e	82.00 f	114.67 d	138.67 c	147.33 bc	154.67 b	171.00 a
Moisture content (%)	11.52 a	10.25 c	10.78 b	11.01 b	11.63 a	10.32 c	10.91 b
PSBRc10	0	15	30	45	60	75	90
Peak viscosity	179.67 a	184.33 a	173.67 ab	170.33 abc	158.33 cd	155.67 d	163.67 bcd
Setback	147.67 ab	152.67 a	141.33 bc	147.67 ab	140.67 bc	131.00 d	136.33 cd
Breakdown	6.00 ab	3.00 bc	2.67 bc	0.67 c	2.33 bc	0.67 c	8.33 a
Consistency	153.67 a	155.67 a	144.00 b	148.33 ab	143.00 b	131.67 c	144.67 b

**Table 4.** (Cont'd) Effect of storage period on the pasting characteristics of different rice varieties harvested during the 1998 dry season. All viscosity measurements are expressed in rapid visco units (RVU).

Variety/ Pasting characteristics	Storage period (days)						
	0	15	30	45	60	75	90
Moisture content (%)	11.65 a	10.26 d	10.57 c	10.74 bc	11.53 a	10.76 c	10.87 b
PSBRc14	0	15	30	45	60	75	90
Peak viscosity	244.67 a	252.67 a	245.00 a	247.00 a	231.67 ab	192.33 b	218.67 ab
Setback	6.00 f	13.33 e	19.00 d	21.00 d	26.00 c	31.33 b	38.67 a
Breakdown	116.67 a	108.67 a	100.00 b	101.33 b	93.00 c	87.67 d	83.33 d
Consistency	117.67 c	122.00 ab	119.00 bc	123.00 a	120.33 abc	119.00 bc	122.00 ab
Moisture content (%)	11.14 ab	10.01 e	10.38 d	10.51 d	11.30 a	10.41 d	10.84 bc

Note: in a row, means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test (DMRT).

**Table 5.** Effect of storage period on the texture of cooked rice for different rice varieties harvested during the 1997 wet season (hardness =  $\times 10^5$  dynes/cm<sup>2</sup>, adhesion =  $\times 10^3$  dynes/cm<sup>2</sup>).

Variety/Texture	Storage period (days)						
	0	15	30	45	60	75	90
IR64	0	15	30	45	60	75	90
Hardness	4.18b	4.77ab	4.28b	4.31b	4.56b	4.73ab	5.30a
Adhesion	2.34a	2.28a	2.45a	1.85b	1.84b	1.45a	1.79b
IR74	0	15	30	45	60	75	90
Hardness	6.04b	5.99b	5.90b	6.63ab	6.43ab	6.65ab	6.92a
Adhesion	3.80a	3.43a	3.12a	2.82a	2.82a	3.31a	3.19a
PSBRc10	0	15	30	45	60	75	90
Hardness	5.96ab	6.49ab	5.25c	5.88c	5.94ab	6.59a	6.60a
Adhesion	1.18cd	0.96cd	1.46bc	1.81b	2.40a	0.70d	0.77d
PSBRc14	0	15	30	45	60	75	90
Hardness	4.25bc	4.85 ab	4.52bc	4.12c	4.54bc	4.44bc	5.23a
Adhesion	2.35ab	2.39a	2.19ab	1.92bc	1.96bc	1.66c	1.95bc

Note: in a row, means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test (DMRT).

Minimum viscosity of IR64, PSBRc10, and PSBRc14 increased with increase in storage period during the wet season, but an opposite trend was observed for the dry-season harvest.

An increase in cooked paste viscosity was noted for all varieties harvested during the wet season as the storage period increased. The final viscosity of IR64 and PSBRc10 decreased as the storage period increased during the dry season. The final viscosity of IR74 increased as the storage period increased during the dry season, but this characteristic in PSBRc14 was not significantly affected by aging.

Setback values increased as the storage period increased for IR74 and PSBRc10 during the wet season and for IR64, IR74, and PSBRc14 during the dry season. The highest increase was observed for IR74 (47 RVU) during the dry season. A decrease in setback values occurred after 90 days of storage for IR64 and PSBRc14 during the wet season and for PSBRc10 during the dry season.

All four rice varieties showed increases in breakdown values as the storage period increased during the wet season. The highest increase observed was for PSBRc10 (40.33 RVU) while the lowest was

for IR64 (13.33 RVU). IR64, IR74, and PSBRc14 also increased in consistency values as the storage period increased during the dry season. IR74 registered the highest increase (75 RVU) while the lowest was for PSBRc14 (4.33 RVU). A decrease in 9 RVU units was noted for PSBRc10 after 90 days of storage.

#### *Cooked rice texture*

An increase in cooked rice hardness occurred within 15 days of storage for PSBRc10 and PSBRc14 both for the wet and dry-season harvests, as shown in Tables 5 and 6. Changes in cooked rice texture occurred within 60 days of storage for IR74. The hardness of IR64 from the wet and dry-season harvests remained unaffected all throughout the 90-day aging period.

The adhesiveness of cooked rice of varieties IR64 and PSBRc14 gradually increased as the storage period reached 45 days and 60 days, respectively. After these periods, however, the adhesiveness gradually decreased up to the end of the 90-day storage period. The adhesiveness of IR74 increased up to 75 days of storage, but significantly decreased at the end of 90 days.

**Table 6.** Effect of storage on the texture of cooked rice for different rice varieties harvested during the 1998 dry season (hardness =  $\times 10^5$  dynes/cm<sup>2</sup>, adhesion =  $\times 10^3$  dynes/cm<sup>2</sup>).

Variety/Texture	Storage period (days)						
	0	15	30	45	60	75	90
IR64							
Hardness	5.12 a	5.95 a	5.89 a	5.13 a	5.93 a	5.86 a	6.08 a
Adhesion	12.28 cd	10.79 d	17.81 bc	31.51 a	20.82 b	17.53 bc	15.57 bcd
IR74							
Hardness	5.57 d	5.87 bcd	6.42 ab	5.72 cd	6.62 a	6.22 abc	6.40 ab
Adhesion	2.45 d	2.94 cd	3.19 cd	4.01 bc	4.54 ab	5.39 a	3.43 bcd
PSBRc10							
Hardness	5.88 b	6.54 a	6.28 ab	6.42 ab	6.55 a	6.78 a	6.52 a
Adhesion	2.45 c	2.70 bc	3.43 ab	3.56 a	2.82 abc	3.56 a	2.70 bc
PSBRc14							
Hardness	4.08 b	4.89 a	4.73 a	4.73 a	4.93 a	4.78 a	4.69 a
Adhesion	9.56 c	9.78 c	15.08 ab	18.09 a	16.40 a	15.47 ab	12.90 b

Note: in a row, means followed by the same letter are not significantly different at 5% level by Duncan's multiple range test (DMRT).

## Conclusion/Recommendation

The results of this study show that slight changes to some of the physico-chemical properties of rice occur during storage. The storage period at which these changes occur, however, varies between rice varieties. It was previously reported by Perez and Juliano (1981) that the minimum storage period for major changes to occur in the hardness of cooked rice, gel consistency, and amylograph viscosity was 3 months. In this experiment, texture changes in cooked rice tended to be greatest within 15–45 days of storage. Pasting characteristics as measured by the Rapid Visco Analyzer seemed to stabilise after 60 days of storage. Thus, measurements of these characteristics should be carried out on rice samples aged for at least 2 months

after harvest. Sun-drying may have contributed to the rapid aging of the rough rice samples.

## References

- Chrastil, J. 1990. Chemical and physicochemical changes of rice during storage at different temperatures. *Journal of Cereal Science*, 11, 71–85.
- Juliano, B.O. 1985. Criteria and tests for rice grain qualities. In: *Rice chemistry and technology*. St Paul, Minnesota, The American Association of Cereal Chemists, 480–486.
- Normand, F.L., Hogan, J.T. and Deobald, H.J. 1964. Improvement of culinary quality of freshly harvested rice by heat treatment. *Rice Journal*, 67(13), 7–11.
- Perez, C.M. and Juliano, B.O. 1981. Texture changes and storage of rice. *Journal of Texture Studies*, 12, 321–333.

# Production Performance of Poultry Layers Consuming Aflatoxin-contaminated Feed

E.T. Begino\*

## Abstract

This study was conducted to relate quantitatively the aflatoxin residue found in table eggs, via feed intake, of poultry layers fed with aflatoxin-contaminated feeds, with or without the addition of a mycotoxin binder. The experimental animals were given feeds naturally contaminated with aflatoxin B<sub>1</sub> ranging from 20.27 to 167.96 parts per billion (ppb) for 7 weeks on a commercial farm in the Philippines, during the post-peak period. Egg collection started at week 36 with egg production at 82.69% for the control group and 70.13% for the treated group; and concluded at week 43 with egg production performance at 71.53% and 62.28%, respectively. The group treated with the mycotoxin binder produced eggs with aflatoxin B<sub>1</sub> contamination at a level of 0.016–0.45 ppb, compared to 0.03–0.69 ppb for the control group. Aflatoxin M<sub>1</sub> contamination for the treated group ranged from 0.04–1.08 ppb while the control group registered 0.49–2.54 ppb. Comparison of the overall production performance between groups proved favourable for the use of the mycotoxin binder in layer feeds, with improvements in both egg production and egg quality—in terms of aflatoxin M<sub>1</sub> contamination.

IN THE Philippines, where the relative humidity is high, deterioration of agricultural products through increasing levels of aflatoxin can be anticipated. In recent years, many countries have adopted legislation aimed at not only improving the volume of animal production, but also its hygienic quality with regard to human health. Hamilton (1987) reported that high levels of aflatoxin in the diets of laying hens led to high mortality and a decrease in egg production, which continued to decline even after aflatoxin was removed from the diets (Hamilton and Garlich 1971). Residues of aflatoxin B<sub>1</sub> have been found in eggs from layers fed with contaminated feed (e.g. Jacobson and Wiseman 1974; Trucksess et al. 1977). Egg production by hens exposed to aflatoxin declines after the exposure but not during the time of feeding with the aflatoxin-contaminated feed.

The use of improved feeds is the most important step in increasing productivity and profitability in the livestock industry (Cruz and Begino 1990; Alcasid

1993). Unfortunately, the present state of aflatoxin prevention and control in feeds is still far from ideal, particularly from a regulatory aspect in developing countries, where effective management is needed to reduce the problem, if not totally eliminate it. There is a lack of thorough understanding and appreciation of the problem among producers, traders, and consumers. At the Bureau of Animal Industry, we (as a rule) have adopted international standards for tolerable levels of aflatoxin for processed feeds and feedstuffs in our national grades and standards, even with commodity exports and imports, but surveys have indicated a high incidence of aflatoxin contamination (Begino et al. 1993; Begino 1996).

Compared to developing countries, there is a greater appreciation in developed countries among the people and their governments about food and feed contamination issues and problems. There are many things that can be done to help control and limit the effects of mycotoxins in animals. To this end, this study investigated the production performance of layer chickens fed with aflatoxin-contaminated feed, and feed treated with a mycotoxin binder commonly used in the Philippines.

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## Materials and Methods

3,120 Hy-line layers at the post-peak period were used in the study. Before the start of the feeding trial, samples of feeds and eggs were examined. The layers were divided into 624 cages, with 5 birds in each cage. Group A were treated with mycotoxin binder (MycotoxR) at the rate of 500 g/t of feed. As a control, group B was given feed naturally contaminated with 20.27–167.96 parts per billion (ppb) aflatoxin B<sub>1</sub>. 308 cages were used for group A, and 316 cages for group B. Feed and clean water were given ad libitum. All birds were reared under the same management conditions with the trial running for 4 weeks.

The aflatoxin content in the feed was determined using the modified NRI phenyl bond-elut bi-directional high performance thin layer chromatography (HPTLC) method (Coker et al. 1990; Bradburn et al. 1991). The aflatoxin content in the eggs was determined according to AOAC (1980) for clean-up and quantification by HPTLC. Standards of aflatoxin M<sub>1</sub> and B<sub>1</sub> were purchased from Sigma Chemicals.

### Solvent extraction and column clean-up

The desired weight/aliquot of samples was extracted with 70–80% acetone in a shaker for 45 min and the extract was then filtered through a Whatman No. 1 filter paper. Duplicate 5 mL portions of extract were applied to a phenyl column in methanol/acetic acid buffer using lead acetate for clean-up. The aflatoxin absorbed on the column was eluted with an appropriate volume of chloroform, and the elutes were

dried at 45% under a stream of nitrogen gas in a sample concentrator.

### Quantification using bi-directional high performance thin layer chromatography (HPTLC)

An activated aluminum HPTLC silica-coated plate was used for spotting. To lessen the edging effect, a 2 mm band of silica was scraped off each edge of the plate, parallel to the direction of development. Dry aflatoxin film was dissolved in benzene:acetonitrile (98:2) as a suitable solvent for spotting. After spotting, the plate was inverted and developed using diethyl ether for 5 min. The plate was dried and the lower portion cut away, leaving 9 mm from the spot area, then developed again in the normal way with chloroform:xylene:acetone (6:3:1 v/v/v) for 20 min. The plate was then air-dried to avoid ghosting effects, before running it again for another minute using the same solvent so that the spots were well separated. After drying, the plate was placed in an oven at 100°C for 1 min. The plate was scanned by CAMAG TLC scanner supported by appropriate software (Coker et al. 1990; Begino et al. 1993). The aflatoxin level was determined by the intensity of fluorescence of the standard and sample spots.

## Results and Discussion

Table 1 summarises the levels of aflatoxin content in the feed, and residues of aflatoxins B<sub>1</sub> and M<sub>1</sub> in the eggs of layers. Aflatoxin residues tend to decrease

**Table 1.** The levels of aflatoxins B<sub>1</sub> and M<sub>1</sub> (parts per billion; ppb) in eggs produced by layer chickens fed with aflatoxin-contaminated feed. In the ‘treated’ group, the feed had mycotoxin binder added at the rate of 500 g/t.

Level of feed contamination (ppb)	Mycotoxin B <sub>1</sub>		Mycotoxin M <sub>1</sub>	
	Treated	Control	Treated	Control
113.79	–	–	–	1.25
80.83	0.016	0.04	0.04	1.61
167.94	0.025	0.22	0.85	2.54
167.96	0.12	0.69	1.08	1.61
34.12	0.45	0.03	0.50	1.66
64.83	0.05	ND	0.47	0.78
20.27	0.02	0.08	ND	0.49
37.73	ND	ND	0.76	1.02

Note: ND = not detected.

with the inclusion of mycotoxin binder at the rate of 500 g/t of feed. Aflatoxin B<sub>1</sub> is the most toxic and carcinogenic metabolite among aflatoxins. It is very reactive because of the presence of the *pi* bond at the 2–3 position, which is converted to 2–3 epoxide, which is a strong alkylating agent of deoxyribonucleic acid (DNA). This alteration of DNA structure, if not repaired, can lead to mispairing and then mutation. It may be possible that the *pi* bond is attacked by the phenolic group of oxyquinol, which is an active ingredient of the mycotoxin binder, when mixed in the diet, neutralising the toxin and alleviating the toxic effect in general. The action of oxyquinol is to bind the toxin, inhibiting interaction of aflatoxin with the cellular constituents, thus preventing entero-hepatic absorption, resulting in its elimination from the body via biliary excretion and further excretion directly through the faeces, urine, milk and eggs. Another active ingredient of the mycotoxin binder is di (chloro-4-thymol) sulfide 2 which acts as a powerful intestinal anti-fungal and antiseptic agent which aids the mycotoxin binding action of oxyquinol and as a final active ingredient, the micronised brewer's yeast in the binder successfully counteracts the adverse effects induced by fungi and their toxins by restoring the integrity of the hepatic cells and the balance of the intestinal flora.

Table 2 shows the production performance of layers fed feed with or without the mycotoxin binder. Group A, treated with the mycotoxin binder, started with a production rate of 70.13% and ended with 62.28%, compared to control group B (no binder)

which started with a production rate of 82.69% and ended with 71.53%. Over the 7-week observation period, the levels of aflatoxins B<sub>1</sub> and M<sub>1</sub> in eggs from laying hens fed with treated feed were, on average, 50% less than eggs from the control hens. Comparison of the overall performance between groups proved favourable for the use of a mycotoxin binder in the layers' feed. Not only was the production performance better, but so was the quality of the eggs in terms of a reduction in aflatoxin residues. The rate of incorporation, however, should be adapted to the severity of the problem, depending on the production stage, supply of raw materials, and the toxin levels.

## Conclusion

The presence of aflatoxins in animal feeds is of public health importance. The effect of ingestion by animals of contaminated feed can vary from lowered production efficiency to diseases, and even death. The use of a mycotoxin binder in the diet of layer hens successfully reduced aflatoxin contamination in their eggs, as well improving their overall productivity.

## Acknowledgment

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**Table 2.** Production performance (%) of layers fed with aflatoxin-contaminated feed. In the 'treated' group, the feed had mycotoxin binder added at the rate of 500 g/t.

Criteria	Treated	Control
Production at start of trial	70.13	82.69
Production at end of trial	62.28	71.53
Variance	7.85	11.16
Mortality	10.0	12.0
Production increase <sup>a</sup>	(+) 6.11	(+) 2.51
Production drop <sup>b</sup>	(-) 8.73	(-) 16.50

<sup>a</sup> Production increase refers to the highest value above production at the start of the trial attained by the group

<sup>b</sup> Production drop refers to the lowest value below production at the start of the trial attained by the group.

## References

- Alcasiid, R.N. 1993. The role of food and feed control service at domestic and export levels: processed feed commodities. Paper presented at the Regional Workshop on Mycotoxin Prevention and Control Programs in Asia, 6–9 December 1993, Manila, Philippines.
- AOAC (Association of Official Analytical Chemists) 1980. Official methods of analysis: natural poisons, 13th edition. Arlington, Virginia, AOAC, 423p.
- Begino, E.T., Agaceta, L.M. and Miranda, C.O. 1993. Survey on the aflatoxin content of commercially available feeds in the Philippines. Paper presented at the 110th International Symposium of World Association of Veterinary Food Hygienists, Bangkok, Thailand.
- Begino, E.T. 1996. An update on aflatoxin levels in feeds and feedstuff in the Philippines. Paper presented during the 110<sup>th</sup> Association of Official Analytical Chemists (AOAC) International Annual Meeting and Exposition in Orlando, Florida, USA, 8–12 September 1996.
- Bradburn, N., Coker, R.D. and Jewers, K. 1991. Chromatography, 29, 435.
- Coker, R.D., Jewers, K. and Blunder, G. 1990. Chromatography, 29, 177.
- Cruz, M.S. and Begino, E.T. 1990. Pathology reports. Bureau of Animal Industry, Quezon City, Philippines, unpublished report.
- Hamilton, P.B. 1987. Why the animal industry worries about mycotoxins. Proceedings of Symposium of Recent Development in the Study of Mycotoxin, A, 1–12.
- Hamilton, P.B. 1971. A natural and extremely severe occurrence of aflatoxicosis in laying hens. Poultry Science, 50, 1880–1882.
- Hamilton, P.B. and Garlich, J.D. 1971. Aflatoxin as possible cause of fatty liver syndrome in laying hens. Poultry Science, 50, 800–804.
- Jacobson, W.C. and Wisemen, H.G. 1974. The transmission of aflatoxin B<sub>1</sub> into eggs. Poultry Science, 53, 688–692.
- Trucksess, M.W., Stoloff, L., Pon, W.A. Jr., Cucullu, A.F., Lee, L.S. and Franz, A.O. Jr. 1977. Thin layer chromatographic determination of aflatoxin B<sub>1</sub> in eggs. Journal of the Association of Official Analytical Chemists (AOAC), 60, 795–798.

# Model Predicting the Shelf Life of Edible-coated, Minimally Processed Salak

S. Wuryani, I.W. Budiastira, A.M. Syarif and H.K. Purwadaria\*

## Abstract

This study aimed to assess a model for predicting the shelf life of edible-coated, minimally processed 'Pondah' salak, related to its respiration parameters and critical quality degradation.

A respiration model based on facilitated diffusion phenomena was proposed for predicting the respiration rates as a function of internal oxygen. The model parameters, namely  $R_{O_2}^{max}$  and  $K_{1/2}$ , were found to be exponential functions with respect to storage temperature. These parameters were later used in the model to predict the shelf life of the edible-coated, minimally processed salak under atmospheric conditions.

The critical quality parameter of the edible-coated, minimally processed 'Pondah' salak was hardness, and the degradation rate followed the mixed effect model which was influenced by the steady state internal oxygen and the storage temperature.

The model successfully predicted the shelf life of the edible-coated, minimally processed 'Pondah' salak at the level of 0.94 compared to the experimental data. The model can be implemented at the storage temperature range of 5–27°C.

IN RECENT years, consumers worldwide have been more health-conscious in their eating habits, but at the same time have less time to prepare their meals. As a result, the market demand is increasing for 'ready-to-eat' fresh fruits and 'ready-to-cook' vegetables which have been washed, skinned, cut and sliced into various forms. Fruits and vegetables handled in this way are said to be minimally processed or lightly processed, and are produced without applying any preservation treatment which could change the physical characteristics of the products (Shewfelt 1987). Siriphanich (1993) indicated the criteria for fruits to be minimally processed, including the risk of otherwise obtaining poor quality pulp, peeling difficulties, and the weight reduction for transportation.

Salak is one of Indonesia's original fruits. The fruit has a round or triangle shape, composed of skin, edible flesh and seed. The skin of salak is brown, brownish black or yellow in colour and has small, unseen needles. The edible part of salak is non-fibrous, has a sweet taste and crispy texture, and is yellowish white

to brown in colour with 1–3 big fingers. Minimally processed salak will be appreciated by consumers since it is very tedious to peel the salak and the small needles on the skin often hurt the consumers if they are not careful.

Studies have been carried out to assess various minimally processed (MP) fruits such as kiwifruit, papaya, cantaloupe, pineapple, honeydew melon and apples (O'Connor-Shaw et al. 1994; Cameron et al. 1995). The problem with MP fruits is that they deteriorate faster than the whole fruits under similar low storage temperatures. One alternative to reduce the rate of respiration in MP fruits is to cover the exposed flesh with an edible-coating film. Edible coating is a continuous film made out of edible materials and applied to the food products by soaking or spraying. The functions of edible coatings include: acting as a barrier to the mass transfer of certain materials (e.g. water vapour, oxygen, lipids, soluble materials); as a carrier for food additives; facilitating food handling; maintaining the cell structural integrity; and hindering the losses of volatile compounds (Kester and Fennema 1986; Nisperos-Carriendo et al. 1990; Krochta 1992; Gennadios et al. 1994). Edible coating has been applied to sliced apples (Wong et al. 1994), and

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tomatoes (Park et al. 1994). Baldwin et al. (1995) found that edible-coated, sliced apples had a shelf life of 3 days under normal atmospheric conditions.

The application of edible coating on MP 'Pondoh' salak and its characteristics have been assessed (Setiasih et al. 1998; Setiasih 1999; Purwadaria and Wuryani 1999; Wuryani et al. 1999). The researchers have also developed the standard operational procedure for the minimal processing and the edible coating of 'Pondoh' salak. However, understanding the respiration process needs further elaboration. The objectives of this study were (1) to identify the respiration parameters of the edible-coated, minimally processed (ECMP) 'Pondoh' salak, (2) to develop a respiration model, and (3) to observe the quality changes of the ECMP 'Pondoh' salak under low temperature storage conditions.

## Theoretical Considerations

Explanations of the symbols used throughout this paper are given in Table 1.

In general, the respiration process for fruits and vegetables can be expressed by the following reaction equation (Kader 1989):



Equation (1) indicates that the respiration rate could be determined by the  $O_2$  uptake. If oxygen is the solute in facilitated diffusion mass transfer phenomena (Cussler 1987) from atmospheric to material through edible coating, then  $O_2$  uptake as respiration rate can be expressed as follows (Wuryani 1999):

$$O_2 \text{ uptake}^T = \frac{R_{O_2}^{\max, T} (O_2)_{\text{int}}}{K_{1/2} + (O_2)_{\text{int}}} \quad (2)$$

where  $R_{O_2}^{\max, T}$  and  $K_{1/2}^T$  are respiration parameters whose values determined by linearising equation (2) by using the Hanes-Woolf method (Shuler and Kargi 1992).

Permeability to  $O_2$  per weight unit can be determined by the following equation (Cameron et al. 1995):

$$\epsilon_{O_2}^T = \frac{A \rho P m O_2^T}{l W} \quad (3)$$

The effect of the temperature on the permeability of edible coating to  $O_2$  can be approximated by the Arrhenius equation as follows (Latriyanto 1998):

$$P m O_2^T = 2.1239 \text{ Exp}(-1856/T) \quad (4)$$

The oxygen flux to fruit tissue through edible coating can be expressed by this equation:

$$J_{O_2} = \epsilon_{O_2}^T \left\{ (O_2)_{\text{ext}} - \Phi(O_2)_{\text{int}} \right\} \quad (5)$$

Assuming that there is no accumulation of  $O_2$ ,  $O_2$  diffusion to the fruit tissue will be equal to  $O_2$  uptake at a specific time, so that Equation (5) will be equal to Equation (2). At this time,  $(O_2)_{\text{int}}^T$  can be determined by Equation 6 (at bottom of page)

The quality degradation during storage can be described as the rate of kinetic reaction inside the fruit during storage (Man and Jones 1994) and expressed as

$$\Phi \frac{dQ}{dt} = k Q^n \quad (7)$$

Assuming that  $n = 1$  for salak when edible coating, Equation (7) could be expressed as linear equation

$$\ln Q_t = \ln Q_0 + \Phi k t \quad (8)$$

The quality degradation constant,  $k$ , is dependent on the  $(O_2)_{\text{int}}$  involved respiration parameters as expressed in Equation (6) as well as the storage temperature. The relationship between these parameters is modelled in the following equation:

$$\ln k = a + b \ln (O_2)_{\text{int}} - E/RT \quad (9)$$

$$(O_2)_{\text{int}}^T = \frac{\left( \frac{\epsilon_{O_2}^T R_{O_2}^{\max, T}}{\Phi_{TM}} + K_{1/2} \Phi(O_2)_{\text{ext}} \right) + \sqrt{\left( \frac{\epsilon_{O_2}^T R_{O_2}^{\max, T}}{\Phi_{TM}} + K_{1/2} \Phi(O_2)_{\text{ext}} \right)^2 + 4 K_{1/2} (O_2)_{\text{ext}}}}{2} \quad (6)$$

**Table 1.** Explanation of symbols used in this paper.

Symbols	Explanations
a, b	Constants
A	Surface area of barrier, m <sup>2</sup>
$\beta_{O_2}^T$	Total permeability of barrier to O <sub>2</sub> per kg of product at temperature T, mol.kPa/kg.s
$dO_2/dt$	Oxygen concentration gradient, %/h
$\frac{dQ}{dt}$	Quality gradient
E	Activation energy, J/mol
$JO_2$	Oxygen flux to fruit tissue, g.mol/cm <sup>2</sup> .s
k	Constant of quality degradation, days
$k_{hd}^T$	Hardness degradation rate at temperature T
$K_{1/2}$	Internal O <sub>2</sub> partial pressure at the half level of $R_{O_2}^{max}$ , kPa
l	Film thickness, m
O <sub>2</sub> uptake <sup>T</sup>	Rate of oxygen consumption at temperature T, mol/s/kg
(O <sub>2</sub> ) <sub>int</sub>	Steady state partial pressure of internal O <sub>2</sub> , kPa
(O <sub>2</sub> ) <sub>int</sub> <sup>T</sup>	Steady state partial pressure of O <sub>2</sub> inside the packaging at temperature T, kPa
(O <sub>2</sub> ) <sub>ext</sub>	Steady state partial pressure of O <sub>2</sub> outside the packaging, kPa
$Pm O_2^T$	Permeability of edible coating to O <sub>2</sub> , at temperature T, nmol.m/m <sup>2</sup> .kPa.s
Q	Quality index
Q <sub>0</sub>	Initial critical quality
Q <sub>t</sub>	Limit of the shelf life of the fruit
R	Gas constants, J/mol.K
$R_{O_2}^{max, T}$	Maximum rate of O <sub>2</sub> uptake, mol/kg/s at temperature T
T	Storage temperature, °C
ts	Shelf life, days
V	Void volume inside the packaging, m <sup>3</sup>
V <sub>b</sub>	Chamber volume, L
W	Weight of fruit samples, kg

Substituting equation (9) with equation (7), the shelf life of 'Pondoh' salak,  $t_s$ , under edible coating could be predicted by the equation:

$$t_s = \frac{\ln Q_0 \Phi \ln Q_t}{\text{Exp}\left\{a + b \ln(O_2)_{\text{int}} \Phi E / RT\right\}} \quad (10)$$

where  $Q_0$  is the initial critical quality of the fruit and  $Q_t$  is the limit of the shelf life of the fruit.

## Research Methods

'Pondoh' salak from a farmer's orchard in Sleman Regency, Yogyakarta, was harvested at commercial maturity (150 days after fruiting). The essential chemicals used for the edible coating film were soy protein isolate, low methoxy pectin, alginate acid, sodium alginate, glycerol 87%, beeswax, lauric acid, and stearic acid.

An experiment to measure the internal gas inside the ECMP fruits, in this case the oxygen, was set up as illustrated in Figure 1. The procedure used a 5 L desiccator filled to 90% capacity with distilled water and de-aerated. The ECMP sample was placed under an inverted glass funnel and the apparatus then was closed. A vacuum pressure of 550 mm Hg was applied for 3 min. The gas bubbling out of the sample was collected at the top of the funnel, and analysed using a Varian Gas Chromatograph equipped with a thermal conductivity detector to determine the percentage of internal oxygen, abbreviated to  $(O_2)_{\text{int}}$ . The experiments were repeated three times.

To determine the relationship of  $(O_2)_{\text{int}}$  (kPa) with the respiration rate (the  $O_2$  uptake), fruit samples about 195 g were put inside a chamber under similar storage temperatures with the internal oxygen measured every hour. The  $O_2$  uptake was calculated using the following formula (Nugroho 1995):

$$O_2 \text{ uptake} = \frac{\frac{dO_2}{dt} \cdot V_b \cdot 10^{\Phi}}{22.4 \cdot \left[ \frac{T_M}{273.15} \right] \cdot W} \cdot 3600 \quad (11)$$

These experiments were also repeated three times.

The critical quality changes of the ECMP 'Pondoh' salak were determined based on organoleptic score. An organoleptic score below 3.5 was used to indicate the limit of consumer acceptance, thus the parameter which first acquired a score of 3.5 was deemed to be the critical quality parameter. Hardness was determined by the Bourne method (Bourne 1982).

## Results and Discussion

The development of  $(O_2)_{\text{int}}$  and  $O_2$  uptake for the ECMP 'Pondoh' salak under various storage temperatures is illustrated in Figure 2. The results indicate that the  $(O_2)_{\text{int}}$  in the fruit tissue was retained more at the lower temperature—the amount of oxygen used was lower due to the lower respiration activity, thus a smaller  $O_2$  uptake.

The characteristics of the respiration rate were further represented as the  $R_{O_2}^{\text{max}}$  to the maximum  $O_2$  uptake, and the  $K_{1/2}$ —meaning the internal oxygen pressure as half  $R_{O_2}^{\text{max}}$ . Figure 3 shows the function of both  $R_{O_2}^{\text{max}}$  and  $K_{1/2}$  over storage temperature for 'Pondoh' salak. It shows that the relationships between  $R_{O_2}^{\text{max}}$ ,  $K_{1/2}$  and temperature are exponential. This result agrees with that found by Cameron et al. (1994) and the Rusmono model (Rusmono et al. 1998). The function can be expressed as follows:

$$R_{O_2}^{\text{max}, T} = 0.087 \text{Exp}(0.0286T), R^2 = 0.9958 \quad (12)$$

$$K_{1/2}^T = 0.011 \text{Exp}(0.0155T), R^2 = 0.9962 \quad (13)$$

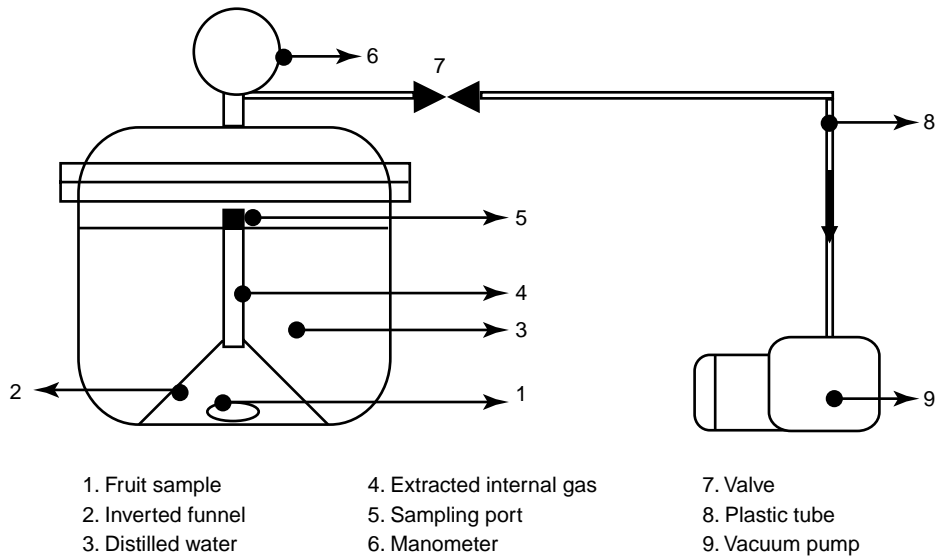
Table 2 presents the results of organoleptic tests for ECMP 'Pondoh' salak stored at 5°C. The critical quality parameters for ECMP 'Pondoh' salak were determined to be colour and hardness, since these parameters were the first to achieve an organoleptic score below 3.5. Since the rate of quality degradation for hardness was higher than for colour, the critical quality for ECMP 'Pondoh' salak was hardness (Wuryani 1999) and the shelf life of ECMP 'Pondoh' salak was determined based on hardness.

The equation for describing hardness quality degradation is:

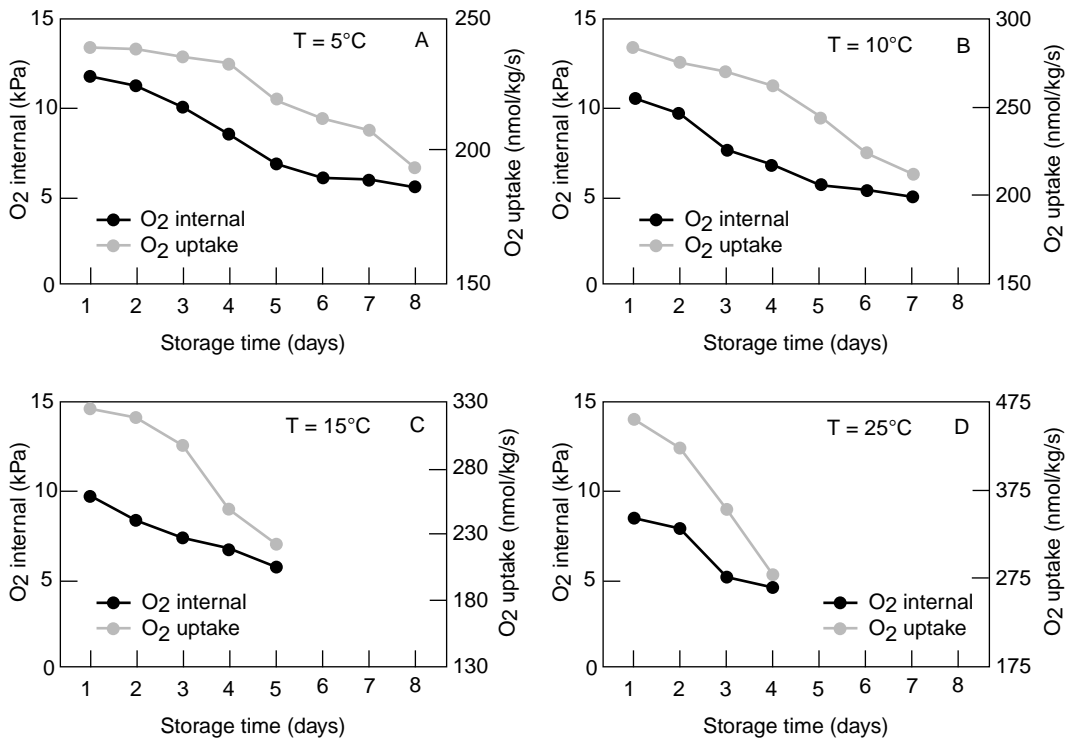
$$k_{\text{hd}}^T = \text{Exp}\left[12.59 + \frac{2.83 \ln(O_2)_{\text{int}}}{T} \Phi \left[ \frac{6306.31}{T} \right] \right] \quad (14)$$

The model for predicting shelf life of ECMP 'Pondoh' salak can be expressed as follows:

$$t_s^T = \frac{\ln 100 \Phi \ln 84.92}{\text{Exp}\left[12.59 + \frac{2.83 \ln(O_2)_{\text{int}}}{T} \Phi \left[ \frac{6306.31}{T} \right] \right]} \quad (15)$$



**Figure 1.** Experimental set-up for internal gas measurement.



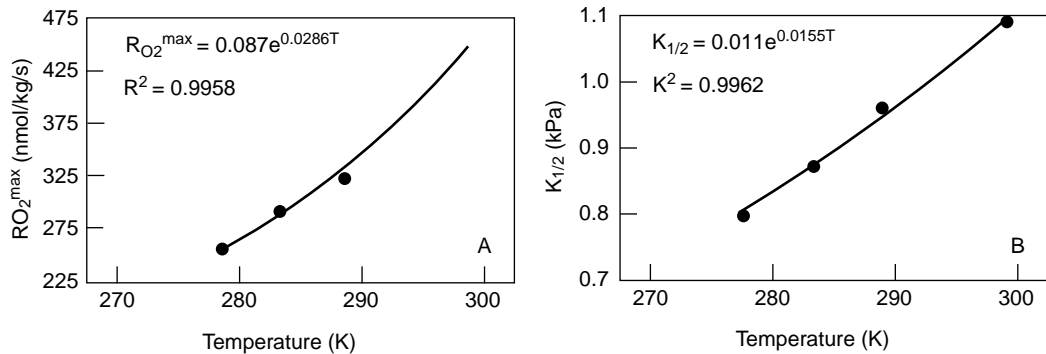
**Figure 2.** Internal oxygen and oxygen uptake changes of edible-coated, minimally processed 'Pondoh' salak under various storage temperatures: 5°C (A); 10°C (B); 15°C (C); and 20°C (D).



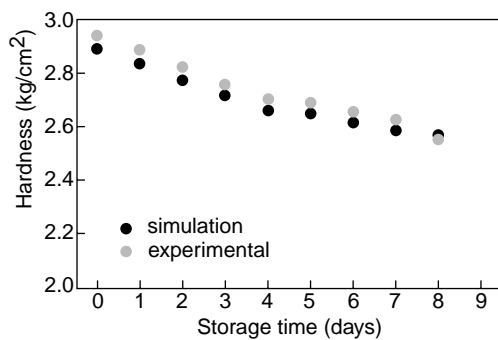
**Table 2.** Results of organoleptic tests for edible-coated, minimally processed (ECMP) ‘Pondoh’ salak stored at 5°C.

Day	Score of quality parameters				Score of total acceptance
	Colour	Aroma	Hardness	Taste	
0	4.95	4.92	4.95	4.99	4.95
1	4.8	4.76	4.71	4.86	4.68
2	4.66	4.45	4.51	4.8	4.51
3	4.45	4.32	4.33	4.66	4.14
4	4.12	4.05	4.14	4.59	3.98
5	3.98	3.86	3.80	4.45	3.71
6	3.73	3.75	3.71	4.32	3.66
7	<b>3.35</b>	3.57	<b>3.49</b>	4.05	3.51
8	3.22	3.51	3.29	3.68	<b>3.33</b>
9	2.90	<b>3.14</b>	2.79	<b>3.29</b>	3.03

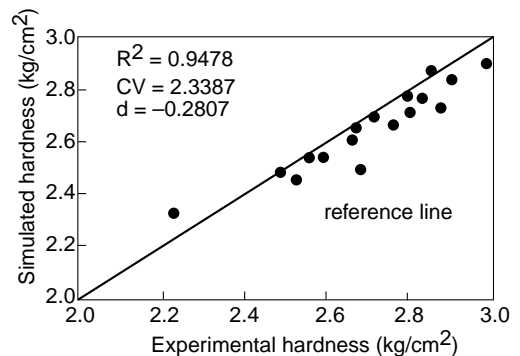
Note: scores in bold are under the acceptable limit.



**Figure 3.** The effect of temperature on (A)  $R_{O_2}^{max}$  and (B)  $K_{1/2}$  for edible-coated, minimally processed ‘Pondoh’ salak.



**Figure 4.** Change in hardness over time predicted by the model compared with the experimental results.



**Figure 5.** The results of validation of the model.

Figure 4 shows the change in hardness predicted by the model compared to experimental results at the storage temperature of 5°C. The predicted values closely agree with the experimental values.

Figure 5 show the results of validation of the model. The low coefficient of variation, the high correlation coefficient, and small bias indicate that hardness predicted by model is not significantly different to that experimentally determined. Thus, the model could be used to predict the shelf life of ECMP ‘Pondoh’ salak stored at temperatures of 5–27°C and atmospheric conditions.

$$k_{hd}^T = \text{Exp} \left[ \frac{12.59 + 72.83 \ln(O_2)_{int}^T}{6306.31} \right] \Phi \quad R^2 = 0.9920 \quad (16)$$

$$(O_2)_{int}^{spT} = \frac{\Phi \left[ \frac{R_{O_2}^{max,T}}{A.Pm(O_2)^T / W.l} + K_{1/2}^T \Phi(O_2)_{atm} \right] + \sqrt{\left[ \frac{R_{O_2}^{max,T}}{A.Pm(O_2)^T / W.l} + K_{1/2}^T \Phi(O_2)_{atm} \right]^2 + 4K_{1/2}^T \Phi(O_2)_{atm}}}{2} \quad (17)$$

3. The model to predict shelf life of ECMP ‘Pondoh’ salak was developed and validated, that is:

$$ts_{hd}^T = \frac{\ln 100 \Phi \ln 84.92}{\text{Exp} \left[ \frac{12.59 + 72.83 \ln(O_2)_{int}^T}{6306.31} \right] \Phi} \quad (18)$$

4. The model successfully predicted the shelf life of ECMP ‘Pondoh’ salak at a level of 0.94 compared to experimental data. The model can be implemented at the storage temperature range of 5–27°C.

### Acknowledgment

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### Conclusions and Recommendations

1. The maximum  $O_2$  uptake and steady state partial pressure of internal  $O_2$  ( $K_{1/2}$ ) for ECMP ‘Pondoh’ salak had exponential relationships to storage temperature, and could be expressed as shown in Equations 12 and 13.
2. The critical quality for ECMP ‘Pondoh’ salak was hardness and the degradation followed the mixed effect model which was influenced by steady state internal  $O_2$  and storage temperature as expressed by the following equations:

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### References

- Baldwin, E.A., Nisperos-Cariedo, M. and Baker, R.A. 1995. Edible coating for lightly processed fruits and vegetables. *Journal of Horticultural Science*, 30, 35–37.
- Bourne, M.C. 1982. *Food texture and viscosity: concept and measurement*. Tokyo, Academic Press, 247–274.
- Cameron, A.C., Beaudry, R.M. Banks, N.H. and Yelanich, M.V. 1994. Modified atmosphere packaging of blueberry fruits: modeling respiration and package oxygen partial pressure as a function of temperature. *Journal of American Horticultural Science*, 119, 534–539.
- Cameron, A.C., Talasila, P.C. and Joles, D.W. 1995. Predicting film permeability needs for modified atmosphere packaging of lightly processed fruits and vegetables. *Journal of Horticultural Science*, 30, 25–34.

- Cussler, E.L. 1987. Diffusion. Mass transfer in fluid systems. Melbourne, Cambridge University Press.
- Gennadios, A., McHugh, T.H., Weller, C.L. and Krochta, J.M. 1994. Edible coatings and films based on proteins. In Krochta, J.M., Baldwin, E.A. and Nisperos-Carriedo, M.O., ed., Edible coating and films to improve food quality. Lancaster, Pennsylvania, Technomic Publishing Co., 201–278.
- Kader, A.A. 1989. Respiration and gas exchange of vegetables. Davis, University of California.
- Kester, J.J. and Fennema, O.R. 1986. Edible films and coatings: a review. *Food Technology*, 40(12), 47–59.
- Krochta, J.M. 1992. Control of mass transfer in foods within edible coatings and films. In: Sing, R.P. and Wirakartakusumah, M.A., ed., Advances in food engineering. Boca Raton, CRC Press, 517–538.
- Lastriyanto, A. 1998. Determination of the edible film permeability to oxygen and carbon dioxide. MSc thesis, Bogor Agricultural University, Indonesia.
- Man, C.M.D. and Jones, A.A. 1994. Shelf life evaluation of foods. London, Bleckie Academic and Professional.
- Nisperos-Carriedo, M.O., Shaw, P.E. and Baldwin, E.A. 1990. Changes in volatile flavor component of pineapple orange as influenced by applications of lipid and composite film. *Journal of Agricultural and Food Chemistry*, 38, 1382–1387.
- Nugroho, L.P.E. 1995. Study on quality preservation of fresh agricultural products under controlled atmosphere conditions. PhD thesis, Tokyo University of Agriculture and Technology.
- O'Connor-Shaw, R.E., Robert, R., Ford, A.L. and Nottingham, S.M. 1994. Shelf life of minimally processed honeydew kiwifruit, papaya, pineapple and cantaloupe. *Journal of Food Science*, 59, 1202.
- Park, H.J., Chinnan, M.S. and Shewfelt, R.L. 1994. Edible coating effect on storage life and quality of tomatoes. *Journal of Food Science*, 56, 568–570.
- Purwadaria, H.K. and Wuryani, S. 1999. Respiration model for edible coated minimally processed mango. Paper presented at the 6th International Mango Symposium, Pattaya, Thailand, 6–9 April 1999.
- Rusmono, M., Wuryani, S. Purwadaria, H.K. and, Syarif, A.M. 1998. Respiration model and concentration gas in the package of modified atmosphere for edible coated minimally processed fresh fruits. Paper presented at the Seminar and Congress PERTETA, Yogyakarta, Indonesia, July 27–28 1998.
- Setiasih, I.S. 1999. Application of edible coating film on minimally processed pondoh salak. Paper presented on Postgraduate Seminar, Bogor Agricultural University Bogor, Indonesia, 22 February 1999.
- Setiasih, I.S., Zulfebriadi, Fardiaz, D. and Purwadaria, H.K. 1998. Characteristics of edible coated minimally processed mango. Paper presented the Seminar and Congress PERTETA, Yogyakarta, Indonesia, July 27–28 1998.
- Shewfelt, R.L. 1987. Quality of minimally processed fruits and vegetables. *Journal of Food Quality*, 10, 143–156.
- Shuler, M.L. and Kargi, F. 1992. Bioprocess engineering. Basic concepts. New Jersey, Prentice Hall.
- Siriphanich, J. 1993. Minimal processing of tropical fruits. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., Postharvest handling of tropical fruits. Proceedings of an international conference held at Chiang Mai, Thailand, 19–23 July 1993. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 127–137.
- Wong, D.W.S., Tilin, S.J., Hudson, J.S. and Pavlath, A.E. 1994. Gas exchange in cut apples with bilayer coatings. *Journal of Agricultural and Food Chemistry*, 42, 2278–2285.
- Wuryani, S. 1999. A simulation model of the shelf life prediction for edible coated minimally processed fruits under the atmospheric condition: Arumanis mango and Pondoh salak. PhD dissertation, Bogor Agricultural University, Indonesia.

# Conservation of Rambutan and Longan in Polyethylene Bags

Do Minh Hien, Thai Thi Hoa and Pham Hoang Lam\*

## Abstract

A major problem of postharvest handling of rambutan and longan is that their skin colour browns within 2 days of harvest because of water loss. The use of plastic films enables an environment of high humidity to be created, resulting in a near-saturated package atmosphere. Polyethylene bags were used to maintain rambutan and longan fruits in combination with low temperature. Fruits harvested in Tiengiang Province were sent to the laboratory for sorting, cleaning and bagging in polyethylene bags. Bagged fruits were stored at 8°C. Good quality of rambutan and longan could be maintained for 2 and 4 weeks after harvest, respectively, without any skin colour changes. In addition, using polyethylene bags reduced weight losses during storage.

LONGAN AND RAMBUTAN are two crops popularly grown in the Mekong River Delta and the south-eastern region of Vietnam. In 1998, longan crops covered nearly 30,000 ha and rambutan over 8,000 ha, with production of about 344,000 t and 158,000 t/year, respectively. The area under cultivation of these crops is expanding every year. However, harvested longan and rambutan fruits have short shelf lives and the fruit rind turns brown within 2–3 days after harvest because of water loss. This problem results in a limited market for the crops, reduced income for the growers, and increases postharvest losses.

Reducing water loss from the fruit skin allows fruit freshness to be maintained. A simple and low-cost measure is to use polyethylene bags to create a high-humidity atmosphere around the fruits. This paper reports some experiments carried out on longan and rambutan.

## Materials and Methods

### Longan

Longan fruit ('Tieu' longan) at the fully mature stage were harvested from trees grown in Tiengiang Province and sent to the laboratory on the same day.

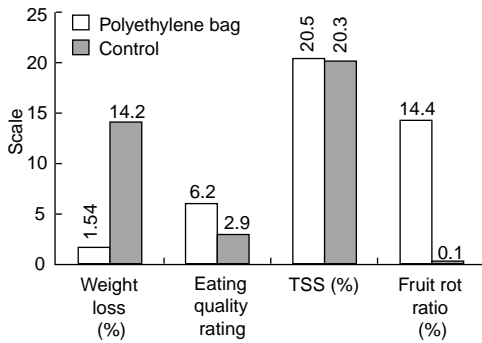
Harvested fruit were trimmed, then sorted to obtain uniform fruit. Selected fruit were washed with tap water and dried using an electric fan. The fruit were divided into two groups—the first group was packed in polyethylene bags (4 µm thickness), and the second was not packed (control). Each group was further divided into two subgroups, one of which was treated with benomyl at a concentration of 500 parts per million (ppm) while the other was not treated. Each subgroup was again divided into two parts—one stored at ambient temperature, and one was stored at 8°C.

Fruit were checked during storage and rated according to: weight loss, eating quality (on a hedonic scale of 1–9), total soluble solids (by refractometer), and fruit rot ratio.

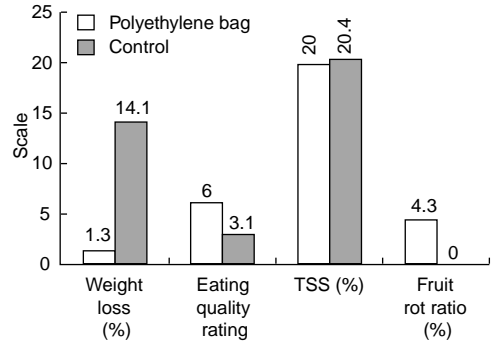
### Rambutan

Fruit ('Java' rambutan) were harvested when the fruit rind reached red in colour. Treatments and experiments were carried out similarly to those described for longan.

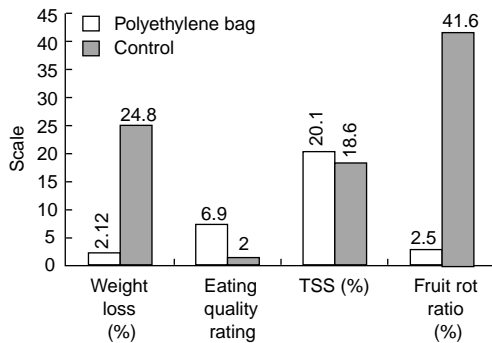
\* Southern Fruit Research Institute (SOFRI), Box 203 My Tho, Tiengiang, Vietnam.



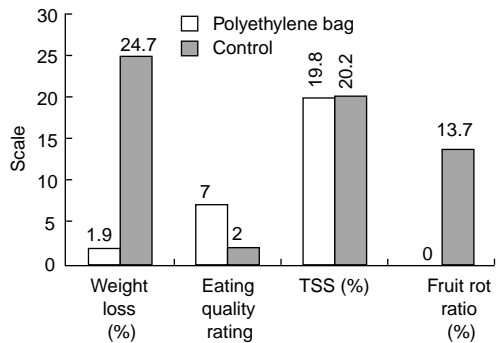
**Figure 1.** Effect of polyethylene bagging on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Tieu’ longan after storage for 7 days at ambient temperature.



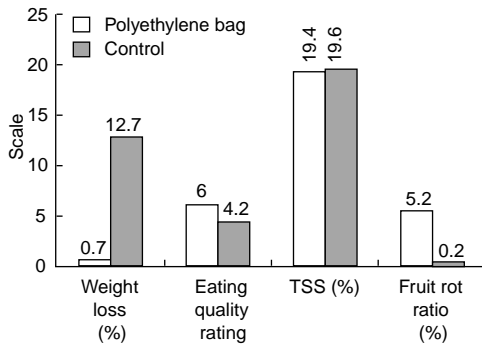
**Figure 2.** Effect of polyethylene bagging in combination with a 500 ppm benomyl treatment on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Tieu’ longan after storage for 7 days at ambient temperature.



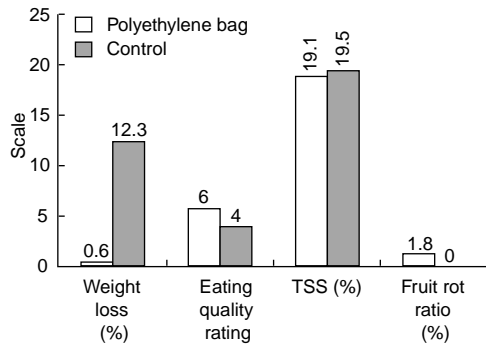
**Figure 3.** Effect of polyethylene bagging on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Tieu’ longan after storage for 28 days at 8°C.



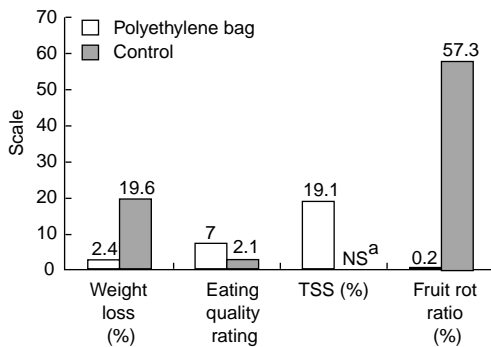
**Figure 4.** Effect of polyethylene bagging in combination with a 500 ppm benomyl treatment on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Tieu’ longan after storage for 28 days at 8°C.



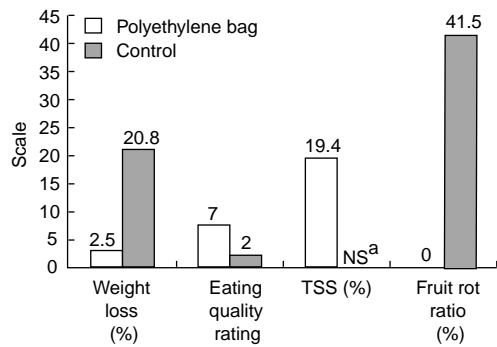
**Figure 5.** Effect of polyethylene bagging on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Java’ rambutan after storage for 5 days at ambient temperature.



**Figure 6.** Effect of polyethylene bagging in combination with a 500 ppm benomyl treatment on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Java’ rambutan after storage for 5 days at ambient temperature.



**Figure 7.** Effect of polyethylene bagging on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Java’ rambutan after storage for 14 days at 8°C. <sup>a</sup> NS = data not shown.



**Figure 8.** Effect of polyethylene bagging in combination with a 500 ppm benomyl treatment on weight loss, eating quality rating (on a scale of 1–9), total soluble solids (TSS), and fruit rot ratio of ‘Java’ rambutan after storage for 14 days at 8°C. <sup>a</sup> NS = data not shown.

## Results and Discussion

Polyethylene bagging of longan fruit increased the relative humidity around the fruit to nearly 90% compared to the atmosphere outside the bags (60–70%), therefore preventing evaporation of water on the fruit skin to the air. This markedly reduced weight loss during storage, maintained the original light colour of the fruit, and the eating quality of bagged fruit was significantly better than fruit that were not bagged in all experiments (Figure 1). However, bagged fruit stored at ambient temperature had a higher percentage of decay than control fruit, even when were treated with benomyl, because pathogens developed rapidly under high humidity and temperature conditions (Figure 2). Thus, at room temperature, polyethylene bagging could only keep fruit in good condition for up to 7 days.

When the storage temperature was lowered to 8°C fungal development was prevented, as shown by the low percentage of decayed fruit. The storage life of fruit could be prolonged to 4 weeks (Figure 3). Benomyl treatments effectively reduce fruit rot, especially in combination with polyethylene bagging and low temperature (Figure 4).

The storage life of rambutan fruit was shorter than longan. External and internal quality could be maintained for 5 days after harvest in polyethylene bags at room temperature, compared to the control which could not be stored for more than 2 days (Figures 5 and 6). Bagging rambutan fruit in combination with benomyl treatment and storage at 8°C extended the shelf life of fruit in good condition for up to 2 weeks, with rind colour retaining its original red colour (Figures 7 and 8). Fruit that were not packed in polyethylene bags and stored at 8°C risked chilling injury at the end of storage. Polyethylene bagging significantly reduced significantly weight loss; this was shown in all treatments.

## Conclusion

- Bagging ‘Tieu’ longan fruits after harvest could maintain quality for 7 days at ambient temperature (28–32°C) and 4 weeks at 8°C.
- ‘Java’ rambutan fruit bagged in polyethylene bags retained good appearance and eating quality for 5 days at room temperature and up to 2 weeks at 8°C after harvest.

# Harvesting Maturity of 'Long' and 'Tieu' Longan in the Mekong Delta, Vietnam

Do Minh Hien and Thai Thi Hoa\*

## Abstract

As 'Long' and 'Tieu' longans become more popular and production of these cultivars increases, it is increasingly important to define the optimum stage for harvesting the fruit. This study investigated the changes in some of the physico-chemical characteristics of the fruit which could be used as maturity indices. To obtain the best quality and yield, 'Long' and 'Tieu' longans in the Mekong Delta should be harvested at 11<sup>th</sup> and 14<sup>th</sup> week after fruit set, respectively.

In the Mekong River Delta, 'Long' and 'Tieu' longan cultivars are becoming popular and there is increasing potential in their production. These two cultivars have been planted in quite a large area and production has reached 344,000 t/year in the region. Although the fruits are small and the seeds are rather big, they have good sensory qualities and trees give high yields. However, the guides for maturity of these cultivars have yet to be determined. It is therefore necessary to define the right time for harvesting to obtain the best quality fruit. This investigation aimed at observing the changes in some physico-chemical characteristics of 'Long' and 'Tieu' longan from which the indices of maturity could be developed.

## Materials and Methods

About 100 clusters of longan inflorescences of each cultivar were tagged at the fruit setting stage. Samples were taken from three trees at an orchard in Tiengiang Province. Fruit set was defined as the time at which the fruit were initially formed and fruit size varied from 1–2 mm in diameter.

Fruit were initially harvested from approximately the 9<sup>th</sup> week ('Long') or 12<sup>th</sup> week ('Tieu') after fruit set, when they had marked changes in appearance and odour. They were then harvested at weekly intervals until marketing quality was unacceptable. Harvested

fruit were sent to the laboratory for analysis on the day they were harvested.

On arrival at the laboratory, 50 fruit harvested at each stage of fruit development were observed for external and internal appearance. The physical characteristics determined were fruit diameter, fruit weight, rind weight, flesh weight and seed weight. Chemical analyses were carried out on the same fruit. The fruit were analysed for total soluble solids (TSS) using a Scale Atago Refractometer.

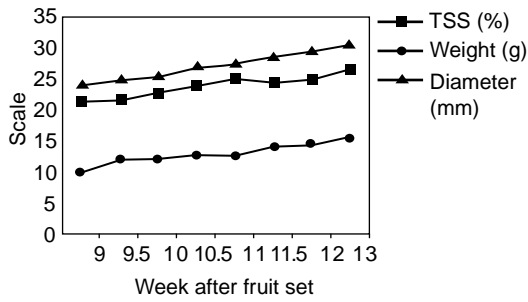
A simple sensory evaluation was also conducted on fruit at particular stages of maturity. The fruit were rated on their acceptability.

## Results and Discussion

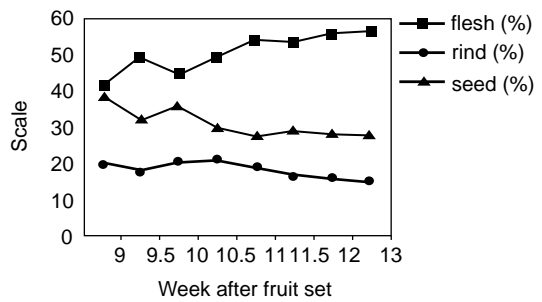
For the 'Long' cultivar, in the 9<sup>th</sup> week after fruit set, fruit ripening was indicated by changes such as: odour became apparent; skin colour changed from green to ivory–white; fruit diameter increased rapidly; and flesh became sweet and juicy. After the 9<sup>th</sup> week, TSS, fruit weight and fruit diameter continued to increase (Figure 1). Increase in fruit weight was mainly due to an increasing flesh ratio (edible), while the proportion of fruit weight belonging to the seed no longer increased, and that of the rind decreased (Figure 2). In the 13<sup>th</sup> week after fruit set, both the TSS and fruit weight kept increasing, however the fruit were overripe, fruit flesh became soft and watery, skin colour changed to brown, and the skin surface was easily attacked by fungus (Table 1).

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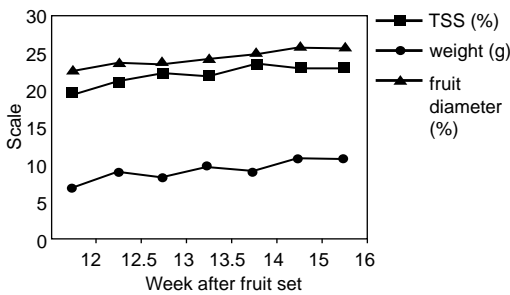




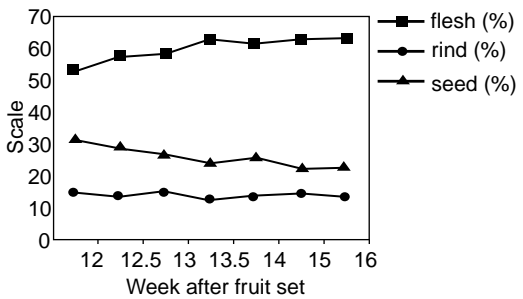
**Figure 1.** Changes in total soluble solids (TSS), fruit weight, and fruit diameter in 'Long' longan after fruit set.



**Figure 2.** Comparative development of the fruit flesh, rind and seed in 'Long' longan after fruit set.



**Figure 3.** Changes in total soluble solids (TSS), fruit weight, and fruit diameter in 'Tieu' longan after fruit set.



**Figure 4.** Comparative development of the fruit flesh, rind and seed in 'Tieu' longan after fruit set.

**Table 1.** Sensory evaluation of fruit quality ('Long' cultivar).

Harvesting stage (weeks after fruit set)	Rind colour	Fruit odour
9	Light green	Odour becomes apparent
9.5	Green with ivory	Very light odour
10	Ivory–white	Light odour
10.5	Ivory–yellow	Specific flavour
11	Light yellow	Strong flavour
12	Light yellow with spots	Declining slightly in flavour
13	Dark yellow	Weak odour

For the 'Tieu' cultivar, fruit ripening took place later compared to the 'Long' cultivar. At the 12<sup>th</sup> week after fruit set, external and internal characteristics changes as shown in Figures 3 and 4, and Table 2. Table 2 also shows that the fruit odour of 'Tieu' longan

was not stronger than that of 'Long' longan. After the 15<sup>th</sup> week, many small black spots appeared on the fruit rind which developed a darker colour due to fungal activity.

**Table 2.** Sensory evaluation of fruit quality ('Tieu' cultivar).

Harvesting stage (weeks after fruit set)	Rind colour	Fruit odour
12	Dark green	Odour can be detected
12.5	80% green, 20% yellow	Very light odour
13	60% green, 40% yellow	Light odour
13.5	40% green, 60% yellow	Light odour
14	100% yellow	Sweet smelling
15	Yellow with small black spots appearing	Light odour
16	Dark yellow spots	Light odour

## Conclusion

Longan fruit of 'Long' and 'Tieu' cultivars should be harvested in week 11 and 14 after fruit set, respec-

tively, for obtaining good quality in appearance, flavour and weight without a decrease in yield.

# Enhancing Philippine Horticultural Postharvest Research, Development and Technology Transfer through Networking, Demonstration and Thesis Support Grants

R.P. Estigoy and A.E. Badua\*

## *Abstract*

The Republic of the Philippines is an archipelago of 7,100 islands. Being an archipelago has many disadvantages in the conduct of research, development and technology transfer projects. Problems associated with this include: overlapping and duplication of research and development (R&D) agenda; uncoordinated implementation of R&D; and unsystematic, fragmented technology transfer projects.

The Bureau of Postharvest Research and Extension (BPRES; formerly NAPHIRE) under the Philippines' Department of Agriculture devised strategies to cope with these above-said problems. A generally unified postharvest R&D agenda has been mapped out through the creation of the Philippine Postharvest R&D network, composed of 22 agencies.

Similarly, the transfer of research based-designs, technologies and information is facilitated through the Technology Demonstration Project. This project aims to systematically disseminate research results in postharvest horticulture and processing to the stakeholders through training, information campaigns and demonstration activities at the Technology Demonstration Centers (TDCs). The Centers have become a venue for hands-on learning opportunities in the latest postharvest technologies among smallholder entrepreneurs before undertaking ventures related to postharvest business. Seven TDCs have been established in different island groups to cover commodities such as potato, mango, squash, carrot and some nuts which are considered high value crops. The TDCs have bridged the gap between business and research.

Another mechanism to speed up the R&D process is the provision of thesis support grants to students who are involved in postharvest research as a requirement for graduation in agricultural colleges and universities. Thesis support grants have already assisted 52 students enrolled in Bachelor of Science, Master of Science and Doctor of Philosophy from 1992–1998. Horticultural crops covered by the research projects include carrot, lemon, banana, papaya, mango, potato, cabbage, onion, and rose. These research results are a take-off point for further generation and development of postharvest technologies.

With these strategies, it is expected that scarce R&D resources are judiciously and efficiently used as a result of coordinated, unified and systematic R&D and technology transfer programs.

## **Rationale**

THE postharvest sector forms a vital link between the production and eventual use of food. Because of this, efforts are being focused on postharvest research and development (R&D). The Philippines, being an archi-

pelago, faces many disadvantages in the conduct of R&D and technology transfer. Added to this, several institutions and agencies are involved in the conduct of postharvest R&D which has resulted in overlapping and duplication of R&D efforts as these efforts have not been coordinated. This has resulted in wasteful and inefficient use of scarce resources. It has also promoted inefficient strategies for addressing the various ills of the postharvest sector. When research results are disseminated to end users the same

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problems arise. Extension strategies are fragmented and unsystematic, and this negates the gains of R&D.

The Bureau of Postharvest Research and Extension (BPRE) is mandated to spearhead the generation, application and extension of appropriate postharvest technologies for agricultural crops and other food and feed commodities. Its aim is to minimise quantitative and qualitative food losses in the production–postproduction chain.

To realise its mandate, it needs to devise schemes to address the above-mentioned problems. As such, the Bureau created the Philippine Postharvest Research and Development Collaborative Network (PhNet), and implemented the technology demonstration project and thesis support grants. This paper discusses the features of each strategy.

## **The Philippine Postharvest Research and Development Collaborative Network (PhNet)**

Started in 1996, PhNet aims to institute a network that can address the various postharvest problems and thereby fast-track technology development and dissemination. PhNet formulates and evaluates strategies and plans to effectively implement and carry out the programs, projects and activities on postharvest handling and processing of strategic commercial crops.

### **Organisation and management**

A management committee (MANCOM) provides the framework and formulates the policies, thrusts and strategies of PhNet.

The Commodity Co-ordinating Committee formulates R&D plans for commodity concerns, evaluates and recommends, monitors R&D activities on perishables, durables, industrial and root crops. A secretariat based at BPRE was also created to backstop these committees.

### **Terms of collaboration**

A separate memorandum of agreement (MOA) defines the specific terms of collaboration which include: the approval and effectiveness of the project; the manner and release of finances, obligation, appointments, cooperation, ownership; and utilisation of inventions, discoveries and improvements. In general, discoveries, technologies and information,

invention, and improvements that generated from R&D are jointly owned by the collaborator and BPRE.

### **Status of PhNet activities**

The commodity coordinating committees have prepared their program frameworks on perishables, durables, industrial crops and root crops. PhNet took two years to prepare the program frameworks and project proposals are yet to be implemented.

### **Benefits of networking**

Member agencies, specifically state college and universities, are equipped with R&D facilities and have ongoing R&D work on postharvest topics. Likewise, there are existing experts on postharvest R&D covering a wide gamut of disciplines. Added to this, almost all R&D agencies have existing extension programs and facilities.

#### *Research and development agencies*

1. Bureau of Postharvest Research and Extension
2. Philippine Council for Agriculture Forestry and Natural Resources Research and Training Centre
3. Central Luzon State University
4. Benguet State University
5. Camarines Sur State Agricultural College
6. Western Luzon Agricultural College
7. Mariano Marcos State University
8. University of the Philippines at Los Baños
9. Philippine Rootcrops Research and Training Centre
10. Central Mindanao University
11. Visayas State College of Agriculture
12. Isabela State University
13. Northern Philippines Rootcrops Research and Training Centre
14. University of Southeastern Philippines
15. Tarlac College of Agriculture
16. Don Severino Agricultural College
17. Fiber Industry Development Authority
18. Bureau of Agricultural Research
19. University of Southern Mindanao
20. Bureau of Plant Industry
21. State Polytechnic College of Palawan
22. Bicol University

## Future project

A journal of R&D results in postharvest is targeted to be published to consolidate information for easy access and dissemination.

### Establishment of Postharvest Demonstration Centres for High Value Crops

These centres were established because of the huge postharvest losses (40–50%) of high value crops. Fruits and vegetables require efficient postharvest handling to reduce these losses. The centres provide a support system to showcase existing technologies in postharvest handling and processing of high value crops.

The centres serve as venues for technology transfer using micro, small-scale and village-level postharvest and processing equipment. They serve as an indispensable primary step towards encouraging and preparing smallholder-entrepreneurs (SHEs) to engage in postharvest and processing activities. Would-be investors can gain exposure and expertise on value-adding activities of horticultural produce. Consequently, these SHEs become more confident to engage in micro or small-scale enterprise related to postharvest or processing of high value crops.

### Objectives of the project

The overall objective of the project is to promote the commercial use of improved postharvest processing technologies, facilities and equipment of selected commercial crops in order to increase income derived from value-added processing operations and reduce postharvest losses.

Specifically, the project aims to:

1. Accelerate the utilisation of postharvest and processing technologies for high value crops among various stakeholders, especially smallholder-entrepreneurs.
2. Encourage the participation of various stakeholders, especially smallholder-entrepreneurs, in the postharvest and processing operations of high value crops.
3. Provide equitable access and opportunities to various stakeholders, especially smallholder-entrepreneurs to communication systems, and training, technical and support services.

4. Provide an opportunity for the local government units (LGUs) to generate additional income through the provision of custom servicing and/or rental of the Technology Demonstration Center (TDC) equipment/facilities to their interested constituents.
5. Document the processes and effects of technology utilisation in the local community.
6. Provide an opportunity for developed postharvest technology to be demonstrated for possible commercial utilisation.
7. The TDC serves as 'one-stop-information-shop' for stakeholders involved in the commodity.

### Project description

The Technology Demonstration Center (TDC) Project for High Value Crops (Postharvest) showcases more efficient and effective technologies that already exist but which have not been sufficiently promoted and/or others that have been recently developed by research on postharvest handling and processing of commercial crops. This includes the postharvest and commercial processing of white potato, cashew, mango, squash, carrot, pili nut and other crops. A total of seven TDCs have been established nationwide. Commercial-scale models of different postharvest handling and processing facilities/equipment of high value commercial crops are installed to provide first-hand familiarisation for farmers on such technologies and processes.

Generally the TDCs' main function is to serve as hands-on laboratories for the training of smallholder-entrepreneurs, such as farmers, housewives, businessmen, processors, and other parties interested in the processing of their produce. General and specialised training courses on postharvest technology and processing are conducted in the centres. TDCs function as channels for the spread of new livelihood opportunities for farm households and develop interaction among farmers and government officials. They also serve as 'one-stop-information-shops' for the commodity concerned. Farmer-growers, entrepreneurs and other stakeholders who need training and information can avail themselves of these services.

In addition, The TDC is envisioned to be operated by the local government unit (LGU). Thus, during the times that these facilities are not used for training, the LGU can operate the TDC to provide custom services on postharvest and processing to its various clients. Furthermore, the LGU can rent/lease the facilities to

interested users for certain period to further maximise its benefits. The LGU staff members who are assigned in the TDC have been intensively trained by BPRE in collaboration with state colleges and universities and other allied research agencies on the rudiments of the actual operation and management of the TDC. The LGU staff provide the necessary skills and expertise for successfully operating the TDC as a service enterprise.

Research activities are to be integrated at the TDC to document technology adoption. This will provide feed forward and feedback mechanisms and guide directions for further research and development activities.

Specifically, it will determine the correlates—factors associated with the adoption and commercialisation of these technologies. This will generate empirical data regarding correlates of adoption and commercial utilisation. Similarly, it will find out the eventual effects of adoption on the technological, socioeconomic and institutional sectors of end users and their communities.

## Project implementation

Tables 1, 2 and 3 provide details of the Technology Demonstration Centers established to date.

**Table 1.** Locations, target commodities, postharvest/processing technologies and facilities at the Technology Demonstration Centers established to date.

Location	Commodity	Existing postharvest/processing technologies	Facilities installed
La Trinidad, Benguet	Potato and carrot	Potato postharvest care and handling	Multi-crop dryer Slicer
Muñoz, Science City	Mango	Mango postharvest care and handling	Hot water tank Multi-purpose dryer Slicer
Gubat Sorsogon <sup>a</sup> Roxas, Palawan	Pili Cashew and mango	Cashew and mango postharvest care and handling	Cashew nut sheller Hot water tank Multi-purpose dryer Slicer
Jordan, Guimaras	Mango and cashew	Cashew and mango postharvest care and handling	Cashew nut sheller Hot water tank Multi-purpose dryer Slicer
Malaybalay, Bukidnon	Potato and squash	Potato postharvest care and handling	Roller cutter Multi-purpose dryer Slicer
Digos, Davao del Sur	Mango and potato	Mango and potato postharvest care and handling	Multi-purpose dryer Hot water tank Slicer

<sup>a</sup> Newly established centre

**Table 2.** Activities conducted at the Technology Demonstration Centers (1998–1999).

Location	Training and demonstrations		Information campaigns (IC)		Research
	Number of sessions	No. of participants	Number of sessions	No. of participants	Number of projects
La Trinidad, Benguet	6	170	8	321	–
Muñoz, Science City	4	180	7	145	–
Gubat Sorsogon <sup>a</sup>	5	179	2	35	–

<sup>a</sup>Newly established centre

**Table 2.** (Cont'd) Activities conducted at the Technology Demonstration Centers (1998–1999).

Location	Training and demonstrations		Information campaigns (IC)		Research
	Number of sessions	No. of participants	Number of sessions	No. of participants	Number of projects
Roxas, Palawan	20	292	7	529	–
Jordan, Guimaras	7	473	25	511	4
Malaybalay, Bukidnon	5	345	6	100+	–
Digos, Davao del Sur	16	947	15	1,130	–

<sup>a</sup>Newly established centre

**Table 3.** Technology Demonstration Center (TDC) project locations.

TDC	Location
Benguet	Wangal, La Trinidad, Benguet ( Cordillera Administrative Region)
Muñoz Science City	Catalanacan, Muñoz Science City (Region 03)
Sorsogon	Gubat, Sorsogon (Region 05)
Palawan	Roxas, Palawan (Region 04)
Guimaras	San Miguel, Jordan, Guimaras (Region 06)
Malaybalay	Capitol Site, Malaybalay, Bukidnon (Region 11)
Davao del Sur	Agriculture's Compound, Digos, Davao del Sur (Region 11)

## Thesis and Dissertation Support Project

### Background and rationale

Government agencies involved in R&D often practice applied research. Conduct of basic research is usually within the confines of the academic community.

Basic research is the building block of technology generation and application. Hence, it is important that in any conduct of action-oriented and problem-focused R&D, basic research be a requisite.

With this in mind, the BPRE devised a linking mechanism with state colleges and universities. BPRE through its University Training and Extension Program on Postharvest grants thesis/dissertation support to students pursuing postharvest-related studies.

Output of these students could provide a reliable premise for further development of technologies or in formulating policies geared towards improving the postharvest industry.

### Objectives

This project serves as a venue for the continuous conduct of basic and, to some extent, applied research. Specifically, its aim is to generate more data and information on postharvest which could serve as inputs in the conduct of applied R&D works, to tap the academic resources in the conduct of postharvest R&D, to build up postharvest industry manpower via the academic community, and to encourage students to establish a career in postharvest R&D.

### Who may apply

Qualified applicants are bonafide students of any college or university with average or above-average class standing, of good moral character and who are not recipients of any other scholarship or grant.

### Amount of grant

Bachelor's Degree	P15,000.00
Masters Degree	P30,000.00
Doctoral Degree	P50,000.00

## Scope

All proposals should address information gaps on postharvest issues and problems related to the Medium Term Agricultural Development Program, i.e. studies on high value crops.

## Intellectual property rights

All outputs of the theses/dissertations are jointly owned by the BPRE, the school and the grantee-researcher. Any publication arising from the conduct of the research or other activities undertaken under the memorandum of agreement (MOA) shall identify BPRE as the source of outputs.

The BPRE reserves the right to use all data and findings of the research projects in the pursuit of its research programs. The grantee shall, however, be added/duly acknowledged in the reports.

Patents may be applied for within the school for technologies found to be suitable for commercialisation. BPRE and the researcher are the patent owners.

## Status

Tables 4, 5 and 6 give the names of the grantees awarded Bachelor of Science (Table 4), Master of Science (Table 5) and Doctor of Philosophy (Table 6) degrees from 1992–1999 and the titles of their theses.

**Table 4.** Bachelor of Science grantees (1992–1999).

Name	Title of thesis
Valencia, Hector G.	Design and development of coconut milk extractor
Vales, Raquel G.	Design, construction and performance testing of essential oil extractor
Empleo, Herminia C.	Design, construction and performance testing of a root crop rotary cleaner/washer
Dela Austria, Elias Jr. A.	Design, construction and testing of pili nut oil extractor
Falla, Ma. Cristina B.	Effects of edible coatings and films on the fungi-infected mango fruits
Polsito, Concepcion K.	Postharvest evaluation of carrots washed using a manually-operated carrot washer
Rogelio, Marivic A.	Effects of methods of waxing on the shelf-life of calamansi fruits ( <i>Citrus mandurensis</i> )
Pascual, Christopher A.	Performance evaluation of three manually-operated cashew nut decorticators
Zamora, Jonathan A.	Effect of different levels of ethylene scrubber on the postharvest life of Lacatan banana ( <i>Musa</i> sp. var. Lacatan)
Bute, Ailyn M.	The effect of different ripening substrates on the occurrence of postharvest diseases of mango
Waclin, Malonia S.	Breaking dormancy of potato ( <i>Solanum tuberosum</i> cv. Granola) tubers With various ethephon concentrations
Caouli, Reynold C.	Design, construction and evaluation of a cashew nut shell liquid (CNSL) extraction machine
Rentutar, Estrellita I.	Occurrence of diseases and shelf-life of banana var. Lakatan in response to postharvest treatments
Sumcad, Betty A.	Control of bacterial softrot of cabbage, chinese cabbage and lettuce using alum
Nebsan, Carmelita S.	Benchmark information on the common postharvest losses of lettuce at La Trinidad Trading Post
Cambari, Edna V.	Occurrence of postharvest diseases and shelf-life of papaya ( <i>Carica papaya</i> ) var. Solo in response to storage practices
Castillo, Jose Edwin L. and Orpilla, Dexter L.	Design, fabrication and performance test of onion grader by weight basis



**Table 4.** (Cont'd) Bachelor of Science grantees (1992–1999).

Name	Title of thesis
Ladiao, Jaime Z. and Tuates, Andres Jr. M.	Modification, fabrication and performance test of an onion grader by size
Dapat, Joy Ruth D.	Shelf-life quality of roses ( <i>Rosaceae</i> spp.) in response to postharvest treatments, packaging and storage conditions
Ramos, Chyrel A.	Longevity and quality of gladiolus ( <i>Gladiolus grandiflorus</i> L.) var. Carqueranni cutflower in response to postharvest treatments and polyethylene sleeve
Barra, Elvie G.	Fungal incidence in stored pili kernels treated with tuba seed
Mira, Wilfredo B.	Identification of postharvest insect pests in pili
Abonado, Jeunah B.	Knowledge gained on Burong Mangga preparation messages communicated via Teknogiya by some housewives in Brgy. Rizal, Bansalan, Davao Del Sur
Cartagena, Luz A.	Knowledge gained from multi-lingual leaflet disseminating banana flour making technology among Maguindanaoans in Malamote, Matalam, Cotabato
Hora, Mariedith C.	Knowledge gained on mango puree preparation messages communicated via bilingual leaflet by mango growers in Sangat, Mlang, Cotabato
Dela Cruz, Arminda E.	Development of a technology package for the postharvest handling of peanut in prevention of aflatoxin contamination
Cervantes, Honeylee Faith C.	Moisture sorption properties of selected seedboard-approved Philippine variety peanuts

**Table 5.** Master of Science grantees (1992–1999).

Name	Title of thesis
Calica, Helen R.	Postproduction practices and training needs of cashew farmers in San Marcelino, Zambales and Limay, Bataan
Capariño, Ofero A.	Mango powder production by freeze drying process
Tolentino, Genaro M.	Effect of pre-conditioning treatments and degree of dryness on the extraction and quality of cashew kernel
Mohammad Yamin	Sprout and rotting inhibition of onion through MH-30 application, curing, bagging and cold storage
Velilla, Allan D.	Ethylene production and pectic enzyme activity in papaya ( <i>Carica papaya</i> L. cv. 'Solo') fruit infected by <i>Lasiodiplodia theobromae</i> (Pat) Griff. and Maubl.
Marañon, Ramon P.	The effect of location and harvest season on the histo-physiological characteristic of Guimaras grown mango
Artes, Leonisa A.	Role of CO <sub>2</sub> , O <sub>2</sub> and C <sub>2</sub> H <sub>4</sub> in the development of ripening disorders in 'Saba' banana

**Table 6.** Doctor of Philosophy grantees (1992–1999).

Name	Title of thesis
Roldan, Marissa B.	Anatomical and biochemical mechanism of tissue hardening in heat-treated ‘Solo’ papaya ( <i>Carica papaya</i> L.) fruits
Dela Cruz, Anselmo Q.	Astringency removal in cashew ( <i>Anacardium occidentale</i> L.) apple treated with carbon dioxide and ethanol
Anterola, Marrietta G.	An exploratory study of gender participation in selected mango postharvest activities on Region III
Abon, Carlos Jr.	Production and postharvest activities on soybean
Amestoso, Felix J.	Single screw extrusion processing of sweet potato flour into artificial grains for snacks
Mpayamaguru, Josue	Correlates to soybean processing technology adoption for utilisation in human diet in selected towns of Nueva Ecija

## Conclusion

With these strategies, it is expected that scarce R&D resources will be judiciously and efficiently used as a result of coordinated, unified and systematic R&D and technology transfer programs.

# Foliar Application of Benzothiadiazole and Protection of Postharvest Rockmelons and 'Hami' Melons from Disease

Y. Huang\*, B.J. Deverall\*, W.H. Tang†, W. Wang†, F.W. Wu§ and R. Li¶

## Abstract

A pre-flowering foliar spray of an activator benzothiadiazole (BTH) at 50 mg/L a.i. combined with a fruit dip in the fungicide guazatine at 500 mg/L a.i. at harvest substantially decreased disease in stored melons. Major diseases occurring on the tested rockmelons and 'Hami' melons were caused by *Fusarium* spp., *Alternaria* spp., *Rhizopus* spp. and *Trichothecium* sp. The BTH treatment alone was significantly effective in many but not all situations. Guazatine alone significantly decreased infection by *Fusarium* spp. but had a lesser effect on that caused by *Alternaria* spp. and *Rhizopus* spp.

CURRENTLY there is a lack of effective control measures against *Rhizopus* and *Alternaria* rots. Control of other diseases is dependent on the application of protectant fungicides such as guazatine (Wade and Morris 1983). Further research is required because the use of fungicides is becoming restricted due to concerns for the environment and health, as well as the increased cost of developing new fungicides. Withdrawal of some fungicides, such as benomyl that was used in the postharvest treatment of melons in Australia and captan for control of postharvest diseases, is a clear signal for this requirement (Janisiewicz 1991).

Systemic induced resistance (SIR) is under extensive investigation for the minimisation of plant diseases, and has been demonstrated in several plant families (Kessmann et al. 1994; Hammerschmidt and

Kuc 1995). Biotic inducers of systemic resistance in the cucurbit family include locally infecting fungal pathogens (Caruso and Kuc 1979; Martyn et al. 1991). Synthetic activators such as dichloroisonicotinic acid and benzothiadiazole (BTH) have been reported to cause SIR in cucurbits and other crop species (Métraux et al. 1991; Friedrich et al. 1996; Görlach et al. 1996).

This paper explores the effect of the activator BTH as a foliar spray in melons on the susceptibility of the fruit to postharvest pathogens during storage, and its potential when combined with a protective fungicide to provide a new control system against postharvest disease.

## Materials and Methods

Benzo (1,2,3) thiadiazole-7-carbothioic acid S-methyl ester (BTH, CGA 245704), formulated as 50% a.i. in wettable granules, was obtained from Novartis Crop Protection Australasia. Guazatine formulated in liquid was provided by Rhone-Poulenc Rural Australia.

Crops of 'Eldorado' rockmelon were grown at a farm in Mildura, Victoria, Australia. BTH at 50 mg/L a.i. was sprayed onto the melon crops before blossom.

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Melons were harvested 8 weeks after treatment. Melons were sorted for uniform size and absence of obvious injuries, then washed for 1 min in a solution providing 100 parts per million (ppm) available chlorine. Half of the melons from each field regime were dipped in guazatine 500 mg/L a.i. for 1 min. Melons were then placed in cartons. The cartons were then kept at 2–8°C for 3 weeks. Four treatments were compared: control; BTH preharvest spray; guazatine postharvest dip; and BTH preharvest spray plus guazatine postharvest dip. Three replicates were established for each of the four treatments.

Crops of ‘Early Yellow Hami’ melons were grown and treated in a similar way in Xinjiang Province, China, except that the melons were harvested at full maturity 7 weeks after spraying of the foliage, and storage was on 5 cm thick straw layers at room temperatures of 26–29°C for 9 days.

Each melon was inspected after storage and results recorded as the percentage of total melons, firstly with any symptoms, and secondly with specific types of rot. Fungi associated with rots in ‘Hami’ melons were isolated, established in pure culture and used to re-inoculate healthy melons, which were kept at 20–25°C for 48 h. Fungi that caused rots were then identified by microscopic inspection of mycelia and spores.

Estimates of disease severity were made for some experiments based on the numbers and areas of lesions according to the scale: 0 = no symptoms; 1 = one lesion less than 1 cm in diameter; 2 = one lesion between 1–3 cm, or two lesions each with an area less than 2 cm; 3 = one lesion larger than 3 cm but smaller than 5 cm, or two lesions each larger than 2 cm but

smaller than 3 cm; 4 = one lesion > 5 cm, or more than 3 lesions. The percentage data were transformed to arcsine and analysed, to give disease severity =  $Z$  (rating of each symptom)/number of melons. Least significant differences were used to assess the effects of treatments.

## Results

Application of BTH to rockmelon foliage before flowering had a major effect on the disease susceptibility of fruit produced on the farm in Mildura, Australia. There was a significant decrease in the incidence of disease after low temperature storage of the fruit (Table 1). A postharvest application of guazatine to the fruit had a greater effect, and the use of both applications in succession almost prevented disease.

In this experiment, *Alternaria* rot was a major disease, occurring on the sides of rockmelons that had touched the ground during crop growth. These sides were soft and fragile when the fruit were removed from storage and yielded typical symptoms of *Alternaria* rot 2 days later, where no treatments had been applied. In contrast, comparable sides were firm after the application of both treatments in succession, but less frequently after one treatment alone. *Fusarium* rot mainly occurred on the stem-end scars of melons which received no treatments and its incidence was significantly decreased by pre-flowering application of BTH and prevented by a postharvest dip of fruit in guazatine alone (Table 1).

**Table 1.** Effect of benzothiadiazole (BTH) and guazatine on disease in ‘Eldorado’ rockmelons after storage.<sup>a</sup>

Treatment	Diseased	Percentage of fruit <sup>b</sup> infected by	
		<i>Alternaria</i>	<i>Fusarium</i>
Control	88.5 a	55.6 a	50.0 a
BTH	55.6 b	32.5 b	26.6 b
Guazatine	21.8 c	21.6 c	0.0 e
BTH +guazatine	2.0 d	2.0 d	0.0 e

<sup>a</sup> BTH (50 mg/L a.i.) was applied as a spray to foliage in 1997 before flowering. Guazatine (500 mg/L a.i.) was applied as a fruit dip after harvest. The melons were stored at 2–8°C for 3 weeks.

<sup>b</sup> Figures followed by different letters within the first column and separately in the last two columns were significantly different at 5% by least significant difference (LSD).

Experiments of a similar design were carried out in Xinjiang, China, but using ‘Hami’ melons and post-harvest storage at room temperature. Fungi isolated from diseased ‘Hami’ melons were *Fusarium chlamydosporum*, *F. equiseti*, *F. semitectum*, *F. culmorum*, *F. sambucinum*, *F. oxysporum* ssp. *cucumerinum* and *F. moniliforme* var. *subglutinans*, *Alternaria pluriseplate* and *A. alternata*, *Rhizopus stolonifer* and *R. arrhizus*, and *Trichothecium roseum*. Minor pathogens included *Penicillium* spp. and *Geotrichum candidum*.

*Fusarium* rot had the highest incidence, occurring at the stem end and in cracks on the skin surface. *Alternaria* rot mainly occurred at places that had touched the ground during growth. *Rhizopus* rot was mainly on the sides of fruit. *Trichothecium* rots were found randomly at the stem end, flower end, and on the sides of fruit. Either pre-flowering application of BTH or a postharvest dip of fruit in guazatine reduced overall disease, but BTH did not decrease *Trichothecium* rot (Table 2). Successive treatments were no more beneficial in minimising total disease, but they were effective against the *Alternaria* and *Rhizopus* rots.

## Discussion

The experiments confirmed that postharvest diseases in rockmelons include *Alternaria*, *Fusarium* and *Rhizopus* rots, and showed that these diseases were also responsible for loss in ‘Hami’ melons in China. Guazatine gave quite effective control of *Fusarium* and *Rhizopus* rots, but was less effective against *Alternaria* rot, especially in prolonged storage of rockmelons. No fungicide is registered in China for the protection of postharvest melons, and guazatine is the only fungicide that the Australian melon industry

currently relies on for this purpose. The potential for reinforcement of this method and a widening of its effectiveness against all major pathogens was shown by its use as a postharvest dip combined with BTH as a preharvest foliar spray.

One spray of BTH to leaves of melon crops prior to flowering without postharvest treatment decreased the incidence and extent of postharvest diseases to some degree. This remarkable result opens a new approach to minimisation of postharvest melon diseases, because BTH has no direct anti-microbial action, but it has given protection in several other plant species through the induction of systemic resistance (Friedrich et al. 1996; Görlach et al. 1996; Lawton et al. 1996; Siegrist et al. 1997; Dann et al. 1998; Jensen et al. 1998). BTH, therefore, is hypothesised to decrease postharvest disease in melon after foliar application by activating systemic resistance, as it is reported to do in cucumber roots after foliar application (Benhamou and Belanger 1998).

## Acknowledgments

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**Table 2.** Effect of benzothiadiazole (BTH) and guazatine on disease in ‘Early Yellow Hami’ melons after storage.<sup>a</sup>

Treatment	Diseased	Percentage of fruit <sup>b</sup> infected by			
		<i>Alternaria</i>	<i>Fusarium</i>	<i>Rhizopus</i>	<i>Trichothecium</i>
Control	73.5 a	25.4 c	53.3 a	21.9 c	9.3 e
BTH	50.0 b	13.0 de	44.3 b	1.2 g	8.8 e
Guazatine	29.7 c	10.0 de	11.6 de	1.2 g	0.0 h
BTH + guazatine	23.2 c	4.5 f	15.7 d	0.0 h	10.0 de

<sup>a</sup> BTH (50 mg/L a.i.) was applied as a spray to foliage on in 1998 before flowering. Guazatine (500 mg/L a.i.) was applied as a fruit dip after harvest. The melons were kept on a straw layer (5 cm thick) at room temperature for 9 days.

<sup>b</sup> Figures followed by different letters within the first column and separately in the last four columns were significantly different at 5% by least significant difference (LSD).

## References

- Benhamou, N. and Belanger, R.R. 1998. Induction of systemic resistance to *Pythium* damping-off in cucumber plants by benzothiadiazole: ultrastructure and cytochemistry of the host response. *The Plant Journal*, 14, 13–21.
- Caruso, F.L. and Kuc, J. 1979. Induced resistance of cucumber to anthracnose and angular leaf spot by *Pseudomonas lachrymans* and *Collectotrichum lagenarium*. *Physiology Plant Pathology*, 14, 191–201.
- Dann, E., Diers, B., Byrum, J. and Hammerschmidt, R. 1998. Effect of treating soybean with 2,6-dichloroisonicotinic acid (INA) and benzothiadiazole (BTH) on seed yields and the level of disease caused by *Sclerotinia sclerotiorum* in field and greenhouse studies. *European Journal of Plant Pathology*, 104, 271–278.
- Friedrich, L., Lawton, K., Ruess, W., Masner, P., Specker, N., Gut Rella, M., Meiers, B., Dincher, S., Staub, T., Uknes, S., Métraux, J.-P., Kessmann, H. and Ryals, J. 1996. A benzothiadiazole derivative induces systemic acquired resistance in tobacco. *The Plant Journal*, 10, 61–70.
- Görlach, J., Volrath, S., Knauf-Beiter, G., Hengy, G., Beckhove, U., Kogel, K.H., Oostendorp, M., Staub, T., Ward, E., Kessmann, H. and Ryals, J. 1996. Benzothiadiazole, a novel class of inducers of systemic acquired resistance, activates gene expression and disease resistance in wheat. *Plant Cell*, 8, 629–643.
- Hammerschmidt, R. and Kuc, J. (ed.) 1995. *Induced resistance to disease in plants*. Amsterdam, Kluwer Academic Publishers.
- Janisiewicz, W.J. 1991. Control of postharvest diseases of fruit with biocontrol agents. In: Bay-Petersen, J. ed., *The biological control of plant diseases*. Based on proceedings of the international seminar: Biological control of plant diseases and virus vectors, Japan, 17–21 September 1990, 215p.
- Jensen, B.D., Latunde-Dada, A.O., Hudson, D. and Lucas, J.A. 1998. Protection of *Brassica* seedlings against downy mildew and damping-off by seed treatment with CGA 245704, an activator of systemic acquired resistance. *Pesticide Science*, 52, 63–69.
- Kessmann, H., Staub, T., Hofmann, C., Maetzke, T., Herzoc, J., Ward, E., Uknes, S. and Ryals, J. 1994. Induction of systemic acquired resistance in plants by chemicals. *Annual Review of Phytopathology*, 32, 439–459.
- Lawton K.A., Friedrich, L., Hunt, M., Weymann, K., Delaney, T., Kessmann, H., Staub, T. and Ryals, J. 1996. Benzothiadiazole induces disease resistance in *Arabidopsis* by activation of the systemic acquired resistance signal transduction pathway. *The Plant Journal*, 10, 71–82.
- Martyn, R.D., Biles, C.L. and Dillard, E.A. 1991. Induced resistance to *Fusarium* wilt of watermelon under simulated field conditions. *Plant Disease*, 75, 874–877.
- Métraux, J.P., Ahl Goy, P., Staub, T., Speich, J., Steinmann, A., Ryals, J. and Ward, E. 1991. Induced systemic resistance in cucumber in response to 2,6-dichloroisonicotinic acid and pathogens. In: Hennecke, H. and Verma, D.P.S. ed., *Advances in molecular genetics of plant–microbe interactions*, volume 1. Dordrecht, Kluwer Academic Publishers, 432–439.
- Siegrist, J., Glenewinkel, D., Kolle, C. and Schmidtke, M. 1997. Chemically induced resistance in green bean against bacterial and fungal pathogens. *Journal of Plant Diseases and Protection*, 104, 599–610.
- Wade, N.L. and Morris, S.C. 1983. Efficacy of fungicides for postharvest treatment of muskmelon fruit. *HortScience*, 18, 344–345.

# Using Perforated Plastic Packaging for Extending the Shelf Life of Okra Pods

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## Abstract

Perforated plastic bags were tested for use in extending the shelf life of okra pods (*Abelmoschus esculentus* L. Moench). Okra pods were packed in four different types of perforated plastic bags: (1) 4 holes, polyethylene bag; (2) 12 holes, polyethylene bag; (3) 4 holes, polypropylene bag; and (4) 12 holes, polypropylene bag. Packed okra pods were stored at 10°C for 10 days. Firmness, fibre content, weight loss, gas composition, visual appearance, and shelf life of okra pods were determined during storage. The results showed no significant differences in either the gas concentrations within the packages nor the firmness and fibre content of the okra pods. However, okra pods packed in polypropylene bags perforated with four holes had the best visual appearance and lower weight loss than the other treatments and resulted in an extension of the shelf life of good quality okra pods from 6 days to 10 days.

OKRA, *Hibiscus esculentus* L. (*Abelmoschus esculentus* (L.) Moench), is a tropical vegetable of high export potential. It is desirable to harvest okra pods daily or frequently at the young and tender stage, since mature pods become fibrous and tough (Snowdon 1991). The immature fruit are used as a boiled or fried vegetable. They are particularly popular for adding to soups and stews. Okra pod is a non-climacteric fruit/vegetable which has a high respiration rate, is extremely perishable (Hardenburg et al. 1986), and is prone to discoloration and toughening (Snowdon 1991). The immature pods have a very high respiration rate and their metabolism changes rapidly, resulting in a short storage life. High quality pods should be bright green, firm, and free from yellow blemishes. Soft and high fibre content pods are of low quality and will be rejected by consumers.

Modified atmosphere storage was reported to be effective in extending the storage life of okra (Anandaswamy 1963). In Thailand, packaging of fresh horticultural produce using various plastic bags has been shown to be useful for extending their shelf life. However, fresh produce like okra stored in such packages in cold storage—commonly found in retail

markets—has a limited shelf life due to desiccation, decay or injury caused by excessive moisture. Condensation is an important problem for the conservation of fresh horticultural produce. Presence of free water on the surface of the produce enhance risks of fungal growth and often leads to a bad appearance which makes the produce unsaleable (Kader 1991).

The main aim of this research was to determine the effect of perforated plastic bags in reducing water loss and biochemical changes in fresh okra packages. Moreover, the number of perforations per package and the type of plastic bags most suitable for the optimal conservation of okra were determined.

## Materials and Methods

### Sample preparation

Okra pods (*Abelmoschus esculentus* L. Moench) were hand-harvested using a knife. They were transported from Ratchaburi Province in the western part of Thailand to the Postharvest Laboratory at King Mongkut's University of Technology Thonburi by air-conditioned bus within 4 hours and stored at  $10 \pm 3^\circ\text{C}$  and  $87 \pm 10\%$  relative humidity (RH). Experimental samples which were uniform green in colour and 8–10 cm long were selected. Samples were then randomly

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divided into four groups (treatments). Each group had four replications of eight pods per replication.

The bags used were approximately 15 × 23 cm (6 × 9 inches). Two kinds of perforated plastic bag were tested—polypropylene and polyethylene. The diameter of each hole (perforation) was 0.5 cm.

## Monitoring of gas composition

The gas composition within each bag was monitored during storage using gas chromatography. 1 mL of internal gas was withdrawn from each bag using a gastight syringe fitted with a 25 G stainless steel needle. Gas samples were analysed for O<sub>2</sub> and CO<sub>2</sub> by injection into a gas chromatograph fitted with a thermal conductivity detector equipped with a stainless steel column (3 mm × 1.5 m) containing porapak Q (80/100 mesh) (Shimadzu, GC-8A, Japan). The temperature of the injector and detector was 100°C and the column temperature was 50°C. Helium was used as the carrier gas. C<sub>2</sub>H<sub>4</sub> was determined by injecting 1 cc of internal gas atmosphere into a gas chromatograph fitted with a flame ionisation detector equipped with a stainless steel column (3.2 mm × 2.5 m) containing 20% carbowax 20 m, 60/80 mesh (Shimadzu, GC-14B, Japan). The temperature of the injector and detector was 120°C and the column temperature was 85°C. Nitrogen was used as the carrier gas.

## Analytical methods

*Percentage weight loss.* Determined by comparing the average weight of 100 g samples taken from each treatment at each sampling date to the initial weight.

*Soluble solids.* Measured (°Brix) with an Atago refractometer (model N1) at 20°C.

*Texture.* Shear resistance was determined by measuring the force required to cut through four raw okra pods using a Texture Analyzer TA-XT2 equipped with a 500 kg load cell, fitted with 7 × 12 cm knife (3.2 mm thick blade). The pods were placed horizontally in the cell and were cut 3.0 cm from the base. Crosshead and chart speed were 100 mm/min and 300 mm/min, respectively. The crosshead speed chosen was the most consistent in relating shear strength to pod maturity and quality (unpublished data). The maximum value on the force scale was taken as a measure of shear resistance.

*Colour.* Measurements were determined with a Hunter Lab Tristimulus Color Model (Minolta DP-301) calibrated with a white standard tile (X = 92.40; Y = 0.3134; Z = 0.3195). L\* and b\* values were

assigned as the average for four representative samples, with two replications for each treatment. The b\* is positive value for yellow fruits and L\* is positive value for lightness.

*Titrateable acidity.* The method of the Association of Official Analytical Chemists was used (AOAC 1990).

*Ascorbic acid.* The method of the Association of Official Analytical Chemists was used (AOAC 1990).

*Fibre content.* Determined using an alkali extraction method. The pods without seeds (10 g) were cooked for 10 min in boiling water, macerated with 12.5 mL 50% NaOH and boiled for 5 min. Fibre was filtered and washed through a 25–30 mesh screen to separate the fibre. Fibre was then dried at 100°C for 2 h and weighed (Gould 1977).

## Statistical analysis

Statistical analyses performed on the data included analysis of variance (ANOVA) using the General Linear Models Procedure by SAS (SAS Institute, Cary, NC.), Duncan's multiple range test, and standard deviation calculations. The experimental design used for analytical measurements was completely randomised with four replications.

## Results and Discussion

### Changes in gas composition of the package atmosphere

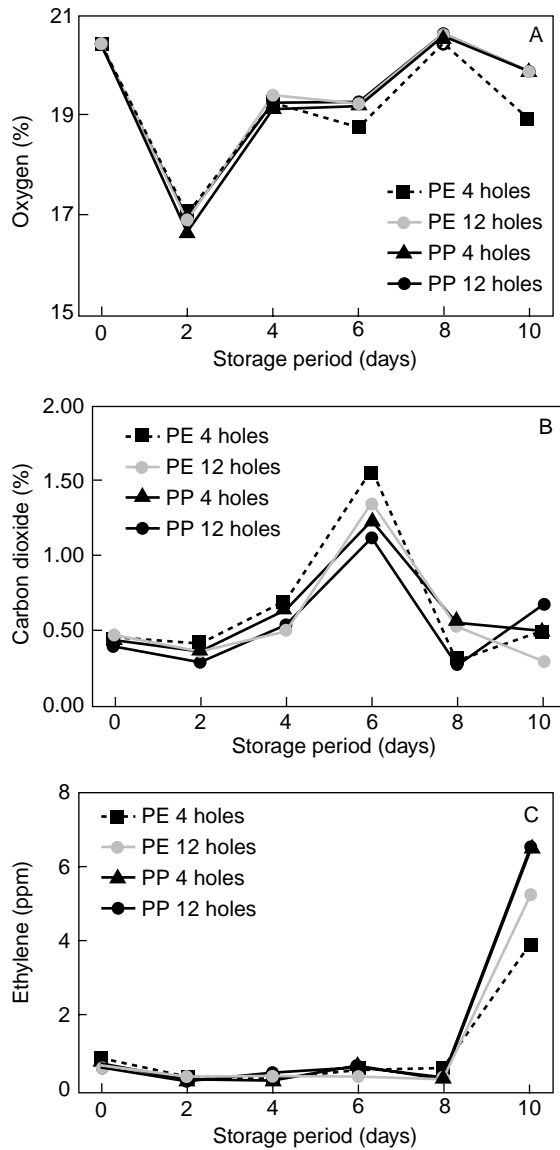
#### *Oxygen and carbon dioxide concentrations*

In the initial period of storage, rapid changes in CO<sub>2</sub> accumulation and O<sub>2</sub> depletion were observed. Levels of O<sub>2</sub> and CO<sub>2</sub> inside the packages were 17% and 1.5%, within 2 and 6 days, respectively, as shown in Figures 1A and 1B. Thereafter the concentration of O<sub>2</sub> and CO<sub>2</sub> gradually changed over time according to the rate of okra respiration. Okra used O<sub>2</sub> in the package for its respiration and produced CO<sub>2</sub>.

### Ethylene levels

Figure 1C shows that the C<sub>2</sub>H<sub>4</sub> concentrations within the perforated plastic bags at 10°C showed no significant difference between treatments. It was noted that the rate of ethylene diffusion from the fruit internal atmosphere may have obscured the rates of ethylene evolution and contributed to relatively low levels of ethylene inside the packages during the first 8 days of storage.



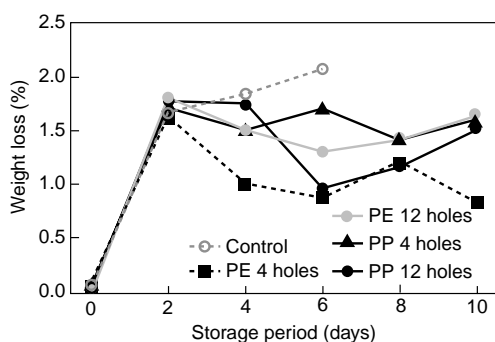


**Figure 1.** Changes in headspace gas levels of (A) oxygen, (B) carbon dioxide and (C) ethylene inside packages of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control).

## Quality of okra

### Assessment of weight loss

The percentage weight loss for okra packed in perforated packages was lower than for pods stored unpacked (Figure 2). Weight loss of each package was almost constant for the first 8 days, although it was slightly higher on the first 2 days. Weight loss decreased slowly, because of a reduction in the water vapour gradient between the outside surface of the product and the air. Polypropylene (PP) bag + 4 holes reduced weight loss of okra pods more than PP bag + 12 holes, polyethylene (PE) bag + 12 holes, and PE bag + 4 holes, respectively.



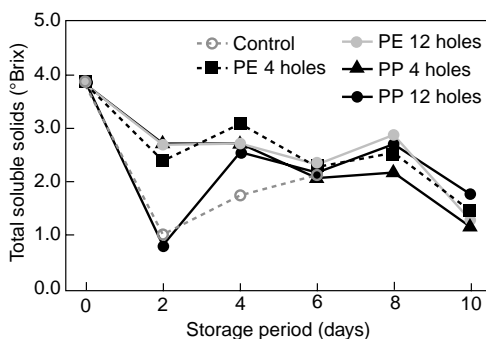
**Figure 2.** Weight loss (fresh weight basis) of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control).

### Change in soluble solids

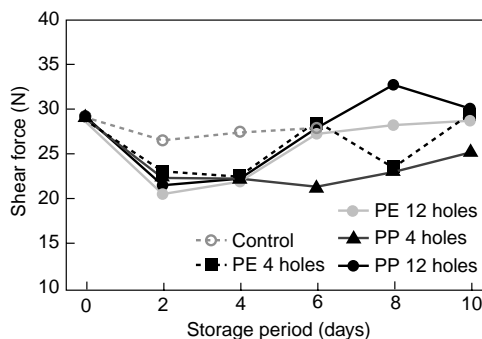
Total soluble solids (TSS) loss was lower in okra pods packed in perforated plastic bags compared to the control (Figure 3). In spite of the apparent decrease in TSS during storage, there was statistically significant increase ( $P > 0.05$ ) between 2 and 4 days. The overall decrease in soluble solids in all packages was due to the respiration of okra pods which consumed the soluble solids (Wills et al. 1981).

### Texture

Toughness was expressed as the shear resistance value which was lower in okra pods stored in perforated packages than in the control (Figure 4). Toughness is an important quality criterion of fresh okra because tough pods are inedible. A shear force of ~30 N has been equated with good quality of okra pods.



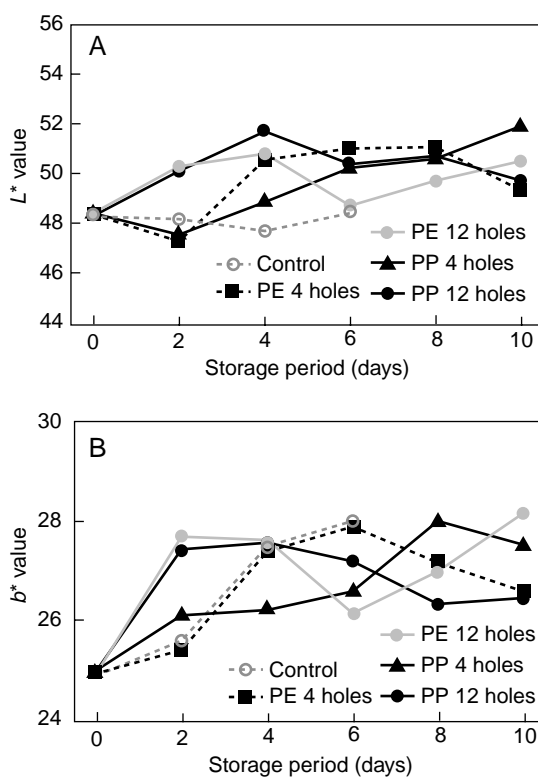
**Figure 3.** Changes in total soluble solids content of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control).



**Figure 4.** Changes shear force of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control)

### Pod colour

A bright green appearance is the most important characteristic of fresh okra quality because brown pods will be rejected by consumers (Baxter and Waters 1990). Pod colour was measured as  $L^*$  (lightness) and  $b^*$  (yellowness). The fruit colour at each sampling time is presented in Figure 5. There were no significant differences in  $L^*$  and  $b^*$  values of pods over time. A higher value of  $L^*$  was observed for pods packed in perforated bags after 4 days of storage, compared with unpacked, due to the yellowing of some pods in this control.



**Figure 5.** Changes in pod colour expressed as (A)  $L^*$  (lightness) and (B)  $b^*$  (yellowness) of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control).

#### *Titrateable acidity*

Acidity generally increased during storage, with the rate of increase being slower in okra pods packed in perforated bags compared to the control (Figure 6).

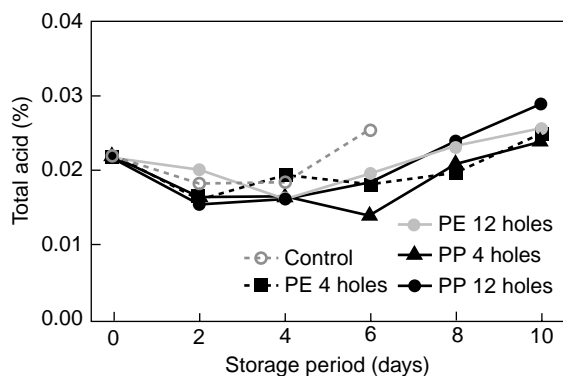
#### *Ascorbic acid*

Vitamin C content generally decreased during storage. The decrease was slower in okra pods packed in perforated bags than in the control (Figure 7). Vitamin C had decreased by the 4<sup>th</sup> day of storage but had increased by the 6<sup>th</sup> day. This phenomenon could be explained by the fact that glucose is a precursor of

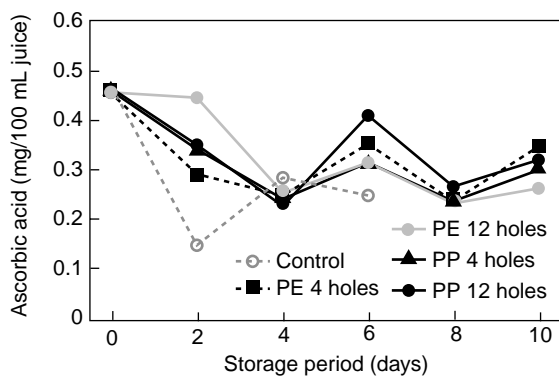
ascorbic acid and some glucose could have been converted to ascorbic acid by the 6<sup>th</sup> day (Isherwood and Mapson 1962). However, the vitamin C content of both pods stored in perforated bags and control was no different.

#### *Fibre content*

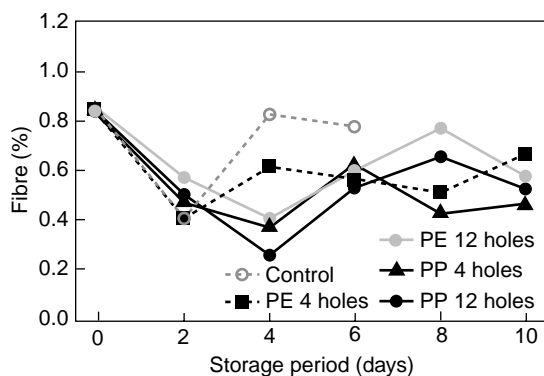
After an initial decrease, the fibre content of both pods stored in perforated bags and control generally increased over time in storage. This increase was slower in okra pods stored in perforated bags than in the control (Figure 8).



**Figure 6.** Changes in total titratable acidity of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control).



**Figure 7.** Changes in ascorbic acid content of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control).



**Figure 8.** Changes in fibre content of okra pods stored for 10 days at 10°C in polyethylene (PE) or polypropylene (PP) bags perforated with 4 or 12 holes, compared with unpacked pods (control).

## Conclusion

Perforated plastic packaging reduced weight loss compared to the control. Okra pods packed in PP bag + 4 holes delayed weight loss more successfully than okra pods in PP bag + 12 holes, PE + 12 holes, and PE + 4 holes, respectively. Moreover, storage in PP bag + 4 holes gave the best visual appearance, resulting in an extension of the marketing period of good quality okra pods from 6 to 10 days.

## References

- Anandaswamy, B. 1963. Prepackaging studies on fresh produce. IV. Okra (*Abelmoschus esculentus* L.). Food Science (Mysore), 12, 332–335.
- AOAC (Association of Official Analytical Chemists) 1990. Official method of analysis. Virginia, Association of Official Analytical Chemists, 1298p.
- Baxter, L. and Waters, L. Jr 1990. Controlled atmosphere effects on physical change and ethylene evolution in harvested okra. HortScience, 25, 92–95.
- Gould, W.A. 1977. Food quality assurance. Connecticut, The AVI Publishing Company, 314p.
- Hardenburg, R.E., Watada, A.E. and Wang, C.Y. 1986. The commercial storage of fruits, vegetables, and florists and nursery stocks. United States Department of Agriculture Handbook, 66p.
- Isherwood, F.A. and Mapson, L.W. 1962. Ascorbic acid metabolism in plants, part 2. Biosynthesis. Annual Review of Plant Physiology, 13, 329–348.
- Kader, A.A. 1991. Postharvest biology and technology: an overview. In: Kader, A.A., ed., Postharvest technology of horticultural crops, 2<sup>nd</sup> edition. University of California, Publication 3311, 15–20.
- Snowdon, A.L. 1991. A color atlas of postharvest diseases and disorders of fruit and vegetables. Volume 2: vegetables. Aylesbury, Wolfe Scientific, 416p.
- Wills, R.H.H., Lee, T.H., Graham, D., McGlasson, W.B. and Hall, E.C. 1981. Postharvest. An introduction to the physiology and handling of fruits and vegetables. Sydney, New South Wales University Press, 161p.

# Changes in Polyamine Levels and Peroxidase Activity in 'Khakdum' Papaya (*Carica papaya* L.) under Low Temperature Storage Conditions

S. Setha, S. Kanlayanarat and V. Srilaong\*

## Abstract

'Khakdum' papaya fruits were stored at 5°C or 15°C to study the relationships of polyamine content and peroxidase activity to chilling injury. Chilling injury of papaya stored under 5°C was developed as a pitting symptom on the peel after 15 days of storage. The injury became more severe (over 20% damage) after 30 days of storage. Polyamine content, as measured by putrescine, spermidine and spermine levels, gradually decreased over time. Peroxidase activity increased gradually until it reached a peak at 10 days storage, after which it fell slightly. At the end of storage, chilled papaya fruit stored at 5°C could not ripen normally, while the fruit stored at 15°C showed a climacteric rise and normal ripening.

PAPAYA (*Carica papaya* L.) is a member of family Caricaceae and is a popular fruit crop throughout tropical and subtropical regions. Papaya is tropical in origin and the fruit changes rapidly, both physiologically and biochemically, after harvest. Postharvest losses of papaya quality could be minimised by storage at low temperature. Under such conditions, fruit metabolism, respiration and the ripening process are retarded. Papaya fruit are sensitive to temperatures below 12.5°C and chilling injury is observed as a pitting symptom on the peel surface (Chen and Paull 1986). The physiological and biochemical alterations occur in response to chilling stress which induces the degradation process in membranes and disrupts metabolism (Raison and Orr 1990). In a previous study, it was found that oxidative damage was an early response of sensitive tissue to chilling and many free radicals were induced (Hariyadi and Parkin 1991). Polyamines are free radical scavenger agents that can protect membranes from peroxidation (Kramer and Wang 1989). Furthermore, peroxidase also has free radical scavenger properties under chilling stress conditions (Burris 1960). The objective of this study was

to investigate the changes in polyamine content and peroxidase activity in papaya in response to chilling.

## Materials and Methods

### Sample preparation

Papaya fruit (*Carica papaya* L.) of the 'Khakdum' cultivar were harvested from an orchard in Chantaburi Province in the eastern part of Thailand. The fruit selected were uniform in size and 5–10% yellow in colour. Selected fruit were dipped in 500 ppm thiabendazole (TBZ) for 5 min to control microorganisms, then well drained and placed in a coolroom at 5°C or 15°C and 90–95% relative humidity (RH).

### Sample analysis

Samples were withdrawn every 3 days to determine: polyamine as putrescine, spermidine, and spermine content; peroxidase activity; respiration rate; and chilling injury index (see below). The means of three replications for each treatment are presented. Least significant difference (LSD) was used to compare mean differences.

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The severity of chilling symptoms was calculated using the following equation:

$$\text{Chilling injury index} = \left[ \frac{\text{level of severity} \times \text{number of chilled fruit}}{\text{total no. of fruit}} \right] \quad (1)$$

Levels of severity were determined as: 0 = normal, 1 = pitting less than 10%, 2 = 10–20% pitting, and 3 = pitting more than 20% (Martinez-Tellez and Lafuente 1997).

## Respiration rate

Each fruit sample was sealed in a 1.17 L chamber and incubated for 3 h at room temperature. A 1  $\mu$ L gas sample was withdrawn with a syringe. Samples were injected into a gas chromatograph (Shimadzu GC-8A, Porapak N column, TCD, 60°C) for determination of carbon dioxide levels.

## Assay for peroxidase activity

Pulp tissue (100 mg) was homogenised in 12 mL cold 0.1 M phosphate buffer (pH 6.1) containing 90 mg of insoluble polyvinylpyrrolidone (PVP) and 30 mg sodium ascorbate in chilled mortars and pestles. The homogenate was filtered through four layers of miracloth and centrifuged at 12,000 g for 10 min at 4°C. The supernatant was used for the peroxidase assay. The assay mixture contained 0.1 M phosphate buffer (pH 6.1), 4 mM guaiacol as hydrogen donor, 3 mM H<sub>2</sub>O<sub>2</sub> as substrate and 0.4 mL crude enzyme extract. The total reaction volume was 1.2 mL. The rate of change in absorbance (optical density—OD) at 420 nm was measured using a spectrophotometer (Shimadzu UV 160 A). The levels of enzyme activity were expressed as OD difference/min/mg protein (Wang 1995).

## Polyamine analysis

Each sample (1 g) was extracted in 10 mL of 5% cold HClO<sub>4</sub>. After extraction for 1 h in an ice bath, samples were pelleted at 48,000 g for 20 min. The supernatant phase contained the ‘free’ polyamine fraction. The crude extract of 0.5 mL was mixed with 2 mL of 4 N NaOH and 5  $\mu$ L of benzoylchloride was immediately added, mixed with a vortex for 15 s, and incubated at 35°C for 20 min in a water bath. 4 mL of saturated NaCl was then added. Benzoyl polyamine was extracted in cold ether. After centrifugation at 1,500 g for 10 mins, 2 mL of the top solution (ether

fraction) was collected, evaporated to dryness under nitrogen gas, then redissolved in 200  $\mu$ L acetonitrile and injected into a high performance liquid chromatography (HPLC) apparatus. Densyl polyamine was separated by the HPLC system with a C<sub>18</sub> reverse column. The mobile phase used was acetonitrile:water, 1:1 (v/v) at a flow rate of 1 mL/min. Ultraviolet (UV) waves were detected at 254 nm. Sensitivity was set at 0.04 a.u.f.s. (McDonald and Kushad 1986).

## Results

### Chilling injury index

The physiological changes to papaya fruit caused by chilling temperature (5°C) were observed as slight pitting on the peel after 15 days of storage. This symptom was more severe when the fruit were transferred to room temperature. The level of chilling injury correlated with storage time and most severe symptom of more than 20% was observed after 30 days of storage (Figure 1). The fruit stored at 15°C showed slight chilling injury after their maximum storage life of 20 days (Figure 1), after which time they decayed.

### Respiration rate

Low respiration rates of approximately 3–5 mg CO<sub>2</sub>/kg/hr were measured in fruit chilled at 5°C, while the rate of 15–20 mg CO<sub>2</sub>/kg/h were measured in fruit stored at 15°C (Figure 2). A respiration climacteric peak was not detected in papaya fruit stored at 5°C. Furthermore, the fruit did not ripen as normal. However, papaya that stored at 15°C showed a climacteric rise after 3 days of storage and ripened gradually until 20 days of storage (data not shown).

### Peroxidase activity

Activity of peroxidase is an indicator of chilling injury symptom. The peroxidase activity of papaya fruit stored at 5°C was higher than at 15°C. The peroxidase activity of fruit stored at 5°C increased up to 10 days, then rapidly decreased after 15 days until the end of storage. Papaya stored at 15°C had only slight changes in peroxidase activity throughout the storage period (Figure 3).

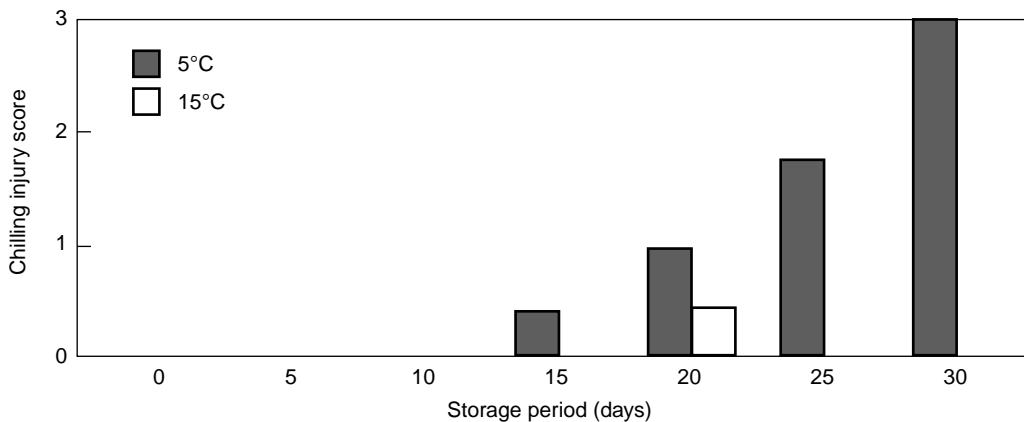
## Polyamine content

The polyamine content of papaya pulp tissues was analysed by measurement of putrescine, spermidine and spermine levels. Papaya fruit stored at 5°C had lower levels of putrescine than those stored at 15°C (Figure 4). At 15°C, the putrescine content increased to a maximum at 5 days storage, then declined. The spermidine content decreased throughout storage, especially in fruit stored at 15°C which showed a sharp initial decrease (Figure 5). The level of spermidine in fruit stored at 5°C showed only a slight decline, indicating that papaya fruit kept at 5°C maintained their spermidine content better than those kept at 15°C. The spermine content sharply decreased within 5 days of

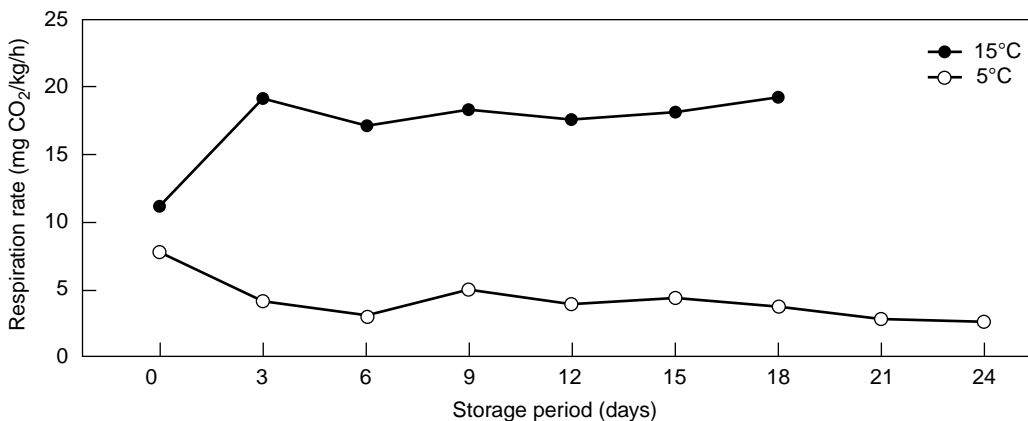
storage at both temperatures, although the rate of decrease was faster in fruit stored at 15°C than at 5°C (Figure 6).

## Discussion

The effect of chilling injury on 'Khakdum' papaya stored at 5°C was observed as a pitting symptom. During exposure to the chilling temperature, the symptom was only slightly apparent, however it was clearly observed after transfer to a warmer temperature. Moreover, this symptom led to a reduction in postharvest life and left the fruit more susceptible to fungal attack. Chen and Paull (1986) reported that the

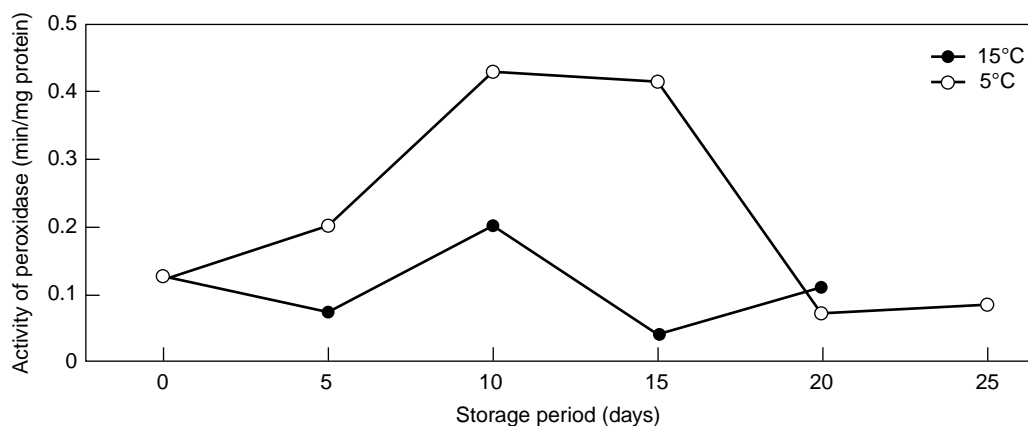


**Figure 1.** Chilling injury scores of 'Khakdum' papaya during storage at 5 or 15°C (0 = normal, 3 = severe).

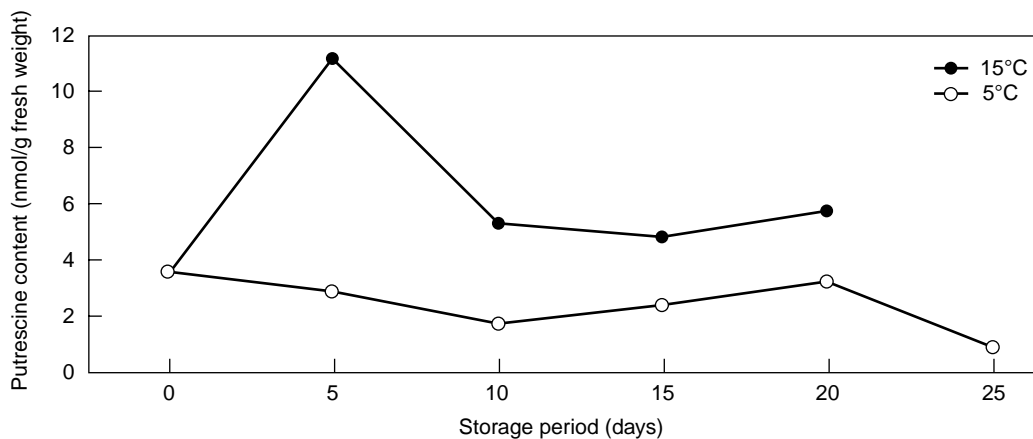


**Figure 2.** Respiration rates of 'Khakdum' papaya during storage at 5 or 15°C.

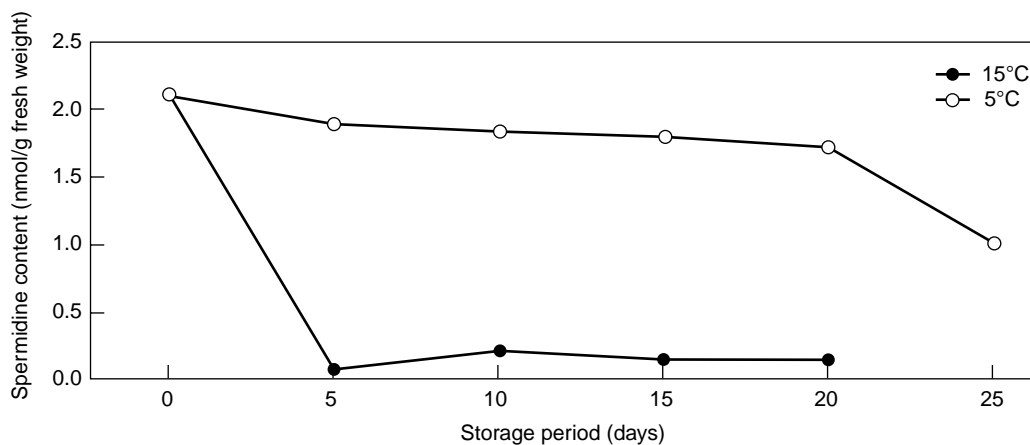




**Figure 3.** Peroxidase activity of 'Khakdum' papaya during storage at 5 or 15°C.



**Figure 4.** Putrescine content of 'Khakdum' papaya during storage at 5 or 15°C.



**Figure 5.** Spermidine content of 'Khakdum' papaya during storage at 5 or 15°C.

symptoms of chilling injury in 'Kapoho Solo' papaya were skin scald, hard area in the pulp around the vascular bundles, water soaking of tissue and failure of fruit to ripen. The results of our study show the lack of a climacteric rise and inability to attain normal ripening in fruit stored at 5°C compared to 15°C. Eaks (1976) obtained similar results in avocado fruit, where fruit stored at chilling temperatures of 5°C and 0°C for periods longer than 1 week failed to show a normal climacteric rise. The mechanism responsible for this abnormal phenomenon is not clearly known, but it appears to be associated with the metabolic disturbance caused by chilling.

Free radical processes are involved in several membrane-associated disorders, including chilling injury (Purvis and Shewfelt 1993). Many free radicals are highly reactive chemically and can induce the oxidative breakdown of double bonds in the fatty acids of membrane lipids. Several enzymes are involved in the production and scavenging of free radicals in plant systems. Peroxidases are ubiquitous enzymes that catalyse the decomposition of H<sub>2</sub>O<sub>2</sub> and liberate free radicals instead of oxygen (Burris 1960). These free radicals are highly phytotoxic. Increased activity of peroxidase is also related to injury induced by chilling (Hodgson and Raison 1991). In our study, peroxidase activity was found to increase in papaya tissue during 15 days of storage. Chilling temperature was previously reported to enhance peroxidase activity in mango fruit (Zauberman et al. 1988).

Changes in polyamine biosynthesis in plant tissues have been correlated with various kinds of stress. Most recently, putrescine and spermidine have been linked to chilling stress (Wang 1987). Papaya stored at 5°C

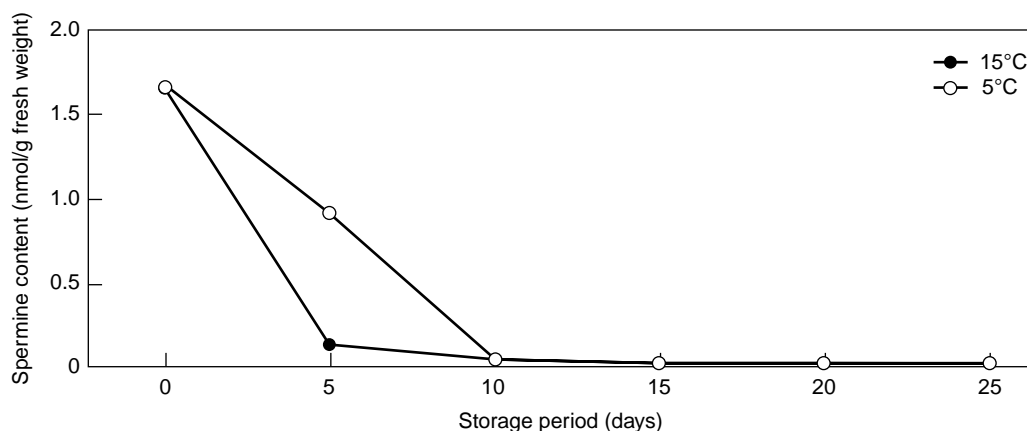
had lower putrescine content and higher spermidine and spermine content than fruit stored at 15°C. However, there were decreasing trends with storage time in all three polyamines (Figures 4–6). During cold storage (0°C in air, 1% O<sub>2</sub>) of Chinese cabbage, all polyamines declined linearly with storage time (Wang 1988). Kramer and Wang (1989) demonstrated that the preconditioning reduced chilling injury and led to a significant increase in spermine and spermidine levels in zucchini squash. It was suggested that polyamines can act to prevent chilling injury in squash by a mechanism which involves protecting membrane lipid from peroxidation. However, the exact role of polyamines on chilling injury in papaya is still not clear.

## Conclusion

The effect of chilling injury on 'Khakdum' papaya fruit stored at 5°C was shown as a pitting symptom. Low respiration rates and inability to ripen normally were observed. Moreover, peroxidase activity increased while putrescine, spermidine, and spermine levels decreased.

## References

- Burris, R.H. 1960. Hydroperoxidase (peroxidase and catalases). In: Ruhland W., ed., *Encyclopedia of plant physiology*, volume 12. Berlin, Springer-Verlag, 365–400.
- Chen, N.M. and Paull, R.E. 1986. Development and prevention of chilling injury in papaya fruits. *Journal of*



**Figure 6.** Spermine content of 'Khakdum' papaya during storage at 5 or 15°C.

- the American Society of Horticultural Science, 111, 639–643.
- Eaks, I.L. 1976. Ripening, chilling injury, and respiratory response of 'Has' and 'Fuerte' avocado fruits at 20°C following chilling. *Journal of the American Society of Horticultural Science*, 101, 538–540.
- Hariyadi, P. and Parkin, K.L. 1991. Chilling-induced oxidative stress in cucumber fruits. *Postharvest Biology and Technology*, 1, 33–45.
- Hodgson, R.A.J. and Raison, J.K. 1991. Superoxide production by thylakoids during chilling and its implication in the susceptibility of plants to chilling-induced photoinhibition. *Planta*, 183, 222–228.
- Kramer, G.F. and Wang, C.Y. 1989. Correlation of reduced chilling injury with increased spermine and spermidine levels in zucchini squash. *Physiologia Plantarum*, 76, 479–484.
- Martinez-Tellez, M.A. and Lafuente, M.T. 1997. Effect of high temperature conditioning on ethylene, phenylalanine ammonia-lyase, peroxidase and polyphenol oxidase activities in flavedo of chilled (Fortune) mandarin fruit. *Plant Physiology*, 150, 674–678.
- McDonald, R.E. and Kushad M.M. 1986. Accumulation of putrescine during chilling injury of fruits. *Plant Physiology*, 82, 324–326.
- Purvis, A.C. and Shewfelt, R.L. 1993. Does the alternative pathway ameliorate chilling injury in sensitive plant tissue? *Physiologia Plantarum*, 88, 712–718.
- Raison, J.K. and Orr, G.R. 1990. Proposals for a better understanding of the molecular basis of chilling injury. In: Wang, C.Y., ed., (Editor), *Chilling injury of horticultural crops*. Boca Raton, CRC Press, 145–164.
- Wang, C.Y. 1987. Changes of polyamines and ethylene in cucumber seedlings in response to chilling stress. *Physiologia Plantarum*, 69, 253–257.
- Wang, C.Y. 1988. Changes of polyamine content in chinese cabbage during storage in air or low oxygen atmosphere. *Journal of Food Quality*, 11, 289.
- Wang, C.Y. 1995. Effect of temperature preconditioning on catalase, peroxidase, and superoxide dismutase in chilled zucchini squash. *Postharvest Biology and Technology*, 5, 67–76.
- Zauberman, G., Fuchs, Y., Rot, I. and Wexler, A. 1988. Chilling injury, peroxidase, and cellulase activities in the peel of mango fruit at low temperature. *HortScience*, 23, 732–733.

# Status of Quality Standards in the South African Fruit Industries

L. Korsten and E.S. de Jager\*

## *Abstract*

Improving quality standards is inevitable if the South African fruit industries are to conform to increasingly stringent regulations on export consignments and maintain their competitive edge. This paper reviews the development of standardisation including export product standardisation and the impact of sanctions and deregulation on South Africa's international trade. The establishment of various International Standards Organisation (ISO) 9000 and Hazard Analysis and Critical Control Points-based quality certification systems is described. South Africa's commitment to the observance of internationally agreed core labour standards, addressing global environmental problems and ensuring the quality and safety of its products through legislation is reviewed.

SOUTH AFRICA is a country of extremes in terms of climate and topography. The variability in rainfall, temperature and soil types makes it extremely difficult to farm effectively and produce optimal yields of high quality. Of the total area of 122 million hectares, 101 million hectares are farmland. Of this, only 13.5% is arable land and a mere 3% is land of high potential (Huntley et al. 1989). Notwithstanding the limitations in climatic and physical conditions, a diversity of agricultural products are produced and even exported. Indeed, in the Southern Hemisphere, South Africa sets the pace in the development of a strong export-oriented industry, particularly in citrus and deciduous fruit growing (Davies and Albrigo 1994).

Global expansion in trade in agricultural products resulted in specific discussions of these topics at the Uruguay round of the General Agreement on Tariffs and Trade (GATT). The most important outcome of this agreement was the establishment of a new set of rules regarding international agricultural policy development (Satin 1999). Agriculture traditionally evaded GATT measures, but now had to comply with the new rules. The agreement on sanitary and phytosanitary measures dealt more specifically with questionable health and safety concerns often disguised as trade

barriers. Countries could still set their own safety standards but they had to be based on sound scientific evidence. The use of accepted international standards has been encouraged and provides great potential for new products and emerging markets.

Free trade and the removal of restrictions on the movement of goods and people are typically associated with increased globalisation. The dynamics of world trade are continuously and rapidly changing and local industries in South Africa have been addressing critical quality issues to remain a small but key player in world trade. In order to gain access to newly emerging markets and remain competitive in traditional markets frequented by South African exporters, consistent product quality of the highest standard had to be assured. Quality remained a critical factor in accessing competitive new markets and all effort has been made to ensure that all products meet and exceed established standards.

Traditionally, quality was the accepted norm in international trade, but with globalisation came increased human exposure to newly emerging infectious food-borne diseases and more resistant groups of pathogens. Chemical contamination of products or the environment, and fair trade principles, are also changing the face of minimum export criteria to which growers and exporters have to adhere. Ensuring food safety along the food chain has become one of the

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minimum requirements of First World countries, for both locally produced and imported food products. These new challenges are currently sweeping through the world, and growers and exporters have in many instances been caught unprepared for new legislation of minimum food safety standards required by most major First World countries such as the United States of America (USA) and in the European Community.

South Africa is one of the many countries that entered the new millennium unprepared for the new minimum export requirements. Both the government and industry are currently haphazardly trying to deal with the new incoming legislation, requirements and guidelines. This review presents an overview of quality assurance systems in South Africa.

## Economic Overview

Official census statistics indicate that South Africa's population has increased by 62%, from 25 million in 1980 to 40.6 million in 1996, when the last official census was conducted. The current South African population is estimated at 44 million. However, the ongoing influx of illegal immigrants from mostly other African countries, estimated by some as being as high as 10–12 million, distorts figures and significantly contributes to widespread poverty and inequality (Feneyes 1996). Furthermore, the country's economic development has not kept pace with the rapidly increasing population. The economically active group within the population has increased by 5% only from 8.7 million in 1980 to 9.1 million in 1996. Thus, whereas 35% of South Africa's population was economically active in 1980, this number dropped to 22% in 1996 (Abstracts of Agricultural Statistics 2000).

The contribution of agriculture to South Africa's gross domestic product (GDP) decreased from 6.1% in 1980 to an estimated 4% in 1998. During the same period, the percentage of the economically active population in agriculture dropped from 35% to less than 10%. Notwithstanding the general decline in agriculture, the horticultural sector has maintained steady growth, from 14% of the gross value of agriculture in 1980 to 25% (about \$1.65 billion) at present. This has been achieved on only 4.7% of the total agricultural land. Fruits contribute 48.5% of the total value of horticultural produce. Citrus is the largest single contributor, accounting for 32.8%, subtropical fruits contribute 12.9% and deciduous fruit combined with table grapes, 54.3% (Abstracts of Agricultural Statistics 2000).

South Africa's return to the international fold in the early 1990s resulted in a major boom for exporters. Since 1990, fruit exports have increased dramatically from less than Rand (R) 1 billion to an estimated R4 billion per annum. New export markets opened up and new trade agreements were established once sanctions were lifted. Provided South African fruit exporters remain competitive in terms of quality and price and the industry can adapt to changing requirements, this growth could be maintained in the years to come.

## Development of Quality Standards and Certification Systems in South Africa

Quality standards evolved in South Africa long before the arrival of Western civilisations. However, colonialism greatly influenced and structured quality standards over the past 300 years. Indigenous black nations were applying quality standards in metal and wood works, tribal architecture, agriculture and trade. In 1652, the first Dutch settlement was established at the then Cape of Good Hope (Cape Town), to provide fresh produce to Dutch ships, which were en route to the East Indies, based on Dutch standards. British standards were introduced with the first occupation of the Cape in 1795 by the English and were used alongside Dutch measuring and weighing standards even after the Cape was handed back to the Dutch in 1802. With the second British occupation in 1806, the British imperial system was introduced and trade and agricultural standards in South Africa were based on the British systems for the remainder of the 19<sup>th</sup> century.

### South African standards

In 1910, the Union of South Africa was formed as a member of the British Commonwealth. The British Standard Institute (BSI), which was eventually replaced by the South African Bureau of Standards (SABS), had a strong influence on the development of quality standards in South Africa. SABS was officially formed in 1945 to improve the quality of South African products through the development of generally accepted standards. Acceptance of standards was voluntary for the most part and compulsory standards were only enforced in exceptional cases. With the appearance of poor quality products in certain sectors, minimum standards were introduced to prevent the sale of such inferior products.

Based on the development of "The Operational and Evaluation of Quality Assurance Systems" (BS 5179:1974) in Britain, the first quality management standards were published in South Africa (Pelser 1995). Based on BS 5179, the first quality management standard was published in South Africa, namely SABS 0157 of 1979. Increasing demand for the implementation and certification of such quality management systems necessitated the establishment of a listing scheme. The national listing scheme for quality auditors, namely the South African Committee for the Certification of Quality Auditors (SACCQA) was established during the mid-eighties and is still responsible for the independent listing of quality auditors. The first company was listed in 1983 and by 1999 the number of listed companies had grown to approximately 3,000, representing companies from all sectors but mostly mechanical engineering companies (40%). Seventy-six certified companies (2.5%) are in the food and beverage industry.

The International Standards Organisation (ISO) 9000 document was published in 1987 and SABS 0157 of 1979 was revised to that of SABS 9000 in 1992. Today, the SABS ISO 9000–9004 series of standards form the backbone of quality schemes used by South African producers or marketers to benchmark against international competition.

In 1990, with the debanning of the African National Congress, South Africa entered a new era with regard to politics and economics. Apartheid ended and a new government came in power in 1994 under leadership of President Nelson Mandela. A new South Africa was born accompanied by a drive to improve the quality of life of all its people. The SABS initiated an extensive plan to implement quality standards nation-wide working within existing social, political and economic restraints. This initiative resulted in the registration in 1991 of the South African Quality Institute as a non-profit company in terms of Section 21 of the Companies Act.

The rapid growth in global trade has necessitated the need for international standards to be harmonised in order for all countries to compete equally and fairly. South Africa became a signatory to the Agreement on Technical Trade and Barriers (TBT) of the World Trade Organization (WTO) in 1994, agreeing to comply with its code of good practice for the preparation, adoption and application standards. In 1995, South Africa also signed the General Agreement on Tariffs and Trade (GATT) treaty that necessitated a revision of its existing standards legislation. Consequently, in order to allow other organisations, both

locally and internationally, to test products for compliance with the SABS standards, the range of SABS marks was modified. Before South Africa's acceptance of GATT in 1995, SABS was the only body authorised to apply certification marks to products, but this new standard legislation introduced an element of competition which countered the monopolistic position of SABS in the field of quality certification. Currently a number of certification schemes exist in direct competition to SABS certification, including Safe Quality Food (SQF™), SGS International Certification Services (Pty) Ltd, and Vertitas. Despite being aimed at different target markets, all of these certification schemes embrace the same concepts of total quality management, quality assurance, quality control and ISO 9000 and/or Hazard Analysis and Critical Control Points (HACCP) principles.

## Industry schemes

A number of voluntary schemes are in place in the United Kingdom (UK), which require adherence to standards or codes by members of trade associations. Some of these are completely self-regulated and others involve use of third-party auditors, assessors or inspectors. Since the bulk of the South African exports go to the UK, these industry schemes would be applicable and regulated from abroad.

In South Africa, the different growers' associations are in the process of presenting minimum production guidelines to growers based on good farming practices. Most of these codes have been developed specifically for South African growers taking into account our unique socio-political situation, geographical position, climatic conditions, cultural practices, and export markets and their requirements. The most notable of these is the previous Outspan quality production guidelines and integrated pest management certified programs. The Sunshine Seal of Quality and the quality management system have been implemented successfully with most growers and packers exporting through Capespan. However, this remains a contentious issue with citrus growers exporting through other channels who do not have access to this information. Although Capespan regard this as their competitive edge, 'outside' growers feel that the system was initially developed before deregulation and the information is therefore a national asset. More recently, the South African Mango Growers' Association has completed their quality assurance guideline for both internal and external markets and

the South African Avocado Growers' Guideline is almost complete.

The deciduous fruit industry has followed an integrated fruit production (IFP) system since 1992. Currently this system is being upgraded to a complete grower guideline in line with new legislation on food safety and compliance with international standards of Good Agricultural Practices (GAP). The establishment of necessary guarantees to satisfy international markets and to audit the system are being developed for implementation in 2001 as part of a vision 2010 strategic plan.

### **Distributors' own brands and contracts**

Most distributors' own brand products—also referred to as 'own label' products—are produced by third-party packers against very specific standards. The majority of the brand owners conduct technical audits of their suppliers at regular intervals and/or use third-party auditors for this purpose. ISO 9001 certification can assist in reducing the depth of audit in the quality systems area and minimise duplication of effort where one producer is manufacturing for several distributors' own brands (Bolton 1997).

Fruit producers from South Africa supplying international supermarket and retailer groups (e.g. Tesco and Euro Retailer Group) must also adhere to internal codes of conduct or GAPs as stipulated by these customers. The codes of conduct and quality prerequisites prescribed by these supermarket and retailer groups are typically more stringent than minimum standards required by UK and European Union legislation. It is thus possible to encounter a requirement to meet ISO standard components without there being a requirement to hold the certification itself.

In South Africa, retail groups (e.g. Woolworths) and their suppliers (e.g. GEEST) have their own grower guidelines based on GAPs. These distributors' own brands are currently regarded as special niche markets in South Africa and are gaining in popularity. This is particularly evident since deregulation, where bigger commercial growers opted for direct super chain store linkages.

### **Ethical trade**

Over the past year, corporate codes of conduct have become an increasingly important issue, particularly since the formation of the Ethical Trading Initiative (ETI) in 1997. Supermarkets are playing an important role within the ETI, and the main European Union

supermarkets are in the process of introducing codes of conduct to their suppliers (Barrientos et al. 1999). Worldwide human rights issues such as child labour, exploitation of workers—particularly female workers, unfair wages etc. have become a contentious issue. A large proportion of the workforce within developing countries is female, particularly in the production of food. This is especially so in the case of fresh produce in South Africa.

Ethical trade covers the assurance of good labour and environmental standards in export production, within all developed and developing countries (Barrientos et al. 1999). Several fair trade assigned organisations, i.e. Max Havelaar, are currently negotiating with South African producers to market their fresh products abroad under the fair trade banner. These selected niche markets are currently gaining popularity in South Africa as a viable alternative for disadvantaged producers.

### **Previously disadvantaged producers**

Another selected niche market developing in South Africa is partnerships between growers and farm labourers. In certain partnerships, growers (particularly grape growers) have given labourers part of the land, guidance, training in specific skills, equipment and funding from (generally) non-government organisations, to establish and develop their own products. One such success story is Thandi Wines produced in a partnership with Paul Cluver Wines, with a vision to assist the historically disadvantaged community in reaping the fruits of their labour.

### **Harmonized Generic Framework for African Codes of Practice for the Horticultural Sector (COLEACP)**

In eastern and southern African countries several Codes have been, or are being, developed under separate initiatives by the respective export trade associations. The use of several African Codes containing different standards risks undermining the position of African export products in the European markets by creating confusion in the marketplace. In order to improve market recognition of African produce and to respond to the market demands for environmentally and socially responsible conditions of production, COLEACP took the initiative to encourage horticultural export associations from eastern and southern

African countries to move towards harmonisation of their Codes of Practice.

During a November 1999 meeting, a harmonised framework was developed which will be evaluated on a yearly basis. The specific objectives and core criteria include:

- a) Ensure the welfare of workers and out-growers (fair remuneration, fair labour conditions, no exploitation of minors and fair purchasing policy for producers /out-growers);
- b) Ensure workers' occupational health and safety (preventing risks and adequate provision of health services);
- c) Control and reduce environmental degradation from agrochemical use (reducing quantity used; ensuring safe transport, usage, storage and disposal thereof; and minimising or avoiding environmental contamination);
- d) Safeguard soil, water and air (sustainable water resource and land use management, soil conservation, management of hazardous waste, reduction in use of non-renewal energy resources, use of environmentally friendly packaging);
- e) Safeguard consumer health (through due diligence in crop production and pesticide use, safeguarding of product from contamination throughout the chain, identification and control of hazards, ensuring the personal hygiene of workers, effective temperature management to prevent spoilage, and ensuring that packaging material is not a source of contamination).

## **Development of South African Agricultural Export Product Standardisation**

The Cape Government requested the appointment of an officer to inspect export fruits shipped from Cape Town Harbour in 1899. Inspection Regulations were drafted and in 1904 an official inspection officer was appointed. However, participation in inspections was voluntary until 1910 with the establishment of the Union of South Africa. The Export Fruit Act No. 1 of 1910 was publicised and inspections of export fruits became compulsory. The Fruit Export Control Board (FECB) was established in 1925 to distribute and assign vessel space to citrus and deciduous fruit exporters. The FECB board was replaced in 1926 by the Perishable Products Export Control Board (PPECB) through Act No. 53 of 1926. Its main

objective was to ensure equal space allocation for exporters of all perishable products. In addition, PPECB was responsible for formulating temperature regimes and for treatments of various products, and to ensure that these were effectively applied throughout the export and marketing chain.

Extensive investigation by the Commission of Administration led to the privatisation of PPECB and promulgation of the Perishable Products Export control Act No. 9 of 1983. This Act provided for PPECB control of all perishable products intended for export from South Africa and all matters connected therewith. Following specific requests by major export industries, the Ministry of Agriculture in 1990 delegated all export quality inspection functions of agricultural products to PPECB in terms of the Agricultural Product Standard Act No. 119 of 1990. This Act provides for control over sales and export of agricultural and related products and all relevant matters related to endpoint inspections and quality assurance along the marketing chain 'from the gate to the plate'. PPECB is responsible for 226 different types of products at 679 permanent inspection points around South and southern Africa (including Zimbabwe, Mozambique, Swaziland and Namibia). The total volume of sea exports handled by PPECB is seven million m<sup>3</sup> per annum (p.a.), valued at R24 billion p.a., and exports have grown at an average of 30% p.a. over the last five years.

Today, PPECB is an independent statutory body functioning under the two acts, and is divided into four independent departments namely (a) quality assurance and logistics; (b) technical services; (c) financial services; and (d) human resources and development. Only relevant issues pertaining to the first two departments will be discussed.

## **Department of Quality Assurance and Logistics**

The objective of this department is to verify export product conformity to specific regulations and the maintenance thereafter, including handling, storage and transport. All products are inspected at the point of dispatch. Upon approval, an export certificate is issued and pallets marked with the PPECB mark of approval. Product samples are also tested at two state laboratories for maximum pesticide residue levels and dangerous substances. All ship holds and containers are inspected and temperatures monitored to comply with prescribed standards.



## Department of Technical Services

This department is responsible for research, and product, equipment and systems development. This is achieved through cooperation with research institutes such as the Agricultural Research Council (ARC), universities and various international institutes. Product handling, storage and transportation systems are refined and improved and recommendations made accordingly. New opportunities in technology and marketing are identified, evaluated and developed into practical commercial applications. Product systems for various South African perishable product export industries have been developed according to internationally prescribed procedures such as ISO and HACCP. The department is accredited by the United States Department of Agriculture (USDA) and other state departments of agriculture, including those of Japan and Taiwan.

## Deregulation and Its Effect on the South African Agricultural Sector

The new government of national unity, elected in 1994, introduced numerous policy changes directly affecting agriculture. These included the promulgation of the Marketing of Agricultural Products Act, No. 47 of 1996. This act nullified the era of controlled, single marketing, which was established during the 1930s for most agricultural products. The objectives of the new Act were to promote efficiency in agriculture, increase market access, optimise export earnings and promote the viability of the sector (Kirsten and Vink 2000). In addition, the National Agricultural Marketing Council was set up, with the main function of monitoring the limited market interventions and thereby preventing market distortions. The main functions of the previous Act (the control boards) were to implement market interventions.

In addition, the new government embarked on a process of trade policy reform aimed at reversing decades of 'inward industrialisation' strategies (Kirsten and Vink 2000). This exposed business to tariffs that were often below the bound rates negotiated at the Uruguay round of GATT. However, tariffs on agricultural goods had been reduced faster than required by GATT. The fact that South Africa gained membership of the Cairns group signalled the countries intention to unilaterally liberalise farmer support programs. In the interim, South Africa has successfully negotiated a free trade agreement with the European Union, has agreed to the new South African

Development Counties (SADC) protocol and re-negotiated the new Southern African Customs Union treaty (Kirsten and Vink 2000).

The final aspect was labour market reforms, which resulted in new legislation becoming more applicable to the agricultural sectors. Other new agricultural policy initiatives focused strongly on the transformation, reconstruction and development of small-scale farmer systems. These programs are becoming more important to ensure sustained growth in agriculture within an equity structure (Van Rooyen and Nene 1996). In future, systems will increasingly be introduced to establish new and emerging farmers in the wider South African environment.

The competitive status of agribusiness in South Africa was recently determined and revealed that the majority of commodity chains are marginally competitive (Esterhuizen and Van Rooyen 2000). Except for wheat, maize, apple and pineapple chains, the competitive index generally decreases when moving from primary to processed products. This implies that value-adding opportunities in South Africa are restricted. In order to ensure global competitiveness, improvements in the whole supply chain should be made. It is no longer good enough for growers to compete globally at the farm-gate level. Due to long held market interventions, regulation and control, growers grew complacent in taking responsibility for the quality of their product all the way through the marketing chain. It was generally perceived in South Africa that the growers' responsibility stopped at the farm gate and that the regulatory control board had to take the full responsibility from the gate to the plate. This incorporated marketing, transport, shipping and selling that is often managed through a pool system. In certain cases these systems of no traceability and non-accountability bred mediocrity and suboptimal quality through sloppy management practices.

With increased global competition South African exporters will now have to take more responsibility for their product and be accountable for its standards and safety. This is inevitable if our agricultural export industry is to survive, as increased competition from more sophisticated and adaptive competitors can easily destroy our competitive edge in the marketplace. Adding to these internal political and social changes, ongoing restructuring processes and major transformations in agriculture all contribute to uncertainty and insecurity, which further threaten our export industry. Taking note of new changes in the marketplace and adapting to new minimum requirements for food safety and quality can ensure that we 'ride the

storm' and thereby strengthen our export-orientated fruit industries.

Deregulation has had a positive impact on the consumer price index with food inflation declining from a high of 25% in 1992 to around 7.5% currently. Deregulation has also attracted new business and investments from domestic and foreign investors and created new business and job opportunities in farming and associated industries to replace the activities of the various control boards. This is illustrated by the fact that new company registrations in the agricultural and fishery sectors increased by 209% between 1994 and 1997. Deregulation has also resulted in changes in cropping patterns with the focus shifting from uncompetitive field crops to the cultivation of high value horticultural production.

## Land Reform and Redistribution

With current redistribution policies in Zimbabwe, South African landowners are very much aware of the disproportional ownership of agricultural land in the hands of white commercial farmers. Current South African government policies are aimed at redistributing land through organised programs and hope to avoid the land grab chaos eminent in Zimbabwe. Current estimated figures place 70% of agricultural land in the hands of white commercial farmers (Huntley et al. 1989). Current emphasis on development, research and extension services for emerging black farmers, small-scale farmers and subsistence farmers are high on the agenda of government departments and funding organisations such as the USA Kellogg's Foundation. Developing quality assurance and food safety systems for these categories of farmers are another high priority for the Department of Agriculture, and are currently being developed by the Department and the post-harvest technology hub of the University of Pretoria and the Scientific Research Council (CSIR).

## Legislation Affecting Quality Assurance or Good Farming Practices

Since the rebirth of a new South Africa in 1994, changing political or economical climates significantly influenced the introduction of new legislation and revisions to existing legislation, incorporating lessons from the past. South Africa is also committed (a) to the observance of internationally agreed core

labour standards, (b) to address global environmental problems and (c) to ensure quality and safety of products through its legislation.

## Core labour standards

Free trade and globalisation increase competition between countries and negatively impact on labour costs. The International Labour Organization founded core labour standards that are used as base codes in the Ethical Trading Initiative (ETI). These are minimum standards that are voluntarily adopted to raise labour standards.

### *Unemployment Insurance Act (UIA), 1993*

This Act is the first labour legislation to cover farm workers and provides for the creation of an Unemployment Insurance Fund (UIF) for farm workers.

### *Occupational Health and Safety Act, 1993*

This Act provides for the health and safety of persons at work, persons in connection with the use of plant and machinery, and the protection of others against health and safety hazards arising out of or in connection with the activities of persons at work.

### *Labour Relations Act, 1995*

This act provides employees with the freedom of organisation to join a union. Unionised employees also have the right to strike. Unions who are sufficiently represented must be allowed to enter farms/workplaces and have access to their members. Employees have also the right to decision-making in the workplace through the formation of a workplace forum. The formation of such a forum is permitted if more than 100 people are employed and if it supports the majority union. Workers that are unfairly dismissed have the right to be represented by their union in subsequent negotiation with their employers and other interested parties.

### *Employment Equity Act, 1998*

The Act aims to provide for employment equity through the implementation of affirmative action programs for a designated group of employees and to eliminate unfair discrimination in the workplace. This designated group of employees includes African people, women and people with disabilities.

### *Skills Development Act, 1998*

This Act aims to develop and improve the skills of the South African workforce and to provide for

education that leads to recognised occupational qualifications.

#### *Basic Conditions of Employment Act, 1997*

The purpose of this Act is to advance economic development and social justice through establishing and enforcing basic conditions of employment and to regulate the variation of basic conditions of employment. The Act also makes provision for farm workers and provides greater protection for temporary and seasonal workers.

#### *Extension of Security of Tenure Act (ESTA), 1997*

This Act protects occupiers living on agricultural farms with the permission of the landowner. The Act prohibits unlawful evictions and provides a greater tenure security to farm workers living on the farm.

### **Global environmental problems**

Agriculture is a prime user of natural resources and despite its advantage as a supplier of foreign exchange, food and employment opportunities in South African economy, a high price has been paid with the degradation of natural ecosystems.

#### *Environmental Conservation Act, 1989*

*(Act No. 73 of 1989)*

This Act provides for the effective protection and controlled utilisation of the environment.

### **Quality and safety**

#### *Trade Metrology Act, 1973 (Act No. 77 of 1973)*

This Act, which replaced the previous Weights and Measures Act, 1958 and amendments thereafter, stipulates that products must conform to quantity statements as indicated and comply to weights, measures and standards regulations.

#### *Health Act, 1977 (Act No. 63 of 1977)*

This Act, which replaced the old Public Health Act of 1919, makes provision for measures to promote the health of South African people. The responsibilities of various health services and the rendering of health services are stipulated. Amongst others, legislation requires that preventative action must be taken to eliminate transmission of infectious diseases.

The latest amendment to the Act, revised on 17 July 1999, specifies requirements relating to hygiene and the transportation of food. Certificates of acceptability by food handlers are now required and regulations stipulate minimum requirements for food premises,

such as building requirements, ventilation, illumination and sanitary facilities. Surfaces should be cleaned and washed before and after food handling with a cleaning material that will not contaminate the food. The Act permits a maximum of 100 viable microorganisms/cm<sup>2</sup> upon analysis taken by the swab technique (SABS Standard Test Method 763). The handling of food is not permitted without handlers wearing suitable protective clothing and food handlers must apply basic hygienic habits. Spitting, smoking, eating or drinking is prohibited in a food handling area. Cleanliness (chemical, physical and microbiological) is a prerequisite for food containers and the parts of vehicles in which food containers are transported. Storage, display and transport of perishable food must be at a core temperature in order to maintain food quality. Inspections of premises may lead to the evacuation, closing and demolition of those premises not adhering to required specifications. Individuals may also be prosecuted for failing to comply with any provision of this Act.

#### *Agricultural Product Standard Act, 1990*

*(Act No. 119 of 1990)*

This Act provides minimum standards for the export of produce. Individual specifications are listed and specifications and regulations are revised on an ongoing basis. Aspects specified in the Act cover quality standards of produce as well as produce compliance with packing requirements, requirements for containers in which produce are packed, the marking and labelling of containers, and inspections. Produce is inspected for uniformity and quality standards, the presence of arthropods and prescribed residue limits. Exporters are also required to provide inspectors with details of the preharvest spray program that was used on trees and postharvest chemical treatments on fruits.

*Regulations regarding control over the sale of organically produced products in the South Africa* was recently drafted as an extension of the Agricultural Product Standards Act, 1990. This new Act provides general standards for organically produced products and makes provision for the improvement of landscape and biodiversity through production measures employed.

*General guidelines for code of practice, regarding general principles of food hygiene, in the agricultural food industry* are being drafted and will be based on phytosanitary, ISO 9000 and HACCP principles.

*Perishable Product Export Control Act, 1983*  
(Act No. 9 of 1983)

This Act provides for the control of perishable products intended for export from the Republic of South Africa and provides for the continued existence of the Perishable Products Export Control Board (PPECB).

The functions of the board are as follows: to (a) control the export shipment of perishable products from the Republic and the order of shipment thereof at all ports; (b) determine which ships are suitable for the conveyance of perishable products and the class of accommodation to which any perishable product shall be assigned; (c) call for and receive from intending exporters of perishable products estimates and other particulars of their intended exports; (d) call for and receive from ship owners or their representatives, information regarding the amount of space suitable for the conveyance of perishable products available on any ship appointed to call at any port in the Republic; (e) arrange for the provision of port facilities and shipping space; (f) divert ships to most suitable ports; (g) investigate conveyance and cold storage requirements for perishable products and make recommendations thereon; (h) make recommendations regarding the way perishable products are handled during transport; (i) promote uniform freight rates in respect of the export of perishable products, with due allowance for particular perishable products, port of export and means of conveyance; and (j) perform such other functions related to the export of perishable products from the Republic as may be prescribed by regulations.

The Act also provides for the imposition of levies payable to the Board by exporters of perishable product to meet expenditures incurred by the Board. Levies are determined by the type of transport, time of year, and the category and quality of the perishable product that has been exported.

*Marketing of Agricultural Products Act, 1996*  
(Act No. 47 of 1996)

The objectives of this Act are to (a) increase the market access for all market participants; (b) promote the efficiency of the marketing of agricultural products; (c) optimise export earnings from agricultural products; and (d) enhance the viability of the agricultural sector. This Act also provides for the establishment of a National Agricultural Marketing Council (NAMC) that replaced various control boards and the National Marketing Council (NMC) created under the previous Act. Whereas the main function of

the now defunct control boards and NMC was to implement market interventions, the NAMC only monitors those few interventions that are permitted to prevent the creation of market distortions that could adversely affect the welfare of the agricultural sector or the country at large.

## Conclusions

With the ever-growing world population there will remain an increased need to store agricultural produce for longer periods of time. This will be required to accommodate global movement of produce to regions where there is a demand for or shortage of the particular commodity and for regional local storage of their crops for periods of extended marketing. Increased competition on the export markets from emerging, underdeveloped countries and the simultaneous 'wider' range of exotic fruits and vegetables they can deliver all year round, will shift the emphasis to effective marketing and quality assurance. According to Basker (1988), quality of a horticultural product is a composite of those characteristics that determine the degree of acceptability by a consumer.

Ensuring food safety throughout the food supply chain requires a comprehensive and coordinated effort. The responsibility to safeguard the food supply is shared by everyone involved, from farmers to consumers. This includes growers, farm workers, packers, shippers, transporters, importers, wholesalers, retailers, government agencies, and consumers.

There is a great need in Southern Africa to develop an economically acceptable, practical management system to minimise microbial food safety hazards. Once prerequisite programs such as GAP are in place, it is important to ensure that the process is working correctly and is sustained. Without accountability to ensure the process is working, the best attempts to minimise microbial food safety hazards in fresh fruits and vegetables are subject to failure.

South Africa is well positioned to extend its market share, providing it can maintain its high level of research and technology development capacity and redress imbalances of the past. A systematic approach of bringing emerging black farmers and small-scale farmers on board the export 'bus', and in particular developing niche markets for these growers, will ensure political and economic stability in the region and continent. The challenges are enormous for South African agriculture and require visionary thinkers that will lead the way.

## References

- Barrientos, S., McClenaghan, S. and Orton, L. 1999. Gender and codes of conduct: a case study from horticulture in South Africa. United Kingdom, Department for International Development (DFID).
- Bolton, A. 1997. Quality management systems for the food industry: a guide to ISO 9001/2. London, Blackie Academic and Professional, 193p.
- Davies, F.S. and Albrigo, L.G. 1994. Citrus. Crop production science in horticulture. Wallingford, CAB International.
- Esterhuizen, D. and Van Rooyen, C.J. 2000. How competitive is agribusiness in the South African commodity chain? On the Internet at <<http://www.up.ac.za/academic/ecoagric/research/index.html>>.
- Feneyes, T.I. 1996. South Africa, Africa and the world: a political economy perspective. *Agrekon*, 35, 73–75.
- Huntley, B., Siegfried, R. and Sunter, C. 1989. South African environments into the 21<sup>st</sup> century. Tafelberg, Human and Rousseau.
- Kirsten, J. and Vink, N. 2000. Agricultural policy in South Africa in the 1990s. On the Internet at <<http://www.up.ac.za/academic/ecoagric/research/index.html>>.
- Pelser, C. 1995. Standardisation in South Africa. Pretoria, South African Bureau of Standards.
- Satin, M. 1999. Food quality and international trade. On the Internet at <<http://www.fao.org/ag/ags/agsi/gtz/5Fhtml.htm>>.
- Van Rooyen, C.J. and Nene, S. 1996. What can we learn from previous small scale farmer development strategies in South Africa? *Agrekon*, 35, 325–330.

# Use of a High-temperature, Forced-air Quarantine (Non-chemical) Treatment for Fiji Export Commodities

S. Kumar\*

## *Abstract*

Exports from Fiji were greatly affected when the fumigant ethylene dibromide was lost as a quarantine treatment. However, the use of a high-temperature, forced-air (HTFA) treatment, introduced to Fiji through the Nature's Way Cooperative (Fiji) Limited, has allowed not only re-establishment but also expansion of the export market for papaya, eggplant and breadfruit. The market potential for these commodities in New Zealand, Australia and Canada is discussed.

INCREASING ENVIRONMENTAL and health concerns of importing countries have created both problems and opportunities for exports. The fumigant ethylene dibromide was lost as a quarantine treatment (fruits and vegetables) in 1992 and methyl dibromide (root crops) is being phased out because of the damage it causes to the ozone layer.

However, meeting the low pesticide residue requirement of importing countries has increasingly become a part of the quality standards that must be met for successful high-value exports. Taken a step further, some Fiji farmers are now starting to take advantage of the significant and growing market for certified organic products.

## **Background**

Fiji's potential for developing significant fresh fruit export industries has been identified in numerous consultancy reports and development plans over the last 20 years or so. At last this potential is now starting to be realised. Nature's Way Cooperative (Fiji) Limited (NWC), through the high-temperature, forced-air (HTFA) quarantine treatment facility it operates, has

contributed to the progress now being made in the diversification of Fiji's agricultural exports.

## **Expanding Exports to New Zealand**

When the fumigant ethylene dibromide was lost as a quarantine treatment in 1992, the modest export trade in fresh fruit to New Zealand and Australia was largely lost. Fiji responded more quickly than most of its competitors, including Australia, by adopting the non-chemical HTFA quarantine treatment technology. NWC's HTFA facility was certified for the export of papaya to New Zealand in October 1996. Certification for eggplant, mango and breadfruit soon followed, and exports to New Zealand have grown steadily (Table 1).

## **Nature's Way Cooperative (Fiji) Ltd**

NWC owns and operates the HTFA facility at Nadi Airport. The Cooperative has 86 financial members, made up of 72 farmers and 14 exporters. NWC provides the quarantine treatment service to its members. The Cooperative also packs the fruit for the exporter after treatment. For this service, exporters are charged a fee of 40 cents/kg of fruit treated. The management of the facility is under the responsibility of a Board of Directors, with day-to-day operations under the direction of the facility manager.

\* Nature's Way Cooperative (Fiji) Limited, PO Box 9825, Nadi Airport, Fiji Islands.

## New Zealand Assistance Received

The Fiji–New Zealand Business Council and the New Zealand Overseas Development Agency (ODA) played a critical role in the success of the NWC. A grant of NZ\$16,500 was received from the Fiji/New Zealand Council for the initial training of NWC staff. New Zealand ODA provided a working capital seed grant of NZ\$40,000 that enabled the quarantine treatment business to become operational. NWC is very appreciative of the assistance that has been provided by New Zealand.

## NWC Operations Are Now at a Watershed

NWC has now proven itself as a substantial and viable business. In 1998, it handled 391 t of produce that had a free-on-board value of around \$1.4 million. However, the Cooperative now faces a major increase in the demand for quarantine treatment. Demand pressures are coming from four main areas:

- increasing eggplant sales to New Zealand;
- the commencement of breadfruit exports to New Zealand;
- the opening up of the Australian market for papaya and eggplant; and
- the re-establishment of the Canadian market for papaya and eggplant.

## Continued Expansion of Eggplant Exports to New Zealand

The emigration of Indo-Fijians has created a strong export market in New Zealand and Canada for eggplant varieties from ‘home’. Also, during the winter, eggplant cannot be grown outdoors in these countries. By the early 1990s, around 100 t was to be exported annually to Canada and around 20 t to New

Zealand. However, the loss of ethylene dibromide (EDB) as a quarantine treatment severely disrupted this trade.

In 1997, NWC’s HTFA unit was certified for the export of eggplant to New Zealand — the first HTFA facility in the world to be certified for eggplant. HTFA treatment, unlike EDB fumigation, achieves outstanding results in terms of fruit quality and shelf life. Thus market development of HTFA-treated eggplant has exceeded all expectations. In 1998, some 185 t were exported. Eggplant exports were previously confined to a narrow winter window when no locally grown eggplant was available, and sales were restricted to the Auckland area. However, with the improved quality and shelf life of HTFA-treated fruit, eggplant shipments now continue year round and are distributed throughout New Zealand. New Zealand’s Fijian community remains the cornerstone of the market. However, Fijian eggplant is now competing with the locally grown product on the broader New Zealand market. The ‘Black Beauty’ variety is now specifically being grown for this market. Thus, eggplant exports to New Zealand were projected to exceed 200 t in 1999 and likely to exceed 250 t in the medium term.

## The Commencement of Breadfruit Exports to New Zealand

Breadfruit, a popular staple for most Pacific Island communities, has market potential approaching that of other root crops in New Zealand, Australia and the United States. However, breadfruit is well known as a fruit fly host. Quarantine restrictions have meant that this potential has not been anywhere near realised. Exports have only been in frozen and cooked form, which has restricted any real market development.

A major breakthrough occurred in February 1999 with the certification of the Fiji HTFA facility for the export of breadfruit to New Zealand — again, a world

**Table 1.** Produce treated by the Nadi high-temperature, forced-air (HTFA) facility, 1996–1998.

Commodities	1996 (kg)	1997 (kg)	1998 (kg)	Total (kg)	Estimated value <sup>a</sup> (F\$)
Papaya	33 037	90 010	85 965	209 012	836 048
Mango	–	23 072	120 209	143 283	429 843
Eggplant	–	69 615	185 155	254 770	891 695
Total	33 037	182 679	391 329	607 063	2 157 586

<sup>a</sup> Free-on-board

first. Breadfruit shipments were expected to commence in June. NWC made a decision to delay the first shipment until growers were registered and a bait spray program was in place. Also, NWC's manager was undertaking shelf life tests for various HTFA-treated breadfruit varieties. It is anticipated that, as with eggplant, HTFA treatment will enhance the shelf life of breadfruit.

In 1998, the value of New Zealand root crop imports was almost NZ\$8 million. A 5% market share for breadfruit of the New Zealand root crop market would not seem unreasonable. This would mean treating in the vicinity of 200–300 t of fruit, concentrated in the two breadfruit seasons. Smaller, but significant, markets could be expected in Australia and the United States West Coast.

### **Opening Up of the Australian Market for Papaya and Eggplant**

Progress in opening up the Australian market for HTFA-treated papaya has been disappointingly slow. Prior to the loss of EDB, Fiji was exporting 50–150 t annually to Australia. Thus, it was assumed that this market would be re-established soon after HTFA-treated papaya shipments started to New Zealand. However, it is only now that the Australian Quarantine and Inspection Service has requested confirmatory tests for papaya to be undertaken at the Nadi HTFA facility. The expectation is that exports will commence reasonably soon after these data have been submitted. Papaya exports are expected to exceed 150 t annually once the supply is available.

It is anticipated that eggplant shipments to Australia will follow reasonably quickly after the certification of

papaya. Australia has a sizeable Fijian community which, based on the New Zealand experience, offers a significant market for HTFA-treated eggplant. Australia's largest ethnic communities, particularly Melbourne's Greek population, offer an even larger potential market.

### **Re-establishment of the Canadian Market for Papaya and Eggplant**

Prior to 1992, there were sizeable exports of papaya, eggplant and other produce to Canada. These air-freight exports were transshipped through Hawaii. However, in 1992, the United States Department of Agriculture (USDA) banned the transshipment of all fruit fly host material through Hawaii. Indications are that this ban will finally be lifted for HTFA-treated produce. As a result of intervention of the United States–Pacific Island Joint Commercial Commission, a high-level USDA mission was to visit Fiji in June 1999 to inspect the HTFA facility.

Based on past export performance, several hundred tonnes of papaya could be exported to Canada, once the supplies are available. NWC's exporters are looking forward to sizeable eggplant exports to Canada. In the past, more eggplant was exported to Canada than to New Zealand.

The HTFA technology was developed by the University of Hawaii and Dr Mike Williamson is the engineer responsible for commercialising HTFA technology. He has been closely involved in the Fiji facility since its inception, commissioning the facility and providing ongoing technical support and training services. Dr Williamson is the Principal of Quarantine Technologies International.



# Induction of Red Grapefruit Resistance to *Penicillium digitatum* and Chilling Injury by a Short Hot Water Brushing Treatment

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## Abstract

Postharvest heat treatments have been used for many years as alternative, non-chemical methods to control fungal diseases and insect infestation in fruits and vegetables. In this study, we examined the effects of a new hot water brushing (HWB) treatment, which sprays hot water on fruit as they move along a belt of brush rollers, on the resistance of red grapefruit (*Citrus paradisi* 'Star Ruby') to green mould decay caused by *Penicillium digitatum* (Pers.: Fr.) Sacc. and on the development of chilling injury (CI) symptoms during cold storage. We found that a 20 s HWB treatment at 59°C and 62°C reduced decay, after artificial inoculation of wounded fruit, by 52% and 70%, respectively, as compared to untreated fruit (control), whereas rinsing and brushing the fruit with tap water (~20°C), or with hot water at lower temperatures of 53°C and 56°C, were ineffective in reducing decay development. The HWB treatments were most effective in enhancing fruit disease resistance when the fruit were inoculated 1 or 3 days after the heat treatments, and were much less effective when the fruit were inoculated on the same day or after 7 days. The HWB treatments at 59°C and 62°C for 20 s also significantly reduced the CI index and the percentage of fruit displaying CI symptoms after 6 weeks of storage at 2°C and an additional week at 20°C by 42% and 58%, respectively, as compared to untreated fruit. Again, rinsing and brushing the fruit with tap water, or HWB treatments at lower temperatures of 53°C and 56°C, had no significant effect on CI incidence. The HWB treatments further cleaned the fruit and improved its general appearance without causing any surface damage, and did not influence fruit weight loss, percentage of total soluble solids in the juice, juice acidity, or fruit colour.

HEAT TREATMENTS, including hot water dips, vapour heat and forced hot air, have been used for many years as non-chemical methods to control fungal rots and insect infestation in various fruits and vegetables (Couey 1989; Barkai-Golan and Phillips 1991; Lurie 1998). In addition, some of these heat treatments have also been used to enhance the tolerance of commodities to chilling injury (CI) development during cold storage (reviewed by Lurie 1998). During the last few years, physical heat treatments have received increasing interest due to the de-registration of a number of chemical treatments that have previously been used to control postharvest pathogens, and because of the public interest in chemical-free produce.

In the present study, we examined the use of a recent improvement in the hot water dip treatment, which has been developed to comprise a hot water rinsing and brushing treatment (Fallik et al. 1999). The advantages of this technique are that it simultaneously cleans and disinfects the fruit; it fits into the packinghouse sorting line; and it requires a much shorter exposure time (10–30 s) than the conventional hot water dip treatments, which usually require a few minutes.

## Materials and Methods

### Plant material and storage conditions

Red grapefruit (*Citrus paradisi* 'Star Ruby') were obtained from a local orchard and used on the day of harvest. For storage experiments, fruit were kept for 6 weeks at 2°C and then transferred for another week to

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shelf-life conditions at 20°C. The relative humidity was 90% in both storage rooms. Each treatment included 4 boxes, each containing 30 fruit, and the experiment was repeated 4 times with similar results.

### Postharvest hot water brushing (HWB) treatments

HWB treatments at 53, 56, 59 and 62°C were applied as a rinse onto fruit moving along a set of brush rollers. The fruit were exposed to the different HWB temperatures for 20 s. As a control, fruit were rinsed and brushed with tap water (~20°C).

### Effects of HWB on fruit resistance to *Penicillium digitatum*

Fruit were kept as control or were rinsed and brushed for 20 s with tap water (~20°C), or at 53, 56, 59 or 62°C. On the same day, or after 1, 3 or 7 days, the fruit were wounded with a dissecting needle (1 to 2 mm deep) at three sites around their stem end, and the wounds inoculated with 20 µL of a *Penicillium digitatum* (Pers.: Fr.) Sacc. spore suspension (10<sup>4</sup> spores/mL). Afterwards, the fruit were incubated at 20°C in plastic trays under humid conditions. The percentage of infected wounds was determined 4 days after inoculation.

### Evaluation of chilling injury (CI)

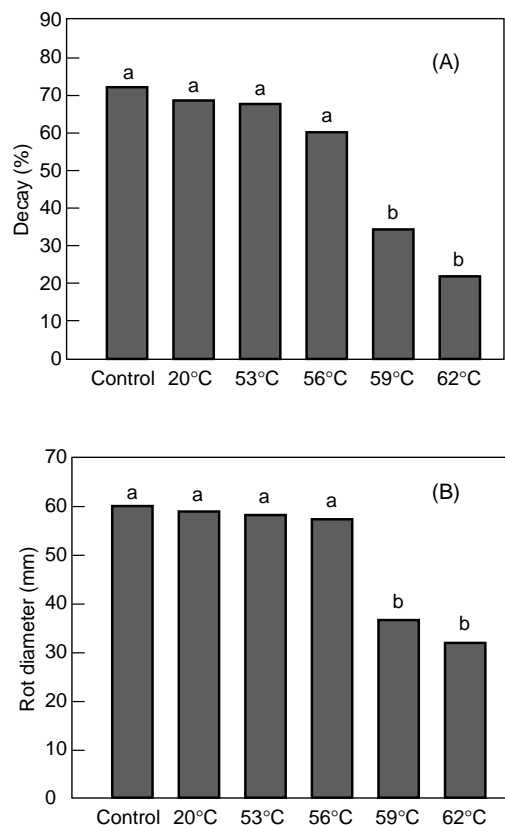
After 6 weeks of storage at 2°C and an additional week at 20°C, fruit were classified into four categories according to their CI severity: 0 = none; 1 = slight; 2 = moderate; and 3 = severe. The CI index was determined for each treatment by multiplying the number of fruit in each category by their score, and then dividing this sum by the total number of fruit assessed. The percentage of fruit exhibiting CI symptoms was also determined.

## Results

### Effects of HWB treatments on fruit resistance to *P. digitatum*

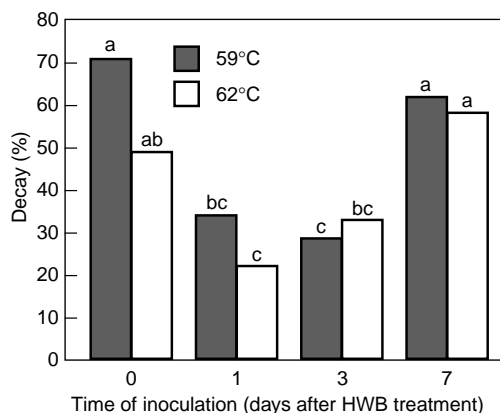
Fruit treated with the HWB machine at various temperatures and inoculated 24 h later with a *P. digitatum* spore suspension developed decay after 4 days at 20°C (Figure 1). HWB treatments at 59°C and 62°C reduced the proportion of wounds that developed decay

symptoms to 35% and 22%, respectively, as compared to 73% in control, non-washed fruit, whereas rinsing and brushing the fruit with tap water, or water at 53°C or 56°C, had no significant effect on decay development (Figure 1A). Moreover, the same HWB treatments at 59°C and 62°C also reduced the rot diameter in the wounds that developed disease symptoms to 37 mm and 33 mm, respectively, as compared to 60 mm in control, non-washed fruit (Figure 1B).



**Figure 1.** Effects of hot water brushing treatments on the resistance of red grapefruit against *Penicillium digitatum*. The percentage of wounds that developed disease symptoms (A) and rot diameter (B) were measured after 4 days of incubation at 20°C. Bars with different letters are significantly different at the 5% level.

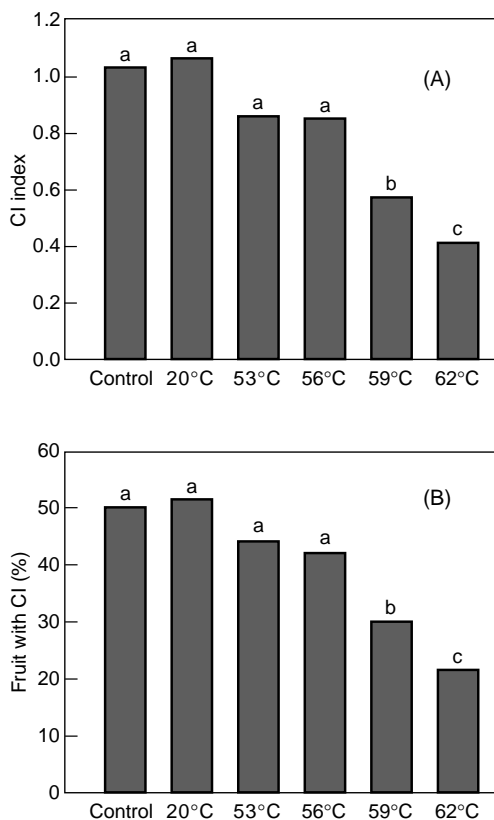
By wounding and inoculating the fruit at different times after the HWB treatments, we found that the 59°C and 62°C HWB treatments most effectively reduced decay development when the fruit were inoculated after 1 and 3 days, but were much less effective when the fruit were inoculated at the same day or after 7 days (Figure 2). Rinsing and brushing the fruit with tap water, or HWB treatments at the lower temperatures of 53°C and 56°C, were ineffective in reducing decay development and in all these cases the rate of decay was 70–80%.



**Figure 2.** Effects of timing of inoculation after the hot water brushing (HWB) treatments (at 59°C or 62°C) on red grapefruit resistance to *Penicillium digitatum*. Bars with different letters are significantly different at the 5% level.

### Effects of HWB treatments on fruit tolerance to CI

HWB treatments at 59°C and 62°C reduced the incidence of CI, as indicated by both the CI index and the percentage of fruit displaying CI symptoms. The HWB treatments at 59°C and 62°C reduced the CI index to 0.59 and 0.42, respectively, compared to 1.03 in control, non-washed fruit (Figure 3A), and reduced the proportion of fruit displaying CI symptoms to only 29.5% and 21.5%, respectively, as compared to 50.0% in control, non-washed fruit (Figure 3B).



**Figure 3.** Effects of hot water brushing treatments on the tolerance of red grapefruit to chilling injury (CI) development during cold storage. Fruit were kept as control or were rinsed and brushed for 20 s at different temperatures. The CI index (A) and the percentage of fruit displaying CI symptoms (B) were measured after 6 weeks of storage at 2°C and an additional week under shelf-life conditions of 20°C. Bars with different letters are significantly different at the 5% level.

### Effects of HWB treatments on fruit quality

None of the HWB treatments had a significant effect on fruit weight loss, percentage of total soluble solids (TSS) in the juice, juice acidity, TSS/acid ratio, or fruit colour (as indicated by their hue angle) and similar results were observed following different storage conditions of 3 weeks at 11°C and an additional week at 20°C (data not shown).

## Conclusion

This new postharvest HWB treatment, that has already been commercially adapted to clean and disinfect various fruits and vegetables, can provide an alternative, non-chemical method to reduce decay development, and allow storage at lower temperatures that are unfavourable to the development the pathogens, without causing any harm to the fruit.

## References

- Barkai-Golan, R. and Phillips, D.J. 1991. Postharvest heat treatments of fresh fruits and vegetables for decay control. *Plant Disease*, 75, 1085–1089.
- Couey, H.M. 1989. Heat treatment for control of postharvest diseases and insect pests of fruits. *HortScience*, 24, 198–202.
- Fallik, E., Grinberg, S., Alkalai, S., Yekutieli, O., Wiseblum, A., Regev, R., Beres, H. and Bar-Lev, E. 1999. A unique rapid hot water treatment to improve storage quality of sweet pepper. *Postharvest Biology and Technology*, 15, 25–32.
- Lurie, S. 1998. Postharvest heat treatments of horticultural crops. *Horticultural Review*, 22, 91–121.

# Implementation of Quality Assurance for 'Arumanis' Mango

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## Abstract

Quality of 'Arumanis' mango is expressed as a combination of characteristics, attributes, and properties which are valued by consumers. Growers and collectors want their fruit to have a good appearance—free of (or few) visual defects, but more importantly, the fruit must score high in yield, disease resistance, ease of harvest and shipping quality. From the consumers' point of view, the important quality attributes include appearance, flavour, and long storage life.

In order to meet these objectives, quality assurance (QA) as a management and marketing tool will become an integral part of commercial fruit production for 'Arumanis' mango in Indonesia. This paper reports on the implementation of a quality assurance system related to operations in the production, distribution and marketing of 'Arumanis' mango which focuses on market requirements, either domestic or international. It also assesses the critical stages necessary to successfully implement quality programs.

QUALITY ASSURANCE (QA) involves produce, services, processes and people. It is a planned and systematic integration of all these business components. According to Bunt and Piccone (1994), in a marketing sense, QA assures customers that they can purchase a product with confidence, knowing that it will meet all their expectations for that product. QA is concerned with building and maintaining a product's reputation. In a production sense, it is concerned with ensuring that the marketing goals are achieved in the most consistent, cost-effective, and efficient manner possible. QA is also designed to consistently satisfy customer expectations by defining objectives, planning activities, and controlling variability.

'Arumanis' mango (*Mangifera indica* L.) is one of the most popular mango varieties in Indonesia. Mango belongs to the family Anacardiaceae and originated in

India and the Southeast Asian area. 'Cengkir', 'Golek', 'Gedong Gincu', 'Kopyor' and 'Manalagi' are the other well known varieties in Indonesia. However, 'Arumanis' mango is unique in its specific taste and aroma, and also its high availability during the mango season. In general, the central production areas in Indonesia are: East Java (Probolinggo, Situbondo, Pasuruan, and Gresik Districts), Central Java (Pati and Rembang Districts), and northern Bali (Buleleng District). Improving farm management would give rise to better fresh fruit quality, which in turn would have a direct impact in increasing the growers' income and welfare. In the long run, rural development could be achieved which would then strengthen the rural economic basis.

Handling of the 'Arumanis' mango fruit is not yet professionally managed on a business scale, particularly at the grower level. Quality standards are not properly applied, and it seems that each district or province has its own standard. This paper attempts to provide some information in regard to the implementation of a simple quality assurance system for postharvest handling of 'Arumanis' mango that may assist in the design of handling systems suited to particular commercial marketing situations.

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## The Current Preharvest Handling Situation

Anthracnose is the most serious disease of 'Arumanis' mango in all growing areas. It is caused by the fungus *Colletotrichum gloeosporioides*, which can affect leaves, twigs, flowers and fruit. Stem-end rot is also a significant cause of wastage in 'Arumanis' mango. This disease is caused mainly by *Dothiorella dominicana*, *Lasiodiplodia theobromae* and *Dothiorella mangiferae*. The symptoms usually first appear at the stem end of the fruit and spread down through the fruit as it ripens, causing a progressive, brownish to black discoloration and premature softening of the fruit. Bacterial spot can also occur on fruit at harvest. Fruit stalks are commonly infected with bacterial spot causing them to become necrotic which results in fruit drop.

Sap burn is a surface injury that occurs on the skin of the mango when it comes into contact with stem sap during harvesting. It appears as spotted or streaked areas on the sides of the fruit. The damaged areas are initially brown in colour but eventually desiccate and darken. It is primarily regarded as a serious problem of 'Arumanis' mango because it detracts from the appearance of the fruit and the injured areas can provide sites for fungal infection.

## Harvesting and Field Handling

Picking can incur significant costs to fresh 'Arumanis' mango crops when maturity, sap stain, stem-end rot and bruising are not given sufficient attention by the pickers. To minimise these problems, it is recommended that fruit should be harvested individually by clipping the stem about 5 cm above the fruit using cutting tools attached to a pole with a catching bag attached. Harvested fruit must be gently placed directly into picking baskets. Harvesting should be done early in the day when the fruit itself and field temperatures are coolest. The harvested fruit should be kept shaded and protected from direct sunlight, and the harvested fruit should remain in the field for the shortest time possible before transportation to the packing shed. The field containers used to hold harvested fruit should provide adequate protection from injury. They should be of a design that will not damage the skin, i.e. no rough surfaces, and not too big. If bamboo baskets are to be employed, they should be appropriately lined.

## Packinghouse Operations

During transport from the field to the packinghouse, care should be taken to avoid compression or impact bruising. On arrival at the packing shed, the stems should be removed by holding the stem end of the fruit downwards and directed so that the sap does not come into contact with other fruit. When packing 'Arumanis' mango into the package destined for market, the fruit should be firmly packed to restrict movement, and over-filling of the package should be avoided. Bamboo baskets currently predominate as the preferred mango container in local trade. However, they do not provide adequate protection to the fruit, as they are generally flexible and their shape is easily distorted. They also can not be stacked, as their weight and shape risks damage to fruit in a lower layer. Wooden crates offer better protection than bamboo baskets due to their rigidity, however rough internal surfaces can still cause fruit injury.

## Post-packing Operations

'Arumanis' mango is a climacteric fruit which shows a large increase in respiration during ripening and a concurrent increase in the production of ethylene. Ripening studies have shown that exposure of mango fruit to ethylene gas will initiate ripening. Continued application of ethylene hastens skin colour development, increases the titratable acidity of the ripe pulp, lowers the pulp pH, decreases the total soluble solids content of the flesh, slightly reduces flavours and general eating quality, and decreases the pulp firmness.

Acetylene is an ethylene analogue and is used widely as a ripening agent where ethylene is not available or is too expensive. Acetylene can be liberated from calcium carbide by the addition of water. Ripening of 'Arumanis' mango will be fully initiated by 100 parts per million (ppm) of acetylene applied for 24 h. Alternatively, ripening can also be induced by dipping the fruit into 500–1,000 ppm ethrel solution.

## Conclusion

In order to achieve good quality of fresh fruit, application of a quality assurance (QA) system in post-harvest handling is required. QA will assist in the design of a handling system which will deliver mango fruit suited to the needs of particular marketing situations. Such a system is urgently needed in Indonesia

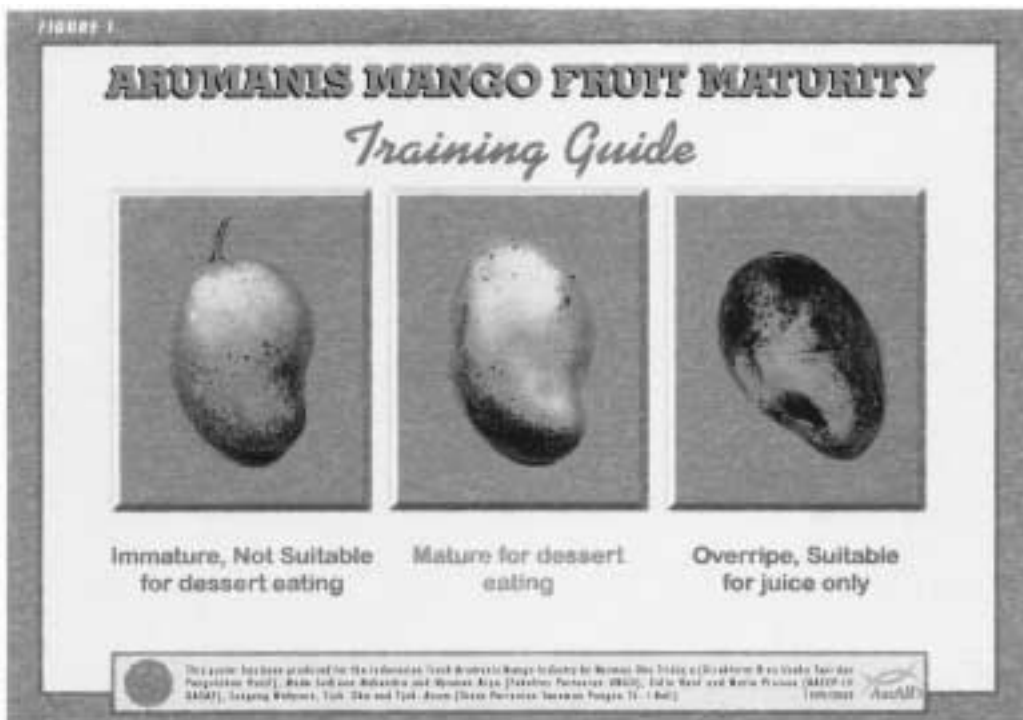


Figure 1. Training guide for 'Arumanis' mango fruit maturity.

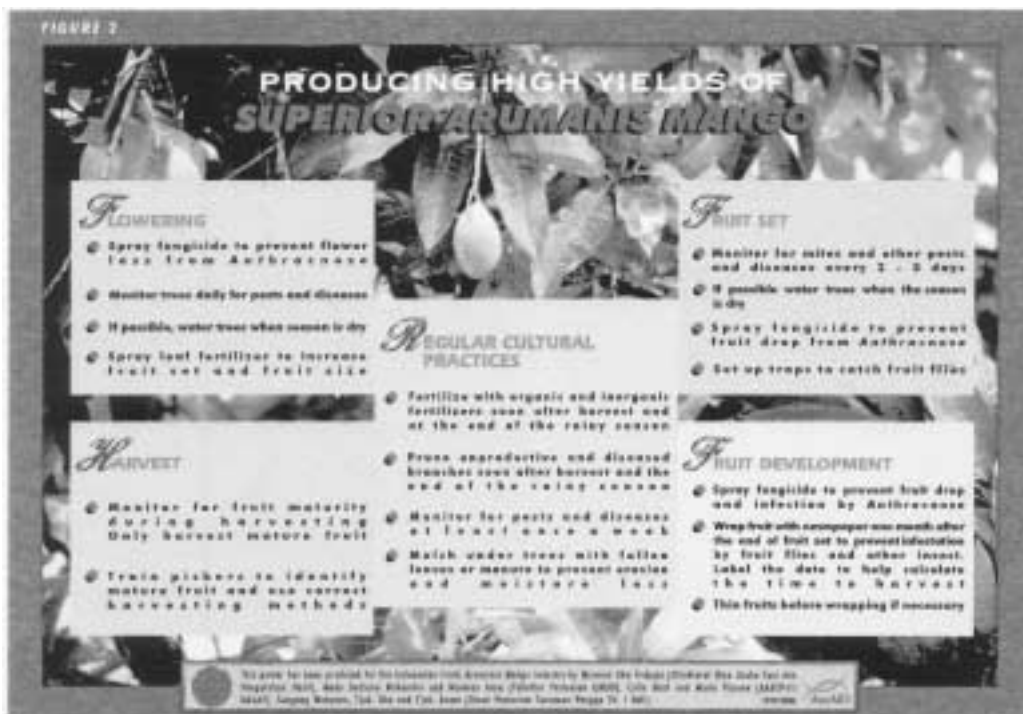


Figure 2. Guide to producing high yields of superior 'Arumanis' mango.

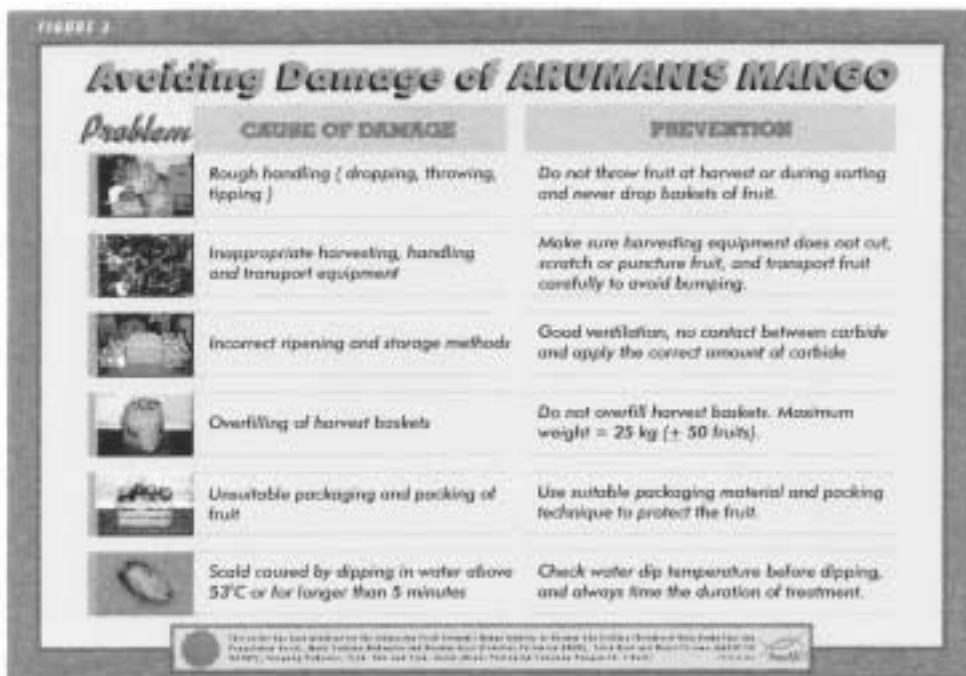


Figure 3. Guide to avoiding damage of 'Arumanis' mango.



Figure 4. Guide to avoiding losses and damage of 'Arumanis' mango.



and elsewhere to increase consumer confidence in this produce. Posters have been produced as part of an extension kit for the Indonesian fresh 'Arumanis' mango industry. The kit was specifically designed by the Association of South-East Asian Nations (ASEAN)–Australia Economic Cooperation Program III Quality Assurance Systems for ASEAN Fruits (AAECP–III QASAF) Project, specifically to guide growers, collectors, wholesalers, and retailers, as shown in Figures 1 to 4.

### **Acknowledgments**

The authors wish to thank AAECP–III QASAF who financially supported this work, and the Australian Centre for International Agricultural Research

(ACIAR) for the presentation of this paper at 19<sup>th</sup> ASEAN/1<sup>st</sup> Asia–Pacific Economic Cooperation (APEC) Seminar on Postharvest Technology, Ho Chi Minh City, Vietnam. The authors also wish to thank Prof. John Janes and Dr Zora Singh (Curtin University of Technology, Australia) for their helpful comments and Mr I.B.K.G. Kertia who typed the manuscript.

### **Reference**

Bunt, C. and Piccone, M. 1994. Quality assurance: a total approach. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., Postharvest handling of tropical fruits. Proceedings of an international conference held at Chiang Mai, Thailand, 19–23 July 1993. ACIAR Proceedings No. 50. Canberra, Australian Centre for International Agricultural Research, 27–31.

# The Effects of Hydro-cooling and Plastic Bag Packaging on the Shelf Life of Chinese Kale (*Brassica albograbala* L.)

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## Abstract

This work was initiated to determine the effects of hydro-cooling prior to packaging on the shelf life of Chinese kale. In addition, the potential for plastic bag packaging in extending the shelf life of Chinese kale placed in supermarkets was evaluated. In the first experiment, Chinese kale (*Brassica albograbala* L.) was harvested and divided into 4 treatments: not cooled, or hydro-cooled at 1, 5 or 10°C. All treatments were then kept at 10°C to simulate shelf conditions. Hydro-cooling resulted in much better appearance, freshness, chlorophyll content and shelf life than not cooling. Chinese kale which was hydro-cooled at 5°C had the best appearance and longest shelf life at 10°C, while that which was hydro-cooled at 1°C was shrivelled after six shelf-life days. In the second experiment, Chinese kale was harvested, hydro-cooled and divided into five treatments: (1) non-packed; (2) packed in non-perforated polypropylene (PP) bag; (3) packed in perforated PP bag; (4) packed in non-perforated polyethylene (PE) bag; and (5) packed in perforated PE bag. All treatments were stored at 10°C. Application of plastic bag packaging improved freshness, chlorophyll content and shelf life of Chinese kale. Non-perforated PE bag packaging resulted in the best appearance, freshness and longest shelf life of the treatments tested. Combining 5°C hydro-cooling with PE bag packaging could extend the shelf life of Chinese kale from 4 to 16 days at 10°C.

CHINESE KALE (*Brassica albograbala* L.) is a tropical vegetable that can grow throughout Thailand, especially in the central region. Chinese kale is herbaceous and undergoes rapid quality changes after harvest, e.g. discoloration, toughening and water loss, and thus has a short shelf life. Rapid deterioration after harvest can be triggered by high temperatures in the field during harvest (Kader et al. 1974). However, optimal pre-cooling methods for tropical vegetable are not well managed in Thailand. In addition, packaging suitable for prolonging the shelf life of perishable produce has not been defined. Hence, the objectives of this work were to determine (1) the optimal temperature for hydro-cooling, and (2) the most appropriate packaging types for optimal storage of Chinese kale.

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## Materials and Methods

### Plant material, hydro-cooling and packaging

In the first experiment, Chinese kale (*Brassica albograbala* L.) was hand-harvested by cutting with a knife in Prathumthani, Thailand, in April, and transported in an air-conditioned car to the Postharvest Laboratory at King Mongkut's University of Technology Thonburi, Bangkok, within 2 hours. After arrival, vegetables were hydro-cooled using water at 1, 5 or 10°C until vegetable temperature was reduced to 10°C. Green, tender vegetables were selected which were uniform in size and colour. They were randomly divided into three groups of four Chinese kale (approximately 0.5 kg per replicate).

In the second experiment, the vegetables treated with the most successful hydro-cooling temperature

(as determined in the first experiment) were packed in one of five packaging materials: non-perforated polypropylene (PP) bags; perforated PP bags; non-perforated polyethylene (PE) bags; perforated PE bags; or not packaged (control).

Both experiments were conducted under the shelf temperature conditions (8–10°C).

### Monitoring carbon dioxide levels

The gaseous composition of the atmosphere within each bag was monitored during storage using gas chromatography. 1 mL of air from inside each bag was withdrawn using a gas-tight syringe fitted with a 25 G stainless steel needle. Gas samples were injected into a gas chromatograph fitted with a thermal conductivity detector equipped with a stainless steel column (3 mm × 1.5 m) containing porapak Q (80/100 mesh) (Shimadzu, GC-8A, Japan) and analysed for CO<sub>2</sub>. The temperature of the injector and detector was 100°C and the column temperature was 50°C. Helium was used as the carrier gas.

### Analyses

Percentage weight loss was determined by comparing the average weight of four 100 g samples at each sampling date to the initial weight.

Levels of ascorbic acid and chlorophyll were determined by the methods of the Association of Official Analytical Chemists (AOAC 1990).

Fibre content was determined using an alkali extraction method. Pods without seeds (10 g samples) were cooked for 10 min in boiling water, before being macerated with 12.5 mL 50% NaOH for 5 min. Fibre was washed and filtered through a 25–30 µm mesh screen, then dried at 100°C for 2 h and weighed (Gould 1977).

### Statistical analyses

Statistical analyses performed on data included analysis of variance (ANOVA) using the general linear models (GLM) procedure of SAS (SAS Institute, Cary, NC.), Duncan's multiple range test, and standard deviation calculations. The experimental design used for analytical measurements was completely randomised and repeated four times.

## Results and Discussion

### Effect of hydro-cooling on quality of Chinese kale

#### *Duration of hydro-cooling*

Water temperature had some effect on the pre-cooling time of Chinese kale. Water at 1, 5 and 10°C lowered the temperature of Chinese kale from 27°C to 10°C within 2, 4 and 17 minutes, respectively. Using water at 1°C was the most efficient, as the difference in temperature between the vegetables and the water was the highest.

#### *Weight loss*

Weight loss occurred in Chinese kale over time in storage. Percentage weight loss was reduced by hydro-cooling. Hydro-cooling Chinese kale at 5°C reduced weight loss better than other the hydro-cooling temperatures (Figure 1).

#### *Ascorbic acid content*

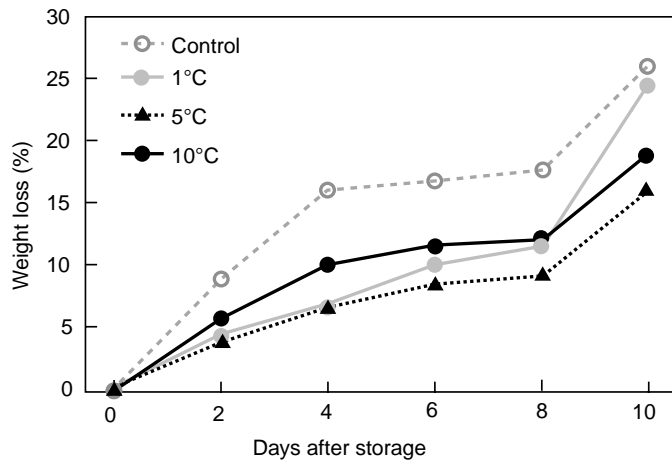
The ascorbic acid content decreased in Chinese kale during storage. The rate of decrease was slower in hydro-cooled vegetables than non-hydro-cooled ones—the latter showed a rapid decline (Figure 2). Hydro-cooling has been previously shown to maintain ascorbic acid content and reduce weight loss in broccoli (Toivonen 1997).

#### *Chlorophyll content*

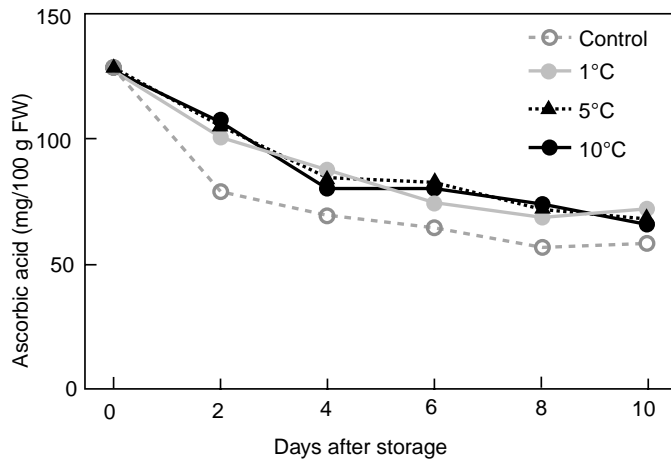
Chlorophyll levels decreased rapidly in non-hydro-cooled Chinese kale. Hydro-cooling allowed a much better level of chlorophyll to be maintained (Figure 3).

#### *Fibre content*

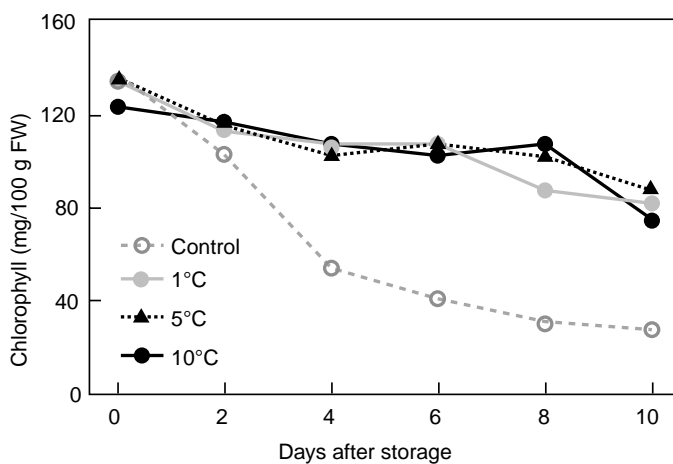
The fibre content of both hydro-cooled and non-hydro-cooled Chinese kale increased over time in storage. The fibre content of the 10°C hydro-cooled Chinese kale increased rapidly on the sixth day of storage. Apart from this, the rate of fibre increase was very similar between all treatments and the control (Figure 4).



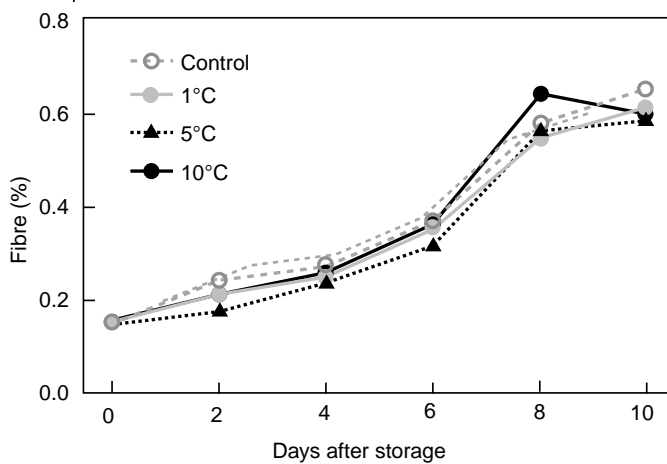
**Figure 1.** Weight loss of Chinese kale hydro-cooled at 1, 5 or 10°C, or not hydro-cooled (control), then kept at 10°C for 10 days.



**Figure 2.** Ascorbic acid content (mg/100 g fresh weight; FW) of Chinese kale hydro-cooled at 1, 5 or 10°C, or not hydro-cooled (control), then kept at 10°C for 10 days.



**Figure 3.** Chlorophyll content (mg/100 g fresh weight; FW) of Chinese kale hydro-cooled at 1, 5 or 10°C, or not hydro-cooled (control), then kept at 10°C for 10 days.



**Figure 4.** Fibre content of Chinese kale hydro-cooled at 1, 5 or 10°C, or not hydro-cooled (control), then kept at 10°C for 10 days.

## Effects of packaging on the shelf life of Chinese kale

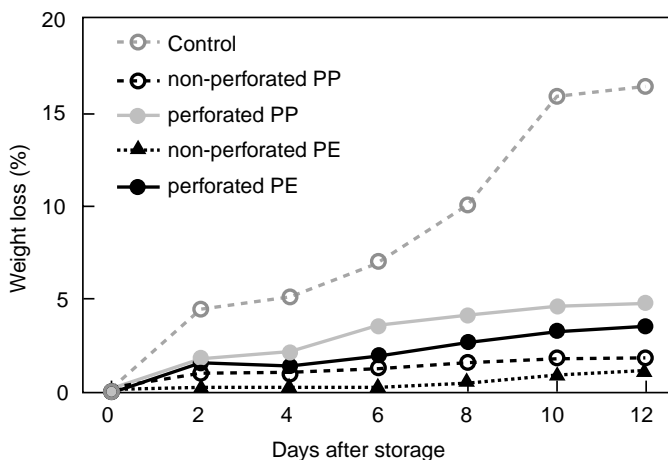
### Weight loss

Percentage weight loss was lower for Chinese kale stored in non-perforated plastic bags than in perforated plastic bags or non-packaged (control) (Figure 5) because the non-perforated bags reduced the water

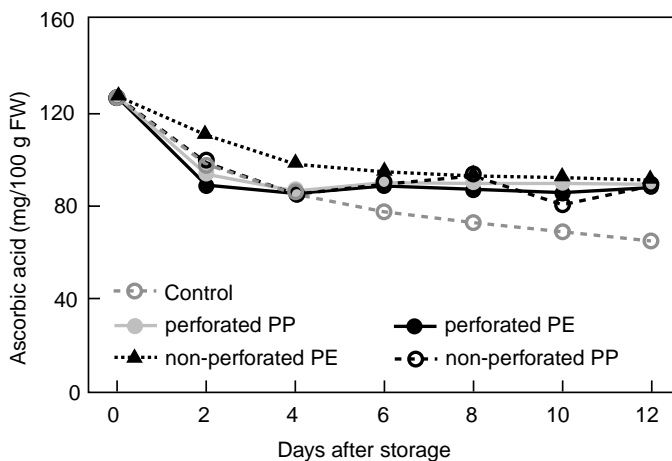
vapour gradient between the outside surface of the product and the air.

### Ascorbic acid content

The level of ascorbic acid decreased during storage, with a slower rate of decrease in Chinese kale stored in plastic bags (both perforated and non-perforated) compared to non-packaged (control) (Figure 6).



**Figure 5.** Weight loss of Chinese kale stored at 10°C for 12 days in various plastic bag packaging (PE = polyethylene, PP = polypropylene), or non-packaged (control).



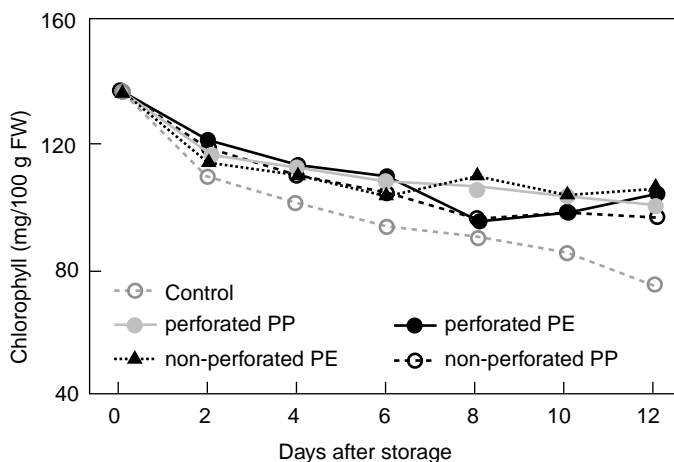
**Figure 6.** Ascorbic acid content (mg/100 g fresh weight; FW) of Chinese kale stored at 10°C for 12 days in various plastic bag packaging (PE = polyethylene, PP = polypropylene), or non-packaged (control).

### Chlorophyll content

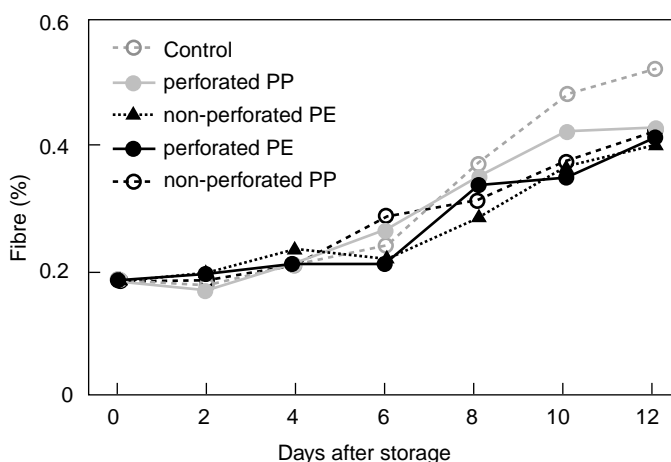
Chinese kale stored in plastic bags maintained its chlorophyll content better than the control samples (Figure 7). This was due to the higher concentration of CO<sub>2</sub> in the packages, which can reduce the degradation of chlorophyll (Zhuang et al. 1994; Paradis et al. 1996).

### Fibre content

The fibre content of Chinese kale stored in plastic bags increased more slowly than that of control samples (Figure 8). This is probably because of a reduction in peroxidase activity which leads to lower fibre production (Watada et al. 1987).



**Figure 7.** Chlorophyll content (mg/100 g fresh weight; FW) of Chinese kale stored at 10°C for 12 days in various plastic bag packaging (PE = polyethylene, PP = polypropylene), or non-packaged (control).



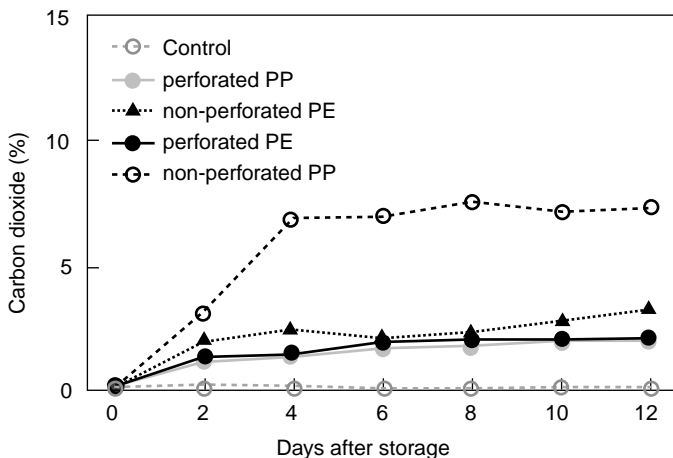
**Figure 8.** Fibre content of Chinese kale stored at 10°C for 12 days in various plastic bag packaging (PE = polyethylene, PP = polypropylene), or non-packaged (control).

## Change in composition of package atmosphere

The CO<sub>2</sub> content increased during storage. Chinese kale packed in non-perforated PP bags had the highest CO<sub>2</sub> (Figure 9).

## Conclusion

From these experiments, we conclude that the optimal conditions for prolonging the shelf life of Chinese kale is hydro-cooling using water at 5°C, followed by packing in non-perforated polyethylene (PE) plastic bag and storage at 10°C.



**Figure 9.** Headspace levels of carbon dioxide for Chinese kale stored at 10°C for 12 days in various plastic bag packaging (PE = polyethylene, PP = polypropylene), or non-packaged (control).

## References

- AOAC (Association of Official Analytical Chemists) 1990. Official methods of analysis. Virginia, Association of Official Analytical Chemists Inc., 1298p.
- Gould, W.A. 1977. Food quality assurance. Wesport, Connecticut, AVI Publishing, 314p.
- Kader, A.A., Lyons, J.M. and Morris, L.L. 1974. Postharvest responses of vegetables to preharvest field temperature. *HortScience*, 9, 1523–1527.
- Paradis, C., Castaigne, F., Desrosieers, T., Fortin, J., Rodrique, N. and Willemot, C. 1996. Sensory, nutrient and chlorophyll changes in broccoli florets during controlled atmosphere storage. *Journal of Food Quality*, 19, 303–316.
- Toivonen, P.M.A. 1997. The effects of storage temperature, storage duration, hydro-cooling and micro-perforated wrap on life of broccoli (*Brassica oleracea* L. Italica Group.) *Postharvest Biology and Technology*, 10, 59–65.
- Watada, A.E., Kim, S.D., Kim, K.S. and Harris, T.C. 1987. Quality of green beans, bell peppers and spinach stored in polyethylene bags. *Journal of Food Science*, 52, 1637–1640.
- Zhuang, H., Barth, M.M. and Hildebrand, D.F. 1994. Packaging influences total chlorophyll, soluble protein, fatty acid composition and lipoxygenase activity in broccoli florets. *Journal of Food Science*, 59, 1171–1174.



# Investigation into Postharvest Loss of Cantaloupe

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## Abstract

Factors responsible for the postharvest loss of 'Huanghemigua' cantaloupe were investigated. Postharvest loss in cantaloupe under commercial practice in Gansu, China was as high as 29.3% and was mainly caused by postharvest disease. The diseases caused by pathogens were related to the handling methods used during harvest and transport.

THE HEXI CORRIDOR in western Gansu has always been a traditional and major cantaloupe production area in China due to the favourable climatic conditions—dry, hot and with a large temperature difference between day and night in summer. In the past decade, melon production has been growing rapidly in western Gansu. Over 70% of the cantaloupes produced there are transported more than 2,000 km (on average) to the markets in other provinces, since the local marketing capacity is quite limited by its small population. Careless handling practices during harvesting, loading, unloading and transport, with very simple or even without packaging, have all contributed to melon loss, which is harmful to the economic benefit of both farmers and salesmen, consumers' acceptance and the reputation of Gansu melon produce. In spite of their rough rind, cantaloupes have a short shelf life. Morris and Wade (1985) reported that cantaloupe could be stored safely for only 7–15 days, even under suitable temperatures (5–7°C), and that the main limiting factor was postharvest disease caused by various pathogens such as *Fusarium* and *Alternaria*. In an investigation of Chinese 'Hami' melon decay during transport, Zhang Weiyi et al. (1990) found that the traditional handling techniques employed in melon harvesting and shipping offered much opportunity for the fruit to be damaged and infected by diseases. We report in the present paper the relationship between weight loss (caused by water evaporation and decay)

and maturity, mechanical injury and packaging of 'Huanghemigua' cantaloupe under normal air temperature conditions as a first step toward devising alternative techniques for harvest and postharvest handling to minimise fruit loss and marketing risk.

## Materials and Methods

### Materials

The experiment and survey were carried out in 1997–1998. The cantaloupe variety employed was 'Huanghemigua' (honeydew type) from commercial melon fields in Wuwei and Mingqin. Fruit were shipped to Lanzhou the day after picking and initial treatment.

### Determination of water loss

Melons were picked at physiological maturity of 70% (about 35 days after blossom) or 90% (about 50 days after blossom), then each melon was weighed and labelled on the rind with a bold oil pen on the same day, packed in cartons, plastic net bags or not packed. The samples were then sent to Lanzhou and kept at room temperature (17–22°C). For every treatment 3 replicates of 24 melons each were investigated. Melon samples were weighed and assessed for disease spot diameter and disease percentage the day after they were sent to Lanzhou, and subsequently at the end of the 1<sup>st</sup>, 2<sup>nd</sup>, or 4<sup>th</sup> week after harvest.

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## Measurement of fruit injury

The whole harvesting procedure was divided into four stages, including picking, transport from the field, loading on and off tractors, and transport to the packing site. 72 mature fruit were divided into 3 groups, wrapped with soft paper and packed in cartons after each of the above stages. The melon samples were then transported to Lanzhou and visually examined for surface injury on the 3<sup>rd</sup> day after transport. The degree of injury was rated on a scale of 1–5 where: 1 = cracked; 2 = punctured; 3 = bruise diameter >2 cm; 4 = bruise diameter 1–2 cm; and 5 = bruise diameter <1 cm. The total degree of injury for each melon was determined by summing products of injury spots and their degree scale values. Melon disease and rot were investigated at 1 week, 2 weeks and 30 days after harvest.

## Disease investigation

Sample melons stored at room temperature were examined five times at 5 or 10-day intervals in 1997, or six times at 5 or 7-day intervals in 1998 and diseases were identified according to their symptoms. Disease spot location and diameter were also recorded. Disease severity was categorised into three grades according to the diameter of the disease spots, where: small = <1 cm; medium = 1–2 cm; and large = >2 cm. Melons with at least one large disease spot or two medium spots were thought to be unacceptable and lost.

## Results and Discussion

### The reasons for weight loss

The natural loss rates of ‘Huanghemigua’ melons stored for different periods after truck transport were investigated (Table 1). The results show that the weight loss of melon fruit increased as storage time increased. The peak loss period was in the 2<sup>nd</sup> week after harvest and was caused mainly by disease rot. In the 1<sup>st</sup> week after picking, weight loss of melons was severe due to water evaporation promoted by the high water content of the fruit and many wounds and bruises produced during picking and transport. A high respiration rate including wound respiration, which caused metabolism consumption, contributed

to the water loss. Melon fruit of different physiological status and under different transport conditions revealed different weight losses (Table 2). Less mature fruit lost slightly more weight than fully matured ones—even under the same transport conditions—because of their less developed protective structure. Unpacked and bagged melons lost more water than those packed in cartons due to different injury severity.

### Postharvest diseases and their major causes

Table 3 shows the main diseases causing post-harvest melon rot. During the initial 2 weeks in storage, the major decay was caused by *Rhizopus*, followed by pink rot caused by *Trichothecium* sp. The incidence of the two main diseases was well related to fruit injury before storage—the more severely the melon was injured, the more quickly it decayed.

### The relationship between packaging and fruit injury

At various harvest stages, fruit loss due to disease was a major factor in postharvest weight loss and shelf life of ‘Huanghemigua’. Wounds and bruises sustained during harvest and transport were responsible for the main infection by pathogens, for water loss and respiration consumption. Therefore, weight loss during storage and marketing was, in fact, dependent upon the severity of fruit injury (Table 4).

The results show that, under present commercial operations, melons were severely damaged during each of the investigated harvest stages. Approximately 45% of melons were injured with four spots per melon when being carried out of the field in bags. Transport by tractor on a rough path to the truck loading site in net bags or without any packaging brought about the most severe damage to the melons—many wounds were made at this stage.

The possibility of being bruised during harvest and transport was almost the same regardless of maturity, however fully matured melons presented more wounds than less mature ones since their flesh had already softened. Melons transported in net bags or unpacked sustained a higher number and more severe injuries than those in cartons (Table 5).

**Table 1.** Postharvest fruit loss of 'Huanghemigua' melons after various lengths of time in storage.

Days after harvest	Water loss (%)			Loss to disease (%)			Diseased fruit (%)
	Rate of fresh weight loss	Ratio in total loss	Rate of fresh weight loss	Ratio in total loss	Ratio in total loss		
7	7.9	48.3	8.4	51.7	2.9		
14	9.9	33.8	19.4	66.2	24.4		
30	13.1	33.1	26.5	66.9	39.4		

**Table 2.** Water loss of harvested melon fruit in storage.

Treatment	Weight at picking (g)	4 days after harvest		7 days after harvest		14 days after harvest		30 days after harvest	
		Weight (g)	Loss (%)	Weight (g)	Loss (%)	Weight (g)	Loss (%)	Weight (g)	Loss (%)
70% mature in net bags	1 335.5	1 250.8	6.2	1 216.6	8.9	1 180.6	11.6	1 131.2	15.2
90% mature in net bags	1 615.7	1 525.2	5.6	1 491.3	7.7	1 452.5	10.0	1 399.2	13.4
70% mature in cartons	1 584.2	1 504.0	5.1	1 471.7	7.1	1 452.6	8.3	1 416.3	10.6
90% mature in cartons	1 677.0	1 579.7	5.8	1 542.8	8.0	1 512.6	9.8	1 457.3	13.1

**Table 3.** The relationship between mechanical injury and fruit disease in melon, where RR = *Rhizopus* rot; PM = pink mould; FR = *Fusarium* rot; and AR = *Alternaria* rot.

Treatment	Injury spots			Diseased melons in 2 <sup>nd</sup> week (%)						Diseased melons at 30 days (%)			
	Spots/melon	Degree	Total	RR	PM	FR	AR	Total	RR	PM	FR	AR	Total
Ck <sup>a</sup>	4.8	4.0	19.5	5.6	5.6	5.6	2.8	27.2	19.5	13.9	8.3	8.3	9.6
A <sup>b</sup>	5.2	3.9	19.6	2.8	2.8	8.3	5.6	30.6	19.6	19.5	8.3	5.6	41.7

<sup>a</sup> Ck = harvested under commercial practice and transported unpacked

<sup>b</sup> A = harvested under commercial practice and transported in net bags

<sup>c</sup> B = harvested under commercial practice and transported in cartons

<sup>d</sup> C = wrapped with soft paper and packed in cartons after the 3<sup>rd</sup> harvest stage

<sup>e</sup> D = wrapped with soft paper and packed in cartons after the 1<sup>st</sup> harvest stage

**Table 3.** (Cont'd) The relationship between mechanical injury and fruit disease in melon, where RR = *Rhizopus* rot; PM = pink mould; FR = *Fusarium* rot; and AR = *Alternaria* rot.

Treatment	Injury spots			Diseased melons in 2 <sup>nd</sup> week (%)					Diseased melons at 30 days (%)				
	Spots/melon	Degree		RR	PM	FR	AR	Total	RR	PM	FR	AR	Total
B <sup>c</sup>	3.5	4.4		11.1	0	5.6	5.6	22.3	16.7	13.9	5.6	5.6	33.4
C <sup>d</sup>	2.2	4.5		5.6	2.8	5.6	5.6	13.9	11.1	11.1	5.6	2.8	27.8
D <sup>e</sup>	0.6	4.8		2.8	2.8	5.6	5.6	11.1	5.6	11.1	8.3	5.6	22.2

<sup>a</sup> Ck = harvested under commercial practice and transported unpacked

<sup>b</sup> A = harvested under commercial practice and transported in net bags

<sup>c</sup> B = harvested under commercial practice and transported in cartons

<sup>d</sup> C = wrapped with soft paper and packed in cartons after the 3<sup>rd</sup> harvest stage

<sup>e</sup> D = wrapped with soft paper and packed in cartons after the 1<sup>st</sup> harvest stage

**Table 4.** Fruit injury sustained during various stages of harvest.

Harvest stage	Injured fruit (%)			Bruises		Wounds	
	Number of spots/melon	Severity		Number of spots/melon	Severity	Number/melon	Severity
Picking	36.6	0.6		0.6	4.8	0	0
Transport out of the field	82.1	1.7		1.7	4.6	0	0
Loading on and off tractors	90.2	2.2		2.2	4.6	0.04	2.0
Transport to packing site	92.6	2.9		2.9	4.5	0.1	2.0

**Table 5.** The relationship between injury and melon maturity or packaging.

Treatment	Number in sample		Injured fruit (%)		Bruises		Wounds	
	Number of spots/melon	Severity	Number of spots/melon	Severity	Number of spots/melon	Severity	Number/melon	Severity
70% mature	108	96.3	4.4	4.5	1.8	0.16		
90% mature	108	97.2	4.2	4.4	1.3	0.28		
Transported unpacked	72	97.2	4.1	4.8	1.6	0.35		
Transported in net bags	72	98.6	3.9	5.2	1.7	0.22		
Transported in cartons	72	94.4	4.4	3.6	1.9	0.07		

## Conclusion

- ‘Huanghemigua’ melon fruit lost most of their weight in two weeks after harvest when kept at room temperature, and the major factor responsible for weight loss was postharvest disease.
- Melon injury during harvest and transport contributed to postharvest diseases and water loss.
- Injury-dependent weight loss was related to harvesting and transport as well as packing practices.

## References

- Morris, S. and Wade, N. 1985. Postharvest handling of vegetables. In: Vegetable growing handbook. Griffith, Australia, Irrigation Research and Extension Committee, 127–138.
- Zhang Weiyi, Bi Yang and Zhang Manyu 1990. Problems and the treatments in muskmelon transportation. In: Research reports for storage techniques and postharvest physiology of muskmelon. Xingjiang, PR China, Agricultural College.

# Postharvest Technology for Vietnamese 'Buoi' Mangoes

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## Abstract

Mango is an important fruit crop in Vietnam. Despite their excellent eating quality, export marketing of important varieties such as 'Buoi', 'Thom' and 'Cat Hoa Loc' is currently limited due mainly to inadequate postharvest techniques to maintain fruit quality. Postharvest losses also result from incidence of diseases such as anthracnose, stem-end rot, and physiological disorders. The aim of this research program was to characterise the quality attributes of 'Buoi' mango by investigating the effects of storage temperature, harvest date and postharvest treatments on quality attributes during cold storage. Our results showed that avoiding the harvesting of fruit at very early maturity, and applying a postharvest hot water treatment at 52°C for 5 min were beneficial in reducing the incidence of physiological diseases as well as minimising mass loss and shrivel. Flesh firmness declined significantly ( $P < 0.05$ ) with increasing length of storage and increasing storage temperature. Cold storage at 7°C or 12°C maintained fruit firmness and extended storage life better than storage under ambient conditions.

POSTHARVEST DISEASES and disorders such as anthracnose lesions and stem-end rot have been known to cause major quality and quarantine problems in the mango export trade all over the world (Johnson et al. 1990; McIntyre et al. 1993). Mango anthracnose caused by *Colletotrichum gloeosporioides* Penz. (Dodd et al. 1997) is the most common cause of decay of mango fruit in Vietnam (Minh et al. 1993). Anthracnose occurs pre and postharvest and is associated with high rainfall and humidity (Dodd et al. 1992).

Postharvest hot water treatment is now accepted worldwide to satisfy quarantine requirements for control of anthracnose in mango (McIntyre et al. 1993; Suhardjo et al. 1994). For hot water treatment, different dipping conditions have been recommended to control anthracnose effectively, but a general conclusion is that the water temperature should be between 50 and 55°C and the dipping time must be at least 5 min (Dodd et al. 1997). The use of hot benomyl dips appeared to be the most effective means of con-

trolling anthracnose development. However, the worldwide concern on the use of agrichemicals because of the danger to food product safety has reduced the use of benomyl dips.

Stem-end rot is the other major mango disease—it is more specific and difficult to control (Huang and Liu 1995). Sangchote (1989) found that dipping fruit in hot water at 55°C for 5 min gave good control of stem-end rot of 'Nam Dorkmai' mango without heat injury. Immersion in hot water (52°C for 5 min) plus benomyl has also been reported to reduce stem-end rot in mangoes (Johnson et al. 1990).

Chilling injury is the most serious disadvantage of refrigeration in extending the storage life of mangoes (Veloz et al. 1977). McCollum et al. (1993) showed that heat treatment can inhibit chilling injury of mango. The authors reported that when 'Keitt' mango were kept at 38°C for 0, 24, or 48 hours before storage at 5°C for 11 days, non-heated fruit developed severe rind pitting and discoloration, whereas chilling injury symptoms decreased with increased duration at 38°C.

In Vietnam, 'Buoi' mangoes are usually harvested over a period of about 1 month, but the effects on quality changes during storage are not known. The purpose of this study was to determine suitable post-

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harvest storage and treatment technologies for maintaining the quality of Vietnamese 'Buoi' mangoes. The specific objectives were to: (a) evaluate the effects of storage temperature on fruit firmness; (b) determine the effects of postharvest hot water treatment on postharvest quality attributes; and (c) investigate the development of anthracnose, stem-end rot, shrivel and chilling injury in 'Buoi' mangoes harvested at different times during storage at 12°C (relative humidity (RH) 85–90%).

## Experimental Design

In experiment 1, mature-green 'Buoi' mangoes were harvested on 24/3/1997 from an orchard in Hoa Loc area, Cai Be District, Tien Giang Province, Vietnam and transferred to a laboratory at the Post-harvest Technology Institute (PHTI) in Ho Chi Minh City. Fruit were harvested based on skin colour and uniform size. A random sample of 480 fruit were selected and divided into 4 groups. Individual fruit were selected on the basis of freedom from mechanical damage, pests, and diseases. Four subsamples of 120 fruit each were stored at each of the following cool-store temperatures: 7°C, 12°C, 17°C ( $\pm 1^\circ\text{C}$ , RH 85–90%) and ambient temperature (27°C). On each testing date, 10 fruit were assessed for firmness using a hand-held Effegi penetrometer (Model FT 327) fitted with a 10.9 mm diameter probe. Each fruit was tested twice on opposite sides along the equatorial axis after removing the skin using a potato peeler.

In experiment 2, fruit were harvested from the same orchard at 3 different times at 14-day intervals representing early (10/3/1997), mid (24/3/1997), and late harvest (7/4/1997). On each date, a sample of 40 fruit without disease and physical injury were randomly selected and divided into 4 subsamples (10 in each subsample). The fruit samples were then randomly assigned to the following treatments and put into cold storage at  $12 \pm 1^\circ\text{C}$  (RH 85–90%): treatment 1 = fruit dipped in hot water at 52°C for 5 min; treatment 2 = fruit dipped in hot water at 52°C for 10 min; treatment 3 = fruit placed in a polyvinyl chloride (PVC) plastic bag; and treatment 4 = control (untreated) fruit. After 25 days of storage, fruit were assessed for mass loss, peel and pulp colour, soluble solids content, anthracnose, stem-end rot, shrivel and chilling injury (Nguyen 1998).

## Data Analysis

Data on fruit firmness, mass loss, peel and pulp colour, soluble solids content, anthracnose, stem-end rot, shrivel and chilling injury were subjected to analysis of variance, and the treatment means were compared using least significant difference (Everitt and Der 1996). In experiment 1, regression models were developed (for each storage temperature) for predicting fruit firmness based on storage time, and for predicting fruit firmness as a function of storage temperature and length of storage.

## Results

### Fruit firmness

The effect of length of storage and storage temperature on flesh firmness of 'Buoi' mangoes is shown in Table 1. Flesh firmness declined significantly ( $P < 0.05$ ) with increasing storage time. Storing fruit under ambient conditions resulted in accelerated ripening and reduction in fruit firmness, and fruit quality became unacceptable between 10–15 days. However, cold storage of fruit at 7°C or 12°C significantly maintained fruit firmness during the 25-day interval.

Fruit firmness was highly dependent on storage temperature such that increasing storage temperature led to a significant ( $P < 0.05$ ) decline in firmness. Regression analyses between fruit firmness and storage time at different storage temperatures showed that length of storage was a good predictor for fruit firmness (Table 2). Combining the effects of temperature and length of storage improved the prediction of fruit firmness during 15 days storage in the range 7–27°C.

### Postharvest treatments

The effects of hot water treatments and storing fruit in plastic bags on fruit quality attributes are summarised in Table 3. Both hot water treatments significantly ( $P < 0.05$ ) increased the rate of peel and pulp colour development compared to plastic bag storage and the control. However, there was no significant difference in peel and pulp colour of fruit dipped in hot water for 5 or 10 min. Fruit stored in plastic bags had the lowest rate of skin and pulp colour development. The harvest date did not affect the colour development of both treated and untreated fruit.

**Table 1.** Effects of storage temperature on flesh firmness of ‘Buoi’ mangoes ( $\pm$  standard error of the mean).

Temp. (°C)	Storage duration (days)					
	0	5	10	15	20	25
7	63.4 $\pm$ 0.87	60.1 $\pm$ 1.15	56.8 $\pm$ 1.40	50.0 $\pm$ 0.78	45.9 $\pm$ 0.97	42.4 $\pm$ 1.26
12	63.4 $\pm$ 0.87	56.2 $\pm$ 0.85	51.8 $\pm$ 0.85	44.1 $\pm$ 0.69	40.7 $\pm$ 0.83	37.6 $\pm$ 0.72
17	63.4 $\pm$ 0.87	53.9 $\pm$ 1.22	43.7 $\pm$ 1.12	36.6 $\pm$ 1.17	32.6 $\pm$ 1.24	30.7 $\pm$ 1.37
27	63.4 $\pm$ 1.80	42.3 $\pm$ 1.73	32.1 $\pm$ 1.64	26.7 $\pm$ 1.44	–	–

**Table 2.** Relationships between flesh firmness (F, Newtons) of ‘Buoi’ mangoes and storage time (T, days) at different storage temperatures (t, °C).

Storage temp. (°C)	Flesh firmness	Regression coefficient, R <sup>2</sup>
7	$F_7 = -0.8823 T + 64.129$	0.8439
12	$F_{12} = 0.0232 T^2 - 1.6158 T + 63.511$	0.9050
17	$F_{17} = 0.0398 T^2 - 2.3432 T + 63.939$	0.9292
27	$F_{27} = 0.157 T^2 - 4.761 T + 63.095$	0.9759
7–27	$F = 81.1950 - 1.9555 T - 1.2545 t + 0.030446 T^2 + 0.003136 t^2$	0.9766

**Table 3.** Effect of harvest date and postharvest treatments on postharvest quality attributes of ‘Buoi’ mangoes after storage at 12  $\pm$  1°C for 24 days.

Postharvest treatments	Fruit quality attributes				
	Peel colour	Pulp colour	SSC <sup>a</sup> (%)	Mass loss (%)	Shrivel <sup>b</sup>
<i>Harvest I</i>					
Control	3.6 b	3.9 b	13.5 b	8.60 b	0.3 b
Plastic bag	2.8 c	3.4 c	12.9 c	6.52 c	0.1 c
Hot water, 52°C, 5 min	4.0 ba	4.2 ab	14.4 a	8.42 b	0.2 bc
Hot water, 52°C, 10 min	4.3 a	4.5 a	14.5 a	9.56 a	0.6 a
<i>Harvest II</i>					
Control	3.6 b	3.8 bc	13.7 b	8.14 b	0.2 b
plastic bag	2.9 c	3.4 c	13.1 c	6.32 c	0.0 c
Hot water, 52°C, 5 min	4.1 a	4.2 ab	14.5 a	8.23 b	0.2 b
Hot water, 52°C, 10 min	4.4 a	4.5 a	14.6 a	9.38 a	0.6 a
<i>Harvest III</i>					
Control	3.7 b	3.9 b	13.8 b	7.78 b	0.2 b
Plastic bag	2.8 c	3.5 c	13.3 c	6.27 c	0.1 b
Hot water, 52°C, 5 min	4.1 ab	4.4 a	14.7 a	7.83 b	0.2 b
Hot water, 52°C, 10 min	4.5 a	4.6 a	14.6 a	9.34 a	0.5 a

<sup>a</sup> SSC = soluble solids content.

<sup>b</sup> Shrivel was assessed on a scale of 0–3 where: 0 = no shrivel; 1 = wrinkles extend to distal region; 2 = wrinkles extend to central region; and 3 = wrinkles extend to proximal region.

Note: means in a column with the same letter are not significantly different ( $P < 0.05$ ) for each harvest date.



The soluble solids content (SSC) of hot water-treated fruit was significantly ( $P < 0.05$ ) higher compared to control fruit and fruit in plastic bags. Also, similar to the effects on colour development, there was no significant difference between SSC of fruit dipped in hot water at 52°C for 5 or 10 min. Fruit in plastic bags had the lowest SSC.

Placing fruit in plastic bags depressed the rate of mass loss ( $P < 0.05$ ) compared to other treatments. Maximum mass loss occurred in fruit treated with hot water at 52°C for 10 min, and there was no significant difference in the mass loss of control fruit and fruit treated with hot water at 52°C for 5 min. Early-harvested fruit lost more mass than late-harvested fruit. Fruit treated with hot water at 52°C for 10 min had the highest incidence of shrivelling, while fruit in plastic bags or treated with hot water at 52°C for 5 min had the lowest incidence of shrivelling.

Table 4 shows the effect of postharvest treatments on anthracnose development of 'Buoi' mango fruit. Hot water treatments at 52°C (for 5 or 10 min) significantly decreased anthracnose disease compared with fruit in plastic bags and untreated fruit. Fruit picked at the first harvest had the highest level of anthracnose disease, especially in plastic bag stored and control fruit.

**Table 4.** Effects of postharvest treatments and harvest date on anthracnose severity (on a scale of 0–4) in 'Buoi' mangoes (I = 10/3/97; II = 24/3/97; III = 7/4/97).

Treatment	Harvest date		
	I	II	III
Plastic bag	1.8	1.5	1.4
Control	1.5	1.3	1.2
Hot water 52°C, 5 min	0.3	0.3	0.2
Hot water 52°C, 10 min	0.2	0.2	0.1

Hot water treatment at 52°C for 5 or 10 min gave good control of stem-end rot compared to the untreated (control) fruit and fruit in plastic bags (Table 5). Dipping fruit in water at 52°C for 10 min controlled stem-end rot better than dipping the fruit for only 5 min. The incidence of stem-end rot was lower in late-harvested fruit.

There was no evidence of chilling injury in fruit dipped in hot water at 52°C for 5 or 10 min, but fruit in plastic bags or control fruit were affected (Table 6). Control fruit were mostly affected by chilling injury,

and fruit picked at the first harvest were more sensitive to chilling injury than those harvested later.

**Table 5.** Effects of postharvest treatments and harvest date on stem-end rot severity (on a scale of 0–4) in 'Buoi' mangoes (I = 10/3/97; II = 24/3/97; III = 7/4/97).

Treatment	Harvest date		
	I	II	III
Plastic bag	1.0	0.9	0.7
Control	0.9	0.7	0.6
Hot water 52°C, 5 min	0.3	0.2	0.2
Hot water 52°C, 10 min	0.1	0.1	0.1

**Table 6.** Effects of postharvest treatments and harvest date on chilling injury severity in 'Buoi' mangoes (I = 10/3/97; II = 24/3/97; III = 7/4/97).

Treatment	Harvest date		
	I	II	III
Plastic bag	1.0	0.7	0.6
Control	1.2	0.9	0.8
Hot water 52°C, 5 min	0	0	0
Hot water 52°C, 10 min	0	0	0

## Discussion

The effects of length of storage and storage temperature on fruit firmness of 'Buoi' mangoes are similar to literature evidence reported by other researchers. Abu-Sarra and Abu-Goukh (1992) showed that mango fruit firmness declined during storage, and the authors explained that the loss of firmness during ripening may have resulted from an increase in pectinesterase activity, a decrease in polygalacturonase and in cellulase activity. Studies by Thompson (1971) on 'Julie' mangoes showed that increasing storage temperature resulted in reduced fruit firmness. Our results indicate that 'Buoi' mangoes handled under ambient storage conditions must be utilised within 10–14 days beyond which over-ripening occurs. On the other hand, cold storage of fruit at 7°C or 12°C extends the storage life to over 3 weeks.

Fruit mass loss and rate of yellow colour development in plastic bags were significantly ( $P < 0.05$ ) lower than hot water treatments or controls, pre-

sumably due to the higher relative humidity (RH) inside the plastic bags. High RH may also contribute to the high incidence of postharvest diseases such as anthracnose and stem-end rot in fruit stored in plastic bags.

Hot water treatment at 52°C for 5 or 10 min gave good control of diseases—anthracnose, and stem-end rot—of ‘Buoi’ mango compared to plastic bag storage and the control ( $P < 0.05$ ). Disease control increased with increased dipping time (mango fruit in hot water at 52°C for 10 min showed a better control of anthracnose and stem-end rot than fruit dipped for 5 min). However, increasing the dipping time led to an increase in mass loss and shrivelling incidence (Table 3). These results are similar to those reported by Sangchote (1989) on ‘Nam Dorkmai’ mangoes. The author indicated that disease control increased with increased temperature and dipping time.

The peel and pulp colour, soluble solids content, and mass loss of fruit dipped in hot water (52°C for 5 or 10 min) increased significantly ( $P < 0.05$ ) compared with fruit in plastic bag and controls. On the other hand, these quality attributes of fruit dipped in hot water at 52°C for 5 were not significantly different ( $P > 0.05$ ) compared with dipping fruit in hot water at 52°C for 10 min. Fruit in plastic bags had the lowest mass loss rate and incidence of shrivelling, but they were more susceptible to anthracnose and stem-end rot than hot water-treated fruit. Harvest date did not significantly ( $P > 0.05$ ) affect the postharvest quality attributes such as peel colour, pulp colour, soluble solids content, and shrivel, but fruit mass loss, incidence of diseases and shrivelling were affected. Fruit picked during the early-season harvest had a higher mass loss rate and were more susceptible to anthracnose, stem-end rot and chilling injury. A higher incidence of chilling injury in early harvested mango fruit ‘Tommy Atkins’ has been reported by Medicott et al. (1990).

There was no evidence of chilling injury in fruit dipped in hot water at 52°C for 5 or 10 min after 24 days of storage at 12°C, while fruit in plastic bags and especially untreated fruit were affected by chilling injury (Table 6). This result indicates that hot water treatment at 52°C for 5 or 10 min can inhibit chilling injury in ‘Buoi’ mango as reported by McCollum et al. (1993) with heat treatment of ‘Keitt’ mangoes.

## Conclusions

Fruit firmness of ‘Buoi’ mangoes declined during storage and with increasing storage temperature. Cold storage at 7°C or 12°C was beneficial in extending

storage life and maintaining fruit firmness. For each storage temperature, regression models were developed for predicting fruit firmness as a function of the length of storage. Including the length of storage further improved the strength of the prediction.

Fruit treated with hot water at 52°C for 5 or 10 min significantly reduced the incidence of anthracnose and stem-end rot disease and also minimised the occurrence of chilling injury compared to fruit stored in plastic bags or untreated fruit. Fruit stored in plastic bags lost less mass than in the other treatments. Although treating ‘Buoi’ mangoes with hot water at 52°C for 10 min gave better control of anthracnose and stem-end rot, immersing fruit in hot water at 52°C for 5 min is recommended because this treatment also reduces mass loss and shrivelling which are very important factors in mango fruit marketing.

Harvest date affected the incidence of postharvest diseases, such as anthracnose and stem-end rot, and chilling injury. Early-harvested fruit lost more mass and were more susceptible to anthracnose, stem-end rot and chilling injury than mid- and late-harvested fruit. It is therefore recommended that very early harvesting of ‘Buoi’ mango fruit destined for long distance markets and for export should be avoided in order to minimise the development of postharvest diseases and disorders and to maintain eating quality. Cold storage at 7°C or 12°C will extend the storage life and enhance the scope for distribution and marketing of the fruit in both domestic and regional markets.

## References

- Abu-Sarra, A.F., and Abu-Goukh. A.A. 1992. Changes in pectinesterase, polygalacturonase and cellulase activity during mango fruit ripening. *Journal of Horticultural Science*, 67, 561–568.
- Dodd, J.C., Estrada, A.B. and Jeger, M.J. 1992. Epidemiology of *Colletotrichum gloeosporioides* in the tropics. In: Bailey, J.A. and Jeger, M.J., ed., *Colletotrichum: biology, pathology and control*. Wallingford, CAB International.
- Dodd, J.C., Prusky, D. and Jeffries, P. 1997. Fruit diseases. In: Litz, R.E., ed., *The mango: botany, production and uses*. Wallingford, CAB International.
- Everitt, B.S. and Der, G. 1996. *A handbook of statistical analyses using SAS*. London, Chapman and Hall.
- Huang, S. and Liu, X. 1995. Control of postharvest stem-end rot of mango. *Tropical Science*, 35, 321–326.
- Johnson, G.I., Sangchote, S. and Cooke, A.W. 1990. Control of stem-end rot (*Dothiorella dominicana*) and other postharvest diseases of mangoes (cv. Kensington Pride)

- during short and long-term storage. *Tropical Agriculture (Trinidad)*, 67, 183–187.
- McCollum, T.G., D’Aquino, S. and McDonald, R.E. 1993. Heat treatment inhibits mango chilling injury. *HortScience*, 28, 197–198.
- McIntyre, A., Wickham, L.D., Wilson, L.A. and Malins, A. 1993. Hot water treatments for the postharvest control of fruit fly and anthracnose in the Caribbean mango ‘Julie’. *Acta Horticulturae*, 341, 533–538.
- Medlicott, A.P., Sigrist, J.M.M. and Sy, O. 1990. Ripening of mangoes following low-temperature storage. *Journal of the American Society of Horticultural Scientists*, 115, 430–434.
- Minh, D., Phong, L.T. and Hoang, V.T. 1993. Mango planting. An Giang, Vietnamese Department of Science, Technology and Environment.
- Nguyen, H.X. 1998. Studies on postharvest cold storage of ‘Buoi’ mangoes. MAppSc thesis, Massey University, Palmerston North, New Zealand.
- Thompson, A.K. 1971. The storage of mango fruits. *Tropical Agriculture (Trinidad)*, 48, 63–70.
- Sangchote, S. 1989. Effect of postharvest treatments on anthracnose (*Colletotrichum gloeosporioides* Penz) and stem-end rot (*Dothiorella dominicana* Pet. Et. Cif.) of mangoes stored in air or modified atmosphere. *Association of South-East Asian Nations (ASEAN) Food Journal*, 4(4), 142–144.
- Suhardjo, Hermanto, C. and Yuniarti 1994. Hot-water control of anthracnose on mango varieties Arumanis, Golek, and Manalagi. In: Champ, B.R., Highley, E. and Johnson, G.I., ed., *Postharvest handling of tropical fruits. Proceedings of an international conference held at Chiang Mai, Thailand, 19–23 July 1993. ACIAR Proceedings No. 50.* Canberra, Australian Centre for International Agricultural Research, 453–454.
- Veloz, C.S., Torres, F.E. and Lakshminarayana, S. 1977. Effect of refrigerated temperatures on the incidence of chilling injury and ripening quality of mango fruit. *Proceedings of the Florida State Horticultural Society*, 90, 205–210.

# Quality Assurance of Fresh Produce in New Zealand – a Personal View

L.U. Opara\*

## *Abstract*

New Zealand is primarily a land-based economy, with 60% of export earnings derived from the primary industries. Despite its small size and long distance from major international markets, New Zealand's agriculture (and related biological industries) has been successful in the international arena and agriculture has been the major source of export income. Well-established marketing cooperatives and stringent quality assurance systems for the production and marketing of high quality products underpin this continued success and competitiveness. Recently in the pipfruit (apples, pears etc.) industry, the quality assurance system has placed greater responsibility on individual growers for the overall quality of their products throughout the supply chain. The objective of this paper is to review the quality assurance schemes employed by the New Zealand pipfruit industry, and to highlight the impact of these schemes on the production, postharvest handling and export marketing of commodities.

NEW ZEALAND (NZ) is located in the South Pacific with a population of 3.6 million people and lies between the 34<sup>th</sup> and 48<sup>th</sup> parallels of the Southern Hemisphere. The subtropical to temperate climate contributes to high crop yields as well as the production of a wide range of crops. The warm, dry summers and cool winters provide an ideal climate for growing fresh produce. Average temperatures are 8–18°C in winter and 21–27°C in summer. Rainfall incidence varies across the fruit growing areas, and declines southwards from Auckland (top of the North Island) to the bottom of the South Island. Average rainfall incidence varies from 1.76 mm in Auckland to 1.28 mm in the Hawke's Bay area, and 1.0 mm in Nelson.

NZ is a land-based economy with dairy, horticulture, forestry, wool, and meat products continuing to dominate both the domestic economy and export

income. Agriculture and horticulture contribute nearly 60% of the value of exports and 6% of the gross domestic product (GDP). The considerable distance from the major markets in the Northern Hemisphere presents unique challenges (and opportunities) for the development and application of cutting-edge technologies in postharvest handling and marketing. Until the early 1970s, up to 95% of NZ's produce was exported to the United Kingdom (UK), but this situation soon changed historically when England became part of the European Community. Combined with rising oil prices worldwide which resulted in very expensive transport costs, survival became a major concern and it became vital for NZ industries to seek new markets and develop new products. Today, NZ pipfruit (apples, pears etc.) is marketed in over 50 countries spread over all continents, although the European Union remains the major export market, accounting for over 61.5% of the 10-year average from 1990–99 (Table 1). Our isolation from major industrial regions, and adoption of environmentally sustainable practices have enhanced our reputation as a 'clean green' country and producer.

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**Table 1.** 10-year export history of New Zealand apples and pears (tray carton equivalents). (Source: ENZA 1999).

Year	European	Scandinavia	Other European countries	Americas	Caribbean	Middle East	Asia/Russia	Pacific	Africa	Grand total
1949	446.8	—	—	55.0	—	—	—	—	501.8	—
1990	7 650.0	547.4	0.6	1 943.4	13.2	91.7	936.0	107.0	—	11 289.2
1991	8 207.7	592.7	9.3	1 638.4	10.4	0.8	916.9	150.0	—	11 526.1
1992	7 808.7	421.3	47.2	2 007.6	7.5	33.2	1 189.7	173.5	—	11 688.6
1993	8 551.6	308.1	61.8	2 022.6	4.6	99.2	1 826.4	166.5	—	13 040.8
1994	6 926.4	251.5	109.9	1 856.0	3.5	45.2	2 516.8	153.4	2.7	11 865.4
1995	9 945.1	508.1	390.1	2 711.8	14.3	16.5	3 951.5	131.6	—	17 669.0
1996	10 119.7	143.4	172.9	3 251.5	—	61.4	3 677.3	112.9	—	17 539.1
1997	9 406.5	80.8	161.4	3 146.7	—	22.4	2 808.3	114.4	—	15 740.4
1998	7 628.4	50.5	125.0	2 757.7	—	62.6	2 412.5	122.8	—	13 159.5
1999	10 356.5	137.6	73.4	3 659.6	—	130.8	2 777.2	162.7	5.8	17 303.7
<b>10-year average (1990–99)</b>	<b>8 660.1</b>	<b>304.2</b>	<b>115.2</b>	<b>2 499.5</b>	<b>5.3</b>	<b>56.4</b>	<b>2 301.2</b>	<b>139.5</b>	<b>0.8</b>	<b>14 082.2</b>

**Table 2.** Comparison of apple utilisation among New Zealand and other Southern Hemisphere producers (extracted from NZAPMB 1995; Burkhardt 1997).

	New Zealand				% of total production			
	Million cartons <sup>a</sup>	Tonnes	New Zealand	Australia	Chile	Argentina	Australia	Australia
Production	29.5	545 750	—	—	—	—	—	—
Exports	17.3	320 000	58.64	19	53	19	11	11
Processed	9.2	170 000	31.19	36	36	55	24	24
Domestic consumption	3.0	55 500	10.17	26	11	26	65	65

<sup>a</sup> 18.5 kg cartons

To be competitive and win the confidence of its discerning consumers, the need for innovation, value-adding and quality became paramount for NZ industries. In particular, the fresh produce industries focused on the top tier of the international market (mainly in Europe), who in turn paid more for premium quality produce. Today, the NZ fresh produce industries are acknowledged worldwide for their competitiveness and consistent top quality products. This success is underpinned by the development of efficient production systems, sophisticated marketing strategies, stringent quality assurance systems, and innovation at all levels in the supply chain. The fresh produce industries in NZ are diverse, with pipfruit and kiwifruit being the most significant. In this article, I will discuss the NZ pipfruit industry and its contribution to the national economy, and offer my personal view on the evolution and implications of the current quality assurance system.

## Development of the Pipfruit Industry in New Zealand

Apples and pears dominate the NZ commercial pipfruit industry, accounting for 97.40% and 2.52%, respectively, of the current export income from the pipfruit sector. The early European migrants brought the first seedlings into the country in the mid-1800s, and by the 1860s apples were grown in sufficient quantities to sell in the domestic market. With increasing recognition of the economic potential of commercial fruit growing, supported by developments in the science of production, postharvest handling and export marketing, fruit sales grew rapidly from 5,650 cases (18.5 kg containers) in 1910 to 68,000 cases in 1914. "To foster, promote and protect the fruit industry", growers came together and formed the New Zealand Fruitgrowers Federation in 1916 (NZAPMB, undated). Up to 50% of the pipfruit crop was exported, and as the industry expanded, growers and the government agreed on a need to set up a controlled marketing strategy.

During World War II, pipfruit growers suffered because the UK government restricted the freight of food items from NZ and demanded only meat and other proteins. After the war, government passed the enabling legislation (The Apple and Pear Marketing Act of 1948) which set up the New Zealand Apple and Pear Marketing Board (NZAPMB) with the power to acquire and market all apples and pears grown in NZ. The Board was set up to protect the benefits to growers

and provide stability and security to a rapidly expanding industry. In pursuance of the aspirations of the growers, the Board's mission statement is to "maximise sustainable export returns to New Zealand and pipfruit growers" (NZAPMB 1995). The 1948 Act required that the Board must accept all pipfruit that meets the grade standards for export. The domestic market for fresh and processed fruit was deregulated by legislation passed in 1993, and the Board now grants specific export licences to third parties under very strict criteria, which are set out in published guidelines. With deregulation, New Zealanders can now buy export-grade fruit in local supermarkets. Today, the Board seeks to maximise the returns to its suppliers primarily by the worldwide marketing of pipfruit, horticultural products and related products and services. The vision is to "be the world's foremost pipfruit marketing organisation in order to achieve premium returns through an effectively integrated volume business and excellence in value creation, customer satisfaction and innovation" (NZAPMB 1995).

Today, there are over 1,600 pipfruit growers with a total of about 13,800 ha planted. Based on 1995 estimates, over 59% of all pipfruit production is exported to 60 countries as fresh produce (17.2 million cartons), which is higher than all our Southern Hemisphere competitors which have much more domestic consumption and lower exports (Table 2). Pipfruit production is carried out in many regions, with Hawke's Bay alone (latitude 39°S, annual rainfall 1,132 mm, average temperature 18.8°C max. and 7.0°C min.) in the North accounting for 48.04% of regional paid crop summary during the past decade (Table 3). In 1997, Hawke's Bay and Nelson accounted for 80.5% of the total exports of pipfruit (Table 4), both having similar growing conditions.

Overall, NZ horticulture is diverse, and has several characteristics (Hewett 1997):

- a maritime climate with good soils and high light intensities;
- successful breeding programs and variety selection;
- a well structured industry;
- an export orientation;
- well educated producers and cost-effective production systems;
- excellent education and research systems;
- a complementary production season to the Northern Hemisphere;
- an international reputation for diversity and quality of products; and
- distance from international markets.

**Table 3.** Regional paid crop summary ('000s cartons) of apples and pears. (Source: ENZA 1999.)

Year	Auckland	Waikato	Gisborne	Hawke's Bay	Wellington	Marlborough	Nelson	Canterbury	Otago	Grand total
1949	11	—	2	166	—	43	317	—	—	539
1990	88	15	72	5 990	3	346	3 977	476	361	11 328
1991	45	130	96	5 722	56	450	4 091	635	599	11 822
1992	65	209	164	6 182	148	393	3 804	588	450	12 003
1993	152	350	195	6 537	185	459	4 280	412	692	13 262
1994	147	354	239	4 549	240	560	4 343	856	691	11 978
1995	203	380	270	8 272	295	698	5 491	1 391	982	17 983
1996	82	360	266	8 940	305	644	5 087	1 572	675	17 931
1997	61	376	221	7 740	222	830	5 112	960	620	16 142
1998	43	354	198	6 377	25	499	5 068	86	470	13 349
1999	46	394	337	8 635	289	785	6 468	99	656	17 709
<b>10-year average (1990–99)</b>	<b>93</b>	<b>292</b>	<b>206</b>	<b>6 894</b>	<b>200</b>	<b>566</b>	<b>4 772</b>	<b>707</b>	<b>620</b>	<b>14 351</b>
	10-year average for the North Island = 7 685 (53.55%)									
	10-year average for the South Island = 6 665 (46.44%)									

**Table 4.** New Zealand pipfruit export crop by growing district, and climatic conditions in major growing areas in 1997.

Region	Export crop (‘000 TCEs <sup>a</sup> )	Temperature (°C) min–max		Climatic conditions		Annual average rainfall (mm)
		Temperature (°C) min–max	Temperature (°C) average	Temperature (°C) average	Annual average rainfall (mm)	
Hawke's Bay	7741	–4.2–36.7	13.8	13.8	798	
Nelson	5112	–2.9–25.3	13.8	13.8	633	
Canterbury	1014	—	—	—	—	
Marlborough	830	–6.1–32.2	13.6	13.6	413	
Otago	620					
Waikato	376					
Gisborne	221					
Auckland	61					

<sup>a</sup> TCEs = tray carton equivalents

## New Zealand Pipfruit—an Economic Success Story

Although NZ has no comparative advantage, as pipfruit is successfully grown in all regions of the world, it is widely recognised as a competitive leader in the global fresh produce market. To overcome this lack of competitive advantage, the industry had to innovate in all aspects of fruit growing, postharvest handling, quality management, shipping and customer-focused marketing. In 1997, NZ accounted for barely 1% of world apple production but was responsible for over 7% of world apple exports.

To demonstrate the economic success of the NZ pipfruit industry, it is relevant to note that we are a small producer in relation to the top 11 apple producing countries (Table 5). The interesting contrast, though, is that our crop yield (Table 6) and quality are high compared with the major global producers, notably China and the United States of America (USA). Given the ability to produce excellent quality fruit that is well sought after by consumers, how did a small producer (NZ) manage to gain dominance of the value of the global pipfruit market in comparison with our competitors (Table 7), despite having higher cost structures than its Southern Hemisphere competitors? How does NZ manage to produce up to 750% higher (in number) First Class cartons per person year, 31% higher in Grade 1 fruit, as well as higher income per ha net of packing costs compared to

a country like South Africa (Table 8) which has a higher economy of scale, lower input costs, and is nearer to the lucrative European market (Dall 1999)?

Armed with top quality products, the New Zealand Apple and Pear Marketing Board (NZAPMB) acknowledges the importance of its global marketing strategies towards achieving success, notably through innovation, differentiated products, control of distribution, and branding (NZAPMB 1994). In 1993, the Board controlled a 39% share of volume and 52% value for the apple import market in North America. A similar trend occurred in the European Community where NZ commanded a 30% share of the volume and 48% share of the value of the apple market. During the same period, NZ also exported a higher proportion of its total apple production in fresh form (53%) compared with its Southern Hemisphere competitors (Chile 51%, South Africa 43%, Argentina 24%, Australia 9%, and Brazil 8%).

During the past three decades, there has been considerable growth in the NZ horticultural industry. Horticultural exports rose sharply from NZ\$18 million in 1970 to top the billion dollar mark (NZ\$1.1 billion) in 1990. From 1983 to 1993, the total volume of fruit exports increased by 153%. For the year ended June 1999, horticultural exports rose by 14% from NZ\$1.518 billion in 1998 to NZ\$1.734 billion (HortNet 2000b) and were dominated by pipfruit and kiwifruit. Fresh fruit accounted for 61% of the 1999 total horticultural exports (HortNet 2000a), and fresh and processed pipfruit and kiwifruit contributed

**Table 5.** Top 11 apple producing countries in 1990 and 1997. (Source: Naegely 1998.)

Country	1990		Country	1997	
	Rank	Production ('000 t)		Rank	Production ('000 t)
USA	1	4 380	China	1	18 009
China	2	4 332	USA	2	4 639
France	3	2 326	Turkey	3	2 350
Germany	4	2 222	Iran	4	1 925
Italy	5	2 050	France	5	1 918
Turkey	6	1 900	Poland	6	1 900
Iran	7	1 524	Russian Federation	7	1 550
India	8	1 094	Italy	8	1 452
Japan	9	1 053	Germany	9	1 400
Argentina	10	975	Argentina	10	1 200
Hungary	11	945	India	11	1 200
Total production of these countries		22 801	Total production of these countries		37 543



28.9% and 27.3%, respectively, to the total horticultural export income. During the same period, export earnings of pipfruit and kiwifruit rose by 28% and 10%, respectively. It is projected that the NZ fruit industry will double exports to NZ\$3.8 billion by 2010. In addition to its success in export and domestic sales, the fruit industry supports a further NZ\$3 billion in economic activity and employs 25,000 people annually in the production support industries such as the postharvest, marketing and distribution sectors.

Overall, the global success and growth of NZ horticulture has been led by pipfruit. For instance, 83% of the growth in the horticultural sector came from apple sales. It is therefore appropriate to examine the quality management system which underpins the this remarkable success.

## Quality Management in the Pipfruit Industry

The NZ pipfruit industry has concentrated on developing new crop varieties, delivery of consistent premium quality produce, research and innovations in postharvest handling systems, branding, and other marketing strategies to run a competitive business that brings good returns to growers. Purity, safety and consumer acceptability of fruit products have been the strategic research issues which run across all fruit sectors. 'Quality' features prominently in the research and development priorities of the pipfruit industry, which have been grouped within (i) new variety development, (ii) product quality, (iii) environmental and food safety, and (iv) market access (FRCNZ 1997).

**Table 6.** New Zealand apple statistics in comparison with other nations. Data are averages of years 1996, 1997 and 1998 (Source: FAO database on the Internet at <<http://apps.fao.org>>.)

	Area (ha)	Production (t)	Yield (t/ha)
China	3 677 697	17 263 668	4.7
USA	192 190	4 785 000	24.9
France	78 000	2 463 667	31.6
Turkey	106 932	2 350 000	22.0
Italy	68 920	2 007 287	29.3
Germany	65 067	1 972 660	30.3
Japan	46 800	930 767	19.9
Chile	34 439	863 333	25.1
South Korea	41 282	651 654	15.8
<b>New Zealand</b>	<b>15 873</b>	<b>557 000</b>	<b>34.0</b>
The Netherlands	13 625	476 667	35.0

**Table 7.** Apple market share of some Southern Hemisphere producers expressed in volume and value terms in 1993. (Source: NZAPMB 1994.)

Country	% share of apple exports to the European Community		% apple exports to North America	
	Volume	Value	Volume	Value
Argentina	9	7	10	8
Australia	0	0	0	0
Brazil	3	4	2	0
Chile	27	21	31	23
<b>New Zealand</b>	<b>30</b>	<b>40</b>	<b>39</b>	<b>52</b>

**Table 8.** A comparative analysis of the New Zealand and South African fruit industries (South African Rand (R) = NZ\$0.31). (Source: Dall 1999.)

	New Zealand fruit industry	South African fruit industry
Cost of bare land with water/ha	R40 000	R30 000
Distance from European market	18 000 km	9 000 km
Distance from east coast American market	16 000 km	12 000 km
Exchange rate fluctuation over the past 3 years/annum	Dollar devalued by 8% per annum	Rand devalued by 18% per annum
Wages/hour, gross	R30	R10 (R5 + benefits)
<i>Income per ha net of packing costs:</i>		
‘Braeburn’	R115 000	R71 210
‘Royal Gala’	R118 800	R54 000
‘Granny Smith’	R69 300	R54 628
No. of ha of apples and pears	13 440	26 000
No. of growers of apples and pears	1 600	~650
Average farm size	8.4 ha	40.0 ha
No. of ha/person year	~3.5	~1.2
No. of First Class cartons/person year	12 250	1 440
% Grade 1 larger than count 150 on tree	75%	44%

### Quality assurance in a fully-regulated, single-desk industry

Historically, ENZA (the marketing arm of the NZAPMB) received the fruit from growers and paid a price, which was pre-set based on returns to growers in previous years. Under this scenario, ENZA took ownership of the fruit, including responsibility for quality problems that arose at any stage in the post-harvest chain. Product quality management was principally guided by a “Specification Manual” which clearly outlined the pipfruit industry quality policy, roles and responsibilities, specific postharvest operations, quality control, cool-store requirements etc. (ENZA 1995). To achieve its quality objectives, ENZA took responsibility for fruit maturity and maintained a research laboratory in the main growing region. The laboratory also assessed fruit chemical residues to ascertain that international standards for minimum residue levels were not exceeded. Staff collected fruit samples from orchards at regular intervals and used the data to predict ‘go’ or ‘open’ dates to begin fruit harvest and ‘close’ dates to stop harvesting of fruit. For each fruit cultivar, these dates were announced in local media and communicated directly to individual growers.

Packinghouse operations (sorting, grading, packaging etc.) and cold storage were run by ENZA and a few contractors, and these operations were monitored by certified quality controllers (QCs) who were staff of the Board. Fruit were also sampled at all stages in the postharvest chain for quality attributes and incidence of physiological disorders and were subject to further grading, repacking or complete removal from the chain. Since the Board assumed complete ownership of fruit after submission, it also took financial responsibility for postharvest losses and passed these on to all growers through a uniform return per tray carton equivalent (TCE). This meant that growers concentrated mainly on producing a high volume of crop to guarantee maximum packout (total fruit packed that meets the quality standards after sorting and grading), while ENZA provided technical support, monitoring of maturity and quality, inventory control, packing or processing, cold storage and shipping. ENZA also oversees the operation of the Fruit Industrial Plant Improvement Agency (FIPIA) which is responsible for the development, marketing and distribution of new pipfruit budwood.

Managing product quality under a highly centralised operation presented several difficulties due to the considerable variations in fruit maturity and

quality attributes across growing regions and even between orchards in the same region. The pooled, standard pre-set price for each fruit cultivar (and even across cultivars many years ago) did not provide sufficient incentives for growers and postharvest operators to invest in quality improvement technology and practices. Indeed, compliance with the ENZA Specifications Manual was becoming more and more difficult for some growers who believed that their crop was unique and had the right attributes, but may not meet the ENZA quality specifications. Growers who invested in quality assurance systems and/or regularly submitted top quality fruit complained that the flat pre-set payment system was unfair. They promoted the notion that the system did not support quality management initiatives, as poor quality growers were 'subsidised' by growers of good quality fruit and cultivars that commanded a premium price.

### **Quality assurance after regulation of the domestic market**

Over the past five years, there have been significant changes in the roles and responsibilities of ENZA, growers, and third party operators (for packinghouses, transportation and cool-storage) in regard to fruit quality management. In particular, grower responsibility and accountability for product quality has increased dramatically, while ENZA has invested in developing the relevant quality assurance guidelines for growers and postharvest operators. Individual growers who choose to submit their fruit to ENZA 'own' their crop until it is sold, and are therefore held responsible by ENZA for product quality problems which arise (called 'inherent vices', which include fruit physiological disorders and diseases). Growers are now responsible for developing and managing their own maturity program to guarantee that their crop meets the product specifications (ENZA 1995). In practical terms, they choose their own 'go' and 'closing' dates to enable them meet ENZA quality standards, achieve maximum packout, and minimise the development of inherent vices during postharvest handling, marketing and distribution. Some growers conduct their own maturity tests, others enlist the services of professional horticultural consultants, while many who do not pack their own crop have formed partnerships with the packinghouse which handles their crop.

As part of the industry strategies to assure produce quality, many packinghouse and cool-store operators have started implementing their own documented

quality systems (DQSs) designed to help achieve consistent, quality and safe product, and to meet market and ENZA requirements. To assist these operators, ENZA has provided guidelines detailed in a 'DQS start-up pack', and the result is that each operator develops her/his own DQS, usually comprised of a manual with an appendix which clearly cross-references to ENZA support material such as wall charts.

In view of the dynamic nature of quality (Opara, New market-pull factors influencing perceptions of quality in agribusiness marketing, these proceedings) and pipfruit business, it is necessary to audit the DQS and revise the manual to reflect current practice necessary meet ENZA quality assurance requirements. In general, the key phases in the development of a DQS are:

- decide who's responsible for it;
- develop the activities flow chart and the organisational structure chart;
- describe present practices;
- integrate ENZA's requirements;
- decide on a system auditor and the system of auditing; and
- action the results of an audit.

One grower who packs his own crop and those of eight others (annual packing shed throughput of about 112,000 tray carton equivalents) outlined the steps he took to develop a simple DQS (ENZA 1997):

- compiled a flowchart of events through the packing shed, detailing all processes followed along the way;
- documented job descriptions for all staff;
- questioned historical processes and justified or amended them as appropriate in order to streamline and/or to comply with ENZA specifications; and
- invited staff to scrutinise the draft DQS manual to ensure it correctly described what happens in practice.

These changes in roles and responsibility for assuring the quality of fresh produce for export enable ENZA to concentrate further on market access and global marketing activities, and providing leadership for quality management. Specifically, ENZA performs the following functions:

- accepts fruit for export that meet set standards;
- markets fruit;
- arranges transport, stevedoring and shipping;
- owns some cool-stores;
- manages overall crop inventory;
- establishes industry standards covering growing, spraying, harvesting, grading, packing and handling; and

- runs an intensive quality inspection program to ensure that fruit meets export standards.

ENZA quality inspectors are audited periodically by MAFQual, a service unit in the Ministry of Agriculture and Fisheries.

In summary, product quality is maintained in the pipfruit industry through:

- maturity management at harvest (by growers);
- strict export grade standards (set by ENZA);
- orchard and packinghouse quality control procedures;
- application of cool-chain concepts and portable controlled atmosphere technology for shipping; and
- monitoring residue levels on fruit by random testing to detect violations in spray diaries.

## Impacts of the Current Quality Management System

### Crop maturity and postharvest operations

Managing fruit maturity and quality programs requires capital investments in appropriate equipment and human resources far beyond the capacity of many individual small-scale pipfruit growers. This has created opportunities for the large-scale growers and postharvest operators to service the needs of the small growers for maturity management, and packinghouse operations for grading and packaging, and transportation. Private entrepreneurs have also invested in new packinghouses and cool-stores capable of handling large volumes of crop. To achieve economy of scale, the number of packinghouses has decreased dramatically during the past few years. In the Hawke's Bay, for instance, the number of packinghouses has declined from over 100 to about 38, with more rationalisation and consolidation expected in the future.

### Grower returns vis-à-vis incentives for 'quality'

To be effective, the changes in fruit quality management strategy described earlier have been linked to growers' returns. In consultation with growers and other customers, ENZA developed and implemented the concept of ENZA Submission Profiles (ESPs) for the classification of fruit submitted to ENZA. Commencing in 1998, the price received by a grower was linked to the quality attributes at harvest and the assurance provided by the grower that the product will

store well over a stated period of time while retaining the desired quality and freedom from storage disorders. Thus, under the ESPs:

- growers take responsibility for fruit quality;
- growers set own opening dates and the ESP on their fruit at harvest, and these are audited by the packinghouse during packing;
- growers receive payment over a range of prices depending on their fruit profile; and
- ENZA pays a premium price for top quality fruit over and above the average pay-out.

During the period 1995–1998, ENZA set up crop maturity programs in all the fruit growing regions, and used the results of this study in conjunction with data accumulated over the past 30–40 years for several varieties to develop three profiles of fruit (A, B, C) to meet its marketing objectives. Non-compliance due to improper quality specifications or following detection of inherent vice during marketing (e.g. scald, water-core, internal browning disorder etc.) requires that the grower must be held responsible for the necessary corrective actions. The affected grower is also held accountable for the cost of cold-storage and shipping if the fruit must be withdrawn from the supply chain. This arrangement suits the marketing focus and objectives of ENZA because fruit with longer storage and shelf life has more value due to the increased flexibility for marketing. Under the ESP system, growers are paid more for better storage characteristics and eating quality.

Under a typical ESP system (Table 9), a grower receives higher payment for being responsible for fruit quality over a longer period of time (both on and off-shore). Considering the 4–5 weeks of transportation required to get our fruit to the Northern Hemisphere, growers will be ill-advised to submit their fruit under a high profile if they have doubts on the storage potential. Table 10 illustrates the effects of ESPs and relative fruit size on final prices for high colour grade 'Fuji' apples during the 1999 season. It is important to note that the target attributes and specifications for assigning fruit to the ESPs are not constant and may vary from season to season to account for changes in consumer requirements and weather and climatic factors affecting crop yield and quality.

## Future Trends and Prospects for Quality Management

Horticulture—and indeed pipfruit production—is dynamic, and so is the consumer demand for quality.

Although fresh fruit is considered generally safe, recent incidences of food-borne illnesses related to the consumption of fresh and processed fruits have heightened public concern for fresh fruit safety (Opara 1999). Consistency in quality, product safety, and the ability to trace the product from retail shops to orchards many thousand miles away have become critical issues for the industry.

Equally relevant to quality management in the pipfruit industry is the increasing influence of other stakeholders such as the ‘greenies’ (environmentalists) and government who can influence public opinion about food supply and food safety. Changing life styles (such as the increasing influence of convenience and demand for fresh foods), cultural attributes and personal attitudes are becoming increasingly important in our food consumption patterns and consumer perceptions of product quality (Sloan 1996; Opara, New market-pull factors influencing perceptions of quality in agribusiness marketing, these proceedings). How would these global trends affect the average producer who grows only a few hectares of fruit but is keen to meet these changing demands of the discerning consumer? With the increasing role and influence in the pipfruit business of third parties such as packinghouse operators, cool-store operators, and supermarket chains, how do we ensure that principles and practice of quality assurance continue to be essential parts of the business practice? Both growers and postharvest operators must meet the customer and consumer requirements for safe growing practices, as well as a safe, clean environment for handling, packing and storage of fruit.

It is foreseeable that grower responsibilities for fruit quality and safety will potentially be transferred to the emerging corporate packinghouses who are expected by ENZA to implement extensive quality assurance procedures for maturity management, quality control, labelling and documentation, and cool-chain management. Similarly, cool-store operators would also need to implement quality assurance systems to manage the cool-store environment (temperature, relative humidity, atmospheric composition) and product security (avoid contamination and facilitate

traceability). As further consolidation occurs in the industry, few large-scale operators will emerge who will combine several small to medium-scale packinghouse and cool-store operations into single enterprises. At the marketing level, these scenarios will transfer the greater responsibilities for product quality from growers to packinghouse and cool-store operators, resulting in the reduction of grower pay-out rates. In terms of overall quality management, this leaves ENZA with the main function of identifying potential risks to product quality and safety, and the recommendation of appropriate corrective actions at all stages of the supply chain. The capacity for ENZA to fulfil this role will rely on its ability fund the necessary research and development to guarantee access to innovative technologies for pipfruit growing and handling systems.

With the potential to deregulate the export market, competing marketers will emerge who may elect to buy the product from growers. While such operators may take over the ownership of the crop after buying the crop from the grower, and therefore assume responsibility for the entire postharvest quality, the implicit responsibility for quality on the part of the grower may translate in reduced pay-outs. The better returns currently enjoyed by NZ growers will come under pressure as our international competitors improve their quality management systems and adopt the enabling postharvest science and technological innovations. Given the limit to what can be achieved by either incremental quality and efficiency improvement, or by reducing costs, it is foreseeable that future success in the pipfruit industry will have to come from strategic initiatives that focus on expanding existing markets, introduction of new innovative product lines, and value-adding. Under this challenging and uncertain scenario, I have no doubt that the NZ pipfruit industry will continue to innovate, particularly in new product lines and value-adding and will continue to exert a major influence in the international fresh produce market.

**Table 9.** Typical payment scheme for Submission Profiles (A, B and C) for pipfruit in New Zealand.

	A	B	C
Payment (% of the pre-set price)	110	100	90
No. of days for which grower is responsible for fruit	90	70	50

**Table 10.** Final prices (NZ\$ per tray carton equivalent) for ‘Fuji’ apples (high colour grade) in 1999. (Source: ENZA 1999.)

ESP <sup>a</sup>	Relative fruit size									
	50	60	70	80	90	100	110	120	135	150
A	32.81	20.80	20.80	20.80	20.80	16.81	16.18	11.55	18.46	15.68
B	29.83	18.91	18.91	18.91	18.91	14.71	14.71	10.50	16.78	14.25
C	26.85	17.02	17.02	17.02	17.02	13.24	13.24	9.45	15.10	12.83

<sup>a</sup> ESP = ENZA Submission Profile

## Concluding Remarks

New Zealand is blessed with favourable agro-climatology for fruit growing. During the past three decades, fruit exports have increased dramatically into a multi-billion dollar business, currently accounting for 72% of the total horticultural export earnings. Pipfruit has been a major contributor to this success, recording a 28% increase in export income during the last season, compared with kiwifruit (10%) which is the other major export fruit.

New Zealand is acclaimed in the international fresh produce market as a successful and competitive producer of high quality pipfruit, which requires a premium to cover the costs of market access, transportation and stringent quality assurance systems. This scenario developed and flourished under a ‘single-desk’ marketing system, which also had a centralised approach to product quality management. In the past five years, significant changes have occurred in the way we manage fruit quality, with a transfer of responsibilities from the marketing agency (ENZA) to growers primarily, and to third-party operators (packinghouses and cool-stores). To succeed, it was necessary to develop and implement the new ENZA Submission Profile-based payment system that recognises conformance to agreed product quality specifications as well as achieving good storage potential of fruit. This has resulted in a consolidation of packinghouses and cool-stores to a few but bigger operators, who are expected to implement documented quality systems as part of the industry overall quality assurance system. Increasing global concern for product and safety, as well as environmental quality, requires that both growers and postharvest operators must implement quality assurance programs to identify potential risks and minimise hazards to the product and consumer. Presently, ENZA—now known as ENZAFRUIT (International)—continues to be responsible for international marketing of pipfruit

as well as the overall role of managing quality in the industry.

Like other major players in global business, the NZ pipfruit industry faces considerable challenges over the next decade. Recent ongoing changes in the industry organisational structure, particularly the potential for complete deregulation of the export market, will introduce new challenges in quality management considering that the present success and reputation for quality has been achieved over a 50-year period of single-desk marketing. With increasing need for quality assurance, including traceability, the cost of non-compliance is likely to increase in the near future, and this could considerably threaten the profitability and survival of our traditional, small-scale family orchards, who are ultimately responsible and accountable for their fruit quality.

As consumers demand value for money, they are increasingly eating fruit and other foods to express their personal aspirations, concerns and values. They require assurances on product and consumer safety, traceability, freshness/naturalness, sustainability, health/nutrition, zero waste and fair trade. Even under the seemingly impossible scenario of satisfying these complex market-pull demands, I have no doubt that the NZ pipfruit industry will continue to innovate, particularly in new product lines and value-adding to continue to exert a major influence in the global fresh produce market. Sustaining our international reputation as a ‘clean green’ country and industry will become increasingly beneficial in light of the these new market-pull factors.

## References

- Burkhart, D. 1997. Growers explore New Zealand growing districts. *Good Fruit Grower*, May, 39–41.
- Dall, P. 1999. The New Zealand fruit industry: one man’s perspective. *Deciduous Fruit Grower*, 49(5), 12–13.
- ENZA 1995. Specification manual. Wellington, ENZA New Zealand (International).

- ENZA 1997. Pipmark (August). Wellington, New Zealand Apple and Pear Marketing Board.
- ENZA 1999. Final prices and statistical information. Wellington, New Zealand Apple and Pear Marketing Board.
- FRCNZ (Fruit Research Council of New Zealand) 1997. Fruit research in New Zealand 1996. Wellington, FRCNZ.
- Hewett, E.W. 1997. Postharvest physiology: some basic concepts. Paper prepared for Block Course 38.756 Postharvest Engineering, 14 March.
- HortNet 2000a. Contribution of horticultural commodity types to total horticultural exports in 1999. On the Internet at <<http://www.hortnet.co.nz>>.
- HortNet 2000b. Summary of horticultural commodity totals. On the Internet at <<http://www.hortnet.co.nz>>.
- Naegely, S. 1998. The great orchards. *Fruit Grower*, 118(9), 6–7.
- NZAPMB (New Zealand Apple and Pear Marketing Board) (undated). Board bibliography. Wellington, NZAPMB (leaflet).
- NZAPMB (New Zealand Apple and Pear Marketing Board) 1994. The New Zealand pipfruit industry. Wellington, NZAPMB.
- NZAPMB (New Zealand Apple and Pear Marketing Board) 1995. Annual report. Wellington, NZAPMB.
- Opara, L.U. 1999. The recent US Food Quality Protection Act (FQPA) and implication on global fresh produce trade. Paper presented at the International Workshop on Quality and Phytosanitary Issues in Agribusiness held at the University of Pretoria, South Africa, 3<sup>rd</sup> December.
- Sloan, A.E. 1996. The top 10 trends to watch and work on. *Food Technology*, 50(7), 55–71.

# Scientific Tools for Quality Management in Agricultural Produce

L.U. Opara\*

## Abstract

Economic production and profitable marketing of quality and safe food products is a major challenge in agriculture. From the acquisition of planting materials, to the growing, harvesting, postharvest handling, storage and retail distribution, the potential changes in quality and safety issues associated with each step must be given adequate consideration. This paper looks at the use of scientific methods and postharvest techniques for quality maintenance as well as management of safety in fresh produce. The application of quality management tools such as Good Manufacturing Practice (GMP), Good Hygiene Practice (GHP), and Hazard Analysis and Critical Control Points (HACCP) to fresh fruit and vegetable industries will be discussed.

AGRICULTURAL (and horticultural) products are inherently variable in quality due to several factors. Differences in agro-climatology (e.g. rainfall, sunshine, humidity, slope, temperature), growing practices, postharvest handling and storage systems, and staff performance at all steps in the supply chain contribute to variations in the product quality. Complex consumer preferences and perceptions of quality, which require considerable product segregation, and assurance of quality and safety further exacerbate the problem of managing these huge sources of variability.

For many years, high production volumes and low costs have been viewed as the key to the profitability of agriculture and other enterprises. With significant advancements in improved breeding and production practices, crop yields have increased dramatically during the past 50 years. The application of sophisticated postharvest handling and storage technologies with efficient marketing structures has guaranteed the year-round supply of most food crops in the international market. Oversupply is a problem in some commodities.

In modern business, however, new scientific tools and management strategies have become available,

bringing with them a surge of interest and opportunities in the competitive implications of product quality (Garvin 1984; Opara, New market-pull factors influencing perceptions of quality in agribusiness marketing, these proceedings). Product quality and its management have now become important strategic weapons used to gain market access and sell products. The objectives of this paper are: (a) to examine the quality problems in produce and the postharvest techniques for quality maintenance; and (b) to discuss the scientific tools for managing product safety in fresh produce.

## Quality Problems in Agricultural Fresh Produce

Quality is a concept. It is dynamic and has several elements related to the agreed specifications, performance and consumer perceptions (Garvin 1984). A quality product (or service) will consistently meet the continuously negotiated expectations of customers and other stakeholders in a way that represents value for all involved (Kruithof and Ryall 1994). The quality of fresh agricultural produce is assessed from the relative values of several attributes which, considered together, determine the acceptability of the produce to the buyer and ultimately the consumer. These attributes may be perceptible by the senses (firmness, colour, flavour) as well as imperceptible (organics/

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naturalness, genetically modified plants, safety, cultural attitudes).

Agricultural fresh produce, such as fruits and vegetables, is prone to problems which downgrade quality or pose health/safety risks to the consumer. In general, quality problems can be caused by physical, chemical, microbiological and environmental factors. Physical impacts, compression, abrasion and cuts manifest as skin damage such as bruising. Bruised produce is downgraded and reduces the profitability of agribusiness. Temperature affects fruit susceptibility to bruising, with a higher level of damage at low temperatures (Crisostos 1993). Produce with cuts, stem punctures and other skin breakage are also downgraded and provide avenues for opportunistic microbial infection and contamination during subsequent handling and storage. Harvested produce must meet standard requirements for minimum residue levels. Opportunities for chemical problems can arise from residues of preharvest spraying and postharvest chemical contamination during handling.

Food safety is a problem in the fresh food industry due to hazards of physical, chemical and microbiological contaminants (Douglass 1999). Microbiological pathogens such as bacteria, parasites and viruses occur in agricultural produce. These get into produce through insects, rodents, birds, contaminated water, soil, and plant and equipment, and through cross-contamination from humans and other produce (meat, milk, eggs) during handling and storage. Contaminated produce become sources of food-borne illness, which can result in death in severe cases. Clinical cases of food-borne illnesses caused by contaminated fruits and vegetables have been recently documented or reported with increasing frequency (Wells and Butterfield 1997, 1999).

Environmental factors such as temperature, relative humidity and light affect the rate of quality degradation and storage life of produce. Indeed, temperature exerts the most influential effect on postharvest quality attributes. Fresh commodities store better at low temperature and high relative humidity. High temperature accelerates the ripening process, resulting in tissue softening, yellowing and water loss. Root and tuber crops store better in the dark to reduce greening and sprouting. Improper environmental storage conditions also result in the development of physiological disorders and diseases in produce. The biological processes involved in product deterioration are temperature dependent. Temperature management is therefore an essential scientific tool to delay product deterioration and assure quality.

After harvest, two strategies are necessary to reduce these losses: first is to apply appropriate postharvest techniques which maintain product quality, and the second is to implement quality systems for managing food safety hazards as well as product quality. The overall approach recognises the fact that the quality of harvested produce cannot be increased—it can only be maintained!

## **Postharvest Technologies for Quality Maintenance**

The postharvest sector is critical in meeting the consumer requirement for consistent quality and safe products. General postharvest operations include cleaning, sorting, grading, packaging, storage and distribution. Postharvest technologies assist in the handling and marketing of agricultural produce by:

- maintaining quality;
- extending shelf life and thereby expanding the marketing season;
- guaranteeing consistent supply;
- providing uniformity of grade standards;
- reducing losses; and
- adding value to the product (such as customised packaging).

To achieve these benefits, specific postharvest technologies are applied for maturity and quality assessment, control of the postharvest built environment to maintain a cool-chain, and improvement of the handling system.

## **Scientific tools for maturity and quality assessment**

Determining adequate crop maturity (readiness for harvest) is vital for optimal postharvest performance. Equipment and techniques exist for maturity and quality evaluation of fresh produce (Bourne 1980; Chen and Sun 1991; Abbott et al. 1997; Stenning 1998). These include physical tests (size, shape, density), chemical (sugar, acidity, flavour, chemical residue) and mechanical (texture) tests. Non-destructive devices exist for maturity and quality assessment as well as for detecting diseases and internal defects such as bruising (Katayama et al. 1996; Abbott et al. 1997; Muir et al. 1998). Sensory science is also employed for taste-testing to provide data on human sensory perceptions of quality. Trained panels or untrained consumers can be used depending on budget limitations and scope of study. Even where

objective tests are used to assess the product, the result obtained must be correlated to subjective human assessment for practical applications.

## **Environmental control and monitoring**

Establishing, maintaining and controlling the temperature, relative humidity and airflow inside the postharvest handling and storage environment (packaging, cool-store, truck) is essential to maintain the cool-chain which is necessary to maintain product quality. The use of ventilated packaging designs enhances airflow around produce to achieve rapid cooling rates and maintain the desired product temperature. Temperature sensors, humidity probes, thermal anemometers (air velocity sensors) are used to measure important environmental fluctuations. Where produce is stored in controlled atmospheres, gas chromatographs are used to monitor the oxygen and carbon dioxide concentrations. Both environmental and gas monitoring can be automated and linked to early warning signal systems.

## **Handling systems**

The mechanisation of fresh produce handling operations has increased the potential for physical damage such as bruising, which can occur at any stage in the postharvest chain. New package designs made up of corrugated fibre-boards with paper-based 'Friday' tray layers assist in absorbing impact and compression forces during handling. Force deceleration devices such as foam pads and cushions are placed on the surface of grading machinery to reduce fruit-to-fruit impacts and fruit impact to hard surfaces. Force sensors (or 'instrumented spheres') containing accelerometers can be used to assess the 'health' of handling systems to demonstrate where improvements may be needed.

## **Quality and Safety Management Tools**

Managing fresh food quality and safety to guarantee the supply of consistent and reliable business is a major challenge facing modern agriculture. Even where agreed product specifications have been met, assurance of food safety and other new market-pull factors have become increasingly paramount (Opara, New market-pull factors influencing perceptions of quality in agribusiness marketing, these proceedings). There is both theoretical and practical evidence that

consumers are willing to pay more for food that they believe is safer and/or of higher quality (Kinsey 1998; Opara, New market-pull factors influencing perceptions of quality in agribusiness marketing, these proceedings).

There is also the social psychology aspect of food safety, which includes fear and vulnerability, along with the hesitancy to give up the security, freedom, convenience, and peace of mind to which we are accustomed as we enjoy our food products. Intriguing as some of these concerns may be, it is worth noting that a recent survey by the World Health Organization concluded that "none of the chemical or physical treatments currently used to disinfect raw fruits and vegetables can be relied on to eliminate all types of pathogens from the surface or internal tissues when using application conditions that will not adversely affect sensory or nutritional qualities" (WHO 1998).

In addition to physical, chemical and microbiological hazards, other food safety challenges in the fresh food industry include genetically modified foods, emerging pathogens, allergens, pesticide residues and mycotoxins. Currently, microbial contamination remains arguably the biggest food safety hazard in the fresh food industry. Therefore, the following discussion will concentrate on managing this hazard, granted that the management systems discussed will inevitably reduce the safety risk associated with the other hazards.

The principles of quality and product safety management are well established and documented, and are often referred to collectively as 'food control'. Several internationally recognised model management systems can be applied to all the production and handling operations to assure the safety and quality of fresh and processed foods. These include Good Manufacturing Practice (GMP), Good Hygiene Practice (GHP), Hazard Analysis and Critical Control Points (HACCP), and other tools of more general application such as quality assurance (QA) methods and systems including the ISO 9000 series of standards and total quality management (TQM). In this paper, GMP, GHP and HACCP will be discussed, with particular attention paid to HACCP applications.

## **Good Manufacturing Practice (GMP) and Good Hygiene Practice (GHP)**

The basic principles of cleaning and sanitation, and good hygiene practice form an integral part of GMP.

GMP may be considered as having two complementary functions—‘effective manufacturing operations’ and ‘effective quality control’ (Porter 1998). GMP covers the fundamental principles, procedures and means needed to design an environment suitable for the production of food of acceptable quality (Jouve et al. 1999).

On the other hand, GHP outlines the basic hygienic measures which business should meet and which are the prerequisite(s) to other approaches, particularly HACCP. Good hygiene practice requires: (a) the hygienic design and construction of food manufacturing premises; (b) the hygienic design, construction and proper use of machinery; (c) cleaning and disinfection procedures (including pest control); and (d) general hygienic and safety practices in food processing. The last requirement covered includes microbial quality of raw foods, hygienic operation of each process step, and the hygiene of personnel and their training in the hygiene and safety of food (Jouve et al. 1999). Based on a definition of hygiene as “ensuring that all measures are taken to ensure the safety and wholesomeness of foodstuffs”, Porter (1998) identified five components of GHP:

- premises—well protected and in good repair;
- people—adequately trained with good standards of personal hygiene;
- equipment—suitable equipment for the job;
- controls—good control over the process, including adequate cleaning and sanitation; and
- systems—assessment of risks and the implementation of written systems and records.

## **Hazard Analysis and Critical Control Points (HACCP)**

HACCP quality and safety management procedures were originally developed in the late 1960s in the United States of America to assure food safety for the space program. In the early 1970s, the Food and Drug Administration started to use an HACCP approach for the inspection of factories manufacturing low-acid foods. Since then, an increasing number of fresh and processed food industries have adopted HACCP to their quality control and assurance programs.

HACCP is a food safety management system involving systematic and logical assessment of all the steps in a food production and processing operation (Savage 1995; MOH 1997; Kennedy 1998). It aims to identify those steps that are critical to the safety of the product, so that management can then concentrate its

scarce technical resources in those processes/steps which critically affect the safety of the product. HACCP transforms a food production and handling operation from the traditional control philosophy, based primarily on end-point testing, to a preventative approach. It provides a structured approach to the assurance of the quality and safety of specific products and their processes, involving:

- identification of hazards of concern (such as pathogens);
- identification of the specific requirements for their control; and
- mechanisms to continuously measure the effectiveness of the HACCP system.

HACCP is comprised of seven basic principles, which must be followed in implementing a HACCP-based quality management program: conducting hazard analysis, identifying the critical points for each step, establishing critical limits, establishing monitoring requirements, taking corrective action, keeping records, and verifying the HACCP system is working correctly.

In the HACCP system, hazard is defined as a potential to cause harm to the consumer (safety) or the product (spoilage). A critical control point is a location, stage, operation, step or raw material which, if not controlled, provides a threat (risk) to consumer safety, or the product acceptability. Although HACCP was developed initially and has still mainly applied to assure the microbiological safety of foods, it is applicable to other forms of hazard such as chemical and physical contaminants. HACCP is also suitable as a management tool to ensure consistent product quality or increased production efficiency.

## **Concluding Remarks and Future Prospects**

The production and marketing of quality agricultural produce is a major challenge facing growers, handlers and marketers, particularly due the myriad of climatic, production, environmental and postharvest handling factors which contribute to a highly variable product. Food safety is now recognised as a problem in the fresh food industry, and consumers and other stakeholders are increasing demanding safe foods that are of the highest quality. Several tools for maintaining the product quality during postharvest operations are described in this paper. They comprise the technologies for assessing and monitoring product quality attributes, technologies for reducing physical damage,

and environmental techniques for maintaining the cool-chain and minimising deterioration.

Quality and safety management tools, which are applicable to fresh agricultural produce are also described, specifically Good Manufacturing Practice (GMP), Good Hygiene Practice (GHP), and the Hazard Analysis and Critical Control Points (HACCP) systems. Although microbial hazard is currently the main safety concern in the fresh food industry, these quality management tools have the potential to provide the agricultural and horticultural industries with new science-based tools to systematically manage other food hazards and product quality.

## References

- Abbott, J.A., Lu, R., Upchurch, B.L. and Stroshine, R.L. 1997. Technologies for nondestructive quality evaluation of fruits and vegetables. *Horticultural Reviews*, 20,1–126.
- Bourne, M.C. 1980. Texture evaluation of horticultural crops. *HortScience*, 15, 51–57.
- Chen, P. and Sun, Z. 1991. A review of nondestructive methods for quality evaluation and sorting of agricultural products. *Journal of Agricultural Engineering Research*, 49, 85–98.
- Crisostos, C.H. 1993. Postharvest factors affecting fruit quality and postharvest deterioration. *Perishables Handling*, 75, 2–5.
- Douglass, P. (ed.) 1999. Food safety in the postharvest industry. Conference Proceedings, Postharvest Convention held at Silsoe College, Cranfield University, Bedford, United Kingdom.
- Garvin, D.A. 1984. Product quality: an important strategic weapon. *Business Horizons*, 27(3), 40–43.
- Jouve, J.L., Stringer, M.F. and Baird-Parker, A.C. 1999. Food safety management tools. *Food Science and Technology Today*, 12(3), 82–91.
- Katayama, K., Komaki, K. and Tamiya, S. 1996. Prediction of starch, moisture, and sugar in sweet potato by infrared transmittance. *HortScience*, 31, 1003–1006.
- Kennedy, G. 1998. Introduction of HACCP into the smallgoods industry. *Food Australia*, 50(2), 80–82.
- Kinsey, J.D. 1998. Food safety—why now? *Cereal Foods World*, 43, 224–226.
- Kruihof, J. and Ryall, J. 1994. The quality standards handbook: how to understand and implement quality systems and ISO 9000 standards in a context of total quality and continuous improvement. Melbourne, The Business Library.
- MOH (Ministry of Health) 1997. An introduction to HACCP. Food safety information for New Zealand businesses, revised edition. Wellington, New Zealand, Ministry of Health.
- Muir, A.Y., Ross, D.W., Dewar, C.J. and Kennedy, D. 1998. Defect and diseases detection in potatoes. In: Stenning, B. ed., Quality assessment for the fresh produce market. Conference Proceedings, Postharvest Convention held at Silsoe College, Cranfield University, Bedford, United Kingdom, 12–15.
- Porter, A. 1998. Quality and product safety management. *Food Science and Technology Today*, 12, 160–165.
- Savage, R.A. 1995. Hazard analysis critical control point: a review. *Food Reviews International*, 11, 575–595.
- Stenning, B. (ed.) 1998. Quality assessment for the fresh produce market. Conference Proceedings, Postharvest Convention held at Silsoe College, Cranfield University, Bedford, United Kingdom.
- Wells, J.M. and Butterfield, J.E. 1997. Salmonella contamination associated with bacterial soft rot of fresh fruits and vegetables in the market place. *Plant Disease*, 81, 867–872.
- Wells, J.M. and Butterfield, J.E. 1999. Incidence of Salmonella on fresh fruits and vegetables affected by fungal rots or physical injury. *Plant Disease*, 83, 722–726.
- WHO (World Health Organization) 1998. Surface decontamination of fruit and vegetables eaten raw: a review. Geneva, WHO/FSF/FOS/98.2.

# Effect of Intermittent Warming on the Reduction of Chilling Injury and Physiological Changes of 'Khakdum' Papaya (*Carica papaya* L.)

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## Abstract

The effect of intermittent warming on the reduction of chilling injury and physiological changes of 'Khakdum' papayas were studied. Fruit were subjected to 5°C, 15°C, or intermittent warming conditions at 15°C or 20°C for 3 days and transferred to 5°C for 2 days. The warming treatments were repeated for two cycles and then stored at 5°C until the end of storage. The fruit stored at 5°C showed a greater extent of the chilling injury pitting symptom and remained unripe when transferred to room temperature. The fruit stored at 15°C showed no symptoms of chilling injury. Intermittent warming reduced chilling injury symptoms when compared to the fruit stored at 5°C. Furthermore, intermittently warmed fruit had normal peel colour development, and polyamine contents were higher than chilled fruit. Fruit intermittently warmed at 15°C had a longer storage life than fruit intermittently warmed at 20°C, but both conditions gave similar results in reducing chilling injury symptoms.

PAPAYA (*Carica papaya* L.) is a tropical fruit (Chen and Paull 1986) that undergoes rapid physiological and biochemical changes after harvesting, causing problems for storage and processing. Storage at low temperature could prolong shelf life and maintain fruit quality by decreasing the rate of metabolism, delaying ripening and controlling growth of microorganisms, but many tropical fruits are sensitive to low temperatures. Chilling injury is physiological disorder induced by low temperatures (below 12.5°C). Sensitive fruits show a variety of symptoms such as surface lesions (pitting, sunken areas, discoloration), water soaking of tissue, failure of fruit to ripen, accelerated rate of senescence and increased susceptibility to decay (Morris 1982).

Several postharvest techniques have shown promise in increasing the tolerance of fruits and vegetables to chilling injury (Wang 1993) such as temperature conditioning, heat treatment, controlled atmospheres, packaging, waxing and other coating etc. Intermittent warming is one form of temperature conditioning that

can be an effective means of alleviating chilling injury. It has been reported to reduce chilling injury in lemon (Cohen et al. 1983), cucumber (Cabrera and Saltveit 1990) and tomato (Artes and Escriche 1994). However, inconsistent results have been reported regarding the effectiveness of intermittent warming in reducing chilling injury and the mechanism of action of intermittent warming is not understood. The objective of our present study was to determine the physiological effect of intermittent warming during chilled storage and to evaluate the effect of intermittent warming on alleviating symptoms of chilling injury.

## Material and Methods

### Plant material

'Khakdum' papaya fruit were harvested at maturity of 5–10% yellow colour from an orchard in Chantaburi Province in eastern part of Thailand. The fruit were treated with thiabendazole (500 mg/L) to reduce fungal decay.

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## Temperature management

There were four temperature treatments: (1) control fruit—continuously held at 15°C; (2) chilled fruit—continuously held at 5°C; and intermittently warmed fruit—(3) warmed at 15°C or (4) warmed at 20°C for 3 days, then held at 5°C for 2 days. Intermittently warmed fruit were subjected to 2 cycles before transfer back to 5°C and relative humidity of about 90–95%. Samples were taken from each treatment (3 replications) every 5 days during storage. Least significant difference (LSD) was used to compare mean differences.

## Determination of skin colour

The external colour of the fruit was determined using a colorimeter (Hunter colour difference meter, minolta model DP-301). All data were given as  $L^*$ ,  $a^*$  and  $b^*$  values and the yellow colour index was calculated as follows:

$$\text{yellow colour index} = L^* \times b^*/|a^*| \quad (1)$$

## Chilling injury evaluation

Chilling injury (CI) was evaluated by means of a subjective scale of visual symptoms, based on pitting on the surface and intensity of ripening: 0 = no pitting; 1 = slight; 2 = medium; and 3 = severe pitting. A chilling injury index was determined using the formula (Martinez-Tellez and Lafuente 1997):

$$\text{CI index} = \frac{\sum \text{Pitting scale} \left( \frac{0 \text{ to } 3 \right) \times \text{number corresponding fruit}}{\text{within each class}}}{\text{total number of fruit}} \quad (2)$$

## Polyamine analysis

1 g of each sample was extracted in 5% cold  $\text{HClO}_4$  (10 mL). After extraction for 1 h in an ice bath, samples were pelleted at 48,000 g for 20 min and the supernatant phase, containing the free polyamine fraction, was collected. 0.5 mL of the crude extract was mixed with 2 mL of 4 N NaOH, then 5  $\mu\text{L}$  of benzoylchloride was immediately added. The mixture was vortexed for 15 s, and incubated at 35°C for 20 min in a water bath, before addition of 4 mL of saturated NaCl. Benzoyl polyamine was extracted in cold ether. After centrifugation at 1,500 g for 10 min, 2 mL of the top solution (ether fraction) was col-

lected, evaporated to dryness under nitrogen gas, then redissolved in 200  $\mu\text{L}$  of acetonitrile and injected to a high performance liquid chromatograph (HPLC). Densyl polyamine was separated by HPLC system with a C18 reverse column. The mobile phase was acetonitrile:water, 1:1(v/v) at a flow rate of 1 mL/min. Ultraviolet waves were detected at 254 nm. Sensitivity was set at 0.04 a.u.f.s. (Flores and Galston 1982).

## Results

### Fruit peel colour

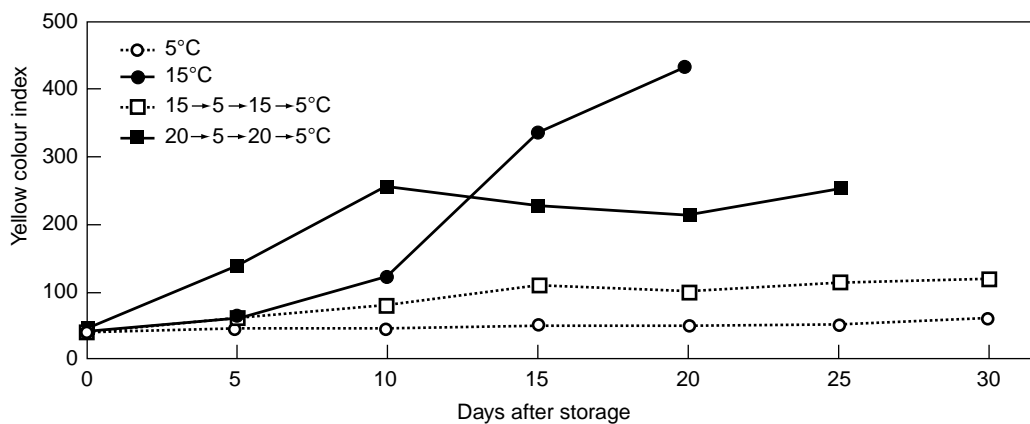
The yellow colour index of the peel of fruit warmed intermittently at 20°C increased on the first day of storage until the 10<sup>th</sup> day, then decreased. In contrast, the yellow colour index in control fruit at 15°C slowly increased until the 10<sup>th</sup> day and then increased sharply. Fruit warmed intermittently at 15°C showed only slight changes in colour index during storage. Colour development was enhanced by intermittent warming treatments when compared with fruit stored at 5°C that had only a slight change in colour during storage. Fruit intermittently warmed at 20°C had higher yellow index than fruit intermittently warmed at 15°C (Figure 1).

### Chilling injury index

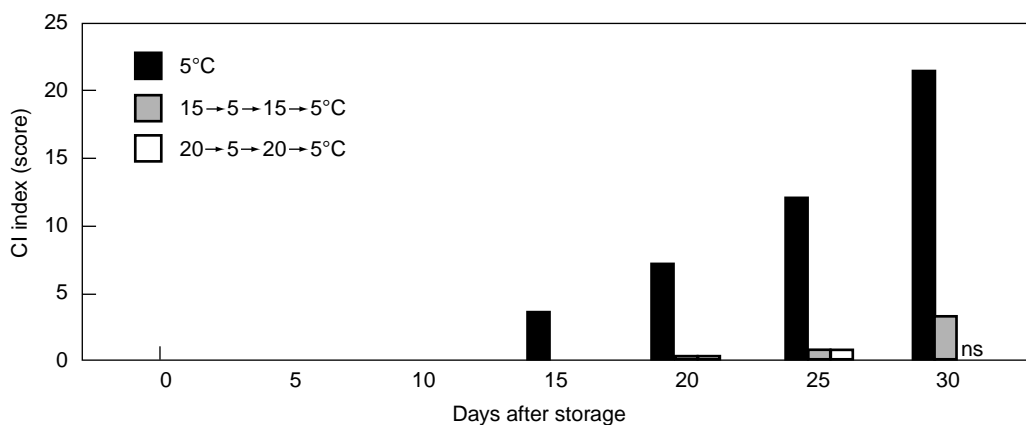
The severity of chilling injuring symptoms was determined by measuring the pitted area. Fruit which had a pitted area of 0.2–0.8 mm in diameter did not ripen normally. Chilling injury was detected in chilled fruit (kept at 5°C) and slight chilling injury symptoms were found in the intermittently warmed fruit (Figure 2). Papaya fruit kept at 5°C developed chilling injury symptoms faster and more severely than intermittently warmed fruit. Control fruit (kept at 15°C) did not develop chilling injury. There was no significant difference in the chilling injury index between the fruit intermittently warmed at 15°C and 20°C.

### Polyamine levels

One of the aims of this study was to determine whether the products of chilling injury resulting from intermittent warming could involve the polyamines putrescine, spermidine and spermine. Figure 3 shows the effect of the treatments on the putrescine content in the pulp. The putrescine content in control fruits at 15°C increased until 5<sup>th</sup> day and then sharply



**Figure 1.** Changes in peel colour of papaya fruit stored at 5°C, 15°C, or intermittently warmed at 15 or 20°C, as shown by the yellow colour index (see Equation 1).

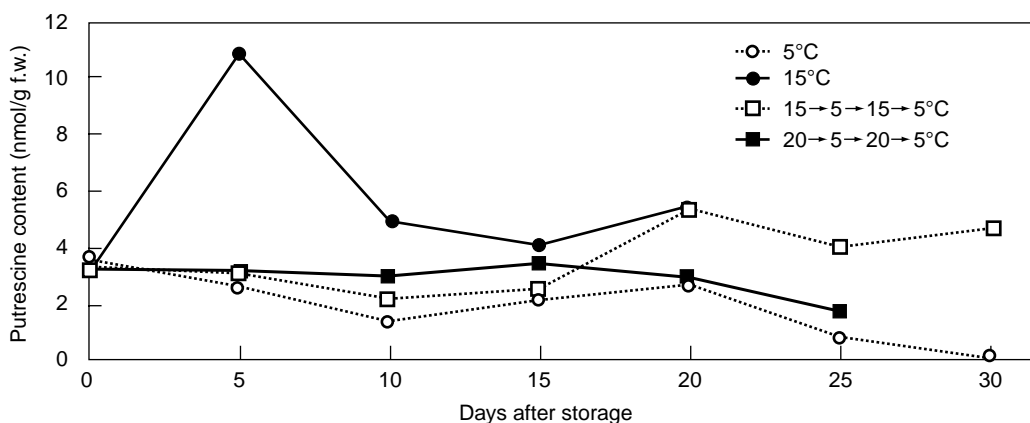


**Figure 2.** Chilling injury (CI) index (Equation 2) of papaya fruit stored at 5°C, 15°C, or intermittently warmed at 15 or 20°C (ns = not shown). Fruit kept constantly at 15°C showed no chilling injury over the storage period.

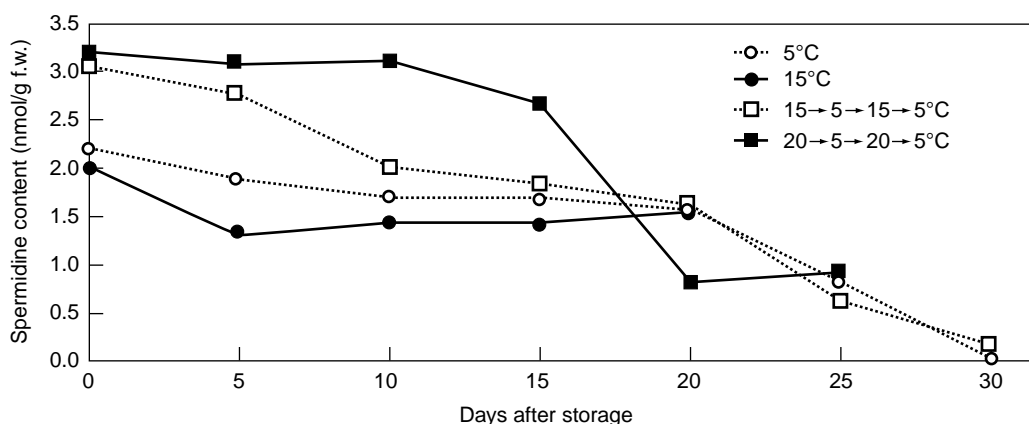
decreased, but remained higher than the other treatments. Putrescine levels in the chilled fruit (kept at 5°C) and intermittently warmed fruit generally decreased over time in storage, but intermittently warmed fruit showed higher putrescine levels than fruit kept at 5°C. Levels of spermidine (Figure 4) and spermine (Figure 5) decreased over time in storage. Both spermidine and spermine levels were higher in intermittently warmed fruit than in chilled or control fruit.

## Discussion

Our results demonstrated that intermittent warming could reduce chilling injury symptoms in 'Khakdum' papaya (Figure 2), as has been found in other fruits such as tomato (Saltveit and Cabrera 1987) and cucumber (Cabrera and Saltveit 1990). Intermittent warming significantly induced the development of fruit peel colour (Figure 1), possibly due to the warm temperature enhancing the metabolism of ripening and related enzymes, such as chlorophyllase, which may be activated during the degradation of chlorophyll (Wills et al. 1981) resulting in yellow colour development.

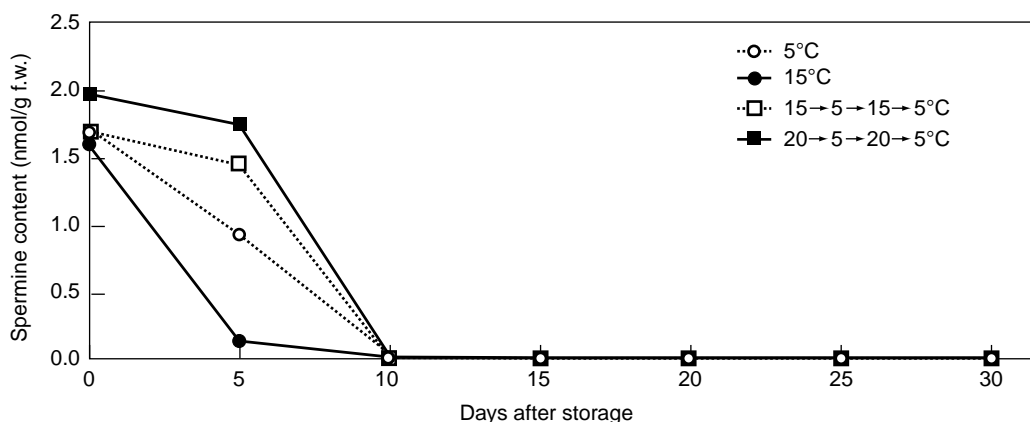


**Figure 3.** Chilling injury index (Equation 2) of papaya fruit stored at 5°C, 15°C, or intermittently warmed at 15 or 20°C.

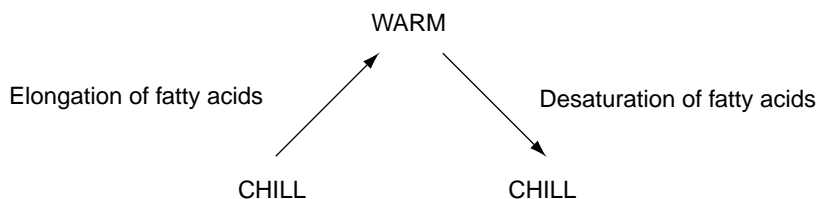


**Figure 4.** Spermidine content of papaya fruit stored at 5°C, 15°C, or intermittently warmed at 15 or 20°C (f.w. = fresh weight).





**Figure 5.** Spermine content of papaya fruit stored at 5°C, 15°C, or intermittently warmed at 15 or 20°C (f.w. = fresh weight).



**Figure 6.** Schematic illustration of possible changes in fatty acids during the process of intermittent warming.

Chilling injury symptoms in fruit resulted in decreases in putrescine, spermidine and spermine contents in the pulp (Figures 3–5), similar to the results of Kramer and Wang (1989) who found that polyamine content relates to chilling injury. It is also thought that polyamines may possess anti-senescence properties (Serrano et al. 1996). The interaction between polyamines and anionic components of the membranes (such as phospholipids) may serve to stabilise the bilayer surface and retard membrane lysis and deterioration.

Although intermittent warming has been shown to be effective in reducing chilling injury of many fruits and vegetables, its mechanism of action is not well understood. Lyon (1973) postulated that warming might allow tissues to rid themselves of toxic substances accumulated during chilling, or allow the tissues to restore materials that were depleted during chilling. Furthermore, Wang (1982) found that intermittent warming increases the fatty acid unsaturation of the polar lipids—the shifting of temperature from cold to warm and then from warm to cold probably induces a rapid readjustment of metabolism that

includes increased synthesis of the unsaturated fatty acids (Figure 6).

## Conclusion

This study demonstrated that intermittent warming has the potential to reduce chilling injury, maintain quality and prolong the shelf life of papaya fruit during cold storage. We found that the main symptoms of chilling injury were pitting, and abnormal ripening and senescence. The use of intermittent warming could reduce chilling injury by maintaining polyamine levels. Moreover, the ability of the fruit to ripen is maintained.

## References

- Artes, F. and Escriche, A.J. 1994. Intermittent warming reduces chilling injury and decay of tomato fruit. *Journal of Food Science*, 59, 1053–1056.
- Cabrera, R.M. and Saltveit, M.E. 1990. Physiological response to chilling temperature of intermittently warmed

- cucumber fruit. *Journal of the American Society for Horticultural Science*, 115, 256–261.
- Chen, N.M. and Paull, R.E. 1986. Development and prevention of chilling injury in papaya fruit. *Journal of the American Society of Horticultural Scientists*, 111, 693–643.
- Cohen, E., Shuali, M. and Shalom, Y. 1983. Effect of intermittent warming on the reduction of chilling injury of Villa Franca lemon fruits stored at cold temperature. *Journal of Horticultural Science*, 58, 593–598.
- Flores, H.E. and Galston, A.W. 1982. Analysis of polyamines in higher plants by high performance liquid chromatography. *Plant Physiology*, 69, 701–706.
- Kramer, G.F. and Wang, C.Y. 1989. Correlation of reduced chilling injury with increased spermine and spermidine levels in zucchini squash. *Physiologia Plantarum*, 76, 470–484.
- Lyon, J.M. 1973. Chilling injury in plants. *Annual Review of Plant Physiology*, 24, 445–466.
- Martinez-Tellez, M.A. and Lafuente, M.T. 1997. Effect of high temperature conditioning on ethylene, phenyl-alanine ammonia-lyase, peroxidase and poly-phenol oxidase activities in Flavedo chilled (Fortune) mandarin fruit. *Plant Physiology*, 150, 674–678.
- Morris, L.L. 1982. Chilling injury of horticultural crops: on overview. *HortScience*, 17, 161–162.
- Saltveit, M.E. and Cabrera, R.M. 1987. Tomato fruit temperature before chilling influences ripening after chilling. *HortScience*, 22, 452–454.
- Serrano, M., Martinez-Madried, M.C., Martinez, G., Riquelme, F., Pretel, M.T. and Romojaro, F. 1996. Review: role of polyamines in chilling injury of fruit and vegetables. *Food Science and Technology International*, 2, 195–199.
- Wang, C.Y. 1982. Physiological and biochemical responses of plants to chilling stress. *HortScience*, 17, 173–186.
- Wang, C.Y. 1993. Approaches to reduce chilling injury of fruits and vegetables. *Horticultural Review*, 15, 63–65.
- Wills, R.B.H., Lee, T.H., Graham, D., McGlosson, W.B. and Hall, F.G. 1981. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*. Sydney, New South Wales University Press, 161p.

# Reducing Bruising in Apple Cartons

C.J. Studman\*

## *Abstract*

Many fruits are packed in cardboard cartons. In some cases paper pulp trays ('Friday' trays) are used for the placement and separation of fruit.

In these studies, two different paper pulp tray designs were compared, by measuring the bruising caused by dropping cartons of apples from a fixed height of 600 mm onto a concrete floor. In addition, a finite element model was developed to describe the strength and deformation behaviour of paper pulp trays.

Deformation of the paper pulp tray is a major energy absorbing process during impact, and so the nature of the tray provides a significant level of bruise reduction during impact. 'Count 88' cartons dissipated 87% of the impact energy by means other than bruising, while 'Count 100' cartons dissipated 97.5% of the impact energy by means other than bruising. Other researchers have shown that in packs without trays, most of the impact energy is absorbed in bruising. In our studies, considerable differences were found in bruising levels as a result of drop impact tests involving Count 88 and Count 100 cartons.

Finite element models have been developed which can be used to simulate a variety of loading situations. These models can be used in the design of improved paper pulp trays for better performance inside and outside the carton.

PAPER PULP trays ('Friday' trays) have been used for the placement and separation of apples for over 50 years (Figure 1). According to New Zealand manufacturers, original patents were taken out in the United States of America (USA) in the mid-1930s, and the trays have been manufactured according to the original designs and specifications ever since. Despite the extensive use of trays within the industry, the specifications for trays in New Zealand are very brief, and the design criteria are not well understood, particularly outside the paper pulp industry. Specifications describe the moisture, weight, colour and dimensions, but give no strength details.

Paper pulp trays perform the following functions:

- positioning of fruit in cartons;
- cushioning of apples during transit;
- part of the presentation of the product to the consumer;
- a means of transferring apples into cartons from automatic tray fillers;
- a means of removing fruit from cartons, particularly at inspection points;

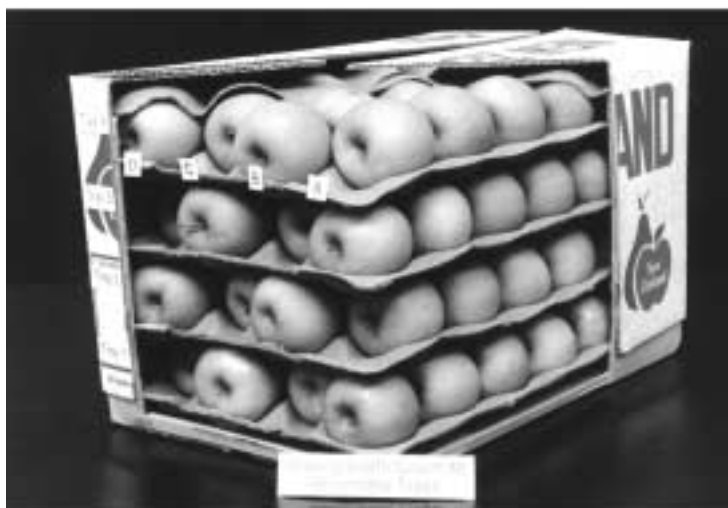
- adds to the mechanical integrity of the carton;
- absorption of water droplets retained on the fruit during grading; and
- contributes to a suitable long-term storage environment for the fruit, particularly during cool storage.

## Experimental Studies

Two main lines of research have been conducted. One study involved an experimental study of the effect of dropping cartons of apples from a fixed height of 600 mm at two moisture contents, representing freshly packed and cool-stored cartons (Heap 1994). The other involved the development of a finite element model (Figure 2) to describe the strength and deformation behaviour of paper pulp trays (Ashdown 1995). Particular attention has been focused on 'Count 88' cartons, following indications of excessive bruising sometimes found on out-turn in this size, in comparison to the five tray 'Count 100' cartons (Figures 3 and 4). Count 88 implies that 88 apples are required to make up a standard carton, weighing  $18.5 \pm 1$  kg.

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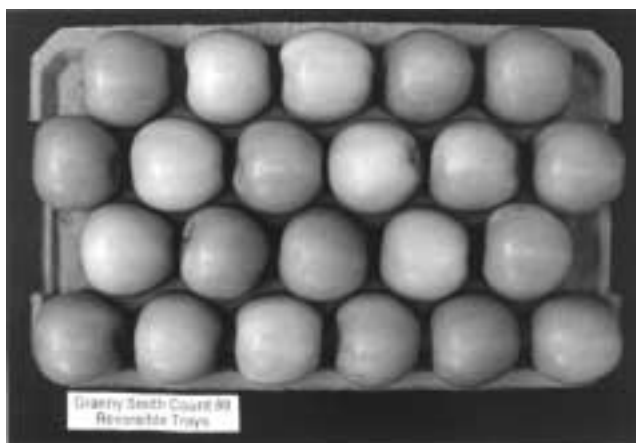
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**Figure 1.** Apple carton (18.5 kg).



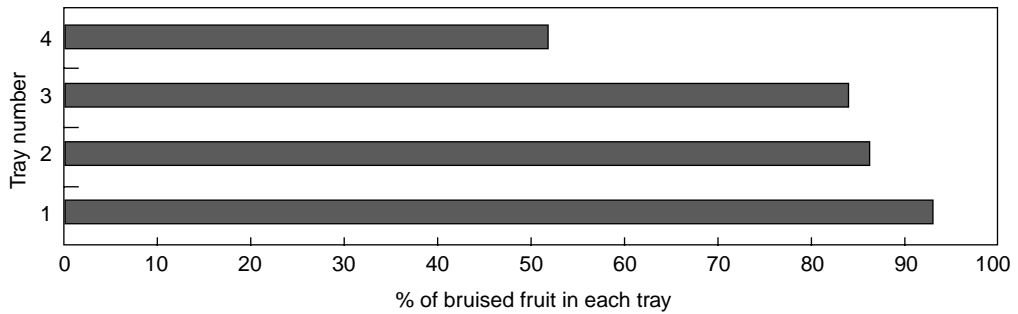
**Figure 2.** Three-dimensional model of a 'Count 88' tray using two-dimensional elements, without apples.



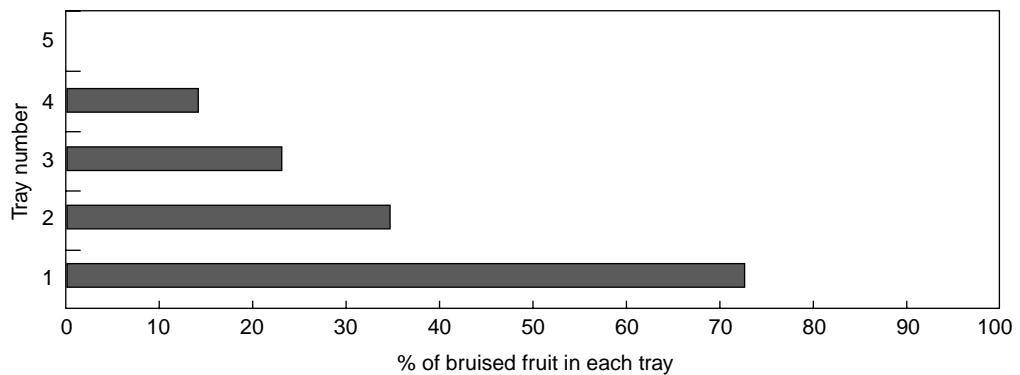
**Figure 3.** 'Count 88' tray (88 apples make one standard carton using 4 trays).



**Figure 4.** 'Count 100' tray (100 apples make one standard carton using 5 trays).



**Figure 5.** Mean percentage of bruised fruit in each 'Count 88' tray at 8% moisture content.



**Figure 6.** Mean percentage of bruised fruit in each 'Count 100' tray at 8% moisture content.



**Figure 7.** Average number of bruises on the top and bottom of fruit in each 'Count 88' tray at 15% moisture content.

The finite element study has now reached the stage where both two and three dimensional models have been run successfully. Loading can be simulated to represent the behaviour of a tray in a carton or it can be examined as a single tray as it is placed into or removed from the carton.

## Results and Conclusions

The main findings of the research are discussed below (see Studman 1994 for further details).

Deformation of the paper pulp tray is a major energy absorbing process during impact, and so the nature of the tray provides a significant level of bruise reduction during impact. In the literature studied, no other material considered by researchers has proved to be superior in reducing bruising. In the present experiments, Count 88 cartons dissipated 87% of the impact energy by means other than bruising, while Count 100 cartons dissipated 97.5% of the impact energy by means other than bruising. In comparison, in packs without trays, most of the impact energy was absorbed in bruising. In fruit packaged in Count 88 cartons, in particular, the cushioning properties of the tray material interposed between the fruit is critical, since the fruit directly abut one another.

Splits in paper pulp trays are caused by impact. On impact, trays are more likely to split if they are dry. Splits do not reduce bruising levels. They are an indication that the carton has been dropped, and that impact energy has been absorbed by the 'Friday' tray.

Considerable differences were found in bruising levels as a result of drop impact tests involving Count 88 and Count 100 cartons (Figures 5 and 6). There was evidence that this was due to a 'hammock' effect in the Count 100 pack where there is more opportunity for

tray deformation in the  $3 \times 2$  configuration than in the  $2 \times 2$  configuration of the Count 88 tray. This arrangement allows a substantial proportion of impact forces to be dissipated at a level below the bruise threshold. The tighter packing arrangement in the  $2 \times 2$  configuration of fruit in the Count 88 carton did not offer the same protection as the looser  $3 \times 2$  packing arrangement under high energy impact situations.

In Count 88 trays, the least bruising occurred in apples positioned at the corners, followed by ends of rows and edge positions. In Count 100 trays, fruit positions with less bruising were evenly distributed throughout the tray. However, the worst apple bruising positions in Count 100 were at the ends of rows or edges in all trays except the bottom layer. Bruising occurred more often on the top of apples than on the bottom in all cases except in the uppermost tray in a carton (Figure 7). Moisture content did not affect the bruising level. In Count 88 trays, bruising was fairly equally distributed between the lower three trays (Figure 5). In Count 100 trays bruising was highest in the bottom tray, and decreased steadily with tray number.

Finite element models have been developed which can be used to simulate a variety of loading situations. These models can be used in the design of improved paper pulp trays for better performance inside and outside the carton.

## Acknowledgements

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also like to thank ENZAFRUIT Ltd for their support for this study.

## References

- Ashdown K.G. 1995. Finite element analysis of apple packaging. Masters thesis, Massey University, New Zealand.
- Heap, R.A. 1994. Performance of recycled paper pulp trays in relation to impact damage in apple cartons. Masters thesis, Massey University, New Zealand.
- Studman, C.J. 1994. Design of pulp paper trays for apple packaging. Report to the New Zealand Apple and Pear Marketing Board.

# Improving the Ergonomics of Apple Grading Tables

C.J. Studman\*

## *Abstract*

The grading table in a packing shed is a key part of the quality chain, as it is the only point at which all fruit are inspected thoroughly. Its design has a major influence on how well the operator is able to perform the task. Key issues are ergonomic design and illumination.

These experiments tested whether the performance and comfort of sorters could be altered by changes to the design of the table. A study was also made of an alternative sorter design, where fruit moved towards the sorter. Finally, experiments evaluated the effect of background colour on sorter perception of defects.

The study showed that the level of comfort of sorters was significantly greater on the conventional table with a barrier placed down the centre to restrict the amount of forward stretch. Studies on the new sorter indicated that this design was even more comfortable for operators. No conclusions were drawn on the effects on performance.

Studies on background colour showed that it had an effect on how fruit defects were perceived by the inspector. In the tests, the most defects were observed against a grey background. Sorters expressed a preference for dark background tables. Overall light levels in the field of view of the sorter could have an effect on comfort, and these should be included in design guidelines.

THE GRADING table in a packing shed is one of the most important components of the quality chain. It is the only point at which all fruit are inspected thoroughly and where the bulk of substandard fruit are removed. It is therefore essential that the table is designed so that sorters can be as effective and accurate in their work as possible.

Despite its importance, there have been virtually no reported in-depth studies aimed at providing data to optimise the design for apple handling systems. Ergonomic studies involving other work tasks have attempted to relate the performance of humans to the physical, sociological and psychological environment. These studies show that, in general, humans are better able to function for longer periods of time when the levels of physical stress are minimised.

In New Zealand, the majority of grading tables are set up so that graders stand to inspect fruit as it moves past them from one side to the other. The lighting source is strip fluorescent tubes normally installed according to guidelines laid down by the export

marketing authority (ENZA FRUIT Ltd), while the grading table itself is usually white in colour.

The purpose of the grading table in New Zealand packing sheds is to remove sub-standard fruit from the product line. This is achieved mainly by human graders (strictly sorters) who inspect fruit visually as it passes in front of them. Sorters identify defective fruit and remove it from the line, placing the reject fruit into an appropriate chute. Sometimes they will roll fruit in order to view the underside of the fruit, even though most grading tables are designed to rotate fruit automatically as it moves past the inspection point. Workers at a grading table are required to make a large number of decisions based on visual observation, and they must also perform physical actions in order to carry out their task. The job is repetitive, and pay rates are not particularly high. The work is also highly seasonal, lasting around four to five months.

There are many sorting criteria: these include most of the criteria associated with quality for fruit and vegetables (Kader 1992; Studman 1994), such as shape, colour, bruising, insect and mite damage or presence, sunburn, rots and cuts, as well as defects which are limited to one or more cultivars, such as stem-end splits in 'Gala' and 'Fuji' apples (Studman 1991;

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Opara 1993; Amos et al. 1994; Studman 1994). Grading standards require that levels of unacceptable defects are kept below specified levels in all packed fruit. The acceptable tolerance levels depend on the defect, and range from absolute zero for major quarantine pests, to a maximum of 2% for a given cosmetic defect. Achieving these levels throughout a 7 or 8-hour working day is a demanding challenge. It is therefore important that graders are provided with the best possible conditions to enable them to conduct their job, and it is good that, in general, the industry is well aware of this fact. However, this means that the table must be designed using all the best known information about human performance, and working conditions should also be optimised. This requires a thorough appreciation of the ergonomic design of grading equipment.

## Review of Literature on Grading Table Design

The design of the grading table has a major influence on how well the operator is able to perform the task. In principle, the fruit must be presented in such a way that the inspector can see the entire surface of the fruit clearly, while it is still within range for removal should a defect be spotted. In a study on marked spheres, Meyers et al. (1990) showed that only 89% of the surface area of a sphere rotating on a conveyor was visible theoretically when viewed from one side.

The table should be at a suitable height so that the sorter can reach fruit comfortably and deposit rejects in the appropriate chute. Relatively few on-line studies of the maximum desirable reach have been conducted to define the optimum size and arrangement of a table, but some researchers have suggested values. These range from 0.4 – 0.5 m (DeGarmo and Woods 1953; Malcolm and DeGarmo 1953; Hunter and Yaeger 1970) for various crops (though none of these studies involved research on apples or stone fruit). Ergonomic theory can suggest maximum reach values based on anthropometric data (Pheasant 1988; Slappendel and Wilson 1992).

The basic economic argument for ergonomic design is that performance of sorters or operators will be improved if the environment and working position is designed to minimise discomfort and strain. In addition, recent public health and safety legislation, and changes to the Accident Compensation Committee's role in New Zealand, has greatly increased the onus on employers to ensure that the work envi-

ronment is safe, and not dangerous to the health and wellbeing of the employee.

As a person leans forward, the loadings on the hip and back extensor muscles increase. Following Pheasant (1988), this is one example of what may be termed postural stress. If postural stress is prolonged, humans experience postural strain. Muscle tissue responds badly to prolonged static mechanical loading. The blood flow to the muscle is affected, and this upsets the chemical balance, with an accumulation of metabolic waste products. This is experienced as muscle fatigue, resulting in operator discomfort. As a result, operators will desire to move about, and to change posture. For example, fidgeting is a subconscious mechanism to relieve muscular strain. Excessive poor posture may result in a large range of painful muscular afflictions, including back, wrist, forearm, shoulder, and neck injuries. Many case studies have been conducted to demonstrate that reduction of prolonged static muscular loading will reduce the incidence of musculoskeletal disease (e.g. Westgaard and Aarus 1980; Kukkonen et al. 1983; Grandjean et al. 1984; Pheasant 1988).

Where a maximum postural effort was used, Corlett and Manenica (1980) showed that the 80% recovery time was about 12 times the period for which the posture was held, and full recovery was considerably longer, so that normal rest periods were insufficient for recovery under these circumstances.

## Sustainable Work Zones

A sustainable work zone (SWZ) based on static anthropometric dimensions for a repetitive upper limb task requiring mild physical effort, is one in which a person is at a comfortable height and distance in relation to their work area, allowing sufficient space for bilateral shoulder/elbow/hand movement in all planes (sagittal, coronal, and horizontal) about the arc of the shoulder joints. This zone is framed by boundaries describing the maximum effective gripping reach of each arm in all planes, without resorting to excessive bending or reaching by using the trunk and spine. Grandjean (1981) recommended between 50 and 100 mm below elbow level as the most suitable working height for delicate and light manipulative tasks, and 150 to 400 mm below elbow level for heavy work. The height of the work surface will be less than this, to allow for the object being handled (Pheasant 1988). Thus, for fruit grading the elbow height should be between 100 and 150 mm above the work surface.

## Lighting and Human Visual Perception

The subject of illumination involves not only the level of lighting but the quality or wavelength distribution of the illuminating source. Sunlight, incandescent bulbs and fluorescent tubes all have very different colour spectrums. Light intensity is normally measured in lux, while light sources are rated by their colour rendering index (Nicholas 1985; Brown et al. 1993). Light levels and quality data must also be combined with information about the sensitivity of the human eye. This depends on the wavelength, with a maximum in the centre of the visual spectrum. The subject was discussed by Brown et al. (1993).

Other key factors include glare, which is caused by an excessively bright source in the field of view and which can affect the ability of the sorter to view the object. Glare may be direct or reflected from shiny surfaces.

Factors which reduce the ability of sorters to see defects are: the inability to concentrate for long periods of time; colour blindness; and other visual defects. Blackwell (1959) and Marsden (1964) showed that the smallest detectable object size decreased as the illumination increased, and that the detectable contrast between the object and the background brightness also fell as the illumination increased, although above 1,100 lux there were only very slight improvements as illumination increased ten-fold. Faulkner and Murphy (1973) demonstrated that overall intensity of illumination is not necessarily the best criterion for a given inspection task. They argued that in some cases this could be detrimental, and that directional lighting can be preferable. They argued that the ideal lighting system will depend upon the specific task being undertaken. Cushman and Crist (1987) discussed the ratio of background to task luminance. As a result of research conducted in the 1920s and 1930s, it has generally been held that the task to surroundings luminance ratio should not exceed 3:1, or be less than 1:3 if the task is darker than the background (Lythgoe 1932; cited in Cushman and Crist 1987). However Cushman and Crist have criticised this research, and Cushman et al. (1984) found that luminance ratios of 110:1 did not adversely affect visual comfort (i.e. the task was illuminated strongly with a dark background). The studies of Brown et al. (1993) tended to confirm these findings.

These studies suggest that for darker objects, sorting efficiency should improve if the light on the target is as high as possible, providing the sorter is not caused discomfort. Since discomfort arises from total light entering the eye, the light on the target can be maximised if the light reflected from the background is minimised. However, experimental validation of this argument is limited, and the hypothesis should be investigated further.

New Zealand lighting specifications for apple grading are based on a review conducted by Nicholas (1985). He recommended that the illumination should be at least 1,000 lux, with a colour rendering index of 90–100, and a colour temperature of over 4,000 K. Tubes should be mounted across the table, and be about the same length as the width of the table.

Although Nicholas (1985) mentioned concern about glare, he offered no suggestions about ideal table background colour, other than to suggest that a green table would affect the ability of the sorters to assess ripeness. The New Zealand Apple and Pear Marketing Board recommendations do not specify a colour, although it allows white or neutral colours for grading tables. Fletcher (1978) recommended the use of a dark background colour for apple sorting.

## Experimental Studies

The data presented below are a summary of a series of experiments, conducted in a New Zealand packing shed. In particular, these experiments considered the effects of the background colour of the table, and the size of the working area of the sorter. Full details are presented elsewhere (Studman 1998).

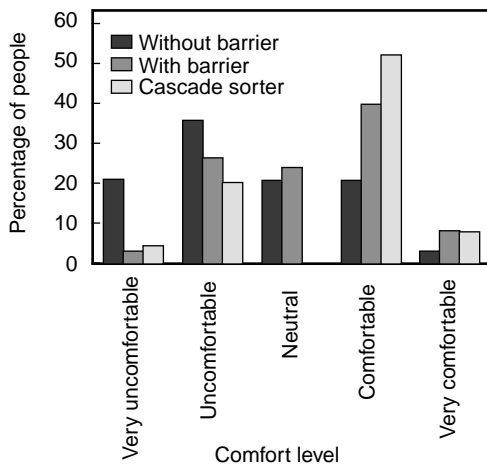
Sorters were observed and movements were recorded over short periods to establish whether their actions were consistent with ergonomic principles. Secondly, a series of trials was conducted to test whether the performance of sorters could be altered significantly by changes to the design of the table. Thirdly, at the end of the shift, sorters were questioned about their level of comfort and their views were requested on the work. Fourthly, an observational study was made on a new 'cascade' sorter which was used at the shed during the latter part of the season. Finally, in-shed and laboratory experiments designed to evaluate the effect of background colour on sorter perception of defects were conducted.



**Figure 1.** Apple sorting table with no barrier.



**Figure 2.** Apple sorting table with barrier.



**Figure 3.** Reported comfort levels of operators using three different styles of apple sorting table.

## Results and Conclusions

The surveys of sorter opinion showed a preference for darker coloured tables, reduced reaching distances, and the opportunity to sit rather than stand. The study showed that sorters working on conventional tables with 900 mm rollers and a reject conveyor immediately between them and the rollers (Figure 1) spent a considerable part of their time stretching to reach fruit outside their sustained work zone. This implied that they would experience greater fatigue and there would be an increased risk of neck and shoulder pain. In end-of-shift surveys, sorters indicated a concern about the amount of stretching required in the work, and often attributed discomfort to these actions. Sorters with shorter reaches tended to report more discomfort at the end of a shift than those with long reaches.

The study showed that the level of comfort of sorters was significantly greater on the conventional table with a barrier placed down the centre to restrict the amount of forward stretch (Figures 2 and 3). Studies on a new ‘cascade’ grader, where fruit move toward the sorter, indicated that this design was even more comfortable for operators (Figure 3).

Sorters in the shed were mostly working at too low a height relative to the table, but they were generally reluctant to change height at the start of the season, as the new position seemed unfamiliar. However, by the end of the season, roughly half the sorters had opted to use standing boards provided by the research team to raise them into an ergonomically better working position.

The literature survey raised concerns about the current Board guidelines on optimum lighting for grading tables. Studies on background colour showed that it had an effect on how fruit defects were perceived by the inspector (e.g. Table 1). Experiments were conducted to determine the number of defects a sorter could find when apples were viewed against different coloured backgrounds. 76 fruit were examined four times. These were mixed with other fruit (changed after each inspection) to prevent the sorter from recognising individual fruit or the level of defects present in the sample. Sorters expressed a preference for dark background tables. It was concluded that the overall light levels in the field of view of the sorter had a significant effect on comfort, and these should be included in design guidelines. A low reflectance background would enable higher light levels to be used, resulting in better lighting levels on the fruit being examined.

Differences in detection rate for various defects were recorded, depending on the colour of the background, and there was a trend for higher colour values to be given on fruit viewed against a dark background. However the differences were not statistically conclusive.

**Table 1.** Percentage (%) of defects identified by apple sorters using different coloured background colours.

Defect type	White	Blue	Grey	Black
Spoilt	40	70	50	70
Sunburn	55	100	91	64
Blemish	71	52	71	48
Bruise	67	50	83	58
Low colour area	56	39	94	39
Average	57.5	62.1	77.9	55.8

## Conclusions

Apart from the spoilt fruit category, the inspector observed the most defects against a grey background (Table 1). This may represent a good compromise between good overall illumination and excessive glare. It was therefore proved that background colour affects the grading of fruit.

## Acknowledgments

The author wishes to thank the staff and management of Grocorp Pacific Ltd (Waipawa) for their cooperation in enabling this study to be conducted. Particular thanks are due to Mr Les Boyd for his dedicated hard work throughout the study. I would also like to thank ENZAFRUIT Ltd for their support for this study.

## References

- Amos, N.D., Ponter, B., Studman, C.J. and Wall, G.L. 1994. Techniques to assist with meeting international standards for the export of fresh produce. In: Proceedings of the XII CIGR (International Commission of Agricultural Engineering) World Congress, Milan, Italy, volume 2, 1587–1594.
- Blackwell, H.R. 1959. Specification of interior illumination levels. *Illuminating Engineering*, June, 317–353.
- Brown, G.K., Marshall, D. and Timm, E.D. 1993. Lighting for fruit and vegetable sorting. In: Proceedings of the 4<sup>th</sup> International Symposium on Fruit, Nut and Vegetable Production Engineering, Valencia, March 1993.
- Corlett, E.M. and Manenica, I. 1980. The effects and measurement of working postures. *Applied Ergonomics*, 11, 7–16.
- Cushman W.H., and Crist, B. 1987. Illumination. In: Salvendy, G., ed., *Handbook of human factors*. New York, Wiley.
- Cushman, W.H., Dunn, J.E. and Peters, K.A. 1984. Workplace luminance ratios: do they affect subjective fatigue and performance? In: Proceedings of the Human Factors Society 28<sup>th</sup> Annual Meeting. Santa Monica, California, Human Factors Society, p991.
- DeGarmo, E.P., and Woods, B.M. 1953. *Introduction to engineering economy*. New York, Macmillan.
- Faulkner, T.W. and Murphy, T.J. 1973. Lighting for difficult visual tasks. *Human Factors*, 15, 149–162.
- Fletcher, T.O.T. 1978. Top fruit grading and blemish detection in artificial light. Ministry of Agriculture, Fisheries and Food (MAFF), Agricultural Development Advisory Service (ADAS), Maidstone and Worcester Divisional Offices, England.
- Grandjean, E. 1981. *Fitting the task to the man: an ergonomic approach*, 2<sup>nd</sup> edition. London, Taylor and Francis.
- Grandjean, E., Hunting, W. and Nishiyama, K. 1984. Preferred VDT workstation settings, body posture, and physical impairments. *Applied Ergonomics*, 15, 99–104.
- Hunter, J.H. and Yaeger, E.C. 1970. Use of a float roll table in potato grading operations. *Maine Agricultural Experimental Station Bulletin No. 690*. Maine, Orono.
- Kader, A.A. 1992. *Postharvest manual*. California, University of Davis.
- Kukkonen, R., Luopajarvi, T. and Riihimaki, V. 1983. Prevention of fatigue amongst data entry operators. In: Kvalseth, T.O., ed., *Ergonomics in workstation design*. London, Butterworths.
- Malcolm, D.G. and DeGarmo, E.D. 1953. Visual inspection of products for surface characteristics in grading operations. United States Department of Agriculture (USDA) Marketing Research Report No. 45. Washington, DC, US Government Printing Office.
- Marsden, A.M. 1964. Visibility and illumination levels. *Light and Lighting*, August, 234–239.
- Meyers, J.B., Prussia, S.E., Thai, C.N., Sadosky, T.L. and Campbell, D.J. 1990. Visual inspection of agricultural products moving along sorting conveyors. *Transactions of the American Society for Agricultural Engineers (ASAE)*, 33, 367–372.
- Nicholas, J.V. 1985. *Colour and light for the inspection table*. Sirtec Publication No. 1. Wellington, Department of Scientific and Industrial Research.
- Opapa, U.L. 1993. *A study of stem-end splitting in apples*. PhD thesis, Massey University, New Zealand.
- Pheasant, S.T. 1988. *Bodyspace: anthropometry, ergonomics and design*. London, Taylor and Francis.
- Slappendel, C. and Wilson, B. 1992. Anthropometric estimates for New Zealand adults. *Ergonomics New Zealand*, 7(3), 5–7.
- Studman, C.J. 1991. *Detection of stem-end splits in red and striped fruit*. Final project report, New Zealand Apple and Pear Marketing Board.
- Studman, C.J. 1994. Quality in fresh fruit—meaning, measurement and maintenance. In: Proceedings of AGENG'94, Milan, Italy, p897.
- Studman, C.J. 1998. Ergonomics in apple sorting: a pilot study. *Journal of Agricultural Engineering Research*, 70, 323–334.
- Westgaard, R.H. and Aarås, A. 1980. Static muscle load and illness among workers during electromechanical assembly work. Oslo, Institute of Work Physiology.

# Investigation and Biological Control of Postharvest Diseases of Muskmelon

Wang Wei\*, Tang Wenhua\*, Huang Yong† and Li Yazhen§

## Abstract

An investigation was made of the postharvest diseases of muskmelon produced from fields across four provinces and cities of China. The pathogenic microorganisms responsible for the decay were isolated by cutting tissues from the leading edge of lesions. These were then incubated on potato dextrose agar (PDA) medium. Koch's postulates were followed to confirm the organisms as the causal agents. Some 324 isolates of fungi were obtained of which 161 were pathogenic. The pathogenic isolates were identified using standard, international taxonomic keys. It was shown that the major postharvest pathogens of muskmelon in China include *Trichothecium roseum* and various species in the genera *Fusarium*, *Alternaria*, *Rhizopus* and *Ascochyta*. The species were *F. chlamyosporum*, *F. equiseti*, *F. semitectum*, *F. culmorum*, *F. sambucinum*, *F. oxysporum* Schl. f.sp. *cucumerinum* Owen, *F. moniliforme* var. *subglutinas* Wr & Peink., *A. alternata*, *A. pluriseplate*, *R. stolonifer* (Ehrenb. Ex Fr.) Vuillemin, and *R. arrhizus* Fisher in Rabenh. The random amplified polymorphic DNA (RAPD) technique was used to identify intra-species genetic variations in the genus *Ascochyta*. The results showed that the isolates of *Ascochyta* cluster into three groups.

In the field, the induced systematic resistance agent benzothiadiazole (BTH) was applied to melon crops before flowering, reducing the latent infection by pathogens. After harvest, the melons were treated with the biological control agents B908, Px, and T4. These were effective in reducing the incidence of disease and in extending the shelf life of muskmelon for 2–3 weeks.

THE CHINESE MELON industry produces more than 6 million tonnes of muskmelons every year. About 70% of the crop needs to be transported more than 1,500 km from the production areas to markets. Muskmelon is produced mainly in the north-western provinces of Inner Mongolia, Gansu and Xinjiang, with melons then transported to markets along the east coast, such as in Beijing, Shanghai and Guangzhou. Postharvest melon losses in China during transport and storage are estimated to be 35–50% (Tang et al. 1998). This is primarily due to poor postharvest handling systems and disease control.

Some 20 diseases have been found infecting melon after harvest (Snowdon 1990). The main diseases reported in melon are *Fusarium*, *Rhizopus* and *Alternaria* rots. In China, there are few reports about the postharvest diseases of melon.

Systemic induced resistance (SIR) is attracting much attention for minimisation of plant diseases, and has been demonstrated in several plant families. Biotic inducers of systemic resistance in the cucurbit family include locally infecting fungal pathogens. Synthetic activators such as dichloroisonicotinic acid and benzothiadiazole (BTH) have been reported to stimulate SIR in cucurbits and other crop species.

Biological control of postharvest fruit diseases has been extensively studied. Bacterial antagonists such as *Pseudomonas* sp. and *Bacillus* sp. have yielded very good control of postharvest citrus diseases (Huang et al. 1991, 1992, 1993), but there are few reports relating to melons.

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## Methods and Materials

### Isolation and investigation

#### *Collection of diseased melons*

'Hami' and 'Huanghe Honey' melons: Melons were transported to Beijing by air and train from Xinjiang and Gansu Provinces. They were held in a coolroom at 5–8°C.

'Elizabethan' melon: The melons were grown in protected fields in Beijing, Hebei, Inner Mongolia and Shandong Provinces. Diseased melons were collected in the field and at the Beijing markets.

#### *Isolation of the pathogens*

Blocks of tissue of 0.2 cm<sup>3</sup> were cut from overlapping parts of diseased and healthy tissues of the melons. The samples were disinfected with 5% NaClO for 3 min, washed 3–5 times with sterilised water, then transferred to potato dextrose agar (PDA) medium. Incubation was for 5 days at 25°C. Microorganisms were then isolated.

#### *Pathogenicity test*

Melons of similar size and condition were surface-sterilised with 75% alcohol. Holes 6 mm in diameter and 2 mm deep were made in the skin. The isolates from the PDA medium were placed into the holes, the holes sealed with rubberised tape, and the melons held at 25°C for 48 hours. Observations were made after 5 days.

The isolates that produced areas of rot of greater than 15 mm diameter were considered to be pathogens.

#### *Identification of the pathogens*

The pathogens were grown on PDA medium at 25°C for one week. The genera were identified on the basis of growth and morphological characteristics.

*Identification of Fusarium species.* The pathogenic *Fusarium* isolates were cultured on PDA medium at 25°C and 30°C for 3 days. The size and morphology of the colony were then recorded. Also, the *Fusarium* were grown on PDA and CLA at 25°C and, after 10 days, the conidia, conidiophores and chlamydo spores were observed under the microscope.

*Identification of Ascochyta species.* The random amplified polymorphic DNA (RAPD) technique was used to detect genetic variation in the genus *Ascochyta*. Total *Ascochyta* and *Didymella* DNA extraction was made by CTAB, and the DNA obtained dissolved in TE buffer (10 M Tris HCl, pH 7.4, 1 mM EDTA) and stored at 4°C.

Five kits made by Operon Technologies, including 100 primers, were used. They were OPG, OPL, OPS, OPH, and OPJ.

Amplification reactions were performed in a total volume of 25 µL, containing 10 mM Tris HCl (pH 8.3), 50 mM KCl, 1.5 mM MgCl<sub>2</sub>, 0.001% gelatin, 50 mM each of dATP, dCTP, dGTP, dTTP, 15 pmol of primer, 25 ng of genomic DNA, and 1 µL Taq polymerase (Promega). Negative controls, in which the DNA template solution was replaced by water, were performed in all experiments to check contamination. The amplification was performed with a polymerase chain reaction (PCR) Sprint Temperature Cycling System (Hybaid Limited, United Kingdom) programmed as follows: 1 cycle for 3 min at 94°C, 1 min at 36°C, and 2 min at 72°C, followed by 40 cycles of 1 min at 94°C, 1 min at 36°C, and 2 min at 72°C, and extended to 10 min at 72°C. The amplification products were separated by electrophoresis in 1.4% agarose gels with ethidium bromide and photographed under ultraviolet lights. Amplification reactions were conducted with each primer on the DNA of the 8 *Ascochyta* isolates and one *Didymella bryoniae* at least twice and in two separate experiments.

The polymorphic bands amplified by 12 primers to *Ascochyta* isolates and *Didymella bryoniae* were used for cluster analysis by 'Ntsys'.

*Identification of Rhizopus species.* The *Rhizopus* isolates were held on PDA medium at 25°C for one week. The morphology of the colony was then recorded and microscopic observations made of the rhizoids, sporangiophores and zygospores. *Rhizopus* was grown at different temperatures to determine its maximal growth temperature.

The important characters used in the identification of *Rhizopus* species are:

- shapes of the rhizoids;
- length of sporangiophores;
- diameter of sporangia;
- colour and diameter of zygospores;
- growth habit of suspensors; and
- upper limit of temperature for continued growth.

*Identification of Alternaria species.* The *Alternaria* isolates were grown on PDA medium at 25°C for one week, the colony morphology described and the morphology of their large conidia observed under the microscope. The primary factor used in the identification of *Alternaria* species is the morphology of their large conidia. They are catenate (formed in chains) or solitary, typically ovoid or obclavate, often rostrate (beaked), pale brown to brown, and multi-celled, with transverse and frequently also oblique or longitudinal

septa. The character of the beak, the length of conidiophores, and the number of transverse septa are most important. The dimensions of the spore body, including the beak, are considered to be an important characteristic of a given species.

*Identification of Trichothecium species.* *Trichothecium* isolates were grown on PDA medium at 25°C for one week, then identified by colony morphology and microscopic observation of the conidia.

## Biocontrol of postharvest diseases on ‘Hualaishi’ melons in China

‘Hualaishi’ melons were grown in a glasshouse and fields in Inner Mongolia Province. Each site was arranged in three blocks. Crops in one block were sprayed with water as the control, and in other two blocks were sprayed once at flowering with 50 mg/L benzo(1,2,3) thiadiazole-7-carbothioic acid S-methyl ester (BTH, CGA 245704) formulated as 50% a.i. BTH. One of the blocks sprayed with BTH at flowering was again sprayed with BTH at 50 mg/L 3 weeks later. Melons were harvested 6 weeks after flowering and stored at room temperature (23–28°C). Eighty melons from each of the two field regimes were dipped in three solutions of biological control agents (*Bacillus* sp. B908, *Trichoderma* spp. T4, or *Pseudomonas* sp. Px), three chemical fungicides (Tocdu, Fongafon or Octae), or water for 3 minutes. The melons were stored at room temperature for 30 days. The melons were checked every week for disease and those in which symptoms of diseases were evident were discarded. The rate of commodity is the percentage of good melons and total melons.

## Results

### Pathogenicity testing

The isolates were inoculated on the melons. Some 324 isolates of fungi were obtained, 161 of which were considered to be pathogenic.

### Identification of the pathogens

Based on growth and morphological characteristics, the pathogens were identified as belonging to the following genera: *Ascochyta*, *Fusarium*, *Alternaria*, *Rhizopus* and *Trichothecium*.

### Identification of *Fusarium* species

Seven species of pathogenic *Fusarium* isolates were identified: *F. clamydosporum*, *F. equiseti*, *F. semitectum*, *F. oxysporum* Schl. f.sp. *cucumerinum* Owen, *F. sambucinum*, *F. culmorum* and *F. moniliforme* var. *subglutinans*. *F. clamydosporum* and *F. sambucinum* are new records for melon.

### Identification of *Ascochyta* species

One hundred primers were used to amplify isolates for DNA priming. 20 primers had polymorphic bands. 12 primers had good polymorphic bands for 8 *Ascochyta* isolates and a single *Didymella* strain (Table 1).

The combined data from all strains were analysed by ‘Ntsys’ to produce a dendrogram (Figure 1). It divided the strains into three major groups. Group 1 contained isolates MF8, MF31, MF24, AS1 and D1. They came from Beijing and Inner Mongolia. Group 2 contained isolates MF5, MF28 and GMF2. They came from Xinjiang, Gansu and Beijing. Group 3 only contained one isolate, MF32. It came from Inner Mongolia. Groups 1 and 2 were very similar.

### Identification of *Rhizopus* species

Two species of *Rhizopus* were identified: *R. stolonifer* (Ehrenb. Ex Fr.) Vuillemin, and *R. arrhizus* Fisher in Rabenh.

### Identification of *Alternaria* species

Two *Alternaria* species were identified: *A. alternata* and *A. pluriseplate*.

### Identification of *Trichothecium* species

Only one *Trichothecium* species was identified: *T. roseum*.

## Biological control of postharvest diseases on ‘Hualaishi’ melon

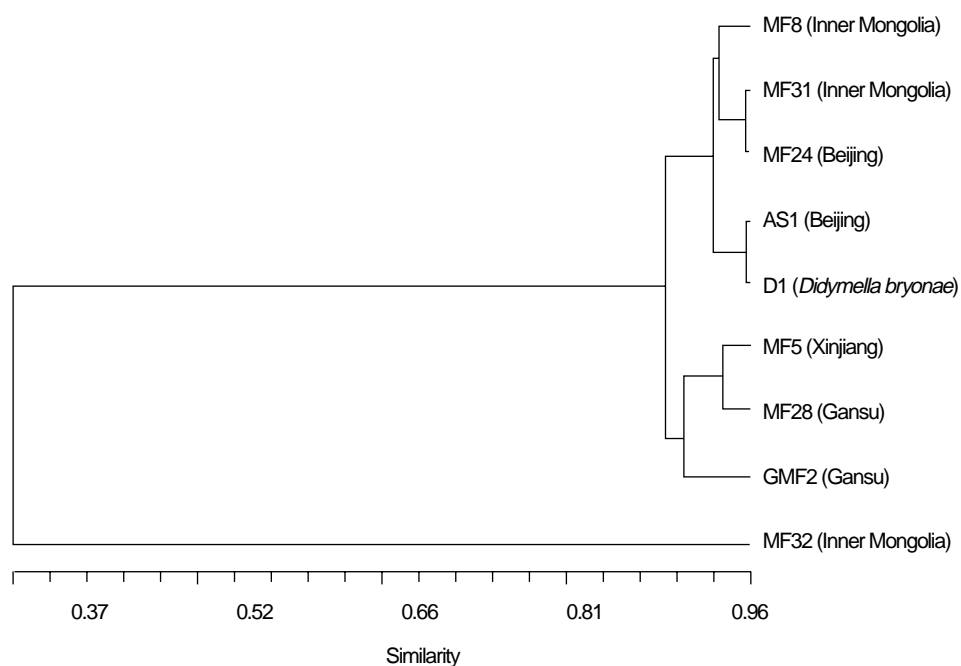
### Greenhouse grown melons

Application of BTH to ‘Hualaishi’ melon foliage before flowering and biological control agents after harvest yielded good disease control (Table 2). There was a significant increase in the rate of commodity. T4 gave the best control for up to three weeks storage. Thereafter, B908 gave better control.

### Field grown melons

The results of field application were similar to those from the greenhouse study. B908 gave a significant control effect for all storage intervals. Px also gave good disease control (Table 3).





**Figure 1.** Dendrogram showing relationships among the eight *Ascochyta* isolates and one strain of *Didymella*.

**Table 1.** The results of random amplified polymorphic DNA (RAPD) analysis of the *Ascochyta* isolates.

Code	Sequence 5'-----3'	Amplified fragment	Polymorphic fragment
OPH-04	GGAAGTCGCC	8	7
OPH-12	ACGCGCATGT	11	7
OPL-19	GAGTGGTGAC	11	10
OPS-16	AGGGGGTTCC	11	10
OPL-09	TGCGAGAGTC	8	7
OPS-11	AGTCGGGTGG	16	12
OPL-12	GGGCGGTACT	12	10
OPS-19	GAGTCAGCAG	10	9
OPL-10	TGGGAGATGG	13	11
OPL-11	ACGATGAGCC	8	7
OPG-10	AGGGCCGTCT	9	8
OPL-07	AGGCGGGAAC	10	9
Total		126	107
Percentage polymorphism		85.4	

**Table 2.** Effect of benzothiadiazole (BTH) and biological control agents on reduction of postharvest diseases in greenhouse-grown ‘Hualaishi’ melons (Dengkou, Inner Mongolia, 1999), where R = rate of commodity (%) and E = effect of control (%).

Treatment <sup>a</sup>	One week		Two weeks		Three weeks		Four weeks	
	R <sup>b</sup>	E <sup>c</sup>	R	E	R	E	R	E
CK	97.43	–	64.10	–	28.76	–	12.82	–
C3	100.0	100.0	84.61	57.13	64.10	49.47	38.46	29.41
C6	95.24	–	73.80	27.02	57.14	39.84	23.81	12.61
BC	100.0	100.0	64.28	0.50	50.00	29.82	28.56	18.05
B1	100.0	100.0	79.92	44.07	61.53	46.0	30.77	20.59
B2	100.0	100.0	75.00	30.36	41.66	18.11	16.67	4.42
B3	100.0	100.0	69.23	14.29	41.03	17.22	25.38	14.41
B4	97.85	16.34	74.28	28.36	55.71	37.83	37.14	27.90
B5	97.85	16.34	78.57	40.31	42.85	19.78	28.57	18.07
B6	100.0	100.0	80.00	44.29	60.00	43.85	26.00	15.12

<sup>a</sup> CK = water at flowering and after harvest; C3 = water at flowering and Tocdu after harvest; C6 = water at flowering and after harvest; B1 = BTH at flowering and Fungaflon after harvest; B2 = BTH at flowering and Octae after harvest; B3 = BTH at flowering and Tocdu after harvest; B4 = BTH at flowering and B908 (*Bacillus* sp.) after harvest; B5 = BTH at flowering and Px (*Pseudomonas* sp.) after harvest; B6 = BTH at flowering and T4 (*Trichoderma* sp.) after harvest.

<sup>b</sup> R = Percentage undamaged commodity.

<sup>c</sup> E = Percentage of control commodity undamaged.

**Table 3.** Effect of benzothiadiazole (BTH) and biological control agents on reduction of postharvest diseases in ‘Hualaishi’ melons grown in the field (Dengkou, Inner Mongolia, 1999), where R = rate of commodity (%) and E = effect of control (%).

Treatment <sup>a</sup>	One week		Two weeks		Three weeks		Four weeks	
	R <sup>b</sup>	E <sup>c</sup>	R	E	R	E	R	E
CK	71.88	–	62.50	–	50.13	–	30.33	–
C3	90.62	66.64	80.62	48.32	70.13	40.10	51.88	30.93
C6	87.88	56.90	84.84	59.57	72.13	44.11	46.34	22.98
BC	78.11	22.16	69.84	19.57	68.92	37.68	46.00	22.49
B1	92.31	72.65	84.62	58.99	84.63	69.18	69.23	55.94
B2	100	100	93.33	82.21	83.33	66.57	61.54	44.80
B3	78.57	23.80	78.57	42.85	77.14	54.16	46.67	23.45
B4	78.57	23.80	76.29	36.77	75.40	50.67	58.06	39.80
B5	87.50	55.55	75.00	33.33	74.12	48.11	56.25	37.21
B6	78.33	22.94	70.00	20.0	69.00	37.84	51.12	29.84

<sup>a</sup> CK = water at flowering and after harvest; C3 = water at flowering and Tocdu after harvest; C6 = water at flowering and after harvest; B1 = BTH at flowering and Fungaflon after harvest; B2 = BTH at flowering and Octae after harvest; B3 = BTH at flowering and Tocdu after harvest; B4 = BTH at flowering and B908 (*Bacillus* sp.) after harvest; B5 = BTH at flowering and Px (*Pseudomonas* sp.) after harvest; B6 = BTH at flowering and T4 (*Trichoderma* sp.) after harvest.

<sup>b</sup> R = Percentage undamaged commodity.

<sup>c</sup> E = Percentage of control commodity undamaged.

## Discussion and Conclusion

Postharvest diseases in melon production are very serious in China. We found that postharvest diseases in melon include *Fusarium*, *Alternaria*, *Rhizopus*, *Trichothecium* and *Ascochyta* rots. The kinds of diseases present varied between different areas of production. *Fusarium* and *Rhizopus* rots had the highest incidence in all areas. *Trichothecium* rot was more prevalent under greenhouse than field conditions. The occurrence of *F. clamydosporum* and *F. sambucinum* were new reports for melon.

In our experiment, the random amplified polymorphic DNA (RAPD) technique was used to determine the intra-specific or interspecific relationships, and to assess genetic diversity among eight isolates of *Ascochyta* from different origins. The results showed that this method yielded DNA fingerprints useful for species' characterisation. We were able to differentiate the isolates into three main groups directly related to their geographic origin. Groups 1 and 2 were very similar, and closely related to *Didymella bryonae*. They may be one species. Group 3, however, might represent another species.

BTH and biological control agents were more effective when used together for control of postharvest

disease in melon. *Bacillus* sp. B908 and *Trichoderma* spp. T4 were most efficacious against *Rhizopus* rot, and *Pseudomonas* sp. Px against *Alternaria* rot. All the biological control agents showed similar effects to the chemical fungicides.

## References

- Huang, Y., Deverall, B.J. and Morris, S.C. 1991. Promotion of *Penicillium digitatum* infection of orange fruit by a strain of *Pseudomonas capacia*. *Phytopathology*, 81, 615–618.
- 1992. Postharvest biological control of *Penicillium digitatum* decay on citrus fruit by *Bacillus pumilus*. *Annals of Applied Biology*, 120, 367–372.
- 1993. Effect of *Pseudomonas capacia* on postharvest biocontrol of infection by *Penicillium digitatum* and on wound responses of citrus fruit. *Australasian Plant Pathology*, 22, 84–93.
- Snowdon, A.L. 1990. A colour atlas of postharvest diseases and disorders of fruits and vegetables. Volume 1. General introduction and fruits. London, Wolfe Scientific, 302p.
- Tang Wenhua, Chen, C., Wang, W. and Huang, Y. 1998. Investigation and biological control of postharvest diseases on melon. *Chinese Journal of Microecology*, 10, 65–67.

# Biotechnology for Improvement of ‘Mas’ (*Musa AA*) Bananas

H. Nair, S. Chandran, N. Khalid, S.N. Mohd Aris and I.D. Wilson\*

## Abstract

Bananas and plantains (*Musa* spp.) economically rank fourth in the world as a food source and form a staple diet for more than 400 million people. Commercially, more than 95% of the banana fruit sold worldwide are of one variety, ‘Cavendish’ (AAA). However, this variety is becoming increasingly susceptible to devastating diseases and there is an urgent need to look for new banana clones. Two major areas for banana improvement have been targeted by biotechnology companies, namely pathogen resistance and increased quality and/or processing value in the fruit. Development of molecular techniques, especially the ability to introduce novel genes through genetic transformation, has allowed research to focus in these areas. In the current climate of public wariness of genetically engineered foods, increasing the intrinsic value of bananas also favours their use as a ‘bio-factory’ for the production of tertiary products that are not necessarily directly eaten.

We have isolated a gene from a local diploid banana (‘Mas’, AA group) that encompasses many of the above considerations. This gene encodes a fruit-specific 31 kDa class III acidic chitinase, the most abundant protein in developing banana fruit. Chitinases have been widely implicated in resistance to fungal diseases. Thus, ectopic over-production of this protein may confer wider resistance of bananas to fungi. The protein also possesses highly conserved signature sequences for a cGMP-binding-protein associated N-terminal transit or signal peptide and an inner membrane attachment site. Such signature sequences are useful in directing different proteins to specific compartments within the cell in order to specifically alter their biochemistry or to redirect synthesis towards desired tertiary products. In depth knowledge of its *in vivo* function and regulation could show whether the system might be put to use to artificially introduce proteins to specific parts of banana fruit cells.

BANANAS AND plantains (*Musa* spp.) economically rank fourth in the world as a food source and form a staple diet for more than 400 million people. Thus, there is significant scope for Southeast Asia to develop a lucrative and exportable banana market based on improved varieties and processed food products. Previously, direct improvement of this crop has been seriously hindered by the inability to breed via classical methods; commercial bananas are sterile and are normally propagated from suckers or by tissue culture. However, in recent years the development of molecular-genetic biotechnology techniques, especially the ability to introduce novel genes through genetic transformation, has allowed research to focus

on improving the qualitative traits of this species. Two major areas for improvement have been targeted by biotechnology companies, namely pathogen resistance in the crop and increased quality/processing ability in ripening fruit—the rationale being increased productivity through reduced losses and an increased market share of a qualitatively improved product. Both the fresh fruit dessert market and the processed foods market have been targeted as areas where improvement of fruit quality traits would be beneficial. The use of the banana as a ‘bio-factory’ is also under serious consideration as is the development of an oral delivery system for antibodies to combat disease in developing countries.

Commercially, more than 95% of the banana fruit sold worldwide are of one variety, ‘Cavendish’ (AAA). Alone, this disease-susceptible variety does not offer sufficient or appropriately coordinated

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genetic diversity from which to sample genes for the desired improvement. Southeast Asia has some 70 additional varieties of bananas including both the AA and BB wild type ancestors. It is this genetic diversity which promises to be an important genetic resource from which to sample for the improvement of the banana crop as a whole. Here we present both immediate and long-term technological approaches that may add to the improvement of bananas in the Association of South-East Nations (ASEAN) region. These include the selection of more disease-resistant varieties, exploitation of the cooking banana varieties in processing, technology for fruit storage, and the use of molecular biotechnology for added crop value.

## Materials and Methods

### Plant material

All the experiments detailed were performed with fruit of *Musa acuminata* 'Mas' (AA) banana, a diploid Pan ASEAN variety characterised by the golden yellow colour attained by the small fruit at the fully ripe stage.

### Vacuum-packed storage and protein profiling

The approaches used for storing 'Mas' banana fruit were as described earlier (Nair and Tung 1992) and the protocols for protein extraction and analysis are detailed in Nair et al. (1996) as well as Chandran et al. (2000). N-terminal sequencing of the gel-purified 31 kDa polypeptide was performed by Dr Maxcy Chung at the Biotechnological Processing Centre (BTC), National University of Singapore, Singapore.

### Extraction of RNA from banana pulp and RT-PCR cloning of the 31 kDa protein

Total ribonucleic acid (RNA) was extracted from different stages of developing and ripening banana fruit pulp tissue using the method of Liu et al. (1998). Reverse transcriptase-polymerase chain reaction (RT-PCR) was performed using the Access RT-PCR system (Promega) with total RNA extracted from mature, unripe banana fruit pulp tissue using the primers 5'-CGGCGCAGCTCATGCATTGGC-3' and 5'-TTTTTTTTTTTTTTTTTTT-3' and following the manufacturer's protocol. The resulting PCR products

were cloned into the plasmid pCRScript SK+ (Stratagene) following the manufacturer's instructions and standard approaches (Sambrook et al. 1989). Automated sequencing of cloned PCR products was performed by the DNA Sequencing Research Service, University of Durham, United Kingdom. Sequence analysis was conducted online using various computational analysis programs, as detailed in the results.

### Tissue culture of 'Mas' bananas

'Mas' banana plants were entered into tissue culture using modifications of methods and approaches described previously (Dhed'a et al. 1991; Panis et al. 1993; Schoofs 1997) to obtain in vitro plant regeneration via shoot tip culture and scalps.

## Results

### Vacuum-packed storage and protein profiles of 'Mas' banana fruit

The physiological effects of the vacuum-packed storage of 'Mas' bananas have been reported previously (Nair and Tung 1992). Essentially, mature fruit, hermetically sealed in polyethylene bags under a vacuum not exceeding 300 mm Hg, could be stored at 17°C for realistic periods of up to 8 weeks. During storage, high CO<sub>2</sub> (10–15% v/v) and low O<sub>2</sub> (3–5% v/v) levels were attained within hours, repressing potential ripening-associated ethylene synthesis. The fruit lost negligible weight and remained green during storage. On release to ambient conditions in air the fruit ripened normally to a quality similar to that of ripened, non-stored fruit.

The developmental protein profiles of mature, vacuum-packed stored and ripening 'Mas' bananas have been reported previously (Chandran et al. 2000). After sodium dodecyl sulfate–polyacrylamide gel electrophoresis (SDS-PAGE) and Coomassie Blue staining, 22 polypeptides were obvious. Seven of these polypeptides increased in apparent abundance during the ripening of non-stored fruit while seven others were observed to decrease. The eight remaining did not show any changes and remained constant throughout ripening. The most dramatic change was observed in a 31 kDa polypeptide which appeared highly abundant in extracts from mature fruit and was significantly reduced in ripe fruit. During three weeks of vacuum-packed storage at 17°C there was little change in the obvious protein profiles. However, the

abundance of the 31 kDa polypeptide decreased significantly during the storage period. On ripening, after release from storage, the profiles attained were similar to those of non-stored, ripened fruit, although the 31 kDa polypeptide was further reduced in abundance.

## Tissue culture of 'Mas' (AA) bananas

In preparation for genetic transformation experiments, sterile, tissue-cultured 'Mas' (AA) banana plants were established and cell suspension cultures of this variety obtained (Figure 1). A complete regeneration protocol is now available.

## 31 kDa protein in developing banana fruit

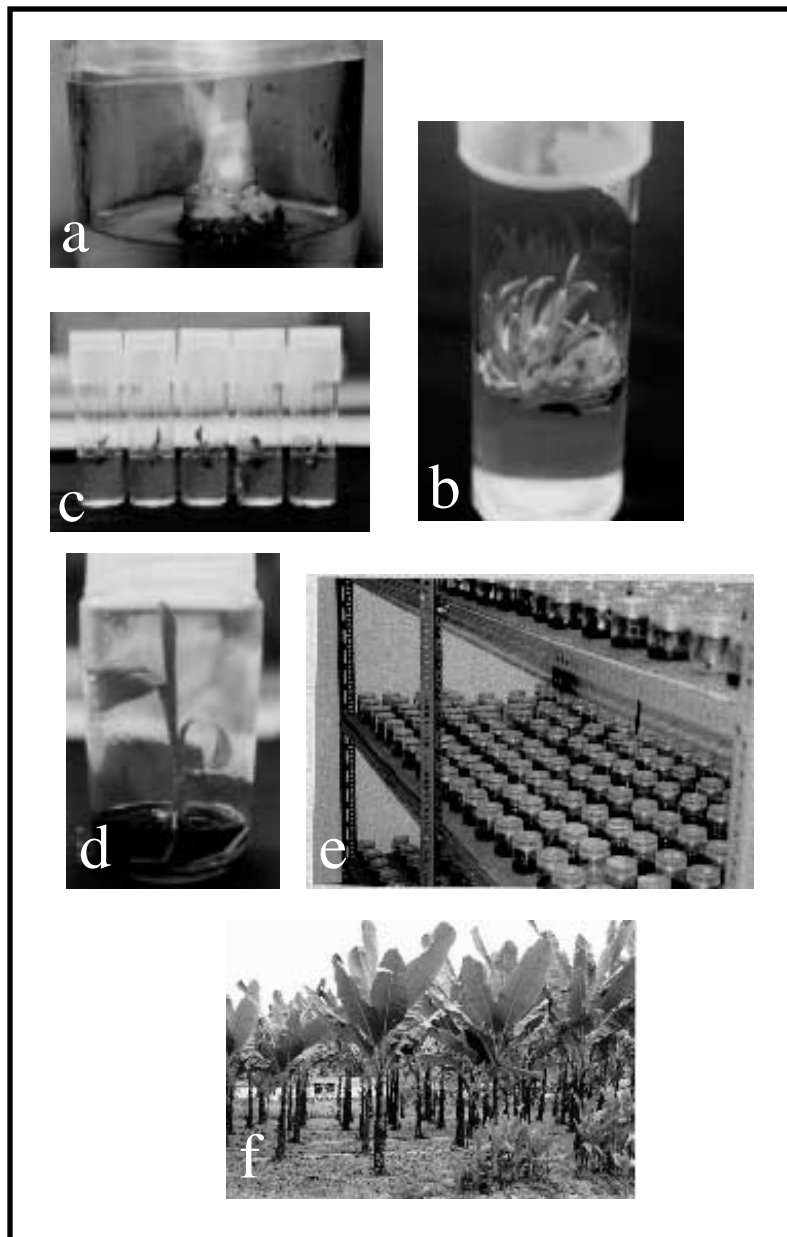
SDS-PAGE analysis of proteins isolated from developing, mature and ripening 'Mas' banana fruit identified a protein of approximately 31 kDa as one of the most abundant protein constituents of this organ. The protein predominantly accumulates in unripe fruit and declines significantly during ripening and during the vacuum-packed storage of mature fruit (Figure 2). Isolation of the protein from one-dimensional polyacrylamide gels and its transfer to PVDF membranes allowed N-terminal micro-sequencing to be performed. Blast homology searches predicted the N-terminal sequence of the extracted protein to be contained within that of the predicted amino acid sequence of a previously reported banana cDNA (Clendennen et al. 1998) encoding a family 18 class III acidic chitinase. Reverse transcribed PCR using the primers indicated in Figure 3 and total RNA extracted from mature 'Mas' banana fruit yielded a single DNA fragment which, when cloned and sequenced, was found to be identical to the previously reported chitinase sequence. Significantly, the N-terminal sequence of the protein purified from 'Mas' banana fruit commences at amino acid residue 26 of the predicted protein. Analysis of the protein sequence using SignalP (Nielsen et al. 1997), a computer program to detect signal peptides and their possible cleavage sites within proteins, indicated that the N-terminal 25 amino acids of the predicted polypeptide comprised a signal peptide that was probably cleaved between amino acid residues A<sub>25</sub> and R<sub>26</sub> (95% certainty). This probable 25 amino acid signal sequence also contained a similar signature sequence (92% similarity) to that for the G-protein binding site found in the rhodopsin-like G-protein coupled receptors. Further analysis of the chitinase sequence revealed some other significant features. In addition to

the conserved chitinase active site residues between L<sub>148</sub> to N<sub>154</sub> with the conserved E<sub>161</sub>, comparison of the sequence against the Prosite and Pfam databases of highly conserved protein motifs and patterns using the program Pfsan, revealed the presence of a cGMP binding site between amino acids A<sub>13</sub> to S<sub>29</sub> (100% identity) and predicted that R<sub>26</sub>R<sub>27</sub>S<sub>28</sub>S<sub>29</sub> is a motif targeted by a cGMP-dependent kinase with either the S<sub>28</sub> or S<sub>29</sub> being the phosphorylated residue (Fremisco et al. 1980; Glass and Smith 1983; Glass et al. 1986). Such analysis also revealed a signature sequence (consensus sequence [LIVMFY] - × (8) - [EQR] - [STAGV] - [STAG] - × (3) - G - [LIVMFYSTAC] - × (5) - [LIVMFYSTA] - [PA] - × (4) - [LIVMFY] - [PKR]) found in protein binding-dependent inner membrane transport proteins (96.7% similarity) between residues L<sub>245</sub> and P<sub>273</sub>. Thus, one of the most abundant proteins in developing banana fruit is predicted to be synthesised as a pre-protein with Mr 35,298 and to be a G-protein binding-dependent targeted, membrane-associated, phosphorylated chitinase with a post-processing Mr of 32,610.

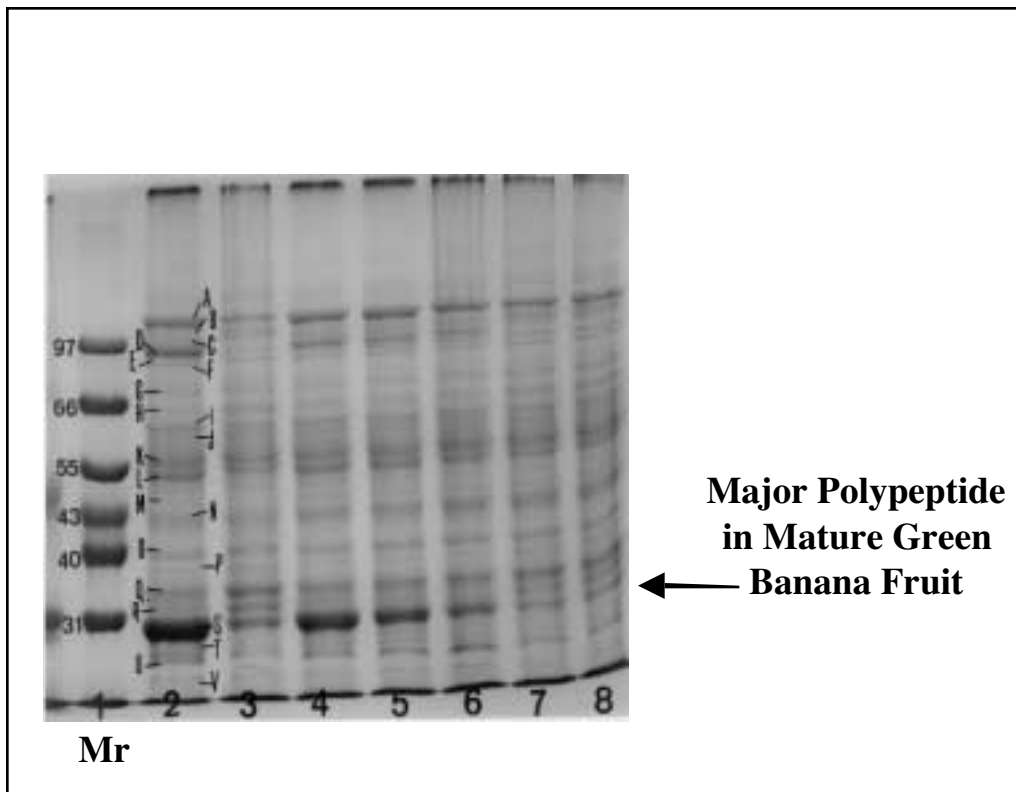
## Discussion

Developing a banana export market for the ASEAN region offers significant economic opportunities, but needs a coordinated approach in order to realise the potential benefits. The region holds much of the genetic diversity with which to gain an improved market share and from which improvements to existing varieties can be made. Increasing the land area in production of local, more disease-resistant varieties, the application of storage and transport technologies for maintaining qualitative improvement, and appropriate marketing are the first of many steps that can be taken to develop the banana market. However, developing a sustainable market share inevitably requires that significant, patentable, added value is attached to the crop. This added value may be achieved through processing to produce higher-value end products. Currently this approach is utilised on a small scale for the production of processed banana food products from some high-starch cooking varieties. However, most of this processed produce is consumed locally.

Alternatively, significant improvements can be made to the qualitative aspects of the fresh fruit. Increasing the spectrum of carotenoids found in the ripe fruit is an obvious example of a commercially desired trait. Current medical opinion is that increasing the antioxidant properties of foods may be beneficial in reducing carcinomas and heart disease.



**Figure 1.** Tissue culture production of 'Mas' banana plants. Various stages of the tissue culture of 'Mas' banana plants are shown; sterile isolated meristem (a), proliferating shoots derived from meristem tissue (b), isolation of individual shoots (c), rooting to produce an individual plantlet (d), scaling up production (e) and application of the technology in the field (f).



**Figure 2.** Protein profiles of 'Mas' banana pulp from mature, unripe and vacuum-packed stored, mature fruit and from fruit ripening without and following storage. SDS-8.5% (w/v)-PAGE (see text) analysis of proteins extracted from mature unripe (lane 2) and ripe (lane 3) 'Mas' banana fruit and from mature unripe fruit stored for 1, 2 and 3 weeks (lanes 4, 5 and 6, respectively) and from half and fully ripened fruit released to ambient conditions after 3 weeks of storage (lanes 7 and 8, respectively). Co-migrating molecular weight markers are shown (lane 1) and the position of the prominent 31 kDa polypeptide is indicated. (Reproduced from Chandran et al. 2000.)



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TTTGGTTGTGCCTAACAGAGAGAGAGACAGACCGATAGCCTCCTCATTCACTATGGCG      60
                                                                                   M A      2
ATCCGATCGCCAGCTTCGCTGCTGTTATTTGCGTTCCTGATGCTTGCCTCACGGGAAGA      120
I R S P A S L L L F A F L M L A L T G R      22
CTGCAGGCCCGGCGCAGCTCATGCATTGGCCTACTGCGGACAAAACACCGACGAGGGA      180
L Q A R R S S C I G V Y W G Q N T D E G      42
AGCTTAGCAGATGCTTGTGCCACAGGCAACTACGAATACGTGAACATCGCCACCCTTTTC      240
S L A D A C A T G N Y E Y V N I A T L F      62
AAGTTTGGCATGGGCCAAACTCCAGAGATCAACCTCGCCGGCCACTGTGACCTCGGAAC      300
K F G M G Q T P E I N L A G H C D P R N      82
AACGGCTGCGCGCGCTTGAGCAGCGAAATCCAGTCTGCCAGGAGCGTGGCGTCAAGGTG      360
N G C A R L S S E I Q S C Q E R G V K V      102
ATGCTCTCCATCGGAGGTGGCGGTCTTATGGCTGAGTTCACCGAAGACGCCAAGGAC      420
M L S I G G G G S Y G L S S T E D A K D      122
GTAGCGTCATACCTCTGGCACAGTTTCTTGGGTGGTTCTGCTGCTCGCTACTCGAGACC      480
V A S Y L W H S F L G G S A A R Y S R P      142
CTCGGGGATGCGGTTCTGGATGGCATAGACTTCAACATCGCCGGAGGGAGCACAGAACAC      540
L G D A V ..... I A G G S T .. H      162
TATGATGAACCTTGCCGCTTTCCTCAAGGCCTACAACGAGCAGGAGGCCGGAACGAAGAAA      600
Y D E L A A F L K A Y N E Q E A G T K K      182
GTTCACTTGAGTGCTCGTCCGAGTGTCTTTCCGGATTACTGGCTTGGCAACGCACTC      660
V H L S A R P Q C P F P D Y W L G N A L      202
AGAACAGATCTCTTCGACTTCGTGTGGGTGCAGTTCCTCAACAACCCTTCGTGCCATTT      720
R T D L F D F V W V Q F F N N P S C H F      222
TCCCAGAACGCTATCAATCTTGCAAATGCGTTCAACAATTGGGTCTATGTCATCCCTGCG      780
S Q N A I N L A N A F N N W V M S I P A      242
CAAAGCTGTTCTTGGGCTTCTGCTGCTCCTGAGGCTGCTCCAAGTGGTGGCTACATT      840
Q K L F L G L P A A P E A A P T G G Y I      262
CCACCCCATGATCTCATATCTAAAGTTCTCCGATCCTAAAGGATTCGACAAAGTACGCA      900
P P H D L I S K V L P I L K D S D K Y A      282
GGAATCATGCTGTGGACTAGATACCACGACAGAAATCCGGCTACAGTTCTCAAGTCAAG      960
G I M L W T R Y H D R N S G Y S S Q V K      302
TCCCACGTGTGTCAGCGCGTTCGTTTCCAACATCTTATCTATGCCGGTGAAGTCTTCC      1020
S H V C P A R R F S N I L S M P V K S S      322
AAGTAAACCTGAACGGCGTAGATGATCGGTGGTGCAGAACTCCGATCATCATGGGTCCCC      1080
K *      323
ATCCGTATCCGTGCGTTGCTACGTTATGGTGTTCCTTGATGTTGGTCTTTTCAATAA      1140

TATAATAAGGGTTAGTTTTACGTTTCCAAAAAAAAAAAAAAAAAAAAA      1148
GTTTTTTTTTTTTTTTTTTT

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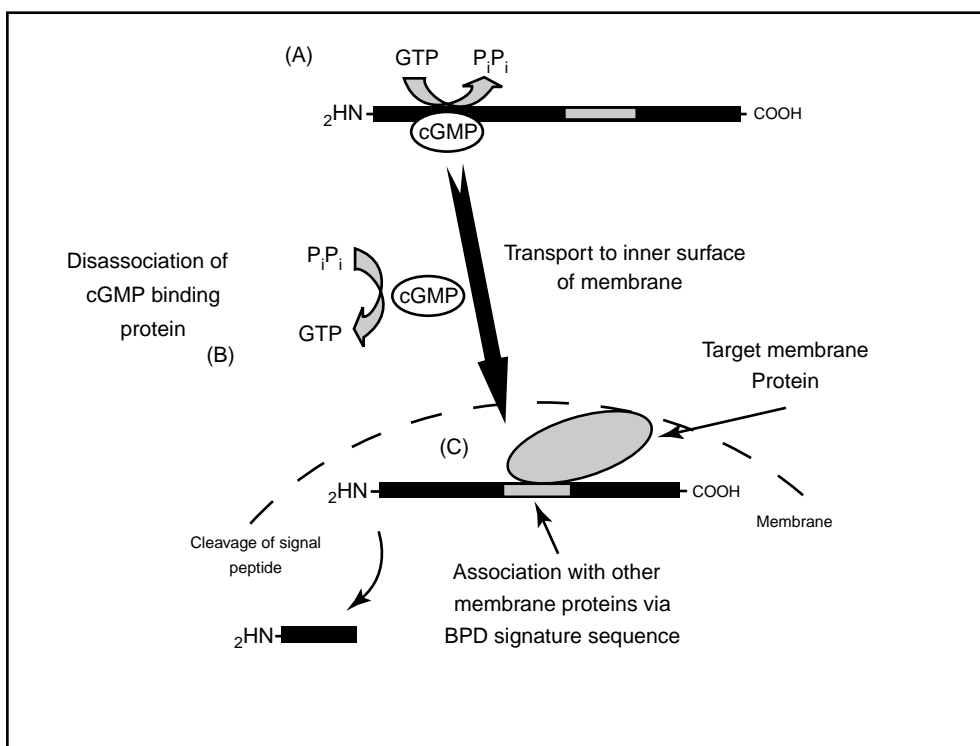
**Figure 3.** Encoding cDNA (Clendennen et al. 1998) and amino acid sequence of the major chitinase from banana pulp. The full length cDNA and polypeptide encoded by the longest open reading frame are shown. Oligonucleotide primers used for RT-PCR (see text) in this paper are shown in bold type with arrows showing direction of DNA synthesis. Amino acid residues (1–25) comprising the probable N-terminal signal peptide are underlined with the cGMP binding (13–25) and phosphorylation site residues (26–29) enclosed in an open box. The amino acid residues comprising the chitinase active (148–154 and 161) site are enclosed in a shaded box. The binding-protein-dependent inner membrane transport protein amino acid signature sequence (245–273) is shown in italics and underlined.

Commercial bananas do not accumulate  $\beta$ -carotenes in either the pulp or peel during ripening. However, some wild-type BB varieties growing in the ASEAN regions do and offer a genetic background from which to sample for such added value. Many other biochemically-determined traits such as texture, taste, size, colour and shape can also be targeted for improvement. Tissue culture of many banana varieties is now feasible as is their genetic transformation using molecular techniques (May et al. 1995; Sagi et al. 1995) and it is now possible to draw on the extensive, genetic resources from other species or from bananas themselves to genetically improve this crop. Where possible, small, but lucrative improvements requiring minimal modifications should be targeted. At present, only thus does molecular research and development become cost effective.

Current public opinion towards the consumption of genetically engineered food produce must also be taken into account when deciding what improvements to make. Many countries have recently expressed concern over the growing consumption of genetically modified foods. Much of the concern centres on issues relating to food labelling and the maintenance of consumer choice, but there are also serious environmental and health issues that have been raised. The concept of the potential transfer of antibiotic resistance marker genes, used to select for transformed plants, to microorganisms, and the wider lethality of introduced insecticidal proteins, have detracted from public faith in genetically engineered foods. The potential out-crossing of herbicide resistance genes to wild-type weed species and the concept that such an approach is encouraging, rather than reducing (as was promised), the use of chemical inputs has also done little to alleviate public anxieties. Some countries have proposed at least a five-year moratorium on the growing and sale of genetically engineered food and have legislated a substantial increase in the level of health and safety testing. Thus, 'designer' disease resistance via the introduction of genes encoding or causing higher expression levels of proteins lethal to bacteria and fungi is probably not a feasible approach if it is determined that such proteins may be (or may be perceived to be) toxic to humans. To some extent, bananas escape the problem of cross-pollination, since the commercial varieties are sterile and do not set seed.

However, balancing socioeconomic development with the public perception of consuming genetically engineered foods may mean that increasing the intrinsic value of bananas and developing an ASEAN export market favours their use as a bio-factory for the production of tertiary products that are not necessarily directly eaten.

One gene, described here, that has been isolated from 'Mas' (AA) bananas encompasses many of the above considerations and may be a good candidate in raising the value of bananas. This gene encodes a fruit-specific 31 kDa class III acidic chitinase, the most abundant protein in developing banana fruit. The gene encoding this protein is potentially useful for a number of reasons. Chitinases have been widely implicated in resistance to fungal diseases. Thus, ectopic over-production of this protein may confer wider resistance of the vegetative tissues to fungi. Already at high levels in fruit, it is difficult to raise objections on the grounds of toxicity following consumption. The tissue-specific expression pattern of the gene itself is useful in that it allows for the isolation of a fruit-specific gene promoter, a useful tool when it is advisable to limit altered biochemistry to this organ alone. The protein itself also possesses highly conserved signature sequences for an cGMP-binding-protein associated N-terminal transit or signal peptide and an inner membrane attachment site. Presumably the protein is targeted to the inner surface of a membrane (Figure 4), potentially that of an organelle, in a manner dependent on association with an unknown cGMP-binding protein. Such signature sequences are useful in directing different proteins to specific compartments within the cell in order to specifically alter their biochemistry or to redirect synthesis towards desired tertiary products. Ongoing research is aimed at determining the potential pathogenic usefulness of this protein in transgenic plants and using  $\beta$ -glucuronidase (GUS) and/or green fluorescent protein (GFP) protein-fusions over-expressed *in vivo* to determine where in fruit cells the protein is localised. The isolation of the associating cGMP-binding protein and an investigation into the physiological signals mediating its activity is also a priority and will allow us to begin to assemble a system for directing artificially introduced proteins to specific parts of banana fruit cells.



**Figure 4.** Proposed scheme for membrane targeting of the 31 kDa chitinase from ‘Mas’ banana fruit. The chitinase pre-protein probably associates with a G-protein which facilitates transport to a specific membrane (A). The association is likely to be dependent on binding of cGMP and phosphorylation. Upon reaching the membrane the G-protein dissociates as the pre-protein crosses the membrane (B). On reaching the inner surface the pre-protein is processed by removal of the N-terminal signal peptide to yield the mature protein which probably couples with other proteins via the binding protein dependent signature sequence contained therein (C).

## Acknowledgments

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## References

- Chandran S., Harikrishnan, J.A., Ong, E.K. and Nair, H. 2000. Changes in protein profiles and starch break-down during ripening and storage of vacuum-packed bananas. Transactions of the Malaysian Society of Plant Physiology, volume 7 (in press).
- Clenennen, S.K., Lopez-Gomez, R., Gomez-Lim, M., Artzen, C.J. and May, G.D. 1998. The abundant 31-kilodalton banana pulp protein is homologous to class-III acidic chitinases. *Phytochemistry*, 47, 613–619.
- Dhed’a, D., Dumortier, F., Panis, B., Vuylsteke, D. and De Langhe, E. 1991. Plant regeneration in cell suspension cultures of the cooking banana cv. ‘Bluggoe’ (*Musa* spp. ABB group). *Fruits*, 46, 125–135.
- Fremisco, J.R., Glass, D.B. and Krebs, E.G. 1980. Optimal spatial requirements for the location of basic residues in peptide substrates for the cyclic AMP-dependent protein kinase. *Journal of Biological Chemistry*, 255, 4240–4245.

- Glass, D.B. and Smith, S.B. 1983. Phosphorylation by cyclic GMP-dependent protein kinase of a synthetic peptide corresponding to the autophosphorylation site in the enzyme. *Journal of Biological Chemistry* 258, 14797–14803.
- Glass D.B., El-Maghrabi, M.R. and Pilkis, S.J. 1986. Synthetic peptides corresponding to the site phosphorylated in 6-phosphofructo-2-kinase/fructose-2,6-bisphosphatase as substrates of cyclic nucleotide-dependent protein kinases. *Journal of Biological Chemistry*, 261, 2987–2993.
- Liu, J.-J., Goh, C.-J., Loh, C.-S., Liu, P. and Pua, E.-C. 1998. A method for isolation of total RNA from fruit tissues of banana. *Plant Molecular Biology Reports*, 00, 1–6.
- May, G.D., Afza, R., Mason, H.S., Wiecko, A., Novak, F.J. and Arntzen, C.J. 1995. Generation of transgenic banana (*Musa acuminata*) plants via *Agrobacterium*-mediated transformation. *Biotechnology*, 13, 486–492.
- Nair, H., Andaikalavan, N. and Tung, H.F. 1996. Some physiological and protein changes during storage of bananas. In: Frisina, C., Mason, K. and Faragher, J., ed., *Australasian Postharvest Horticulture Conference 1995*. Melbourne, Victorian Department of Natural Resources and Environment, 97–104.
- Nair, H. and Tung, H.F. 1992. Low oxygen effect and storage of Mas bananas (*Musa*, AA group). *Acta Horticulturae*, 292, 209–215.
- Nielsen, H., Engelbrecht, J., Brunak, S. and von Heijne, G. 1997. Identification of prokaryotic and eukaryotic signal peptides and prediction of their cleavage sites. *Protein Engineering*, 10, 1–6.
- Panis, B., Dhed'a, D. and Swennen, R. 1993. Embryogenic *Musa* plant cell cultures: current and future applications. *InfoMusa*, 2, 3–6.
- Sagi, L., Panis, B., Remy, S., Schoofs, H., De Smet, K., Swennen, R. and Cammue, B.P. 1995. Genetic transformation of banana and plantain (*Musa* spp.) via particle bombardment. *Bio/Technology*, 13, 481–485.
- Sambrook, J., Fritsch, E.F. and Maniatis, T. 1989. *Molecular cloning. A laboratory manual*. USA, Cold Spring Harbor Laboratory Press.
- Schoofs, H., 1997. The origin of embryogenic cells in *Musa*. PhD thesis, Katholieke Universiteit Leuven, Belgium. *Dissertatione de Agricultural No. 330*, 258p.

# Assessment of Postharvest Handling Systems for Chinese Cabbage in China

Wang Xiangyang and Shen Lianqing\*

## Abstract

The postharvest handling systems for heading and non-heading Chinese cabbages in eastern central China were investigated and some traditional handling methods assessed. With heading Chinese cabbage, the effects of trimming the outer leaves and subsequent exposure to the sun for several hours before transport were studied. With non-heading Chinese cabbage, the effects of root removal, outer leaf trimming, water dipping and water spraying (at market) were studied.

The studies indicated that, with heading Chinese cabbage, trimmed and untrimmed cabbages had an equivalent loss of outer leaves before entry into the retail market sector, but trimming reduced the cost of transport. The practice of exposing trimmed cabbages to the sun significantly reduced rotting, but increased moisture loss. Moisture loss had a greater impact on losses than did rotting in cabbages stored for less than four days. Exposing cabbages to the sun before shipment significantly decreased losses from rotting if cabbages were transported during rainy weather, or were to be stored for longer than a week in summer.

Removal of roots or trimming of outer leaves of non-heading Chinese cabbage at harvest had little impact on subsequent postharvest losses. Weight loss during harvest and short-term storage before transport to market was not more than 10% and could be regained by dipping the plants in water for 90 minutes.

A LARGE amount of *heading* Chinese cabbage (*Brassica rapa* 'Pekinensis') grows in China. It is harvested mainly in winter before freezing temperatures can damage the crop and is stored for 2–3 months on farms in northern China during winter at ambient temperatures. It is a relatively non-perishable crop, but losses of 20–30% (sometimes more than 50%) can eventuate from disease during storage. To reduce rotting, some farmers place Chinese cabbage heads in the sun to wilt the outer leaves before storage. This results in a 15–20% moisture loss from the heads. Heading Chinese cabbage grows in all regions of China in winter, and is sold in local towns or nearby cities.

The handling system for heading Chinese cabbage is quite different in summer. It is grown mainly in northern China and is harvested for local sale and for transport to, and sale in, southern China. For transport

to southern China, moisture control is most important. The heads need to be dry during transport and at the wholesale market, otherwise losses caused by rotting can be large.

We can take Hangzhou City's wholesale market as an example of the handling system. Throughput of heading Chinese cabbage can be 20–30 t/day in Hangzhou City in summer. Most Chinese cabbage comes from Shandong Province or the north of Jiangshu Province, 700–800 km away from Hangzhou City. The transport time is 16–24 hours. The vegetables are carried on open-tray trucks (10–12 t/truck) without packaging. Some wholesalers trim the outer head leaves before transport, while others do so afterwards. No one knows which is better.

The trucks need to reach Hangzhou City late in the afternoon (about 6 pm). After each truck, packed with cabbage, arrives at Hangzhou wholesale market, three people trim off some of the outer leaves and any rotted leaves, then pack the trimmed heads into 60–80 cm plastic net or polyethylene bags. Losses of about 10–15% occur at this time, although some wholesalers incur losses of 40–50% during rainy weather.

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Most of the vegetables are sold from 4–6 am at the Hangzhou wholesale market. Some heading Chinese cabbage is sometimes not sold because of oversupply or the late arrival of trucks from the north. The Chinese cabbage then has to wait in the wholesale market until the next day. Some wholesalers place these heads in the sun for several hours, then shade them with rice straw to reduce losses from rots. However, this leads to about a 10% increase in moisture loss, and there are further losses from the removal of wilted, yellowing outer leaves. Reduced quality results in lower prices. In our study we assessed the effectiveness of placing Chinese cabbage heads in the sun.

Large amounts of *non-heading* Chinese cabbage are also grown in China. The crop is harvested in June and July, 20–50 days after planting. It is a perishable crop like pak choy, suffering heavy losses in summer due to wilting, yellowing, and mechanical damage. The vegetable is harvested in the late afternoon (5–8 pm) or early morning (2–4 am) in summer, and packed into bamboo baskets.

Some farmers harvest this vegetable by pulling it out, leaving the roots intact. They believe that keeping the roots and outer leaves on can protect the inner leaves, and this practice allows faster harvesting. The roots and outer leaves are trimmed off by these farmers at market. Other farmers cut off the roots and outer leaves at harvest. These farmers believe that there is no advantage in keeping the roots and outer leaves, which only cause the vegetables to get dirty.

90% of non-heading Chinese cabbage is delivered to market by the farmers themselves. The vegetable is sold locally or in nearby towns, mainly within 20 km of the farm. The vegetables harvested in the early morning are delivered to wholesale and retail markets immediately after harvest. If the vegetables are harvested in the afternoon, they are stored in the farmer's home for selling next morning. These stored vegetables are covered with paper or sprayed with water to reduce weight loss and wilting during storage, transport and marketing. Non-heading Chinese cabbage is not pre-cooled or stored in coolrooms. Unsold non-heading Chinese cabbage is mainly thrown away. Only a few farmers carry it back to the farm for animal feed or try to store it for sale on the following day. If the vegetable is harvested during rainy weather, it suffers much mechanical injury because of its turgid, tender leaves. Also, rots and yellowing cause large losses.

These traditional handling methods need to be studied and modified.

## Materials and Methods

Heading Chinese cabbage was sourced from the Hangzhou local wholesale market. Non-heading Chinese cabbage was sourced from local farms and arrived at the Hangzhou University of Commerce laboratory within an hour of harvest.

### Instrumental colour analysis

This was performed with a chromatic aberration meter. White board calibration ( $X = 80.727$ ,  $Y = 85.842$  and  $Z = 85.335$ ) was performed before measuring. Derived functions of the  $L^*$ ,  $b^*$  and  $a^*$  values included hue angle or  $\tan^{-1}b^*/a^*$ . Visual change was measured non-destructively by reflectance as hue angle (Shewfelt et al. 1984).

### Heading Chinese cabbage

#### *Placement in the sun*

Twenty-seven heading Chinese cabbage were placed in the sun for: (1) 8 h; (2) 4 h in the sun plus 4 h in the shade; or (3) 8 h in the shade. The treatments were repeated the next day. The cabbages were then stored for 8 days at ambient temperature ( $30 \pm 2^\circ\text{C}$ ). Rot losses were measured as rotted leaves, not whole heads.

#### *Trimming treatment*

Leaves which were old, insect and disease-damaged, mechanically damaged, or wilted outer leaves were trimmed from 24 heading Chinese cabbage before transport. Trimming loss before transport and a second trimming loss after transport in wholesale market were measured. Another sample of 24 cabbages was trimmed only after transport, and losses measured. The cabbages were trimmed according to customer acceptability.

### Non-heading Chinese cabbage

#### *Cutting roots and outer leaves*

Five treatments were applied to non-heading Chinese cabbage (20 plants per treatment) just after harvest: (1) keep roots and outer leaves; (2) remove roots but keep outer leaves; (3) remove roots and one outer leaf; (4) remove roots and two outer leaves; and (5) remove roots and three outer leaves. The hue angles of all remaining leaves were measured at harvest time and after 2 days of storage at ambient temperature ( $30 \pm 2^\circ\text{C}$ ).

### *Irrigation*

Four treatments were applied to non-heading Chinese cabbage grown in pots (20 plants per treatment). The plants were watered 1, 2, or 3 days before harvest; control plants were not watered. Hue angles of all leaves of the plants were measured at harvest time and after 3 and 4 days storage at ambient temperature ( $30 \pm 2^\circ\text{C}$ ).

### *Water dipping*

Detached non-heading Chinese cabbage leaves were placed in the shade for 1 h at ambient temperature ( $30 \pm 2^\circ\text{C}$ ), then 20 outer leaves (two leaves from each vegetable), 20 middle leaves, and 20 inner leaves were dipped in water for 2.5 h. The weights and hue angles of leaves were measured.

## **Statistical analysis**

Statistical analysis of the data was performed using standard analysis of variance, Duncan's multiple range test and multiple correlation techniques (Helwig and Council 1979).

## **Results and Discussion**

### **Effects of exposure to the sun on losses of heading Chinese cabbage**

When heading Chinese cabbage is carried over, or arrives late at wholesale market in summer, and must be stored until the next day, some wholesalers expose the heads to the sun to reduce rot damage. Exposure of heads to the sun for 4 and 8 h caused weight losses of 8.1% and 10.5%, respectively, at the end of one day (Table 1). These were significantly higher than the 3.1% weight loss of the control. There was no rotting during the first 2 days. After 4 days or 8 days storage, losses from rotting were similar for heads exposed to the sun for 4 or 8 h. Both were significantly lower than the control (Table 1).

The results showed that placing Chinese cabbage heads in the sun reduced rotting losses but increased weight loss. If heads are sold soon after harvest (e.g. within 2 days), or have no serious mechanical damage, or are not harvested during rainy weather, they need not be placed in the sun. But if the heads are harvested or transported during rainy weather in summer, or need to be stored for some time, or suffer serious mechanical damage, then to reduce losses from rotting they need to be either exposed to the sun or stored in a coolroom.

### **The effect of timing of trimming outer leaves on losses of heading Chinese cabbage**

After-transport rotting losses in Chinese cabbage heads were higher (10.2% by weight) in cabbages trimmed before transport than in untrimmed heads (6.0%). But untrimmed heads needed much more trimming (22%) after transport, to remove old leaves and mechanical injury. Thus, cabbages both trimmed and untrimmed before transport had similar total losses after transport (Table 2). Nevertheless, trimming heads before transport could reduce transport costs.

The effect of cutting outer leaves and roots at harvest time on non-heading Chinese cabbage leaf yellowing

Keeping the roots on after harvest had no significant effect on the yellowing of leaves of non-heading Chinese cabbage. Removing the outer leaves slightly retarded the yellowing of inner leaves. Cutting off 1, 2, or 3 leaves similarly retarded inner leaf yellowing (Table 3). Cutting off the root and 1 to 3 old outer leaves at harvest time was feasible for increasing net saleable vegetable (less waste) in the market.

### **The effect of irrigation before harvest on yellowing of non-heading Chinese cabbage**

Irrigation before harvest increased postharvest yellowing of leaves (reduced hue angle). The closer irrigation is to harvest, the greater the postharvest leaf yellowing (Table 4). Thus, the vegetable needs be harvested at least 3 days before rainy weather to reduce leaf yellowing after harvest, and crops should not be irrigated within 3 days of harvest.

### **The effect of water dipping on non-heading Chinese cabbage weight and hue angle**

Moisture loss after harvest caused weight loss and yellowing (hue angle decline). Dipping in water for 1.5 hours was the best treatment to restore weight and appearance after the vegetable had lost moisture. It resulted in the highest weight and the most favourable hue angle (Tables 5 and 6).

**Table 1.** Effect of exposure to the sun on postharvest losses of heading Chinese cabbage in summer.

Treatment	Weight loss (%)		Rot loss (%)	
	1 day	2 days	4 days	8 days
8 h in the sun	10.5 a	21.8 a	10.5 b	21.2 b
4 h in the sun	8.1 b	16.4 b	10.3 b	20.5 b
Shade (control)	3.1 c	7.0 c	19.5 a	100.0 a

Note: Treatments followed by different letters are significantly different ( $p = 0.05$ ).

**Table 2.** Effect of trimming outer leaves on postharvest losses of heading Chinese cabbage in summer.

Treatment	Before transport		After transport	Total loss (%)
	Trimming loss (%)	Disease loss (%)	Losses from mechanical injury and removal of old leaves	
Trimmed	15	10.2 <sup>a</sup>	3.4 <sup>a</sup>	28.6
Control	0	6.0	22.0	28.0

<sup>a</sup> Statistically significant ( $p = 0.01$ ).

**Table 3.** Effect of cutting outer leaves and roots at harvest time on yellowing of non-heading Chinese cabbage in summer.

	Hue angle		
	Harvest time	2 days after harvest	Hue angle loss (%)
Retain roots and outer leaves	113.9	108.6	4.65 a
Remove roots and retain outer leaves	113.0	107.6	4.78 a
Remove roots and 1 outer leaf	111.6	106.8	4.30 b
Remove roots and 2 outer leaves	111.0	107.0	3.60 c
Remove roots and 3 outer leaves	111.0	106.6	3.96 bc

Note: Treatments followed by different letters are significantly different ( $p = 0.05$ ).

**Table 4.** The effect of irrigation before harvest on postharvest yellowing of non-heading Chinese cabbage.

Irrigation	Hue angle		
	Harvest time	3 days after harvest	4 days after harvest
1 day before harvest	113.60 b	93.86 b	85.97 c
2 days before harvest	113.60 b	94.42 b	86.38 c
3 days before harvest	115.34 a	95.50 ab	90.43 b
No irrigation	116.09 a	96.79 a	93.53 a

Note: Treatments followed by different letters are significantly different ( $p = 0.05$ ).



**Table 5.** The effect of water dipping on non-heading Chinese cabbage weight change.

	Weight loss (%)			Weight restoration (%)				
	Harvest time	Exposure to sun for 0.5 h	Exposure to sun for 1 h	Dipped for 0.5 h	Dipped for 1 h	Dipped for 1.5 h	Dipped for 2 h	Dipped for 2.5 h
Outer leaves	100	90.0	86.0	90.5	98.7	102.4	102.0	102.2
Middle leaves	100	91.6	87.0	94.1	97.7	106.9	106.6	108.9
Inner leaves	100	91.4	88.2	94.0	93.5	96.4	93.6	94.7

**Table 6.** The effect of water dipping on hue angle in non-heading Chinese cabbage.

	Hue angle						
	Harvest time	After 1 h sun exposure	After dipping for 0.5 h	After dipping for 1 h	After dipping for 1.5 h	After dipping for 2 h	After dipping for 2.5 h
Outer leaves	117.0	112.2	115.5	116.4	116.1	116.5	116.5
Middle leaves	118.3	113.1	116.1	116.6	117.3	116.9	116.5
Inner leaves	118.0	112.9	116.6	116.6	117.9	117.6	116.9

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## References

- Helwig, J.T. and Council, K.A. 1979. SAS user's guide. Carey, New Jersey, SAS Institute, Inc.
- Shewfelt, R.C., Heaton, E.K. and Batal, K.M. 1984. Nondestructive color measurement of fresh broccoli. *Journal of Food Science*, 49, 1612–1613.

# The Effect of Sugar and Ethylene on Postharvest Pak Choy (*Brassica rapa* var. *chinensis*) Leaf Degreening

Wang Xiangyang and Shen Lianqing\*

## Abstract

Sugar is the main energy substrate of pak choy leaves, consisting of glucose and fructose. The sugar concentration in the outer leaves of the pak choy plant decreased sharply during storage at ambient temperature ( $20 \pm 2^\circ\text{C}$ ), while total amino acid concentration increased. Treatment of pak choy by placing leaves in an 8% sugar solution for 2 hours increased the sugar content in the pak choy leaves and retarded leaf yellowing. Hot water treatment was also found to retard both decline in sugar content and leaf yellowing. Initial ethylene production from pak choy stored at  $20^\circ\text{C}$  was low, but increased sharply during storage, concomitant with leaf yellowing. Exposure of pak choy to exogenous ethylene (60 ppm) at  $20^\circ\text{C}$  did not significantly accelerate leaf yellowing, although a significant increase was induced by 600 ppm. Ethylene did not appear to accelerate leaf yellowing of pak choy stored at  $2^\circ\text{C}$ .

PAK CHOY (*Brassica rapa* var. *chinensis*) is an open leafy brassica. It has an inherently short storage life and is usually marketed soon after harvest. Its shelf life is limited primarily by wilting and outer leaf yellowing. Yellowing has been implicated as a limiting factor in storage of pak choy (Hirata et al. 1987; Wang and Herner 1989; O'Hare et al. 1995). Leaf yellowing is associated with the breakdown of chlorophyll during storage and senescence.

Ishii and Shinbori (1988) reported that the initial chlorophyll content and total sugar of older leaves of Japanese turnip (*B. rapa* var. *rapifera*) were already lower than younger leaves at harvest and continued to decline during storage. It was suggested that the rapid decline of these components may have been directly related to product deterioration. Older leaves of spinach (*Spinacia oleracea* var. *read*) declined in sugar levels at a faster rate than inner leaves, with yellowing beginning once sugar levels fell below a critical concentration.

The presence of ethylene, whether produced by plant tissue or an external source, is potentially detrimental to the shelf life of leafy brassicas such as cabbage (Pratt and Goeschl 1969; Pendergrass et al. 1976). It has been proposed that ethylene has an important role in this chlorophyll loss (Aharoni et al. 1985). Broccoli ('Dominador') (*Brassica oleracea* L. var. *italica*) treated at  $45^\circ\text{C}$  for 14 min retained 81% of its chlorophyll for 5 days postharvest (Kazami et al. 1991). A hot water treatment of  $47^\circ\text{C}$  for 7.5 min was selected as the best treatment. This treatment consistently reduced yellowing of floret groups of 'Shogun' broccoli for up to 5 days (Tian et al. 1996).

It is possible that respiratory substrate availability, as well as hormonal factors, may play a major role in the rate of leaf senescence, both of which appear to be of importance in regulating broccoli shelf life (King and Morris 1994a,b; Tian et al. 1995). However, it is unclear whether yellowing of pak choy leaves is regulated by postharvest changes in endogenous ethylene production or total sugars.

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## Materials and Methods

Pak choy was obtained from the local market. The leaves were washed thoroughly with running water.

### Ethylene production measurement

100 g of pak choy was sealed in a 1 L glass bottle at 20°C for 1 h, and a 1 mL gas sample measured for ethylene concentration using a sp-6800 gas chromatogram fitted with GDX 502 column. Treatments were replicated five times.

### Colour analysis

Instrumental colour analysis was performed with a chromatic aberration meter. Visual changes were measured non-destructively by reflectance as hue angle (Shewfelt et al. 1984).

### Measurement of chlorophyll, soluble sugars and amino acids

Chlorophyll changes were destructively assessed using an extraction method based on Batal et al. (1982) for spectrophotometric analysis. Soluble sugars and amino acids were assessed by high performance liquid chromatography (Wade and Morris 1982).

### STS/ethylene treatment

The effect of silver thiosulfate (STS)—as a source of silver ions, which are potent inhibitors of ethylene action—on physiological parameters of pak choy was measured. Three pak choy shoots were dipped in either 4.63 mM STS ( $\text{AgS}_2\text{O}_3$ ) or water (control) for 30 min. Samples were subsequently sealed in 5 L glass bottles which were injected with ethylene to give a final concentration of 4.95 parts per million (ppm). The hue angles of leaves were measured initially and after 3 days at 20°C, and 8 days at 2°C.

20 detached outer leaves and 20 inner leaves were cut into two equal parts by scissors along the central midrib. One half was dipped in 4.63 mM STS for 30 min and the other half dipped in water (control). Both treated and control leaves were sealed together in a 5 L bottle and injected with ethylene as described above. Measurements were similar to above.

The effect of ethylene concentration of physiological parameters was performed similarly to that described above. Detached leaves were sealed in 5 L

bottles with final ethylene concentrations of 0.6, 6, 60, 600 and 6,000 parts per million (ppm).

### Sugar treatment

12 outer leaves (replicated four times) were detached and cut into two equal parts along the midrib and divided into two groups. One group was dipped in 2%, 4%, 6%, or 8% sugar, and the other group dipped in water (control). The leaf halves were taken out of the solutions after 1, 3 or 5 h and washed thoroughly with running water. Treated and control leaves were stored for 2 days under ambient conditions, covered with polyethylene film to minimise moisture loss. Leaves were measured for hue angle both initially and after 2 days.

20 outer leaves (replicated twice) were prepared as above and dipped in water, 6%, or 8% sugar for either 1, 2, 3, 4, or 5 h followed by washing. Leaves were stored as above and measured for hue angle, sugar and amino acid content over 3 days of storage.

### Hot water treatment

Intact pak choy shoots were dipped in hot water (ambient, 38, 40, 42, 44, 46, 48°C) for 10 min. Shoots were subsequently stored at 20°C and 2°C for 3 and 8 days, respectively.

### Statistical analysis

Statistical analysis of the data was performed using standard analysis of variance, Duncan's multiple range test and multiple correlation techniques (Helwig and Council 1979).

## Results

### Ethylene production

Ethylene production of intact pak choy leaves increased rapidly after 4 days of storage at 20°C, but did not exhibit a large increase during 8 days of storage at 2°C (Table 1).

Ethylene production of detached outer leaves stored at 2°C reached 141.82 mL/h/kg (7 days), which was significantly higher than 24.94 mL/h/kg of detached inner leaves. Both were significantly higher than intact pak choy ethylene production which was only 1.66 mL/h/kg after 8 days storage at 2°C.

## Inhibition of ethylene action by silver ions

Yellowing of detached outer and inner leaves was retarded significantly by silver ions when stored at 20°C (Table 2). This was in contrast to 2°C storage, where yellowing occurred very slowly with no significant effect of silver ions (Table 3).

Silver ions did not have a significant effect on the rate of yellowing of intact outer leaves, but could significantly retard yellowing of middle and inner leaves (Table 4).

## Ethylene treatment

Yellowing of detached outer leaves was significantly accelerated by ethylene concentrations of 60 ppm or greater at 20°C. Exposure to less than 6 ppm had no significant effect. Outer-leaf degreening occurred more rapidly than that of inner leaves. Inner

leaves also appeared to be sensitive to 6 ppm ethylene (Table 5).

The hue angle of outer leaves of intact pak choy decreased very rapidly when stored in 600 ppm or greater concentration of ethylene. Ethylene concentrations less than 60 ppm had no significant effect (Table 6).

## Sugar concentration

Pak choy leaves contained glucose and fructose. The sugar content of inner leaves was significant higher than outer leaves (Table 7). Total sugar of outer leaves declined after harvest, with outer leaves containing less than 0.19% after 1 day of storage at 20°C.

Total amino acids of outer leaves increased quickly at 20°C, but the proline content did not increase (indicating that the increase was caused by protein hydrolysis because the protein did not contain proline). Total amino acid of inner leaves was found to initially decrease, then increase. Proline levels also

**Table 1.** Effect of length of time and temperature of storage (up to 8 days) on ethylene production of intact pak choy.

Temperature	Ethylene production (mL/h/kg)					
	1 day	2 days	3 days	4 days	5 days	8 days
20°C	2.00	2.85	1.09	4.37	26.18	–
2°C	nil	nil	nil	2.04	–	1.66

**Table 2.** The effect of silver ions (supplied by silver thiosulfate—STS) on detached leaves stored for up to 3 days at 20°C.

Treatment	Outer leaf hue angle			Inner leaf hue angle		
	1 day	2 days	3 days	1 day	2 days	3 days
STS	115.46	110.29 <sup>a</sup>	106.62 <sup>a</sup>	117.83	111.12 <sup>b</sup>	109.74 <sup>b</sup>
Water	114.88	104.59	98.09	117.46	109.10	106.65

<sup>a</sup> Significant (P = 0.01)

<sup>b</sup> Significant (P = 0.05)

**Table 3.** The effect of silver ions (supplied by silver thiosulfate—STS) on detached leaves stored for up to 3 days at 2°C.

Treatment	Outer leaf hue angle		Inner leaf hue angle	
	1 day	8 days	1 day	8 days
STS	125.30	121.76	128.80	124.81
Water	124.96	122.18	128.08	123.58

Note: not significant.

increased, indicating that the increase in amino acids in inner leaves might not be associated with protein hydrolysis (Table 8).

A rapid increase in total amino acid content and decline in outer leaf chlorophyll occurred when leaf sugar was less than 0.19% at 20°C. At 2°C, the sugar content of outer leaves declined slowly and was still greater than 0.19% after 6 days at 2°C, but less than this by 8 days when degreening was evident. Leaf yellowing was evident when the chlorophyll content fell below 88 mg/100 g (Table 9).

Dipping detached outer leaves in 4% sugar (3, 5 h), 6% sugar (1–5 h) or 8% sugar (1, 3 h) significantly retarded yellowing at 20°C (Table 10). Dipping leaves in 8% sugar for 5 h was observed to cause wilting. The optimal treatment for detached leaves was dipping in 8% sugar for 2 h (Table 11).

Sugar content of detached outer leaves dipped in 6% sugar for 2 h was four times higher than that of the control after 2 days of storage. However, the total amino acid content of treated leaves was only slightly low than that of the control (Table 12).

### Hot water treatment

Hot water treatment significantly retarded leaf yellowing of intact pak choy. Dipping in hot water at 46°C or 48°C water for 10 min had optimal effect (Table 13). Outer leaves of treated intact pak choy had a higher content of sugar than the control after 4 days of storage at 2°C (Table 14).

## Discussion

Ethylene appears to play a significant role in regulating senescence in detached pak choy leaves when stored at 20°C, but not at 2°C. Application of exogenous ethylene, however, did not induce yellowing of outer leaves of intact shoots stored at

20°C, but did accelerate yellowing of middle and inner leaves. It also appears that ethylene will not accelerate degreening of pak choy stored at 2°C.

Ethylene production of broccoli florets held at 20°C has been shown to increase as sepals yellow (Tian et al. 1994). Our research demonstrates that detached pak choy leaves are sensitive to exogenous ethylene at 20°C, however outer leaves of intact pak choy appear to be less sensitive. Ethylene production was observed to increase significantly when leaves were detached, and subsequent ethylene accumulation may enhance detached leaf yellowing.

Leaf removal from pak choy shoots has been shown to hasten deterioration of leaves compared to intact leaves (O'Hare et al. 1995). O'Hare et al. (1995) also reported that the mode of leaf removal significantly influenced the rate of leaf respiration, with leaves cut at the petiole having double the respiration of leaves removed at the abscission zone.

Energy substrates of pak choy were not abundant, with the total sugar content declining during storage at both ambient and low temperatures. A concentration of 0.14–0.19% total sugar may be a critical level at which leaf yellowing will occur. Detached leaves dipped in 6–8% sugar solutions for 2 h showed both an increase in leaf total sugar content and retarded leaf yellowing.

Total amino acids accumulated in the outer leaves when pak choy was stored at ambient temperature, apparently due to protein hydrolysis.

Hot water treatments (46–48°C for 10 min) reduced yellowing of intact pak choy without inducing heat injury. Optimal treatments resulted in better control of yellowing, suggesting there may be commercial application for hot water treatments. Similar findings have also been found with broccoli florets, with lower Fv/Fm ratios associated with maintenance of green colour (Tian et al. 1996).

**Table 4.** The effect of silver ions (supplied by silver thiosulfate—STS) on the leaf hue angles of intact pak choy stored at 20°C for 3 days.

	Hue angle					
	Outer leaves		Middle leaves		Inner leaves	
	initial	3 days	initial	3 days	initial	3 days
STS	118.60	106.18	118.42	114.06 <sup>a</sup>	121.12	118.51 <sup>b</sup>
Water	119.03	106.73	119.16	104.64	122.47	115.30

<sup>a</sup> Significant (P = 0.01)

<sup>b</sup> Significant (P = 0.05)

**Table 5.** The effect of silver ions (supplied by silver thiosulfate—STS) on yellowing of detached leaves treated with ethylene (stored at 20°C for 3 days).

Ethylene (ppm)		Hue angle	
		Outer leaves	Inner leaves
600	Nil	101.60	110.22
	STS	109.91 <sup>a</sup>	114.47 <sup>b</sup>
60	Nil	103.71	112.88
	STS	110.52 <sup>a</sup>	115.32 <sup>b</sup>
6	Nil	109.45	112.05
	STS	109.08	114.50 <sup>b</sup>
0.6	Nil	107.04	117.51
	STS	108.00	119.06

<sup>a</sup> Significant (P = 0.01)  
<sup>b</sup> Significant (P = 0.05))

**Table 6.** Effect of ethylene on hue angle of intact leaves (stored at 20°C for 3 days).

Ethylene (ppm)	Outer leaf hue angle	Inner leaf hue angle
6 000	78.79 b	114.70 a
600	96.84 b	110.94 c
60	110.08 a	113.70 ab
6	109.87 a	113.61 ab
0.6	111.54 a	114.30 ab
Nil	112.48 a	113.31 b

Note: means within a column with the same letter are not significantly different (P = 0.05).

**Table 7.** Effect of leaf position on initial sugar content (%).

	Glucose	Fructose	Sucrose	Total sugar
Outer leaves	0.13 <sup>a</sup>	0.11 <sup>a</sup>	ND	0.24 <sup>a</sup>
Inner leaves	0.33	0.29	ND	0.62

<sup>a</sup> Significant (P = 0.01)  
<sup>b</sup> ND = not detectable

**Table 8.** Effect of storage at 20°C on leaf sugar, amino acid and chlorophyll concentrations.

	Outer leaves					Inner leaves				
	initial	1 day	2 days	3 days	4 days	initial	1 day	2 days	3 days	4 days
Total sugar (%)	0.24	0.19	0.14	0.11	0.16	0.62	0.52	0.41	0.33	0.29
Total amino acids (%)	0.10	0.125	0.225	0.35	0.80	0.40	0.28	0.35	0.65	0.45
Proline (%)	0.001	nil	nil	nil	nil	0.003	0.003	0.003	0.006	0.008
Chlorophyll (mg/100 g)	135	105	69	45	32	134.8	105	88	80	75

**Table 9.** Effect of storage at 2°C on leaf sugar, amino acid and chlorophyll concentrations.

	Outer leaves					Inner leaves				
	initial	2 days	4 days	6 days	8 days	initial	2 days	4 days	6 days	8 days
Total sugar (%)	0.24	0.34	0.19	0.19	0.06	0.62	0.57	0.39	0.35	0.14
Total amino acids (%)	0.10	0.175	0.35	0.21	0.19	0.40	0.20	0.50	0.35	0.15
Proline (%)	0.001	nil	nil	nil	nil	0.003	nil	0.002	0.001	0.004
Chlorophyll (mg/100 g)	130	114	105	94	88	135.1	120	110.4	101.8	90.2

**Table 10.** The effect of sugar dipping followed by storage of 2 days on yellowing of detached outer leaves.

Treatment	Hue angle					
	Dipped 1 hour		Dipped 1 hour		Dipped 1 hour	
	initial	2 days	initial	2 days	initial	2 days
2% sugar	120.53	103.33	119.64	105.66	119.64	105.74
Control	120.56	103.81	120.48	104.62	120.78	104.91
4% sugar	118.54	103.50	120.00	105.50 <sup>a</sup>	118.55	105.82 <sup>a</sup>
Control	118.71	103.87	119.91	103.83	118.80	102.93
6% sugar	119.71	105.15 <sup>a</sup>	119.47	106.37 <sup>a</sup>	120.10	104.63 <sup>a</sup>
Control	119.03	102.32	120.99	102.07	120.38	100.47
8% sugar	119.38	103.80 <sup>a</sup>	118.29	104.77 <sup>a</sup>	118.98	102.38
Control	119.39	101.64	118.00	100.83	119.21	102.73

<sup>a</sup> Significant (P = 0.05)**Table 11.** The effect of sugar dipping time on the hue angle of detached outer leaves over 3 days of storage.

	Hue angle					
	6% sugar			8% sugar		
	initial	2 days	initial	2 days	initial	2 days
Dipped 1 h	126.32	101.99	98.97 <sup>a</sup>	118.32	109.25	104.43 <sup>v</sup>
Control	126.02	101.87	89.91	118.58	109.01	98.19
Dipped 2 h	123.79	108.64 <sup>a</sup>	97.23 <sup>a</sup>	118.84	114.15 <sup>a</sup>	108.63 <sup>a</sup>
Control	124.03	98.97	93.61	118.23	102.42	93.82
Dipped 3 h	126.93	111.02 <sup>a</sup>	100.73 <sup>a</sup>	119.56	107.50	96.92
Control	126.90	108.49	98.15	118.02	107.71	95.48
Dipped 4 h	118.26	111.14 <sup>a</sup>	94.77 <sup>a</sup>	118.10	106.71	91.45
Control	118.79	108.07	92.57	118.99	106.53	90.50
Dipped 5 h	118.45	111.13 <sup>a</sup>	101.47 <sup>a</sup>	118.63	102.40	90.49
Control	119.12	107.81	91.31	119.00	104.92	92.53

<sup>a</sup> Significant (P = 0.05)**Table 12.** The effect of sugar treatment on sugar and amino acid content of detached leaves after 2 days of storage at ambient temperature.

	Total sugar (%)	Total amino acid (%)
6% sugar, dipped 2 h	0.411 <sup>a</sup>	0.28
Control	0.102	0.30

<sup>a</sup> Significant (P = 0.01)**Table 13.** The effect of hot water treatment on the hue angle of outer leaves of intact pak choy.

Temperature	Hue angle	
	Stored at 2°C	Stored at 20°C
48°C	111.2 a	110.3 a
46°C	112.3 a	110.3 a
44°C	106.8 b	104.6 b
42°C	106.4 b	101.5 c
40°C	101.5 c	97.0 d
38°C	100.0 c	94.5 e
Ambient	96.3 d	93.5 e

Note: means within a column with the same letter are not significantly different (P = 0.05).

**Table 14.** The effect of the 48°C hot water treatment on sugar content of intact leaves stored at 2°C for 4 days.

		Glucose	Fructose	Sucrose	Total sugar
Inner leaves	Treated	0.22	0.14	nil	0.36
	Control	0.24	0.15	nil	0.39
Outer leaves	Treated	0.20 <sup>a</sup>	0.16 <sup>a</sup>	0.14	0.50 <sup>a</sup>
	Control	0.10	0.11	nil	0.21

<sup>a</sup> Significant (P = 0.05)

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## References

- Aharoni, N., Philosoph-Hadas, S. and Barkai-Golan, R. 1985. Modified atmospheres to delay senescence and decay of broccoli. In: Blankenship, ed., Controlled atmospheres for storage and transport of perishable agricultural commodities. North Carolina State University, Department of Horticultural Science, 169–177.
- Batal, K.M., Heaton, E.K., Granberry, D.M., and Beuchat, L.R. 1982. Effects of N<sup>6</sup>-benzyladenine and storage temperature on shelf-life and quality of raw and cooked broccoli (*Brassica oleracea* L. var *italica*). Journal of Food Science, 47, 1675.
- Helwig, J.T. and Council, K.A. 1979 SAS user's guide. Carey, New Jersey, SAS Institute, Inc.
- Hirata, K., Chachin, K. and Iwata, T. 1987. Quality changes of some vegetables used in tropical and subtropical areas during storage at various temperatures. Journal of the Japanese Society of Food Science and Technology, 34, 566–573.
- Ishii, K. and Shinbori F. 1988. Respiration rate and the relation between changes in some chemical components and appearance quality of turnips (*Brassica campestris* L.). Journal of the Japanese Society for Horticultural Science, 57, 319–323.
- Kazami, D., Sato, T., Nakagawa, H. and Ogura, N. 1991. Effect of pre-harvest hot water dipping of broccoli heads on shelf life and quality during storage. Journal of the Japanese Agricultural Chemical Society, 65, 19–26.
- King, G.A. and Morris, S.C. 1994a. Early compositional changes during post harvest senescence of broccoli. Journal of the American Society of Horticultural Science, 119, 1000–1005.
- King, G.A. and Morris, S.C. 1994b. Physiological changes of broccoli during early post harvest senescence and through the post harvest continuum. Journal of the American Society of Horticultural Science, 119, 270–275.
- Little, A.C. 1975. Off on a tangent. Journal Food Science, 40, 410.
- O'Hare, T.J., Smith, L.G., Wong, L.S. and Meiburg, G.F. 1995. Low-oxygen storage of whole and minimally-processed pak choi. Proceedings of the Australasian Post Harvest Conference, Melbourne, 18–22 September, 459–462.
- Pendergrass, A., Isenberg, F.M.R., Howell, L.L. and Carroll, J.E. 1976. Ethylene-induced changes in appearance and hormone content of Florida grown cabbage. Canadian Journal of Plant Science, 56, 319.
- Pratt, H.K. and Goeschl, J.D. 1969. Physiological roles of ethylene in plants. Annual Review of Plant Physiology, 20, 541.
- Shewfelt, R.L., Heaton, E.K. and Batal, K.M. 1984. Nondestructive color measurement of fresh broccoli. Journal of Food Science, 49, 1612–1613.
- Tian, M.S., Davies, L., Downs, C.G., Liu, X.F. and Lill, R.E. 1995. Effects of floret maturity, cytokinin and ethylene on broccoli yellowing after harvest. Postharvest Biology and Technology, 6, 29–40.
- Tian, M.S., Downs, C.G. Lill, R.E. and King, G.A. 1994. A Role for ethylene in the yellowing of broccoli after harvest. Journal of the American Society of Horticultural Science, 119, 276–281.
- Tian M.S., Woolf, A.B., Bowen, J.H. and Ferguson, I.B. 1996. Changes in color and chlorophyll fluorescence of broccoli florets following hot water treatment. Journal of the American Society of Horticultural Science, 121, 310–313.
- Wade, N.L. and Morris, S.C. 1982. Rapid determination of sugar in cantaloupe melon juice by high-performance liquid chromatography. Journal of Chromatography, 240, 257–261.
- Wang, H. and Herner, R.C. 1989. Effect of CA storage on the ultrastructure of chloroplasts and chlorophyll content of Chinese mustard. In: Proceedings of the Fifth International CA Research Conference, 2, 9–17.



# Evaluation of the Maturity Index for Durian Fruit by Various Destructive and Nondestructive Techniques

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## Abstract

Durian is one of the most economically important fresh fruits of Thailand. Exported durian are often rejected by the market because of an immature fruit problem. Sorting immature from mature fruit is quite difficult even for an experienced person. Moreover, there is no acceptable, objective index to determine fruit maturity after harvest. In this research, various techniques for maturity evaluation were performed and compared—both destructive and nondestructive. Nondestructive measurements were made by external examination using experienced harvesters, counting the days required for proper ripening, scanning the pulp image to obtain CT numbers using medical X-ray computed tomography (X-ray CT) and scanning the pulp with near infrared spectroscopy (NIRS). The methods were evaluated and compared to the sensory test of the ripened pulp. The results showed that there were correlations between the maturity stages evaluated by the sensory test and several destructive and nondestructive measurements, including visual evaluation, days to ripen, X-ray CT and NIRS.

DURIAN (*Durio ziberthinus* Murray) is one of the most economically important fresh fruits of Thailand. The major problems experienced in exporting durian are the difficulty of differentiating between immature and mature fruit, even by experienced sorters, resulting in a significant proportion of immature fruit reaching the market (10–50%) during the early harvesting season, and uneven ripening during the heavy rainy season. These problems cause a significant loss of confidence in this product and often bring down the market price, since immature or unevenly ripened fruit will not ripen, or else ripen with significantly less flavour and taste, and are usually discarded. Therefore, it would be extremely beneficial to develop an objective, destructive method, as well as a nondestructive evaluation technique, for detecting this problem.

Use of X-rays is a common nondestructive technique for internal quality evaluation of fruits and

vegetables. They can easily penetrate the bulky tissue of most agricultural products. X-ray transmission, which depends on the mass density and mass absorption coefficient of the material, has been used to detect bruises in apples (Diener et al. 1970), spongy tissue in radish head (Marcelis et al. 1995), hollow heart in potatoes (Finney and Norris 1973), and defects and damage in watermelon (Tollner 1993). X-ray computed tomography (X-ray CT) can generate a precise cross-section image of an object electronically using a movable X-ray source and detector assembly. This method has been used to determine vapour heat treatment injury in papaya (Suzuki et al. 1994), woolly breakdown in nectarines (Sonego et al. 1995), internal defects disorder of durian, mangosteen and mango (Yantarasri et al. 1997a; Yantarasri and Sornsrivichai 1998), dry juice sac and granulation of tangerine fruits (Yantarasri et al. 1998) and internal bruising and ripeness of pineapple (Yantarasri et al. 1999).

Near infrared spectroscopy (NIRS) is widely used for the identification of organic compounds. Norris and Hart (1965) studied NIR reflectance and transmittance characteristics of many agricultural products and

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found that radiation in the NIR region of the spectrum can provide information related to many quality factors of agricultural products. Methods using NIRS have been used to determine soluble solids in peach (Kawano et al. 1992; Pieris et al. 1998), satsuma mandarin (Kawano et al. 1993), cantaloupe (Dull 1984), apple (Lee et al. 1997) and mango (Yantarasi et al. 1997b).

The purpose of this paper is to examine the various existing methods, as well as to develop comparative results, so that an objective, standard evaluation method can be established. Furthermore, for quick, on-line and real-time quality assurance in packing operations, the nondestructive technique of X-ray CT and partially destructive NIRS method have been tested as possible tools for determining a quantitative maturity index for durian.

## Materials and Methods

Fresh 'Monthong' durian were harvested at Janthaburi and Trat Provinces, eastern Thailand. Their maturity was evaluated by various destructive and nondestructive techniques. Nondestructive measurements were made by external examination using experienced harvesters, counting the days required for proper ripening, and nondestructively scanning the pulp image to obtain CT numbers using X-ray CT (Spiral Computed Tomography GE model Prospeed SX) at 80kV and 80mA with 3.0 s exposure time and a 10 mm slice thickness of image. For the NIRS test, a commercially available NIR instrument (Model 6500, Foss NIR Systems, Silver Springs, USA) generated spectral data in the wavelength region from 400–2,500 nm. Spectra were acquired after the pulp sample was equilibrated in an air-conditioned laboratory at 22–25°C.

75 durian fruit were used for the experiment. External evaluation of different maturity stages was performed by experienced harvesters. The pulp of the fruit was scored by a sensory panel for flesh colour, odour, sweetness, nutty taste, texture, flesh fibre, and seeds. Each fruit was then measured for its soluble solids content, total sugar and dry weight.

## Results and Discussion

Maturity evaluated by experienced harvesters was significantly correlated with the fruit maturity determined by the sensory panel, with an  $R^2$  value of 0.99 (Figure 1). Days to ripen of each fruit after harvest also showed a good correlation with the sensory panel's evaluation, with an  $R^2$  value of 0.96 (Figure 2). Comparison of taste panel results and chemical analysis for total soluble solids ( $^{\circ}$ Brix), total sugar (%) and dry weight (%) also showed significant correlation with  $R^2$  values of 0.99, 0.98 and 0.97, respectively (Figure 3). Table 1 shows that there was a statistically significant difference in soluble solids and total sugar between 50, 60, 70 and 80% maturity, and a significant difference in dry weight between 50, 60 and 70% maturity, but no difference in dry weight between 70 and 80% maturity.

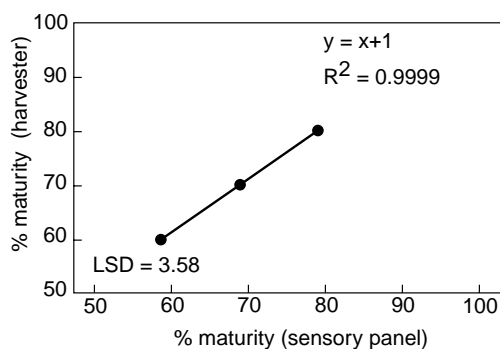
For the nondestructive X-ray CT test, the intensity of the images differed for various parts of the fruit (Figure 4). The darkest region of the image corresponded to the air space outside the fruit, between peel and pulp, and between pulp and seed. A grey region of the image corresponded to the peel, while a lighter grey region corresponded to the pulp. The whitest region corresponded to the seed. The pulp of the mature fruit had a lighter image intensity than the immature one.

**Table 1.** Stage of durian fruit maturity evaluated by a taste panel, and measurement of the soluble solids content, total sugar and dry weight. Means within a column followed by different letters are significantly different (P A 0.01).

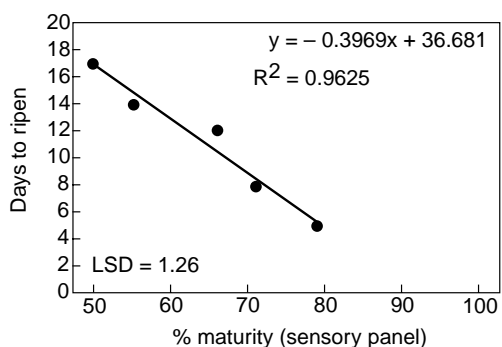
% maturity evaluated by sensory panelists	Soluble solids ( $^{\circ}$ Brix)	Total sugar (%)	Dry weight (%)
50	16.0 d	6.79 d	5.13 c
60	19.4 c	9.26 c	6.10 b
70	23.4 b	11.89 b	7.45 a
80	26.1 a	13.30 a	7.75 a
F-test	***	**	**
CV <sup>b</sup> (%)	10.83	16.78	12.98

<sup>a</sup> \*\* = statistically significant (P A 0.01)

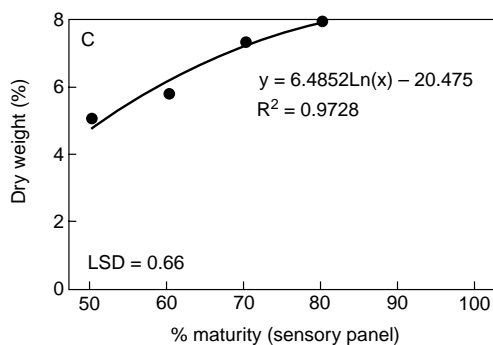
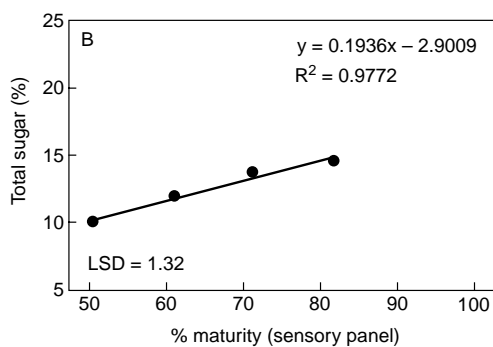
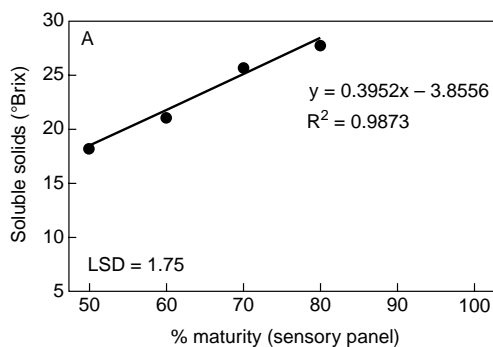
<sup>b</sup> CV = coefficient of variance



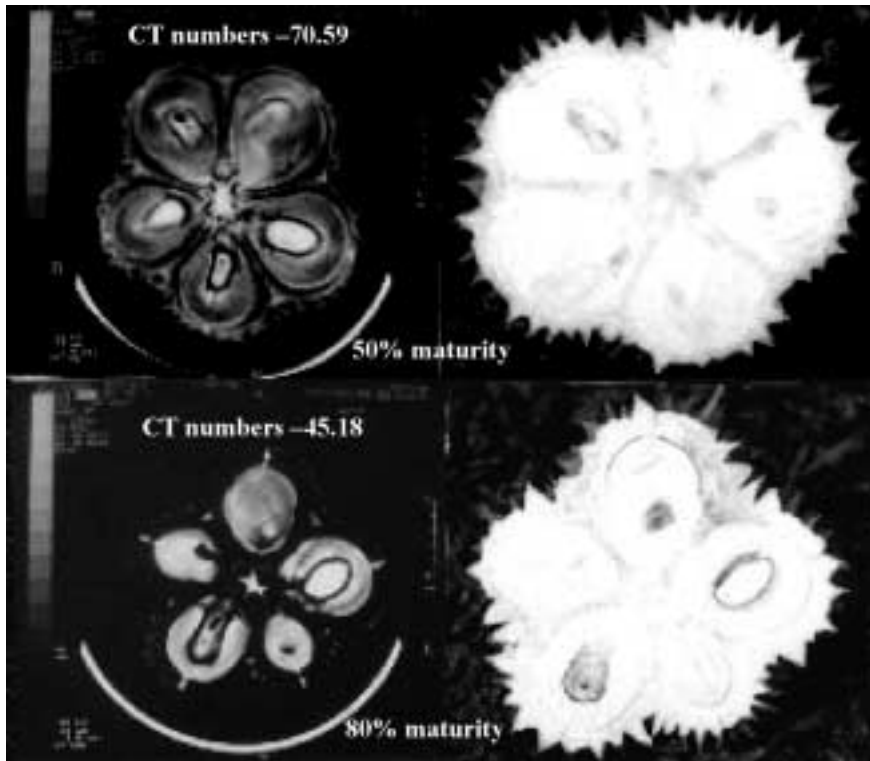
**Figure 1.** Comparison between % maturity as evaluated by the harvester and the sensory panel.



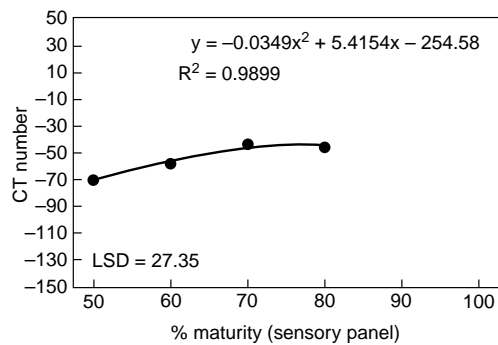
**Figure 2.** Comparison between days to ripen and % maturity as evaluated by the sensory panel.



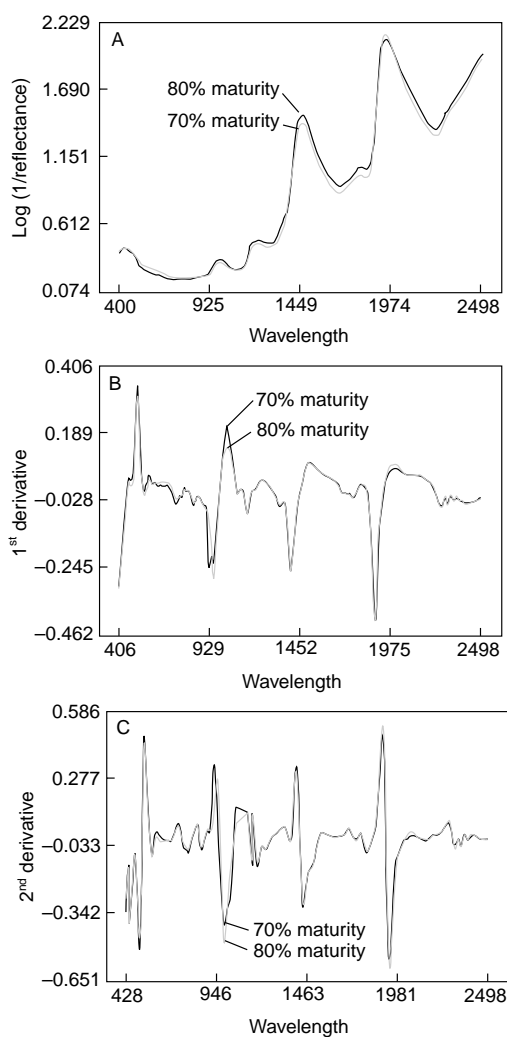
**Figure 3.** Comparison between the chemical analysis of soluble solids (A), total sugar (B) and dry weight (C), and % maturity as evaluated by the sensory panel.



**Figure 4.** X-ray computerised tomography (CT) images, showing CT numbers and actual photographs of durian at two stages of maturity: (A) 50% maturity, and (B) 80% maturity.



**Figure 5.** Comparison between computerised tomography (CT) numbers and % maturity as evaluated by the sensory panel.



**Figure 6.** Comparison of the raw absorption spectra (A), and the first and second derivative spectra (B and C, respectively) for durian at 50% and 80% maturity.

There was a significant difference between fruit of 50% maturity with a CT number of  $-70.59$ , and fruit of 80% maturity with a CT number of  $-45.18$ . The CT number computed from the image intensity shows an increasing trend with increased maturity with a polynomial relationship of  $R^2 = 0.99$  (Figure 5). Brecht et al. (1991) reported a similar finding in tomato, where X-ray CT images showed intense signal in the gel tissue of fully mature tomatoes which was brighter than in immature fruit. Suzuki et al. (1994) reported

CT numbers were lowest in unripened papaya fruit, while ripe fruit had higher CT numbers.

In the NIRS test, the spectra acquired from fruit of 70 and 80% maturity show a similar pattern of absorption ( $\log 1/\text{reflectance}$ ) with less absorption in fruit of 70% maturity than those of 80% maturity (Figure 6). From the conversion of the raw absorption spectra to the first and second derivative spectra, there was a difference in the absorbed value in some specific wavelengths between 70% and 80% maturity. For oil analysis based on 45 samples of mature fruit between 60–80% maturity used for establishing the calibration equation, the highest multiple correlation coefficient,  $R^2$ , of 0.81 was obtained in the linear regression equation at 10 selected wavelengths. For sugar analysis based on 60 samples of mature to ripened fruit for establishing the calibration equation, the highest multiple correlation coefficient,  $R^2$ , of 0.74 was obtained in the linear regression equation at 4 selected wavelengths.

In day-to-day practice, farmers, harvesters, packinghouse sorters and researchers utilise different techniques for the estimation of fruit maturity. There is some general understanding of what ‘maturity’ means, but definitions vary between people and production locations. The lack of a universal definition of maturity can lead to much confusion. Our research shows that total soluble solids, total sugar and dry weight may be used in combination for a destructive, quantitative index of maturity, while the X-ray CT technique shows potential for nondestructive, on-line sorting of immature from mature fruit. The spectrum analysis showed that the NIRS technique could be potentially developed for quick determination of quality as well as maturity of the durian pulp in the future.

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## References

Brecht, J.K., Shewfelt, R.L., Garner, J.C. and Tollner, E.W. 1991. Using X-ray computed tomography to nondestruct-

- tively determine maturity in green tomatoes. *HortScience*, 26, 45–47.
- Diener, R.G., Mitchell, J.P. and Rhoten, M.L. 1970. Using an X-ray image scan to sort bruised apples. *Agricultural Engineering*, 51, 356–361.
- Dull, G.G. 1984. Measurement of cantaloupe quality with near infrared spectrophotometry. *Transactions of the ASAE (American Society of Agricultural Engineers)*, 32, 321–326.
- Finney, E.E. and Norris, K.H. 1973. X-ray images of hollow heart potatoes in water. *American Potato Journal*, 50, 1–8.
- Kawano, S., Fujiwara, K. and Iwamoto, M. 1993. Nondestructive determination of sugar content in Satsuma mandarin using near infrared (NIR) transmittance. *Journal of the Japanese Society for Horticultural Science*, 62, 465–470.
- Kawano, S., Watanabe, H. and Iwamoto, M. 1992. Nondestructive determination of sugar content in intact peaches by near infrared spectroscopy with fiber optics in interactance mode. *Journal of the Japanese Society for Horticultural Science*, 61, 445–451.
- Lee, K.J., Hruschka, W.R., Abbott, J.A., Noh S.H. and Chen, Y.R. 1997. Comparison of statistical methods for calibrating soluble solid measurement from NIR interactance in apples. *Proceedings of the Korean Society for Agricultural Machinery 1997 Winter Conference*, 2, 206–212.
- Marcelis, L.F.M., Verkerke, D.R., van der Burg, W.J., Aartse, J.W., Frankhuizen, R. and Boekestein, A. 1995. Non-destructive evaluation of internal quality of radish tubers using specific gravity. *Acta Horticulturae*, 379, 527–535.
- Norris, K.H. and Hart, J.R. 1965. Direct spectrophotometric determination of moisture content of grain and seeds. *Proceedings of the 1963 international symposium on humidity and moisture*, volume 4. New York, Reinhold, 19–25.
- Pieris, K.H.S., Dull, G.G., Leffler, R.G. and Kays, S.J. 1998. Near-infrared spectrometric method for nondestructive determination of soluble solids content of peaches. *Journal of the American Society for Horticultural Science*, 123, 898–905.
- Sonego, L., Ben-Arie, R., Raynal, J. and Pech, J.C. 1995. Biochemical and physical evaluation of textural characteristics of nectarines exhibiting woolly breakdown: NMR imaging, X-ray computed tomography and pectin composition. *Postharvest Biology and Technology*, 5, 187–198.
- Suzuki, K., Tajima, T., Takano, S., Asano, T. and Hasegawa, T. 1994. Nondestructive methods for identifying injury to vapor heat-treated papaya. *Journal of Food Science*, 59, 855–857.
- Tollner, E.W. 1993. X-ray technology for detecting physical quality attributes in agricultural produce. *Postharvest News Information*, 4(6), 149N–155N.
- Yantarasi, T., Sornsrivichai, J. and Chen, P. 1997a. Nondestructive X-ray and NMR imaging for quality determination of mango fruit. Presented at the 5<sup>th</sup> International Symposium on Fruit, Nut and Vegetable Production Engineering, Davis, California.
- Yantarasi, T., Kawano, S., Sornsrivichai, J. and Chen, P. 1997b. Nondestructive NIR technique for sugar determination in intact mango. Presented at the 5<sup>th</sup> International Symposium on Fruit, Nut and Vegetable Production Engineering, Davis, California.
- Yantarasi, T., Sornsrivichai, J. and Chen, J. 1998. X-ray and NMR for nondestructive internal quality evaluation of durian and mangosteen fruits. *Acta Horticulturae*, 464, 97–101.
- Yantarasi, T. and Sornsrivichai, J. 1998. Internal quality evaluation of tangerines. *Acta Horticulturae*, 464, 494.
- Yantarasi, T., Sornsrivichai, J. and Kalayanamitra, K. 1999. Nondestructive techniques for quality evaluation of pineapple fruits. *The Third International Pineapple Symposium*, Pattaya, Thailand (in press).

# Quality Assurance for Export-oriented Citrus and Tomato Fruit in Morocco

A. Ait-Oubahou and M. El-Otmani\*

## Abstract

Morocco's horticulture sector is among the largest in the southern Mediterranean region in terms of production and export. The country's climatic conditions allow for the production of a wide range of fruits and vegetables of temperate, subtropical and tropical types. Annually, Morocco produces about 6–7 million t of fruits and vegetables, including 1.5 million t of citrus fruits and 450,000–750,000 t of tomatoes. Average export quantities represent about 550,000–600,000 t for citrus and 230,000–250,000 t for fresh tomato. The dominant destination is the European Union markets because of proximity, historical ties (mainly with France and Spain), and trade agreements with many European countries. Since 1986, the year in which Spain and Portugal became full members of the European Economic Community, Moroccan horticultural exports have been facing various barriers and difficulties regarding access to European Union markets. This type of protection aims to reduce free access to European markets and thus to reduce competition between Moroccan products and local production in Europe. These barriers include sanitary measures, quality control at ports of entry, entry fees, and quotas per month for specific products, including fruits and vegetables. As more than 90% of our exported horticultural produce has European Union markets as its final destination, Moroccan professionals have been obliged to develop appropriate means and techniques to improve quality and produce fruits and vegetables that are more competitive in the international markets, particularly those of Europe and North America.

MOROCCO'S CITRUS industry is one of the largest in the Mediterranean basin in terms of land occupation (75,000 ha), with annual production oscillating from 1–1.5 million t. Citrus fruit is by far the most important horticultural export crop, with an annual average of 550,000–600,000 t destined to European markets (MAMVA 1997). Harvest season starts with very early varieties such as 'Bekria' in late September and ends in June with late-season cultivars such as 'Valencia' late orange. Although several varieties are produced commercially, the main varieties which are exported are Clementine mandarins, including 'Fina' and 'Nour', and oranges represented by 'Washington' navel and 'Valencia' late. Clementine mandarin and navel and 'Valencia' late oranges represent more than 80% of citrus plantations. In recent years, plantations of new varieties, mainly the Clementine mandarin types such as 'Nour', 'Afourer' and 'Ortanique' are increasing. Over 70 packinghouses exist in the

country, treating over 1.2 million t of fruit (EACCE 1995). About 30% of that is 'discarded' (unsuitable for export) fruits which are sold either in the local market or used for processing. The percentage of discarded fruits is still high due to the requirements of European Union (EU) markets and the severe certification regulations for export. The citrus export volume to EU markets represents more than 75% of the total export (MAMVA 1997). France alone imports about 30% and Germany 15% of the total exported citrus fruit. Other destinations include Russia (9%), Canada (5%), Poland and Norway (importing 4% each).

The tomato export industry is based on winter production and export to Europe is allowed from October to the end of April, with quotas for each month and an annual total of 150,000 t. In the 1998/99 season, Morocco exported about 230,000 t of tomato, compared to 90,000 in the 1989/90 season (EACCE 1999). This large increase in export quantity is mainly due to the export of 35,000–40,000 t to the Russian market. Over the last decade there has been a substantial increase in export destinations as well as a

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significant improvement in production techniques. Most of tomatoes are exported to France (more than 80%), however this is only allowed in off-season when the European weather conditions do not permit a competitive production.

Since 1986, the year that Spain and Portugal entered the EU, different agreements have been signed with Morocco in order to limit this country's free access to European markets and thus to protect their own production. Preferential access was granted for some products that are not produced in Europe, while other crops were subjected to different restrictions, including annual and monthly quotas, a reference price system, and minimum prices under which taxes were imposed to the export contingent for a certain period. New restrictions include pesticide residue levels in the products, sanitary certification, declaration of importation, banning of certain chemicals, and stipulations on packaging types. In order to overcome these barriers and restrictions, Moroccan professionals have been obliged to meet all the requirements for export to EU markets. Nowadays, new strategies are being developed to comply with the market demand, including sanitary measures and quality considerations. The growers and exporters are thus making the necessary effort to produce and guarantee high produce quality in the foreign market. New strategies of production are now employed as well as introduction of new varieties with sought-after characteristics, including easy-to-peel Clementine mandarins ('Nour' and 'Afourer') and long shelf-life tomatoes.

For tomato, greenhouse production is dominant for winter crops while the open field is largely practiced for processing and summer crops. The production is done in a way to assure tracing the product pre and postharvest. Professionals are helped and supervised by specialists from research institutes, growers' associations, private consultants and experts. This association and collaboration between institutions and growers has improved production practices such as irrigation and fertilisation technology, quality and grade standards, and postharvest handling of different crops.

## Quality Control System

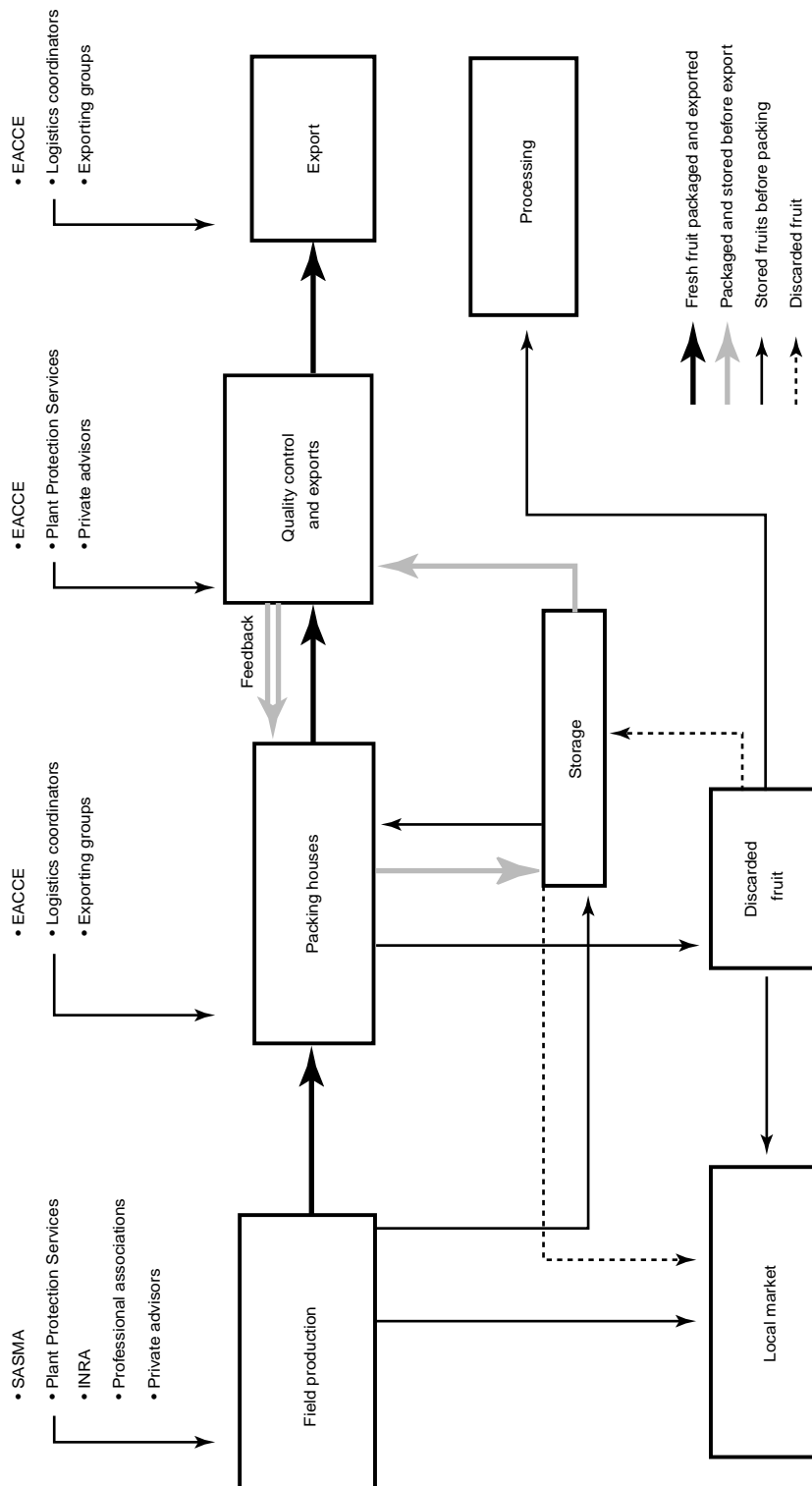
Quality control and standardisation are under the responsibility of a public sector enterprise known as Etablissement Autonome du Contrôle et de la Coordination des Exportations (EACCE). Other activities of this institution include quality inspection (maturity,

pesticide residues etc.), certification for export products (sanitary as well quality standards) and the coordination of exported quantities through consultation with exporting groups and associations. Two laboratories of EACCE, one in Casablanca and another in Agadir, are used for quality analysis of different crops. Quality inspection and certification take place at the port for sea shipments or in the packinghouse for land transport using refrigerated trucks and containers. EACCE has offices in several countries in Europe to follow the quality, quantities and the prices of the products. Adherence to exported quantities quotas, periods of export, marketing regulations and other clauses of the agreements between EU and Morocco are the responsibility of EACCE. This quality control organisation also gives license and authorisation for packinghouses to operate for export purposes. Different criteria related to quality are evaluated objectively and subjectively based on importers' standards and requirements. Société Agricole des Services au Maroc (SASMA), an advisory institution financed by growers' associations of citrus and vegetables, is also participating, through technical support and technology transfer. This institution has laboratories for quality and pesticide residue analysis. Growers can seek information and support free of charge, and receive recommendations for leaf, soil, water, and pesticide residue analysis from SASMA for a minimal fee.

## Preharvest Considerations for Quality Assurance

Both EACCE and SASMA, as well as other institutions such as Institut Agronomique et Vétérinaire (IVA) Hassan II, Institut National de la Recherche Agronomique (INRA), Plant Protection Services and the logistics organisation, are heavily involved with growers and exporters in order to produce and ensure good quality and safe produce for export (Figure 1). Implementation of a field sanitary program to identify and prevent factors that will adulterate the product is becoming an important concern for growers and exporters. Nowadays, fruit production and handling tracing is required by the importers and thus all major operations, from planting to export, must be documented. This approach ensures a better understanding of the steps and conditions to which the fruit has been subject.





**Figure 1.** Different channels of fruit from the field to its final destination (SASMA = Société Agricole des Services au Maroc, INRA = Institut National de la Recherche Agronomique, EACCE = Etablissement Autonome du Contrôle et de la coordination des Exportations).

In addition, sanitary and environmental issues are becoming a major concern in modern agriculture. For tomato production, particularly for the cultivars that are sensitive to nematodes, the use of methyl bromide for soil disinfestation will be totally banned in the near future. At the same time, residues of pesticides and heavy metals in the fruits are not tolerated. The new trend is to use alternatives of disinfestation, such as cultural practices, solarisation, grafted tomatoes using tolerant rootstocks, and implementing the integrated pest management (IPM) strategy. The IPM approach is spreading rapidly among growers in the major areas producing 'primeurs' (winter crops). Other preharvest factors that are regularly monitored include irrigation water quality (with respect to pesticides, nitrates and heavy metals), application methods and nature of chemicals, and hygiene of field workers—mainly during the harvest season where the fruits can be easily contaminated when injured or bruised. Equipment and materials used during harvest are regularly cleaned.

### **Postharvest Considerations for Quality Assurance**

Harvested fruits undergo many changes which lead to senescence and deterioration. The quality of citrus and tomato fruits is determined by preharvest factors (e.g. variety, maturity stage and cultural practices) and postharvest care during harvesting, handling, packaging, transport, storage, and distribution. Each step must be controlled and verified in order to meet quality standards. Citrus and tomato packinghouses are now well convinced of the necessity for certification and thus many of them are implementing strategies to comply with quality system and International Standards Organisation (ISO) 9000 standards. Some of the aspects that are influenced by certification include technical advising, handling, packaging, storage and export systems.

For packing fruits, it is advised that all packinghouses must be isolated from other industrial facilities to avoid any contamination. Several units which were located in urban areas have been moved outside the cities, and are now often built in the production farms. For sanitary reasons, all facility openings are monitored to avoid the entry of animals like birds, lizards, cats etc. Nets are placed on windows and other openings.

The main operations which have a direct effect on postharvest quality are dumping, sorting, sizing, treatment application, packing, and loading onto pallets. Each operation must fulfill the required standards of quality and hygiene. Every point must be checked daily to prevent any damage or contamination of fruits. Different measures, including monitoring, prevention and correction, are taken for each critical point. Continuous monitoring of workers' activities, and quality inspection at different levels of the packing line, is required. Packing lines are designed in such a way as to allow easy access to different operations from dumping fruits to packing tables. Separation of incoming fruits and discarded fruits from the packing line area is obligatory. The dumping area is also separated from the area where other operations of handling are executed. Waste and decayed fruits are removed daily to avoid any contamination of the facility, and decayed fruits are dumped in tanks or buckets containing a solution of sodium hypochlorite. The packinghouses are checked routinely to avoid entry of birds, rats and other contaminants such as insects. Disinfestation of the facility is done frequently through monitoring the level of contamination and the build-up of pathogens. Packing line equipment is cleaned daily and sanitised using a sodium hypochlorite solution. Waste and foreign materials (debris, paper etc.) are removed daily.

Fruits are sorted into different sizes and packaged according to the market requirements and different countries' regulations. Fruits are handled in such a way that none of the different operations will cause any damage. The packing boxes and material must be certified by EACCE before use and no reuse of export boxes is tolerated. The packages are designed to conform with EU standards and must contain information regarding the product variety, size, colour, number of fruits or weight, origin of the product, packinghouse and grower's code, exporting group, product category, type of postharvest treatment applied, length and width of the package, and the number of units per pallet. Other precautions are taken in order to minimise postharvest problems during export and along the marketing channels. The identification of the probable hazards and means of prevention are presented in Table 1.

**Table 1.** Potential hazards during harvesting and postharvest handling.

Operation	Potential hazard	Prevention method
Hand harvest	<ul style="list-style-type: none"><li>• Contamination through dirty hands, faeces and chemicals</li><li>• Cuts and bruises</li></ul>	<ul style="list-style-type: none"><li>• Monitor workers' hygiene (cut nails, washing and clean hands, no smoking)</li><li>• Inspect harvested fruits</li></ul>
Transport containers	<ul style="list-style-type: none"><li>• Contaminated boxes, crates with soil, pathogens, nails, rough surfaces (abrasive)</li><li>• Bruising and damage (overfilled boxes, high speeds during transport)</li></ul>	<ul style="list-style-type: none"><li>• Use clean equipment and material (wash and sanitise with sodium hypochlorite)</li><li>• Avoid damage of fruits</li><li>• Handle with care</li></ul>
Packing line	<ul style="list-style-type: none"><li>• Pathogen accumulation on fruits, equipment, soil, walls</li><li>• Workers—carriers of infectious pathogens</li></ul>	<ul style="list-style-type: none"><li>• Clean equipment daily and sanitise with chlorine</li><li>• Eliminate bruised and decayed fruits daily</li><li>• Disinfect regularly</li><li>• Monitor sanitation and hygiene</li><li>• Clean toilets, provide soap for workers</li><li>• Medical check up and certificate at least once a year</li></ul>
Treatment application	<ul style="list-style-type: none"><li>• Residues on product</li></ul>	<ul style="list-style-type: none"><li>• Monitor concentration and application methods</li></ul>
Packaging	<ul style="list-style-type: none"><li>• Contamination of packages (soil, dirt, birds faeces etc.)</li></ul>	<ul style="list-style-type: none"><li>• Use of clean packages</li></ul>
Storage facilities	<ul style="list-style-type: none"><li>• Build-up of pathogens on walls</li><li>• Decayed fruits</li></ul>	
Transport	<ul style="list-style-type: none"><li>• Microbial accumulation on walls</li><li>• Temperature problems (high/low)</li><li>• Inadequate ventilation</li></ul>	<ul style="list-style-type: none"><li>• Clean and sanitise trucks</li><li>• Monitor temperature and air circulation inside the truck during transit</li></ul>

## References

- EACCE (Etablissement Autonome du Contrôle et de la coordination des Exportations) 1995. Répartition de la capacité de conditionnement, d'entreposage frigorifique et de déverdisage par région. Casablanca, EACCE.
- EACCE (Etablissement Autonome du Contrôle et de la coordination des Exportations) 1999. Bilan chiffré des exportations d'agrumes et primeurs. Casablanca, EACCE.
- MAMVA (Ministère de l'Agriculture et de la Mise en Valeur Agricole) 1997. Bilan de la production et des exportations agrumicoles 1996–1997. Rabat, Direction de la Production Végétale, MAMVA.

# Workshop Reports

# Workshop A

## Fruit Quality

The Fruit Quality Workshop was facilitated by Colin Bunt and Marie Piccone of Piccone PHC, Australia, and was attended by over 45 conference delegates, representing many countries and professional disciplines and each with a wealth of experience.

### *Workshop objectives*

The primary objectives of the workshop were to:

- Facilitate a ‘hands on’ exercise in working in Quality Teams, where groups of people with differing skills and backgrounds work together in solving common problems.
- Consider a range of issues pertinent to the successful development of quality systems in food industries.

### *Activities*

The workshop participants broke into five groups, each of which spent time considering one of the following questions:

- How best can quality networks and teams be established and what are the key success factors in making quality networks function effectively?
- How can market research be used in focusing and ‘driving’ the development of quality systems in the fruit industry?
- How can we measure the true costs of quality and the cost benefits of a well designed and functioning quality system?
- How can quality systems be used to identify, integrate and successfully manage regulatory, business and marketing issues?
- Why is the development and use of a ‘common language’ so important in the development and implementation of quality systems and how can we ensure a common understanding amongst industry sectors?

The questions put to the workshop teams were not meant to be ‘easy’. What they were designed to do was to stimulate discussion amongst the team members and make people think—often about subjects they had not considered before or had limited direct experience of, hence the requirement for a Quality Team approach.

### *Outcomes*

There was very enthusiastic participation from all workshop attendees. The general consensus was that the workshop was ‘good work, good experience and good fun’.

Every person attending the workshop made a contribution to its success.

Many relevant issues and key success factors were identified and discussed in regard to developing quality systems in the food industry.

The workshop proved a valuable exercise in the importance of establishing and working in Quality Teams and the benefits to all parties that can result. It was also recognised by the group that establishment of Quality Teams was the first step in effective quality planning.

*Marie Piccone and Colin Bunt*  
*Co-convenors*

# Workshop B

## Ship Fumigation

This workshop was attended by 28 persons, who actively questioned presentations and participated in discussions arising from presentations made during the workshop.

In-ship fumigation of grains and other commodities is a disinfestation technique that has been developed over the past 25 years. The technique is applied in many countries around the world for both static (in port) and in-transit disinfestation for quarantine or trade (contract) reasons. Worldwide it is estimated that some 40–50 million tonnes of grain and other commodities were disinfested using this technique during 1998.

This workshop specifically drew attention to the extent to which this fumigation technique is used in the South Asian region. For example, during 1999 in India, Vietnam and Thailand alone, it is estimated that approximately 15 million tonnes of grain were disinfested while loaded in ships. In Vietnam this involved about 400 vessels, of which approximately 70% were tween deckers.

Presently in the South Asian region, more than 80% of these fumigations are undertaken using methyl bromide. Use of this fumigant is subject to international controls through the Montreal Protocol due to its powerful ozone-depleting properties, and its use in developing countries (for applications other than quarantine and pre-shipment treatments) is presently due to be phased out by 2015.

The workshop commenced with three introductory presentations by members of the International Maritime Fumigation Organisation (IMFO) that set the scene with respect to:

- current ship fumigation practice worldwide, by Mr Chris Watson;
- current ship fumigation in Vietnam, by Mr Nguyen Bao Son; and
- new developments in ship fumigation practice, by Mr Dennis Bureau.

Given that in-ship fumigation is an established disinfestation technique in the region, and that much of the grain treated in this manner is traded internationally, the speakers highlighted the need to identify safe and effective alternatives to methyl bromide (Watson et al. 1999, Watson et al. these proceedings) to allow the continued use of this technique.

Presently phosphine is the only replacement fumigant available for immediate use with this technique. However, the need to use this fumigant correctly, and sustainably, was highlighted and subject to considerable discussion during presentations at the workshop. Specifically attention was drawn to the need to:

- ensure that fumigant is evenly distributed throughout the stow;
- ensure that lethal fumigant concentrations are achieved and maintained over internationally accepted exposure periods; and
- agree and harmonise application techniques and dosage regimes on a regional basis to facilitate regional and international trade.

With these objectives in mind, participants at the workshop suggested that steps should be taken within the ASEAN region to:

- obtain regional recognition of phosphine as an alternative to methyl bromide for in-ship fumigation;
- obtain regional recognition of phosphine as a disinfestation procedure for phytosanitary and quarantine purposes; and
- codify approved methods for safe and effective in-ship fumigation.

These proposals were submitted to the seminar organisers as recommendations from this workshop for inclusion in the seminar outcomes/recommendations.

#### *Reference*

Watson, C.R., Pruthi, N., Bureau, D., Macdonald, C. and Roca, J. 1999. Intransit disinfestation of bulk and bagged commodities: a new approach to safety and efficacy. In: Jin Zuxun, Liang Quan, Liang Yongsheng, Tan Xianchang, and Guan Lianghua, ed., *Stored product protection. Proceedings of the 7<sup>th</sup> international working conference on stored product protection*, Beijing, People's Republic of China, 14–19 October 1998, volume 1. Chengdu, Sichuan Province, Sichuan Publishing House of Science and Technology, 462–476.

*C.R. Watson and J.E. van S. Graver*  
*Co-convenors*

# Workshop C

## Contaminant Management

This workshop was attended by about 15 delegates. From the floor, a range of contaminants of agricultural produce of concern were recognised. These included:

### 1. Pesticides

- Primary applications for control of pests
- Secondary contamination as a result of environmental contamination, drift and in run-off.

### 2. Mycotoxins

- As natural products of fungal growth
- Highly variable levels of contamination. This raised issues with respect to their measurement.

### 3. Microbes and microbial endotoxins

- *Listeria*, *Salmonella*, *Staphylococcus*, *Esherichia coli* etc.
- Microbial endotoxins.

The concern expressed was a result of perceived impacts in the areas of

#### a. Human health

- Direct toxic effects
- Indirect effects, e.g. carcinogenicity,

#### b. Animal health

- Loss of production
- Antibiotics and reduced effectiveness,

#### c. Responsible agriculture

- Environmental protection.

### Confronting the issues

In confronting the issues involved, a number of factors were suggested as important and needing better definition. These included the following factors:

- acceptable levels of contamination;
- direct toxic effects where there is heavy contamination;
- indirect effects, e.g. carcinogenicity;
- setting maximum residue limits (MRLs), which may vary from country to country, depending on consumption patterns;
- health;
- trade issues;
- meeting MRLs;
- withholding periods and their enforcement; and
- education about all these factors and with the aim of reducing contamination.



### *Solutions*

Monitoring was suggested as the most urgent need. Issues that emerged in discussion included:

- laboratory analysis and aspects such as cost and relative accuracy;
- simple tests, such as enzyme-linked immunosorbent assay (ELISA) techniques, which deliver quick, cheaper analysis and the possibility of much more extensive screening to indicate negatives;
- specificity and screening – the most specific is not necessarily the best analysis where screening for a group of compounds may yield enough information to allow effective action to be taken; and
- official analytical methods versus simple tests.

Attention was drawn to Kennedy et al. 1998. The executive summary of this book provides an excellent prescription for dealing with contamination of agricultural produce with pesticide residues. The key issues and recommendations to which attention was drawn included:

- monitoring of residues in produce and the environment;
- research into contaminant behaviour;
- development of test methods;
- the role of integrated pest management;
- remediation of contaminated produce;
- training and extension; and
- networking and collaboration between researchers and others.

The workshop closed with an affirmation that there was a need for targeted programs adopting these recommendations.

### *Reference*

Kennedy, I.R., Skerritt, J.H., Johnson, G.I. and Highley, E. (ed.) 1998. Seeking agricultural produce free of pesticide residues. ACIAR Proceedings No. 85. Canberra, Australian Centre for International Agricultural Research, 406p.

*Ivan Kennedy and Amanda Hill*  
*Co-convenors*

# Workshop D

## Grain Quality Issues

### *Grain and seed quality problems raised by different countries*

#### *Cambodia*

- Seed germination
- Seed storage
- Seed vigour
- Seed processing
- Mill turnout
- Damage to grain in the milling process

#### *Vietnam*

- Red rice contamination
- Poor milling yield
- Yellowing (grain discoloration), light to heavy
- Control of yellowing, important for export trade
- Cause of yellowing attributed to moisture, heat, fermentation, and generally referred to as moist grain damage
- Damaged grain due to insect pests
- High moisture content during milling

#### *South India*

- High moisture content at point of sale
- Mill-level drying, no mechanical dryers, resulting in spoilage
- Different definitions of storage
- Farm-level shattering of grain

#### *Thailand*

- Few problems
- Grain too dry, seen as cause of cracking during milling  
(note: there are many known causes contributing to cracking)
- Adulteration of fragrant rice
- Rice for blending of fragrant rice, desired by some importing countries

#### *Philippines*

- Varietal mixing starting at the farm, and practiced in the mills
- Yellowing of grains, particularly heavy for the rainy season harvest
- Generally low head rice yields, compared to potential

#### *General issues raised and discussed*

- Lack of functional grades and standards in some countries, e.g. Cambodia, Myanmar and Philippines

- Thailand, India and Vietnam have grades and standards used in their grain trading system
- Quality standards different in different markets
- Grades and standards—need a broader knowledge for commercial trade as against government trade
- Need for greater harmonisation of grades and standards for the region
- Important quality parameters mentioned: grain type, varietal characteristics, percentage of cracked grains, volume expansion when steamed
- Production issues affecting grain quality
  - Uneven crop—water management
  - Nutrition
  - Seed quality, variety
  - Weeds
  - Lodging—weather
- Some information is known about factors affecting grain quality but not commonly available to farmers and processors
- Need for measuring performance of different types of processing machines in regard to milling quality
- Extent of integration of processing operation affects incentives, accountability, and output quality
- Need definition for milling degree, or whiteness
- Lack of information on grain drying as it relates to grain quality
- Lack of incentives for grain quality improvement
- Lack of information on appropriate technology for different levels of users
- Lack of information or knowledge on causes of poor grain quality
- Relationship between poor grain quality and losses is directly correlated
- Significance of percentage head rice:
 

Philippines	medium
Hong Kong	high
Japan	high
Cambodia	low (high for small segment of market)
India	high
Thailand	high
Vietnam	high (for export market)
- Priority: minimise yellowing of grain, damage to grain, and control of moisture
- It was noted that there are several underused, large-scale drying projects.

*Dante de Padua*  
*Convenor*

# **Session Summaries**

# Overview on Quality

## *Chairs*

Mr Nguyen Kim Vu (Post-Harvest Technology Institute, Ho Chi Minh City, Vietnam)

Dr Greg Johnson (Australian Centre for International Agricultural Research)

## *Rapporteurs*

Mr Alistair Hicks (Food and Agriculture Organization of the United Nations)

Prof. Helen Nair (University of Malaya)

## *Agriculture in the context of regionalisation and globalisation: opportunities and challenges*

Mme Bui Thi Lan gave an overview of Vietnamese agriculture, touching on pre- and post-1998 influencing factors in relation to national economic development. In this economy-in-transition, agricultural reforms (or renovations) had a substantial impact, resulting in a 4.5–5% agricultural annual growth rate. Vietnam is now among the leaders in the export of rice, coffee and cashew nut. Key aspects of the policies are:

- expansion and diversification of trade activities;
- promotion of large-scale foreign direct investment;
- integration into the world trade system through the Association of South-East Asian Nations (ASEAN), Asia–Pacific Economic Cooperation (APEC), Common Effective Preferential Tariff (CEPT) and the ASEAN Free Trade Area (AFTA); and
- negotiating access to the World Trade Organization (WTO).

These opportunities, challenges and measures will ensure new opportunities for Vietnam's agriculture, ensuring a bright future for the small farmers who are the backbone of the country.

## *Growth benefits of a broad-based approach to postharvest systems development*

Dr Francesco Goletti presented an integrated tripartite view of globalisation, postharvest systems development and agro-industry development. He argued that:

- globalisation and postharvest systems have a mutual synergy and importance in developing countries;
- a broad-based approach to postharvest and agroindustry development, using small and medium enterprises, is the engine of growth; and used
- agro-industry in the form of the starch industry in Vietnam as a case study of this development—originating in small enterprises, and his modelling showed the potential for development across a continuum, with small and medium feeding the large and multinational concerns. There is potential to enhance income generation for the small farmers engaged in efficient starch agro-industry.

## *Quality assurance*

The concept and its evolution was presented by Dr Wee Chong Wong. Pre and postharvest research is concerned with optimisation of yield, shelf life and nutritional value, and

minimisation of waste, cost, pests and diseases. Globalisation encourages removal of non-tariff barriers, and international standards are concerned with environmental quality, and workplace health and safety. Legal obligations apply to growers and researchers alike, as well as to packers, retailers and shippers. The paper discussed an integrated management system covering quality (International Standards Organisation—ISO 9001), environmental safety (ISO 14001), agriculture and food safety (Hazard Analysis and Critical Control Points—HACCP), workplace health and safety (AS1 NZS4504) and packaged business strategies.

#### *New food processing and preservation technology*

This paper was presented by Prof. Akinori Noguchi, and outlined several types of new food processing and preservation technologies: membrane technology, low temperature technology, use of electromagnetic waves, extrusion cooking, high pressure cooking, Ohmic heating and electroporation. These new food processing and preservation technologies are playing a leading role and the advantages of these techniques include minimal effects on the foods (except extrusion) and ability to minimise bacterial loads.

#### *Standards and quality assurance systems for horticultural commodities*

Dr Ma. Conception C. Lizada outlined in her paper how standards play a critical role in horticultural product safety and competitiveness. She reported that workable standards for horticultural products should:

- develop a culture of quality;
- assure safety and quality;
- expedite and enable trade;
- ensure success in pooled marketing;
- adopt appropriate systems;
- enhance the image of the technologies enterprises; and
- protect the consumer from defective and risky products.

The paper emphasised the importance of considering the production–marketing continuum in formulating standards.

#### *Postharvest handling status and problems of the Pacific Island countries*

Mr Edgar Cocker spoke on Pacific island countries and how they have suffered from poor market support infrastructure to ensure sound postharvest handling. There is a chronic lack of understanding of technical aspects of postharvest technologies, and quality assurance practices. Growers, packers, exporters, inspectors, distributors, carriers and warehouse operators need to be aware of and communicate to each other on proper methods and techniques of postharvest handling.

#### *Quality evaluation of some rice varieties being grown in Vietnam*

Mrs Nguyen Thanh Thuy outlined in her paper the importance of rice in the diet of the Vietnamese people. Vietnam has become a large exporter of rice, however much of this rice is not of high quality. This paper examined the characteristics of some sixty-five varieties of rice grown in the Red River Delta and Mekong River Delta of Vietnam, for milling, commercial, eating, and nutritive qualities. Suggestions were made as to varieties most appropriate for growth in these areas.

# Fruit Quality

## *Chairs*

Dr Le Van To (Post-Harvest Technology Institute, Ho Chi Minh City, Vietnam)

Dr Made Sudiana Mahendra (Udayana University, Indonesia)

## *Rapporteurs*

Dr Graham Alexander (AAECP –III QASAF Project, Palamere Pty Ltd, Australia)

Prof. Tang Wenhua (China Agricultural University)

Eleven papers were presented. The presentation of the other two papers was postponed to the next session due to the limitation of time.

## *Quality assurance systems for ASEAN fruits (fresh and minimally processed)*

This paper was presented by Dr Graham Alexander and Mr Bruce Peacock. They stated that the QASAF Project was established under the auspices of the AAECF Phase III, began in January 1997, and was scheduled to finish in December 1999. The project objectives were to develop quality assurance (QA) systems and minimal processing procedures for durian, jackfruit, 'Arumanis' mango, pineapple, dragon fruit, and longan, which incorporated suitable postharvest technology, and to ensure their continued access to local and export markets. The ASEAN countries participating in the project were Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. Regional and a series of in-country workshops were conducted on QA systems, minimal processing and food safety procedures.

## *Case study on development of a quality system to foster the establishment and growth of the durian industry in Brunei Darussalam*

Mrs Marie Piccone and Mr Colin Bunt presented this paper in which they reported that the concept of quality planning for a durian industry as a model for other horticultural industries in Brunei Darussalam was used as the selected case study. The development of QA system involved data analysis from market and consumer surveys, establishment of market descriptions and Durian Quality Team, and creation of a Durian Quality Plan. A Durian Quality Management Manual for fresh and minimally processed local durian was developed.

## *Postharvest developments for use in QA for durian*

Dr Sonthat Nathachai reported that postharvest handling for both fresh and minimally processed (MP) durian has been developed as part of a QA system project. Ripening and storage of durian were studied. Application of ethrel to initiate ripening and potassium permanganate as an ethylene absorbent to extend the shelf life were confirmed. An iodine–starch test was used to predict the pulp maturity and the use of suitable packaging material for MP durian was studied.

### *Quality assurance system for dragon fruit*

Dr Le Van To reported on activities for setting up a QA system for dragon fruit that were conducted at dragon fruit farms, packinghouses in Binh Thuan Province and the laboratory of PHTI under the AACEP–Phase III QASAF Project. Factors influencing harvest and postharvest handling were studied including: optimum harvesting time; physico-chemical changes during storage; chilling sensitivity; and fungal infection during the postharvest period.

### *Establishment of a quality assurance system for minimally processed jackfruit*

Mr Mohm. Salleh Punan reported that the demand for retailing the fruit as MP product is expanding due to the recent consumer trend towards high quality, ready-to-eat fresh produce. There was a need to develop a proper minimal processing technique for preparation of MP jackfruit. The operation involved harvesting time, in-field handling, sorting, washing, ripening, cutting, selecting individual fruitlets, packing, storage and transportation. The total QA approach implemented regularly was able to provide consistent product quality and safety, and hence the extend buyers' confidence to consume the product.

### *Minimally processed fruits in Singapore*

Mr Kalanithy Karichiappan reported on a survey that was conducted to study the quality and food safety status of MP fruits in Singapore. Physical examination, pH, ethylene and oxygen gas levels, surface colour, total sugar, total acidity and water activity were determined. Pesticide residues and microbiological pathogens were also monitored. He indicated that the relatively safe MP fruits in Singapore do not have a more than 2 or 3 day shelf life.

### *Maturity indices and harvesting practice of 'Arumanis' mango*

Dr Nyoman Tridjaja related his presentation to the target market for optimal maturity of 'Arumanis' mango. He found that best consumption was reached when the fruit was harvested between 13–14 weeks after fruit set, characterised by the value of total soluble solids, total acidity, pH, flesh colour and taste score.

### *Quality assurance implementation in practice: Thailand's experience with fresh longan for export*

Mrs Sing Ching Tongdee reported that with the liberation and reform of agricultural trade, the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) has been used to facilitate as well as restrict international trade. She stated that the new quality concept is about organisation, systems and assurance and those with good management win. A pilot project on implementing QA systems for longan and durian started in Thailand about three years ago involving the cooperation of government and the private sector, and has generated awareness and interest in a national campaign.

### *Study on the postharvest handling system for lychee*

Mr Nguyen Cong Hoan reported that a new methodology was developed in Vietnam to maintain quality and prolong the shelf life of the 'Thieu' lychee including: harvesting, transportation, postharvest handling, packing, storage and distribution. He found out that the fresh life of lychee was extended by CO<sub>2</sub> fumigation, carbendazim dipping and ethylene trapping by a ripening retardant, R3.



*Twist test measurement of mango texture*

Mr Nguyen X. Ha presented his paper the softening of mangoes investigated during storage at 12°C and 85–90% relative humidity. Crushing stress (CS) was affected by harvest date of ‘Buoi’ and ‘Thom’ mangoes. He also found that CS of the outer part of the mesocarp was higher than CS of the inner part when the fruit still firm, but was lower when the fruit became soft.

*Designing effective quality systems for horticultural businesses and organisations*

The last paper was delivered by Mrs Marie Piccone and Mr Colin Bunt, who outlined options involving practical and economical methodologies to design and implement an effective, tailored quality system. They also stated that an effective quality system in any part of the horticultural supply chain should be designed to meet the needs and requirements of the customers, and must make a valuable contribution to the business or organisation developing and implementing it.

# Uptake and Impact

## *Chairs*

Mrs Sing Ching Tongdee (Thailand Institute for Scientific and Technological Research)  
Dr Nguyen Minh Chau (Southern Fruit Research Institute, Vitenam)

## *Rapporteurs*

Mr Rod Jordan (Queensland Department of Primary Industries, Australia)  
Dr Adhi Santika (Ministry of Horticulture, Indonesia)

The session on 'Uptake and Impact' provided a total of nine papers. The subject matter was diverse with presentations on 'state of the art' training and information transfer, approaches to assessing the effectiveness of technology transfer, and how quality systems might be incorporated into village-level production and marketing.

## *Research and development on postharvest handling of fruits and vegetables in Malaysia*

This paper (presented by Mr Abdullah Hassan) provided an overview of the work done over 20 years by the major research and development organisations in assisting the development of technology for both domestic and export markets. Research achievements were identified in storage, handling and packaging for a diverse range of horticultural crops, including commercial export trialing with industry.

## *The effectiveness of the BPRE training program as a technology transfer strategy for the adoption of grains postharvest technology (Ms Helen F. Martinez)*

## *National postproduction loss assessment for rice and maize (Ms Celerina Maranan)*

The authors reported on evaluation of the uptake of technology. Ms Maranan described survey results relating practices to postproduction losses, with a reduction in losses as evidence of an improvement in practices. Ms Martinez reported on training courses as a means of technology transfer, finding that involvement of farmers in a cooperative, as well as the position within the structure of that cooperative, had a positive impact on the level of adoption. Perceived competence of trainers and availability of written material also had a positive impact.

## *Impact assessment of utilisation of an improved maize sheller in three major maize producing provinces in the Philippines*

Dr Rodolfo Estigoy described factors affecting the uptake of technology and the impact of these on users. As before, both effectiveness of training and organisational membership had a positive impact on uptake, although infrastructure, particularly availability of roads, also had an influence. There were also measurable social and socioeconomic impacts of utilisation.

*The quality assurance challenge—can village marketing and cooperatives respond?*

*(Dr Nerlita Manalili)*

*The role of quality assurance on the pooled marketing of horticultural produce from smallholders*

*(Ms Perlita Nuevo)*

Dr Nerlita Manalili's paper and Ms Perlita Nuevo's presentation both considered quality and marketing from the perspective of small, village-scale producers. In broad terms, pooled marketing and cooperative organisation are regarded as being effective methods of marketing horticultural produce in a quality system, provided all required elements of the system are in place.

*The Philippine Rice Postproduction Consortium: needs assessment of the postproduction industry*

Dr Dante de Padua described high-level strategic initiatives to overcome constraints to technology utilisation, by coordination of the major research organisations that work across the whole grains industry. The resulting Philippine Rice Postproduction Consortium has undertaken a range of activities to facilitate technology utilisation.

*Developing a computer-assisted learning (CAL) system to improve training staff in grain quality management in the ASEAN region*

Dr Barry Longstaff reported on progress on the development of the training system in Vietnamese, expanding on the previous Indonesian and English versions. The developers have concluded that the CD-ROM format is the most suitable method of making the system and its information accessible to the greatest number of people at lowest cost.

*Information network on postharvest operations*

Mr Albert Bell provided an overview of the features of the Internet-based network (INP/O) set up by the Food and Agriculture Organization of the United Nations, supported by various international and national organisations. The system maintains a collection of information supplied by users and sponsoring organisations. The discussion surrounding this topic demonstrated widespread support for the concept, but also a recognition that ongoing commitment will be required from agencies, users and suppliers of information to maintain the system's viability and to ensure that information available is as up-to-date as possible.

# Vegetables

## *Chair*

Dr Akinori Noguchi (Japan International Research Center for Agricultural Sciences)

## *Rapporteur*

Mr Abdullah Hassan (Malaysian Agricultural Research and Development Institute)

## *Quality management systems in Australian vegetable and fruit industries*

Mr John Bagshaw reported that supermarkets in Australia are demanding quality management (QM) systems of Australian growers to assure supply of safe, quality fruits and vegetable. The demand is not driven by the government. Supermarkets are concerned about lost sales if they are implicated in a food poisoning outbreak, and concern about litigation. However, small growers have difficulty implementing QM systems due to lack of money, time and relevant skills. Three things for adoption of QM are needed—motivation, understanding and resources. It was also highlighted that the Chinese vegetables produced are mostly for domestic markets and sold within a day of harvest. Refrigeration is only used for export product. Appropriate technology is therefore needed.

## *Extending the shelf life of broccoli florets and pak choy leaves*

Dr Amanda Able reported on the severe effect of yellowing on the shelf life of broccoli florets and detached leaves of pak choy. Application of 0.1–12 parts per million (ppm) of 1-methylcyclopropene (1-MCP) controlled the yellowing effectively, especially during storage at 10 and 20°C. Atmosphere modification of 2% O<sub>2</sub> /5% CO<sub>2</sub> was found to be more effective than 1-MCP in extending the shelf life of pak choy leaves.

## *Assessment of postharvest handling systems of vegetable crops in the Beijing area*

Shufang Zheng's paper was on factors affecting postharvest losses of Chinese cabbage, broccoli and oriental bunching onion in the Beijing area. The factors affecting losses of these vegetables were identified as: lack of proper packaging, no pre-cooling, improper transportation and poor storage techniques. The estimated losses after storage for Chinese cabbage and oriental bunching onion were 20% and 50%, respectively.

## *Postharvest handling of 'Asian' vegetables in the Northern Territory*

Melinda Gosbee's paper reported on Asian-type vegetables that are produced in the Northern Territory of Australia between April and October. Typical vegetables are bitter melon, snake beans, okra, angled luffa, long hairy and winter melon, kang kong and basil. These vegetables are sold locally and interstate up to 4,000 km away from the production region. Storage experiments testing the shelf life and packaging of some of these vegetables have been conducted over several years. It is an issue to educate the growers to thoroughly cool their produce before packing. Information on improved handling is available.

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