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FRESH PRODUCE DEVELOPMENT AGENCY

SELF SUFFICIENCY FOR PAPUA NEW GUINEA

QUALITY MANAGEMENT OF FRESH PRODUCE FROM THE HIGHLANDS OF PAPUA NEW GUINEA

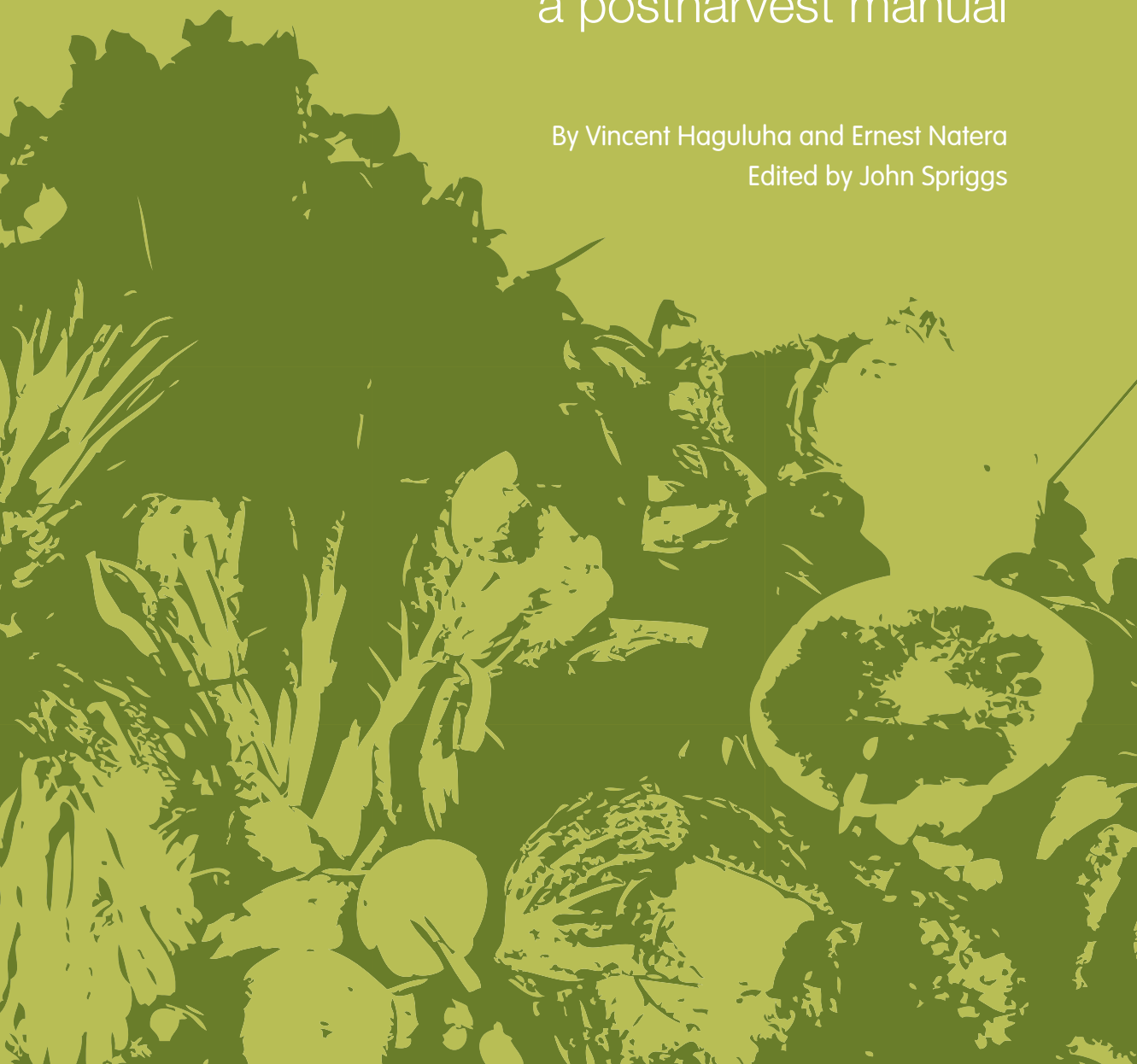
A POSTHARVEST MANUAL

Australian Centre for International Agricultural Research, Canberra 2007

Quality management of fresh produce from the highlands of Papua New Guinea:

a postharvest manual

By Vincent Haguluha and Ernest Natera
Edited by John Spriggs



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FOREWORD

The Papua New Guinea (PNG) highlands represent a unique environment in which high-quality temperate zone fresh produce is grown organically year-round. This region provides not only for subsistence needs, but also is increasingly important as a source of marketed fresh produce for consumers in both the highlands and the populous coastal regions of PNG. Fresh produce grown in the highlands of PNG represents one of the few sources of cash income for poor rural households in that region.

According to many highland farmers, the biggest constraint to developing their fresh produce industry is the marketing system. A common refrain is: 'we know how to grow it but we don't have the market'. Based on these concerns, the Australian Centre for International Agricultural Research (ACIAR) commissioned a research project in collaboration with the Fresh Produce Development Agency (FPDA). The FPDA, based in Goroka, is a key player in the promotion and development of fresh produce in PNG, working to alleviate the various constraints on the industry. That project, entitled 'Improving the marketing system for fresh produce from the highlands of Papua New Guinea', identified a number of issues with the marketing system for highland fresh produce, and developed a number of strategies for dealing with them.

One of the issues identified was a perceived lack of skills in postharvest management and marketing of fresh produce. The production of this manual brings together basic information on these issues in the Papua New Guinea context. It is authored by two of FPDA's professional staff under the editorial guidance of Professor John Spriggs of the University of Canberra. The authors, Vincent Haguluha and Ernest Natera, are postharvest specialists who have extensive knowledge of postharvest technology relevant to the fresh produce industry in PNG and are well placed to author such a publication.

It is hoped that this manual will prove to be a valuable reference for farmers, marketers and extension personnel as they seek to improve the management and marketing of highlands-based fresh produce.

Peter Core
Chief Executive Officer

Australian Centre for International Agricultural Research

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We would like to thank the many people and organisations that have contributed in one way or another to making this resource manual a reality. We wish to acknowledge the financial assistance provided by ACIAR for the coordination and publication of this material. Many thanks also to Professor John Spriggs for his advice in shaping this material as well as extensive editing. We also wish to thank John K. Lark for his input on the case study. Finally, a big thankyou to all our colleagues at the Fresh Produce Development Agency (FPDA) for their support.

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1. Introduction

1. INTRODUCTION

This manual provides guidelines for improving the management of fresh produce to help maintain its quality through the supply chain from the farmer to the consumer. It is intended primarily as a resource manual for extension agents and commercial farmers.

The most important aim of quality management of fresh produce is to extend its storage life. This can be achieved by reducing the rate of respiration (i.e. the rate at which the food made by the plant is burned to produce energy), reducing the rate of transpiration (i.e. the rate at which the plant loses water), and reducing the rate of disease infection. At the same time, storage life can be improved by moving produce quickly from the farm to consumers once it reaches maturity. Consumers prefer and are willing to pay more for good-quality fresh produce that has a good appearance, taste, flavour and texture, and high nutritive value.

Worldwide, commercial sales of fresh produce are in the billions of dollars. Consequently, huge sums are invested in transportation, packaging, storage and marketing facilities to prolong the storage life of produce, as well as in technologies to maintain a continuous supply of fruits and vegetables within and across international boundaries. Although there are no official figures on postharvest losses, technologists agree that in developed countries up to 25% of produce is lost each year before it reaches the consumer. In developing countries such as Papua New Guinea (PNG), this figure could be as much as 50%. There is therefore an urgent need for improved postharvest management of, and technology for, fresh produce, particularly in developing nations.

The idea of improving quality management and technologies for fresh produce in PNG is still a relatively new concept. There is a general lack of appreciation that specific management procedures are required to maintain the quantity, quality, safety, nutrition and value of fresh produce after harvest, especially if it is intended for long-term storage and/or distant markets. The purpose of this manual is to fill this knowledge gap.

Figure 1.1: Some examples of poor postharvest management of fresh produce. Clockwise from top left— kaukau (sweet potato), tomatoes, capsicums, carrots, English potatoes, and cauliflower.

It is hoped that this manual will help extension agents and commercial growers to:

- better understand the biological and environmental factors involved in deterioration
- use quality management techniques that delay senescence (old age—the final stage of development of the plant organ leading to the breakdown and death of plant cells) and maintain the best possible quality.

It aims to do this by providing management guidelines on how to maintain the quality of produce from harvest through to the final consumer, and thereby generate higher returns for farmers and other participants in the supply chain.

Although the manual concerns activities at harvest and during post-harvest, it should be noted that preharvest cultural practices may also contribute significantly to product quality in the marketplace. Such practices include the choice of inputs such as seed varieties, fertilisers and agricultural chemicals, as well as farm management techniques.

Figure 1.1 shows some examples of poor postharvest management of fresh produce. When produce is in such condition it cannot be sold or must be sold at a much lower price.

Section 2 is concerned with quality in fresh produce, and includes discussion of:

- what is meant by quality
- what criteria are used to judge quality
- why produce deteriorates in quality.

In Section 3 the basics of quality management are discussed, including basic practices that all commercial farmers and marketers of fresh produce should be able to follow. These practices are discussed under the headings:

- harvest management practices
- postharvest management practices (handling)
- storage
- transportation
- marketing and postharvest losses.

In Section 4 a guide to basic quality management of individual produce types that are important in the highlands of PNG is provided. They include: asparagus, broccoli, English cabbage, capsicum, carrots, cauliflower, cucumber, lettuce, bulb onions, potato and kaukau (sweet potato).

Further information on the quality management of these and other types of fresh produce may be obtained from:

Market and Infrastructure Division
Fresh Produce Development Agency
P.O. Box 958
Goroka, EHP, Papua New Guinea

Phone: 675-732-3356.

2. Quality in Fresh Produce

2. QUALITY IN FRESH PRODUCE

This section discusses what is meant by quality in fresh produce and what causes quality to deteriorate. It provides background information for Section 3, which deals with the basic management of quality in fresh produce.

2.1 What is meant by 'quality'?

Quality can mean different things to different people. For the grower it could mean produce with high yields and high returns. For a wholesaler it could mean produce with no bruising and a long storage life. For a retailer it could mean produce with no blemishes and a good appearance. And for a consumer it could mean produce with a good appearance, taste and nutrition. Producing a quality product means finding out what quality means to the potential buyer—what exactly the buyer needs. For example, the quality needs of a wholesaler in Mount Hagen may not match those of a supermarket customer in Port Moresby.

The case study in Box 1 shows an example of a grower–marketer of tomatoes who has different types of buyers for his produce, and is successful because he can meet the particular needs of each of his different buyers. One buyer is a tomato sauce processor who only buys red ripe tomatoes, while the other is a supermarket owner who only buys half-ripe firm tomatoes. The supermarket owner sees less quality in red ripe tomatoes than half-ripe firm tomatoes. On the other hand, the processor sees that red ripe tomatoes are what he needs to make tomato sauce and, for him, half-ripe firm tomatoes would not be satisfactory. Quality depends on the customer's needs and is therefore best defined as 'fitness for purpose'.

Because different markets have different quality requirements, suppliers should match the quality requirements of their customers.

2.2 Quality criteria

Judgment of quality can be divided into two types of factors: external and internal.

External factors are those that can be seen, and include:

- appearance, including size, colour and shape
- condition and absence of defects.

Box 1

A farmer–marketer in the Eastern Highlands province grows tomatoes and is able to supply about 2 tonnes of tomatoes. He has been growing tomatoes for about 15 years supplying different markets in Lae—supermarkets, a hotel, a university and the open market. He harvests his own tomatoes and also purchases from other farmers on Thursdays and Fridays.

On Saturdays and Sunday afternoons he grades and packs the tomatoes according to market requirements, as in the table below.

Grade	Characteristics	Markets	Price
A	Half-ripe, medium size No blemishes and no bruises	Supermarkets	High
B	Red ripe, medium size Minor blemishes and bruises	Hotel	Medium
C	Mixture of half-ripe and red ripe, all sizes Blemishes and bruises	University, mass and open markets	Low

The tomatoes are packed into non-collapsible hard plastic 50-kg crates. On Sunday afternoons at about 5 pm he loads them on his truck and travels to Lae. He travels in the afternoon when it is cool so that his tomatoes do not overheat. By 7 am the next morning, he is already at the door of his first customer, usually one of the supermarkets, leaving that buyer's consignment of tomatoes with one of his boys while transporting the remaining tomatoes to other buyers. By Monday afternoon or Tuesday morning he has sold all his tomatoes and returns home on Tuesday afternoon, sometimes with a back load.

This cycle is repeated every week, so he has now built up a good reputation with his buyers. Although there are no contracts signed, the business is done on trust and confidence. He has a very good relationship with his buyers and there is a good flow of information both to the buyers (on what the future supply looks like) and from the buyers (on what are their future needs).

He is able to meet the quality needs of his different buyers and is able to supply them at the right time with the required volume consistently.

Internal factors cannot be seen, and include:

- flavour and texture
- nutritional value and mouth feel.

In PNG external factors are far more widely used as a means of assessing quality. They are easy to use, fast and, to some extent, reliable; and they cost less. Judgment based on external factors relies heavily on experience or learned criteria. External and internal factors are discussed separately.

2.2.1 External factors

Appearance is very important. Most people buy with their eyes and learn from experience to associate desirable qualities with a certain appearance. A rapid visual assessment can be made on the size, shape, colour, freshness (condition) and presence of blemishes and defects (Figure 2.1). It is important to know or find out the particular needs of your buyer concerning appearance and try to supply what he/she requires.

The condition of the produce includes the freshness, stage of ripeness (senescence), extent of mechanical damage, and presence of pests or diseases.

Examples of produce in poor condition include:

- wilted leafy vegetables
- shrivelled fruits due to loss of moisture
- skin blemishes such as bruises, scratches and cuts.

These all give a bad appearance to the produce and are likely to lower the price or be unacceptable to the buyer, even though they may still be good and safe to eat. Thus, during harvesting and handling of the produce after harvest, great care should be taken to avoid or at least minimise deterioration.

Figure 2.1: Good-quality produce in an open market (left) and a supermarket (right).

2.2.2 Internal factors

Flavour is made up of taste and aroma, while texture is the feel of a product especially when gnawed with the teeth. Nutritional value is probably the most difficult internal factor to assess. Generally, people think that the fresher the produce the higher the nutritional value. Therefore, it is important to take into consideration measures that will help in reducing the fast deterioration of the quality of the produce.

2.3 Why does produce deteriorate in quality?

The basic reasons why produce deteriorates in quality are:

- respiration
- transpiration (water loss)
- disease infection
- growth and development
- handling damage.

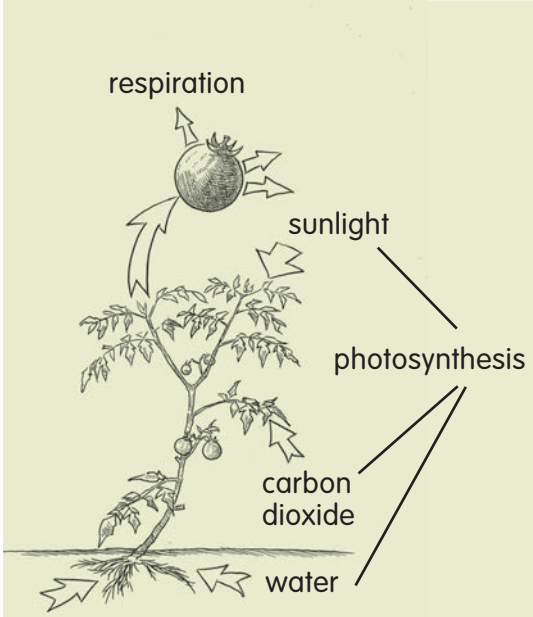
2.3.1 Respiration

Fresh fruits and vegetables are living things. This means they are still respiring and creating energy by 'burning up' carbohydrates, even after harvest. However, the fruits and vegetables are severed from their source of carbohydrates, water and minerals after harvest, and therefore have to rely on their own resources for survival. Through respiration the organic matter in the produce is depleted as the carbohydrates break down into carbon dioxide and water and are 'used up' (Figure 2.2).

Different types of fresh produce have different rates of respiration. Broadly speaking, fresh produce with low overall rates of respiration can be stored for longer periods without loss of acceptability.

Fresh produce can be classified into two basic types:

- **dormant tissue**, e.g. kaukau, carrot, taro and beetroot. These tend to have a *low metabolic rate* and a *long storage life*
- **non-dormant tissue,** e.g. flowers and fruit, stems, leaves. These tend to have a *high metabolic rate* and *deteriorate quickly* unless the rate is slowed down.



During the growing phase of fresh produce the major process taking place in the plant is **photosynthesis**. In this process, carbon dioxide and water are combined with the help of sunlight to create carbohydrates. After harvest the major process taking place in the fresh produce is **respiration**. Fresh produce is still a living organism after harvest, taking in oxygen to break down stored carbohydrate and releasing carbon dioxide and water as by-products.

Figure 2.2: Photosynthesis and respiration in fresh produce.

Apart from the type of tissue involved, respiration is affected by three environmental factors:

- temperature
- the mix of gases (oxygen and carbon dioxide) in the atmosphere
- the presence of ethylene.

These factors are all amenable to control, and knowledge of their effects can therefore be usefully applied to the practical problems of fruit and vegetable storage.

Temperature

Respiration takes place in fruits and vegetables within a certain temperature range. Within this range the rate of respiration normally increases with a rise in temperature, resulting in a faster 'burning up' of carbohydrates and hence a faster loss of quality. Outside this temperature range (i.e. if the temperature is too high or too low), physiological injury occurs. It is therefore advisable to store fresh produce at the lowest temperature within the temperature range in which respiration occurs.

The mix of gases (oxygen and carbon dioxide) in the atmosphere

The normal atmosphere contains 21% oxygen and 0.3% carbon dioxide. In aerobic respiration, oxygen in the atmosphere combines with carbohydrates in the fruits and vegetables to produce carbon dioxide and water. Therefore, one way to restrict respiration is to restrict the level of oxygen in the storage atmosphere. This principle is used in modified atmosphere packaging (MAP), a method whereby the storage life of fresh produce is increased by reducing the level of oxygen available for respiration. This requires considerable expertise as total elimination of oxygen may result in anaerobic respiration, producing alcohol, tissue damage and unpleasant flavours.

The presence of ethylene

Ethylene is a gas formed in small quantities during the ripening of some fruits that can increase the respiration of other fresh produce stored nearby. For example, ripe tomatoes produce ethylene while beans are sensitive to it. Thus, storing ripe tomatoes next to beans will increase the rate of respiration of beans and reduce their storage life. Although ethylene has some good uses, such as in the uniform ripening of bananas, its effects are undesirable from the point of view of maintaining the storage life of fresh produce. It causes sprouting of potatoes and yellowing of broccoli, as shown in Figure 2.3.

Ethylene also causes tomatoes to ripen faster, carrots to become bitter, leafy vegetables like lettuce to become dark and asparagus to become tough. It is thus a good idea to keep ethylene-producing produce apart from ethylene-sensitive produce. Table 2.1 shows a list of the more common ethylene-producing and ethylene-sensitive produce. With low storage temperatures of 4°C and below, the effect of ethylene can be greatly reduced or eliminated entirely.

Figure 2.3: Undesirable effects of ethylene include sprouting in potatoes (top) and yellowing in broccoli (bottom).

Ethylene is also produced by petrochemical reactions, so it is advisable to keep ethylene-sensitive produce away from machine engines that produce heat and light, ripening rooms, rotting produce, gases from aircraft engines, cigarette smoke and rubber material exposed to heat or strong light.

Table 2.1: Ethylene production and sensitivity levels of selected fresh produce

Fresh produce type	Ethylene-producing	Ethylene-sensitive	Principal reaction to ethylene
Apple	• • •	• • •	Loss of crunch
Artichoke	o	•	
Asparagus	o	• •	Toughening of stems, yellowing of tips
Avocado	• • •	• • •	Decay
Banana	• •	• • •	Decay
Beans	•	• • •	Yellowing
Broccoli	o	• • •	Yellowing
Brussels sprouts	o	• • •	Yellowing
Cabbage, English	o	• • •	Shedding of leaves
Cabbage, Chinese	o	• • •	Shedding of leaves
Capsicum	•	•	
Carrot	o	•	Bitterness
Cauliflower	o	• • •	Discolouration
Celery	o	• •	
Cucumber	•	• • •	Yellowing
Eggplant	•	•	Brown spotting
Garlic	o	•	Odour, sprouting
Ginger	o	•	
Grapefruit	o	• •	Mould
Kohlrabi	o	•	
Leafy greens	o	• • •	Brown spotting
Lemon, lime	o	• •	Mould
Leek	o	• •	
Lettuce	o	• • •	Brown spotting
Mango	• •	• • •	Decay
Melons (excl. watermelon)	• •	• • •	Decay
Mushroom	•	• •	
Okra	•	• •	
Onion, bulb	o	•	Odour, sprouting
Onion, green	o	• •	Decay
Orange, Mandarin	-	• •	Mould

Table 2.1 continued

Fresh produce type	Ethylene-producing	Ethylene-sensitive	Principal reaction to ethylene
Papaya	● ● ●	● ● ●	Decay
Parsnip	○	●	
Peas, green and snowpea	○	● ●	Yellowing
Pineapple	●	●	
Potato	○	● ●	Sprouting
Pumpkin	●	●	
Radish	○	●	
Rambutan	● ● ●	● ● ●	
Spinach	○	● ● ●	Yellowing
Stone fruit (peaches, pears, nectarines)	● ● ●	● ● ●	Decay
Strawberries	●	●	Mould
Sweet corn	○	●	
Kaukau	○	●	Off-flavour, discolouration
Taro	○	○	
Tomato (mature green)	○	● ● ●	Ripening, softening
Tomato (ripe)	● ●	● ● ●	Softening, shrinking
Turnip (root)	○	●	
Turnip (greens)	○	● ● ●	
Watermelon	●	● ● ●	Loss of firmness
Yam	○	●	
Zucchini	○	○	

● ● ● = high or very high; ● ● = medium; ● = low; ○ = very low or none

Sources: http://www.ethylenecontrol.com/about.html, http://www.ethylenecontrol.com/about.html and http://www.mindfully.org/Plastic/Ethylene-Gas.htm

2.3.2 Transpiration (water loss)

Water loss in fresh produce leads to a direct loss in saleable weight, which usually means a direct loss in monetary value. It also leads to a loss of quality through its effect on appearance (e.g. wilting and shrivelling) and texture (e.g. a loss of crispness of leafy vegetables like lettuce). Severe wilting of leafy vegetables and other fresh produce can occur in a matter of hours under hot, dry conditions. Water loss can also adversely affect the nutritional value of fresh produce; e.g. the vitamin C level is reduced in water-stressed leafy vegetables.

For those types of produce susceptible to water loss, it is therefore important to ensure that the humidity level is maintained and the produce kept at a cool temperature, from harvest through to the end user. The appropriate humidity levels for different types of fresh produce are listed in Table 3.3. Precooling (fast cooling right after harvest) reduces the total amount of water loss. In addition, it is important to avoid bruising or otherwise damaging produce during postharvest operations as the surface areas can become sites for excessive water loss.

2.3.3 Disease infection

Many bacteria and fungi can cause spoilage of fresh produce. However, most are weak pathogens in that they usually only spread and grow when the produce is wounded. Wounding may occur due to cuts from fingernails, rough handling and overchilling. The wound site releases sugars and food that allow micro-organisms to grow. Healthy fresh produce will resist microbial attack much more readily than stressed or ripe/overripe produce.

Disease infection is also encouraged by higher temperatures and high humidity, which provide a good environment for the growth of disease-causing micro-organisms. Such pathogens grow best in temperatures of 20–25 °C. By contrast, low temperatures slow down not only the chemical processes of the produce, maximising storage life, but also the growth of these micro-organisms. At storage temperatures around 0 °C very few pathogens will pose a problem.

Disease-causing micro-organisms pass through a number of growth phases. Following initial infection it will take some time for them to adapt to the growth conditions surrounding them. It is only after this phase that they start to multiply at an increasingly faster (exponential) rate, and the damage they cause becomes apparent. Because of this time lag, it is quite possible for damage to be caused at harvest or in the early stages of post-harvest. However, it may not show up until some time later, perhaps after the produce has been transported and just when it is to be offered to the buyer.

There have been many stories of grower–marketers who have taken their produce from the highlands to Lae, loaded it onto refrigerated containers and sent it on a 3-day journey to Port Moresby. When they leave their produce in Lae it looks fine, but when it arrives in Port Moresby it is so badly damaged it is not fit for sale. The grower–marketers claim compensation against the shipowner because of damage due to poor storage practices on the ship. However, in some cases it may also be poor handling and storage practices prior to loading on the vessel that may have led to attack by micro-organisms that only shows up days later.

Development of disease during the postharvest period is a problem that requires careful attention. Deterioration resulting from microbial action can be rapid and severe, often incurring major losses and resulting in the need for re-sorting and repacking. Disease prevention during this period can save a lot of money. This is particularly the case for produce that is to be transported over long distances, which may take considerable time. It is important that this produce be carefully handled and packed, preferably using precooling and cool storage to prevent microbial spoilage.

2.3.4 Growth and development

Underground vegetables such as bulbs, roots, rhizomes and tubers may start to sprout when stored in conditions favourable to growth. For instance, sprouting will occur rapidly if bulbs are held for any period at 5–20 °C. This is undesirable since it is both unattractive to consumers and also contributes to deterioration of the produce. During both short- and long-term storage of underground vegetables, try to keep the produce in the most favourable conditions. See Table 3.3 for details of the ideal storage conditions for such vegetables.

2.3.5 Handling damage

Poor handling can damage fresh produce by means of impact, pressure or vibration. Practices to avoid include:

- dropping bags of produce onto the ground
- throwing boxes around
- sitting on top of bags during transportation
- stacking boxes too high
- underfilling or overfilling containers for transport: underfilling can lead to damage from vibration or rolling around, while overfilling can lead to damage from pressure.

Another source of handling damage is temperatures that are too high or too low. High temperatures, especially when produce is left unprotected in the sun, can cause sunburn and boiling of produce. Temperatures that are too low can cause freezing and chilling injury. At all times throughout the supply chain, produce should be protected from temperature extremes. See Table 3.3 for further details on the optimum temperatures for the various types of produce.

PRINCIPLES OF DISEASE PREVENTION

- Begin with healthy non-stressed produce.
- Provide an environment that will maintain the freshness, e.g. low temperature.
- Prevent any mechanical damage during harvesting, grading, packing and transport.
- Use postharvest applications of fungicides/pesticides if produce is destined for long-term transport or storage.
- Follow instructions strictly.

3. Basics of Quality Management

3. BASICS OF QUALITY MANAGEMENT

In this section basic harvest and postharvest management practices to help keep produce from spoiling before it reaches the market will be discussed.

3.1 Harvest management practices

The main issues in harvest management are to make sure crops are harvested at the right stage of maturity, and to use the correct harvesting techniques.

3.1.1 Indicators of maturity

Before harvesting make sure crops are at the right level of maturity. Neither immature nor overmature produce are acceptable since their quality deteriorates sooner, especially during storage and transit, with the development of poor flavour and texture.

Some farmers may want to harvest their produce before it reaches the right level of maturity because of high market demand. Or they may want to leave it to go beyond normal maturity to gain extra weight, since weight is used as the basis for price. However, both practices are unacceptable in the quality market because they contribute to the production of poor-quality produce and consequent damage to the image of the market in the minds of consumers.

But what is the right level of maturity for the market? Generally, there are two levels of maturity: physiological and commercial.

Physiological maturity

Physiological maturity is where the plant (or plant organ) has become fully developed, such as ripening in tomatoes or flowering in lettuce. This is the stage just before senescence begins.

Commercial maturity

Commercial maturity is where the plant (or plant organ) is at the particular level of development *needed for the market*. It typically occurs before physiological maturity. For example, tomatoes will be harvested at an early stage in the ripening process so that by the time they reach the market they are at the optimum level of ripeness. In some cases the market only wants physiologically immature produce, for example lettuce before it has started flowering.

The right level of maturity for the market is **commercial maturity**. This can be measured using **indicators**, which can be *objective* (where measuring instruments are used) or *subjective* (where someone makes a judgment based on the appearance of the produce). In PNG the most widely used indicators of maturity are subjective. Indeed, because harvesting is generally carried out manually, the person responsible for harvest is also responsible for deciding whether or not the product is mature. This ability depends heavily on experience. Subjective indicators may include size, shape, firmness, taste, dryness and surface characteristics such as colour. In Section 4 subjective indicators for many of the more popular types of produce grown in the highlands of PNG are listed according to produce type. The main advantage of subjective assessment is that it is relatively cheap and someone with experience can measure attributes not easily measured objectively. But the main weakness is that subjective assessments will be variable from individual to individual and hence more subject to error.

3.1.2 Harvesting techniques

Using the correct harvesting technique has an important influence on the storage life of the produce. The basic rules are:

- Harvest during the coolest part of the day—early morning or late afternoon. For local markets it is best to harvest in the early morning, while for more distant markets it may be better to harvest in the late afternoon and transport during the night or early the next morning, according to when transport can be arranged.
- Avoid harvesting produce that is wet from dew or rain. Wet produce will overheat if not well ventilated, and is more likely to decay. Some produce will be more subject to damage when wet, e.g. oil spotting and rind breakdown in some citrus fruits.
- Separate out crops that appear unfit for human consumption during harvesting.
- Clean harvesting equipment and containers thoroughly before use, especially if they have been previously used for toxic materials, so as not to contaminate produce.
- Protect harvested produce in the field by putting it under open-sided shade when transport is not immediately available. Produce left exposed to direct sunlight will get very hot and deteriorate rapidly. For example, potatoes left exposed to tropical sunlight for 4 hours can reach temperatures of almost 50 °C.

Apart from these basic rules, there are important differences in harvesting techniques between different types of crops. Some crops (e.g. taro, kaukau, green onion and garlic) can be harvested over a long period of time, so the quantity harvested at any one time should be limited to what can be marketed that day. However, other crops (e.g. watermelon, honeydew melon, eggplant, asparagus, pepper, tomatoes, sweet corn, peas, some berries, cassava and soybeans) pass quickly through the stage of harvest maturity and therefore should be harvested daily or every other day. Frequent and timely harvest of these types of produce is necessary if the grower wishes to supply their market with high-quality produce.

To more clearly see the differences between various types of crops, harvesting techniques for three different types of produce—roots and tubers, vegetables, fruit—are discussed below.

Root and tubers

Most staple roots and tubers that grow beneath the soil are likely to suffer mechanical injury at harvest because of digging tools such as wooden sticks, machetes, spades, hoes and forks.

Harvesting of these crops is easier if they are grown on raised beds or mounds or earthed up, as is common in kaukau growing (Figure 3.1). This enables the digging tool to be pushed into the soil under the roots or tubers (see action 1 in Figure 3.1), which then can be levered upwards (action 2), loosening the soil and reducing the possibility of damage to the crop.

Other root crops such as taro, carrots, turnips and radishes can be loosened from the soil in a similar manner by inserting the tool into the soil at an angle and levering the roots upwards. This method can also be used for celery that has been earthed up or buried to blanch the stem.

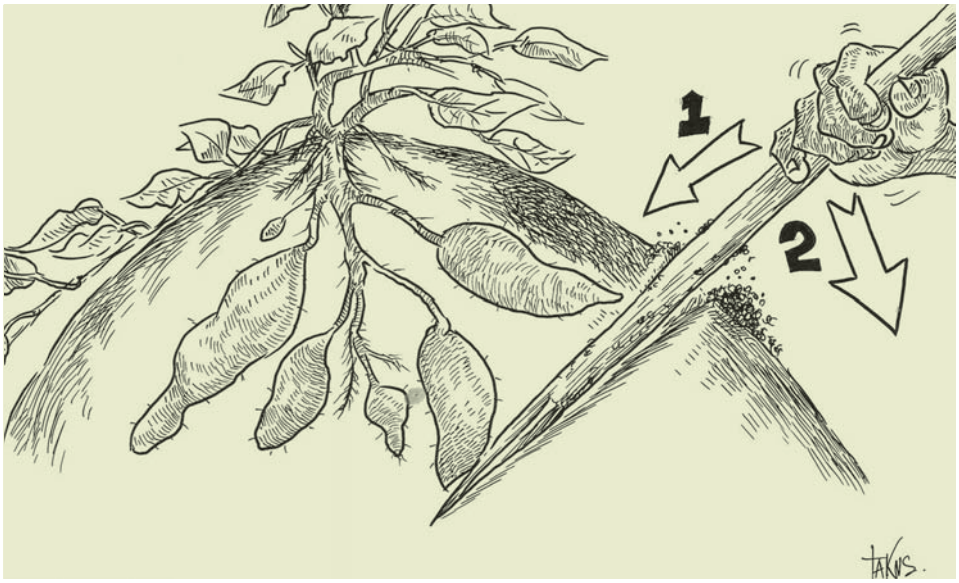


Figure 3.1: Harvesting root and tuber crops with a digging fork. The digging tool is pushed into the soil under the roots or tubers (action 1), which can then be levered upwards (action 2).

Vegetables

Either the whole or part of the vegetative growth can be harvested by hand or using a sharp knife. Knives must be kept sharp and clean at all times to prevent viral diseases spreading from plant to plant. Harvesting methods vary with the plant parts harvested:

- Leaves only (e.g. spinach, rape)—the stem is snapped off by hand.
- Lateral buds (e.g. brussels sprouts)—the stem is snapped off by hand.
- Stem crops (e.g. asparagus)—the stem is cut cleanly with secateurs or a sharp knife.

- Leafy and flower heads (e.g. lettuce, broccoli, cauliflower, cabbage)—the head is pushed slightly to one side and the main stem is cut through with a sharp knife (Figure 3.2.) Trimming is done in the field, taking care not to place the cut stem on the soil.
- Bulbs (e.g. green onions, leeks, matured bulb onions)—immature green onions can usually be pulled from the soil by hand. Leek, garlic and mature bulb onions are loosened by using a digging fork as for root crops such as carrots, and lifted by hand. In addition, simple tractor implements are available for undermining bulbs and bringing them to the surface.
- Seed-bearing structures (e.g. peas, beans, squash, pumpkin)—these are plucked individually by hand at the natural breakpoint of the stalk, which can be easily broken at harvest.

Figure 3.2: Harvesting broccoli with a sharp knife.

Fruits

Many ripe fruits have a natural breakpoint of the stalk that can be easily broken at harvest. However, fruits that are to be harvested in the unripe green state are difficult to pick without causing damage to either the produce or the plant. In this case it is best to harvest by cutting the fruit from the plant using clippers, secateurs or sharp knives. The clippers may be mounted on long poles for tree fruits, with a bag attached to the pole to catch the fruit (Figure 3.3).

Plucking methods vary according to the kind of produce being harvested:

- Ripe fruit with a natural breakpoint, which leaves the stalk attached to the fruit (e.g. passionfruit, sugar fruit, tomato), is best removed by a 'lift, twist and pull' technique, as in Figure 3.4.
- Mature green or ripe fruits with woody stalks that break at the fruit–stalk junction are best clipped from the tree, leaving up to a centimetre of fruit stalk attached. If the stem is broken off at the point where it joins the fruit (e.g. in mango, citrus, avocado), disease may enter the stem scar and give rise to stem end rot.
- Immature fruit with fleshy stems (e.g. zucchini, okra, papaya, capsicum) can be cut with a sharp knife. These can also be harvested by breaking the stem by hand, but this method may damage the plant or fruit and the rough breakage will be more susceptible to decay than would a clean cut.

Figure 3.3: Bag used for catching tree fruits.

With highly perishable produce, damp cloths can be used to give protection against the sun's heat. Field containers should be removed to a shaded area as soon as possible. Some leafy vegetables may be sprinkled with water at intervals to maintain leaf turgidity. Field assembly points, such as a shade house made out of natural materials or a canvas tent, should be used to keep the produce cool and allow ventilation.

FACT

The quality of fruit and vegetables cannot be improved after harvest. All that can be done is slow the rate of deterioration through more careful management practices.

Almost all harvesting of fresh produce in PNG is done manually. Since most farms are small scale, this is appropriate. With careful hand harvesting using the techniques described here, damage to produce should be low, and this means higher incomes. Normally, when it is just the immediate family involved in harvesting the produce, it is not difficult to ensure careful hand harvesting. However, when extra workers are hired for harvesting they must be trained and properly supervised.

After harvesting there are a number of activities required before the crop in the field ends up as a sale in the market. The three main types of activities are handling (Section 3.2), storage (Section 3.3) and transportation (Section 3.4).

Figure 3.4: Harvesting tomato using the 'lift, twist and pull' series of movements.

3.2 Postharvest handling

The main postharvest handling activities include trimming and washing, sorting, grading, packing, weighing, precooling and curing.

3.2.1 Trimming and washing

Trimming involves removing leaves, stems and other plant parts from the harvested produce that are not required by the market. For some crops (e.g. lettuce, cabbage, cauliflower and broccoli) outer leaves may be left to improve the appearance and offer protection to the produce.

Washing removes dirt and other residues (e.g. from sprays and dust) and also improves the appearance of the produce, making it more attractive to the consumer. This is particularly the case for produce with edible parts that come in direct contact with the soil (e.g. lettuce, cabbages, onions, leeks, carrots) (Figure 3.5). However, tubers such as kaukau and potato do not need washing and can be dry brushed after curing to remove dust.

HINT

To minimise disease damage during storage or shipment, rinse vegetables with a chlorinated solution after washing with clean running water.

Figure 3.5: Produce such as carrots that come in direct contact with the soil benefit from washing.

Fruits like citrus and mango, and fruit vegetables like tomatoes, capsicum and zucchini, may be wiped with a soft clean cloth to remove dust and residues.

After the produce is cleaned it should be kept cool to prevent the development of rot organisms.

3.2.2 Sorting

Before packing the produce for market, damaged, bruised, severed, sick, pest-damaged and deformed produce must be sorted out. Figure 3.6 shows two examples of produce that would be removed during sorting. Further examples are shown in Figure 1.1.

Figure 3.6: Deformed carrots (left) and damaged capsicums (right). These need to be removed during sorting.

3.2.3 Grading

Grading involves separating a particular fruit or vegetable into different lots on the basis of specific characteristics such as size, length, colour, firmness—whatever is relevant to the market. Grading ensures that crops are uniform. When produce is graded it looks more attractive to the customers and makes their shopping easier. Even crops of secondary quality when well-graded can be sold faster than poorly graded high-quality crops. Grading may take place before or after sorting (Figure 3.7).

Sorting and grading means that time isn't wasted transporting produce that the buyer will not want or will only take at a discount. It also means that rotten items that may contaminate good produce at later handling stages can be eliminated. Sorting and grading can help build a good long-term relationship with the buyer.

Figure 3.7: Well-graded carrots (top) and capsicum (bottom).

Figure 3.8: Examples of incorrect ways of packing produce and using packing materials. Can you see why?

PUT YOURSELF IN THE PLACE OF YOUR BUYER

What would you say to someone who wanted to sell you produce that was bruised or damaged? And what would you think if they tried to trick you by putting good-quality produce on top of the pack and poor-quality at the bottom?

3.2.4 Packing

The two main functions of packing are to:

- prevent mechanical damage
- sort the produce into an acceptable size for handling and marketing.

Good packing can also enhance the attractiveness of the produce.

Many farmers in PNG pack their produce in whatever cheap packaging materials are available. This is not a bad idea so long as the produce is well protected from physical damage and arrives in good condition. PNG farmers generally do not have to worry about fancy and attractive (and therefore expensive) packaging because when the produce is received by buyers it is typically transferred to the buyer's own packaging materials or directly onto retail shelves for display.

A variety of packaging materials may be used to pack fresh produce including bags, net-bags, cartons, trays, boxes and bilums. Berries are packed into trays while net-bags are used to pack cabbages, bulb onions, carrots and potatoes. Copra bags and flour bags (with holes in the sides) are used to pack potatoes and kaukau. Shade cloth for the plant nursery may be made into bags for packing spring (bunching) onions. Boxes, crates, cartons and string bags (bilums) are used for general purposes.

Fresh produce should be packed properly and neither overpacked nor underpacked. When underpacked, produce tends to move around in the packaging material and can be damaged. When overpacked, damage can result from produce pressing against other produce. Further damage may occur when the packaging materials are incorrectly stacked. See Figure 3.8 for some examples of incorrect packing practices and Figure 3.9 for correct packing practices.

Packing is also a means to sort produce into an acceptable size for handling and marketing. The package needs to be a suitable size for storage and transfer of the produce from the point of production to the point of final sale or consumption. A common problem with overpacking is that it may lead to overheavy and difficult-to-handle packages, which can cause damage by being dropped or handled roughly.

Some growers try to trick their buyers by placing good produce at the top of the pack and poor-quality produce at the bottom. This is not a good idea because the buyer will find out and, in the long run, the grower will lose their buyer.

Figure 3.9: Examples of correct ways of packing fresh produce and the correct packaging materials used.

Various padding materials (e.g. paper, wood strips or dried banana leaves) may be used as bottom cushion pads or between layers of fruit and vegetables to reduce bruising (Figure 3.10).

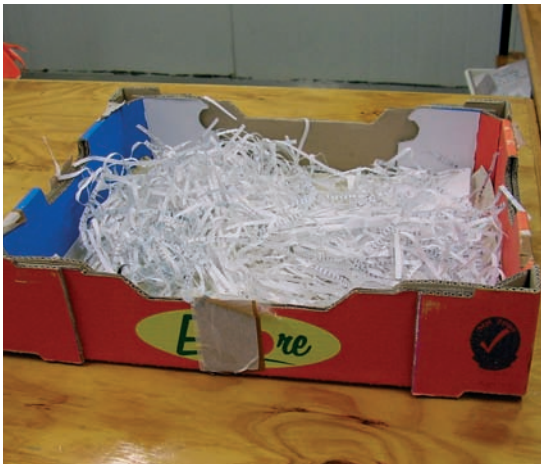


Figure 3.10: Paper strips may be used as effective cushioning material for fresh produce.

3.2.5 Weighing

In the marketing of fresh produce the prices of crops are set according to weight. The weights of both the produce and the packaging material (especially cartons) are taken (Figure 3.11).

3.2.6 Precooling

Following harvest the most important factor affecting storage life is pulp temperature, which is the temperature inside the produce. High pulp temperature typically results in a shorter storage life. One way to keep the

Figure 3.11: Weighing produce in the field (top) and at the buyer's warehouse (right).

pulp temperature as low as possible is to harvest in the early mornings when the air temperature is cool. If possible it is also a good idea to 'precool' the produce.

In the precooling process, field heat is removed from the produce through quick cooling right after harvest and before it goes into storage. This quickly lowers pulp temperature and so helps to lengthen the storage life of the produce. Some different approaches to precooling involve cool rooms, cool moving water, ice or iced water, and fans.

Room cooling

Room cooling involves placing produce in a cool room in small containers so that the cool air in the room can completely surround the containers and remove field heat from the produce. A recent example of an ideal cool room is that developed on an experimental basis jointly by the Department of Agriculture, University of Technology, Lae, and the Fresh Produce Development Agency (Figure 3.12). This cool room is double-walled with the two layers separated by a 3-centimetre gap filled with river sand. Cool water is trickled over the sand, providing a cooling effect and helping to maintain humidity. It ensures that the temperature is kept constant, at about 5–10 °C below the outside air temperature.

Figure 3.12: Evaporative cooling storage room—a low-cost method of cool storage that doesn't require electricity.

Because the temperature reduction is not great, produce intended for room cooling must be tolerant of slow heat removal. To maximise the cooling potential, ensure that the containers (boxes or trays) are small and well vented. Room cooling is commonly used on products that have a longer storage life, e.g. potatoes, kaukau and citrus.

Hydro-cooling

Produce can be cooled more rapidly by contact with moving cool water. Most hydro-cooling involves cold water showering down over produce at 7–10 litres per second per square metre. If there is a cool running creek nearby, this may be used by immersing produce in a wire basket. The use of cold water is an old and effective way of cooling many fruits and vegetables, especially those not sensitive to water. Hydro-cooling may also help in the cleaning of the produce. It is important to ensure that the cold water comes into contact with as much of the surface of the produce as possible to maximise the cooling effect. Also, if the water is to be re-used, soil and debris must be removed to enhance the cleaning and reduce the risk of contamination.

Package-icing and iced water cooling

If ice is available, some produce (e.g. carrots, brussels sprouts, leaks, parsley and broccoli) can be precooled by placing it on crushed ice in packages, or by placing the produce in a bucket, dish or drum containing iced water (Figure 3.13).

Figure 3.13: Iced water is used to precool broccoli.

Table 3.1: Appropriate methods of precooling				
Type of commodity	Room	Hydro	Ice/iced water	Forced-air
Tree fruits				
citrus	✓			
tropical	✓			
Leafy vegetables				
(cabbage, lettuce, spinach, Chinese cabbage, bok choy)		✓		✓
Root vegetables				
with tops		✓		✓
topped		✓	✓	✓
potatoes, kaukau	✓			
Stem and flower vegetables				
asparagus		✓		
broccoli, brussels sprouts		✓	✓	✓
cauliflower				✓
celery, rhubarb		✓		✓
green onions, leeks		✓	✓	
Mushrooms				✓
Pod vegetables				
beans		✓		✓
peas			✓	✓
Bulb vegetables				
(dry onions, garlic)	✓			✓
Fruit-type vegetables				
(cucumbers, eggplant)	✓			✓
Melons				
honeydew		✓	✓	✓
watermelon		✓		✓
Peppers	✓		✓	✓
Sweet corn		✓	✓	✓
Tomatoes	✓			✓
Fresh herbs	✓			✓
Strawberries				✓

Forced-air cooling

If electricity is available, forced-air cooling may be used for many varieties of fruits and vegetables. It is similar to room cooling except that fans are installed to blow air through and around the containers. It is important that containers are well vented and stacked to allow good airflow. The system creates a slight pressure gradient to force air through vents/slots, achieving rapid cooling through the close contact between cold air and warm product.

The most suitable precooling method should be selected depending on the type of produce. For example, strawberries, which cannot tolerate free moisture because of diseases and injury problems, cannot be precooled by hydro-cooling or package-icing. They require fast cooling after harvest so room cooling is not suitable. Thus forced-air cooling is the only effective method for strawberries. Table 3.1 shows which type of precooling is most suitable for a variety of types of produce.

3.2.7 Curing

Curing is a simple technology to enhance the storage life of:

- tubers (e.g. kaukau, potatoes)
- bulbs (e.g. bulb onions, garlic)
- corms (e.g. taro).

Curing helps heal harvesting injuries, reduces water loss and prevents entry of decay-causing organisms during storage. Curing may be done in the field or in curing rooms. It takes place after harvest and before storage or marketing. The conditions of temperature, humidity and time required for curing vary with different commodities (Table 3.2).

In curing of tubers and corms an outer skin (periderm) is developed over cut, broken or skinned surfaces to provide protection. After harvest the tubers and corms are put into rooms/sheds that do not have direct sunlight coming in. Direct sunlight can cause the development of green pigment on potatoes and shrivelling of kaukau, both of which are undesirable. Potatoes and kaukau are spread out on the floor or platform as, for example, in Figure 3.14. Kaukau can be cured for up to a week, while potatoes will take about 2 weeks. See Table 3.2 for details of optimum temperature, humidity and duration of curing.

Table 3.2: Optimum conditions for curing

Produce	Temperature (°C)	Humidity (%)	Duration (days)
Potatoes	15–20	85–90	5–15
Kaukau	30–32	85–90	4–7
Bulb onion, garlic	30–45	60–75	14–21

Figure 3.14: Potatoes being cured on the floor of a curing room.

In curing of bulbs the necks and outer scales are dried to provide protection. After harvest, bulb onions and garlic may be cured by drying in direct sunlight for about 2 hours daily for 2–3 weeks, depending on the available sunlight. The bulbs are spread out to allow them to cure (Figure 3.15). Alternatively, they may be cured on platforms in sheds or by putting them in wire baskets in the fireplace and allowing smoke to cure them. While high humidity is required for curing potatoes and kaukau, low humidity is required for curing onions and garlic (Table 3.2). During wet and cloudy weather it is a good idea to dry bulb onions and garlic in heated rooms with temperatures in the range of 30–45 °C.

3.3 Storage

Storage tends to stabilise prices by carrying over produce from periods of high production to periods of low production. Without storage the producer would be forced to put produce on the market soon after harvest, regardless of the demand. If all growers market their crops at the same time this could result in a glut (excessive supply), and hence low prices and consequent loss to the producer. For most produce, especially vegetables, the main need of storage is for short periods, in many cases for a few weeks only.

Successful storage requires a good product that is harvested at the right stage of maturity for storage and free of diseases and other injury. A diseased or injured product usually deteriorates rapidly in storage,

THE COOL CHAIN

Between harvest and market, fresh produce typically goes through a chain of operations—handling (trimming and washing, sorting, grading, packing, weighing, precooling, curing), storing and transporting. At all times the temperature of the produce should be kept cool and constant. High temperatures, even for a short time, can quickly damage the produce and make it less attractive to buyers.

especially under conditions favourable for the development of storage rot. Apart from these conditions the most important factors affecting storage life are temperature and relative humidity.

3.3.1 Temperature

Temperature is by far the most critical environmental factor that influences the deterioration rate of harvested vegetables. Lowering the temperature decreases respiration, transpiration, and microbial and insect growth. Precooling serves to remove field heat from the produce, but (apart from curing) it is then important during storage to lower the pulp temperature and keep it constant. The optimum temperature is the most favourable temperature for extending storage life—the further the storage temperature is from the optimum, the more the vegetables will deteriorate. A rough rule of thumb is that for every increase of 10 °C above the optimum temperature the storage life can be expected to halve. However, this is not true for all produce. Table 3.3 shows the storage lives of different types of produce, first at the optimum temperature (column 4) and then at average atmospheric temperature (column 5).

Figure 3.15: Onions being cured on the floor of a curing room.

Table 3.3: Ideal storage temperature and relative humidity for various types of fresh produce found in the PNG highlands

Fruit/vegetable	Temperature °C	Relative humidity* (RH)	Storage life	
			At ideal conditions (weeks)	At normal conditions ** (days)
Asparagus	0–4	Very high	2–3	2
Beans, French	5–9	High	1–2	1–2
Broccoli	0–4	Very high	2–3	1–2
Cabbage, Chinese	0–4	Very high	4–6	2–4
Cabbage, English	0–4	Very high	4–16	7
Capsicum	7–13	Very high	2–3	7
Carrots	0–4	Very high	16–24	8
Cauliflower	0–4	Very high	2–3	2–3
Celery	0–4	Very high	4–8	2–3
Cucumber	10–13	Very high	1–2	8
Garlic	0–4	Low	24–28	21–28
Leek	0–4	Very high	8	3
Lettuce	0–4	Very high	2–3	1–2
Onion, bulb (refrigerated)	0–4	Low	4–32	7
Onion, bulb (unrefrigerated)	25–30	Medium	4–8	7
Onions, spring	0–4	Very high	3–4	2–3
Pea, green and snowpea	0–4	Very high	1–2	1–2
Pineapple	7–13	High	2–4	7
Potato	5–13	Very high	20–40	21–28
Silver beet	0–4	Very high	1–2	1–2
Strawberries	0–4	Very high	Up to 1	1
Sweet potato (Kaukau)	13–15	High	16–28	21–28
Tomatoes (mature green)	13–15	Very high	2–3	7
Tomatoes (ripe red)	8–10	Very high	1–1.5	1–2
Zucchini	0–9	Very high	2	2

*Relative humidity: low = 60–70%; medium = 70–80%; high = 80–90%; very high = 90–100%

**Normal conditions for PNG highlands: 25 °C, 60–70% relative humidity

3.3.2 Relative humidity

The air normally contains moisture as water vapour. Sometimes it contains all the water vapour it can hold, in which case it is saturated. Most of the time, though, the air contains less moisture than the maximum, and the ratio of the amount it actually contains and the amount it can hold when it is saturated is called relative humidity. If the air is saturated its relative humidity is 100%. The lower the relative humidity, the drier the air.

Since a vegetable contains 80–90% water, it will lose its water (transpire) if the relative humidity of the air is below this level. The lower the relative humidity of the air below this level, the greater the amount of water lost from the vegetable. As a result, the vegetable will eventually become dry or shrivelled and lose its freshness.

3.3.3 Optimum storage temperature and relative humidity

Different types of produce have different ideal temperatures and relative humidities for storage. In columns 2 and 3 of Table 3.3 these ideal values are shown for the various types of produce discussed in detail in Section 4. If, instead of ideal conditions, the produce is stored at normal atmospheric conditions for the highlands of PNG, storage life can be expected to decline to something like the values in column 5 of this table. Higher temperature and lower relative humidity can greatly reduce the storage life of fresh produce. Thus, it is important to keep produce out of the sun and, preferably, in a cool store. Produce left in the sun will quickly deteriorate and the marketer will lose valuable income as a result.

When produce is stored in a cool room or refrigerated container it is important to check temperature and relative humidity on a regular basis (Figure 3.16).

Figure 3.16: When placing produce in a chiller, regular checks on the temperature and humidity are necessary.

3.4 Transportation

Harvested produce destined for the commercial market must be transported from the point of production to the point of consumption. These points may be within walking distance or thousands of kilometres apart. In general, the farther away the market is from the farm, the more complicated the system of transport required to maintain quality.

Several modes of transportation are used to move fresh produce from shipping points to destination markets, including road, sea and air. In PNG most of the produce is transported by road for at least part of the journey, although some is transported by road from the highlands to the nearest seaport (e.g. Lae and Madang) and then by sea to other centres like Port Moresby and Rabaul. Only a small proportion of produce (perhaps 5–10%) is air freighted. This tends to be the more valuable, more perishable types of produce going from the highlands to coastal markets.

Losses directly attributed to transport conditions can be high. The goal of every person concerned with the transportation of fresh produce should be to keep the produce in their care in the best possible condition during transit, and for the transportation to be as quick and efficient as possible. To this end, produce should be properly packaged and properly loaded on a suitable vehicle.

3.4.1 Road transport

Most fresh produce destined for the market is now moved by road, with lesser amounts going by sea, air or inland waterways. Factors to consider in road transportation are type of road vehicle, handling and stowage practices, and driving practices.

Type of road vehicle

The most commonly used vehicles are open pick-ups and bigger trucks, either open or enclosed. In choosing the type of road vehicle, users may wish to consider the following:

- Open-sided or half-boarded trucks can be fitted with a roof on a frame. The open sides can be fitted with canvas curtains, which can be rolled up or moved aside in sections to allow loading or unloading at any point around the vehicle. Such curtains protect the produce from the elements but still allow ventilation. Where stealing in small quantities is a problem, the sides and rear of the truck must be enclosed in wire mesh. A white-painted roof can also be fixed as a radiation shield 8–10 cm above the main roof. This will reflect the sun's heat and help to keep the produce cool.
- Refrigerated trucks or road or sea containers may be used for long journeys, but the cost of such transport makes it uneconomical for small-scale operations.
- Closed vehicles without refrigeration should not be used to carry fresh produce except on very short journeys, such as local deliveries from farmers or wholesalers to nearby retailers.

Handling and stowage practices

The main aim in transportation is to ensure that the load is stable, well protected against damage and well ventilated. Factors to consider are:

- Avoid overloading, which greatly increases the risk of damage to fresh produce (Figure 3.17).
- Cover produce to protect it from rain and sun during transportation, loading and unloading (Figure 3.18).
- Choose the size and design of packages to give adequate levels of ventilation of the contents with the minimum of wasted space, and ensure the packages are strong enough to protect the contents. Stow carefully to avoid collapse during transport. Packages should not be stacked higher than the maximum recommended by the maker, otherwise the bottom layers may collapse under the weight of those above (Figure 3.19). Load packages on pieces of lumber or slatted racks on the beds of vehicles, or on pallets, in order to allow air circulation around the stacks during transport. Distribute the load evenly on the vehicle.
- Avoid careless handling of packed produce during loading and unloading.
- If the packages are to be distributed to several locations, load them in reverse order to that in which they will be unloaded (i.e. last on, first off).

Figure 3.17: Overloading greatly increases the risk of damage to fresh produce.

Figure 3.18: Cover produce from rain and sun during transportation.

Figure 3.19: Collapsed cartons can lead to damaged produce.

Driving practices

Vibration (shaking) of the vehicle, especially on bad roads, can damage produce. In many cases drivers are induced to speed in order to make more money for themselves or their employers. Remember these tips:

- Whenever possible, only experienced and responsible drivers should be used.
- Restrict transport speeds to a level that will avoid free movement of produce.
- Driving carefully on bad roads is essential. Fast driving should be avoided (Figure 3.20).

Figure 3.20: Bad road conditions can greatly damage produce during transit.

3.4.2 Sea transport

This is used for the transportation of produce around the coast (e.g. from Lae to Port Moresby) or from the mainland to the islands. A significant amount of highland produce is transported by road to a coastal port (e.g. Lae or Madang) and then loaded into a shipping container for sea transport on a container ship to another mainland port or to the islands (Figure 3.21). The shipping containers are either dry (for less perishable crops) or refrigerated (for more perishable crops).

Figure 3.21: Container ship used to transport fresh produce in dry or refrigerated containers.

Highland grower–marketers who want to ship their produce by sea transport need to have good communications with the ship owners to know which day the ship will be loading. For example, if a grower–marketer from Goroka in the highlands brings produce down to Lae on Thursday but the container ship is not loading until the following Wednesday, the produce will be sitting in the port for nearly a week, often without adequate storage facilities. This will be a particular problem for perishable produce as it will markedly deteriorate in the warm humid climate.

3.4.3 Air transport

Air shipment is restricted to high-value, highly perishable types of fresh produce because of the high cost of freight involved (Figure 3.22). But freight cost is not all that needs to be considered when deciding whether to transport fresh produce by air. There is a significant risk of deterioration in the quality of the produce at airports due to careless handling or exposure to the elements.

Figure 3.22: Loading fresh produce into an airplane.

The situation is often made worse by:

- consignments being left behind in favour of passengers
- flight delays owing to bad weather or breakdowns.

It is important to try to minimise this risk by:

- ensuring good packaging
- staying with the produce until it is loaded onto the plane, and arranging for the buyer or someone trustworthy to pick it up at the end of the flight
- arranging refrigeration where necessary.

3.5 Marketing and postharvest losses

When selling produce, whether it is in the local village market or in a distant city market, good quality management can be the difference between making a profit or a loss. In the case study outlined in Box 2, the farmer–trader ended up not even covering his out-of-pocket expenses let alone getting a return for his efforts (or the efforts of his contact in Port Moresby). The lesson to be learned is that it is not sufficient to just look at the buying and selling prices of fresh produce. Although the expected selling prices for the produce were substantially higher than the buying prices, they were outweighed by the costs of shipment. One of the biggest costs, and one that is often forgotten, is the cost of losses in transit due to damage and

Box 2

This is an actual account of a business arrangement undertaken by a farmer–trader from near Goroka. He buys fresh produce from his neighbours and sells through a contact in Port Moresby. Recently, he found he could buy English potatoes for K100/bag (with each bag weighing 50 kg), kaukau for K50/bag (with each bag weighing 85–90 kg) and English cabbage at K42/bag (with each bag weighing 60–65 kg). At the time his contact in Port Moresby told him that English potatoes were selling there for 50% more than the buying price, while kaukau and English cabbage were selling for double the buying price. This looked like a good business proposition and so he bought 40 bags of potatoes, 20 bags of kaukau and 10 bags of English cabbage for shipment to Port Moresby. The out-of-pocket expenses for undertaking this shipment included:

- a vehicle to pick up the produce and deliver it to a trucking company for shipment to Lae—K280
- shipment by the trucking company to Lae (K6.00/bag)—K420
- labour for loading and unloading—K200 (includes bus fare and travel allowance)
- shipment by container ship from Lae to Port Moresby (K0.50/kg)—K2150.

When the produce arrived in Port Moresby, his contact picked it up at the wharf. However, there was some damage and spoilage to the produce in transit.

- Of the 40 bags of potatoes, 7 were sold for K150 each. A further 30 bags were sold for K140 each, and the remaining 3 bags were completely lost.
- Of the 20 bags of kaukau, 10 were sold for K100 each. A further 8 bags were sold for K80 each and the remaining 2 bags were lost.
- Of the 10 bags of cabbage, 5 were sold for K80 each. A further 3 bags were sold for K70 each and the remaining 2 were lost.

Income		
Potatoes—	7 bags @ K150/each	K1,050
	30 bags @ K140/each	K4,200
Kaukau—	10 bags @ K100/each	K1,000
	8 bags @ K80/each	K 640
Cabbage—	5 bags @ K80/each	K 400
	3 bags @ K70/each	K 210
Total sales income		**K7,500**
Out-of-pocket costs		
Cost of goods sold		
Potatoes—40 bags @ K100/each		K4,000
Kaukau—20 bags @ K50/each		K1,000
Cabbage—10 bags @ K42/each		K 420
Transportation		
Farm to trucking company		K 280
Road transport to Lae (70 bags @ K6/bag)		K 420
Sea transport to Port Moresby (4,300 kg @ K0.5/kg)		K2,150
Labour (wages, busfare, travel allowance)		K 200
Total out-of-pocket costs		**K8,470**
Profit		**-K 970**

spoilage. When produce is lost at the destination point, the cost of the loss includes not just how much was paid for the produce but also the cost of handling, storage and transportation of the produce that was ultimately thrown away.

3.6 Summary

What all commercial growers and traders want is a keen buyer and a good price. This is not easy to achieve, but one way to help is to make sure that the fresh produce being supplied to the buyer is of good quality. When fresh produce is to be sold, a supply chain is set up between the grower and the buyer and, as with any chain, it is only as good as its weakest link. Suppose produce is being shipped from the highlands to Lae by truck and then by ship to Port Moresby. It can be kept cool and dry all the way down the Highlands Highway to Lae and then put in a refrigerated container from Lae to Port Moresby. But if it sits in the sun for 2 days at the port in Lae waiting for a ship to arrive then it will be damaged. This is the weakest link.

Every point in the supply chain needs to be looked at and queried as to whether there is anything else that could be done better to maintain the quality of the produce. In this section a number of basic quality management practices have been considered that can be carried out at harvest and post-harvest that will help to ensure the quality is at the highest level when it reaches the buyer. Remember, the more carefully produce is handled at every point in the chain, the less the deterioration as it moves through the rest of the chain.

GENERAL RULES FOR TRANSPORTING FRESH PRODUCE

Keep it as cool as possible.

Keep it dry.

Move it to market as quickly as possible.

4. Quality Management of Individual Produce

4. QUALITY MANAGEMENT OF INDIVIDUAL PRODUCE

This section consists of a guide to quality management during and after harvest of some of the more important produce grown in the highlands of PNG. Each section deals with a specific type of produce, arranged in alphabetical order.

4.1 Asparagus

Asparagus is a crop that can be grown all year round. It looks like bamboo shoots but the shoots are smaller in size. The shoots are called spears and they are harvested (and eaten) just before the leaves open. Asparagus is good for the health as it is a good source of vitamin A, several of the B vitamins, vitamin C, fibre and potassium. It may help to reduce skin and kidney disorders.

4.1.1 Maturity and harvesting

Do not harvest the spears before the recommended time because the roots will not be strong enough; some will die and yields will be low. The first harvest should take place 7–9 months after transplanting from the nursery. At this time remove all the ferns (leaves) and 3–5 days later the spears will emerge. Harvest the spears when they are 25–30 cm long and the leaves are tight and unopened. Do not harvest earlier than this. After the first harvest, apply a matchbox full of NPK fertiliser to each plant and wait 4 months before the second harvest. Repeat this process, i.e. fertilise and allow to rest, prior to the third and subsequent harvests. It is important to include the 4-month resting period between harvests to allow the asparagus to heal properly. Continuous harvesting without a rest period will cause the plant to die.

Harvest the spears by inserting a long-bladed knife close to the base of the shoot and removing it with a sloping cut. Harvesting should be done during the cool hours of the day, either early morning or late afternoon.

Knives must be kept sharp and clean at all times to prevent spreading virus diseases from plant to plant.

Quality requirements for market:

- Must be 20–25 cm long and round.
- Must be soft, not too strong and fibrous.
- Should break easily when bent without forming a U-shape.
- Should have tightly closed tips and leaves.
- Should be straight, either pale green or white or sometimes slightly purple.

4.1.2 Postharvest handling

Precooling

After harvesting the asparagus spears put them in a string bag (bilum) and immediately immerse them in a creek or river (or moving cold water). Leave the asparagus in the moving cold water for about an hour or two. Make sure that the water is clean and drinkable.

Sorting, grading and bunching

Asparagus spears that are broken, short or damaged should be removed. The spears may be graded according to market requirements. Only those that meet the quality requirements are bunched using a rope or rubber band. Bunching asparagus makes it easier to handle and also avoids damage. A bunch should contain 7–10 asparagus spears depending on the size.

Packing and weighing

Asparagus spears break easily so pack them in a small carton carefully and neatly. They can be packed either in a standing position or a sleeping position (Figure 4.1). A carton of asparagus should hold 6–10 kg.

Figure 4.1: Asparagus packed neatly in a sleeping position.

4.1.3 Storage

Asparagus is a highly perishable crop and ideally should be stored under very cold temperatures (0–4 °C) and very high humidity (95–100%). Conditions outside these ranges could result in deterioration of the shoots. If cool storage is not available, asparagus should be sold as soon after harvest as possible. Farmers selling in the local market should sell the same day as the asparagus is harvested.

Asparagus is an ethylene-sensitive product so keep it away from ethylene-producing produce during storage and transportation.

4.1.4 Transportation

During transportation, handle the produce with care. Do not throw the cartons of asparagus during loading and unloading, but lift them and put them down carefully. Do not allow anyone to sit on top of the cartons or allow anything heavy to be placed on them. Do not stack the cartons more than four layers high. Transport asparagus in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.2 Broccoli

Broccoli belongs to the same family group as English cabbage. It is leafy and produces a flower head, which is the part that is eaten. The flower head is made up of many small unopened flowers. Broccoli is good for the health as it contains vitamins C and E and minerals like iron and potassium. Broccoli may help to guard against cancer.

4.2.1 Maturity and harvesting

Broccoli is ready for harvest when the head is a good size (12–18 cm wide) and when the small flowers are green in colour in a tight compact head. If the flowers open and are yellow in colour then it is too late and the broccoli is overmature.

The flower heads can be cut with a sharp knife and trimmed in the field, or snapped off by hand and subsequently trimmed. See Figure 3.2, where the broccoli head is pushed slightly to one side and the main stem cut through with a sharp knife. It is important to leave enough leaf to cover the head to offer protection during handling and transportation. Broccoli should be harvested during the cool hours of the day, in the early mornings or late afternoons.

Quality requirements for market:

- Must have a head that is tight with no hollow stalk.
- Must be of a good average size—not too big or small (12–18 cm wide).
- Should have green unopened flowers on the head (Figure 4.2).
- Must be free from damage by insects or diseases.

Figure 4.2: Good-quality broccoli.

4.2.2 Postharvest handling

Precooling

It is a good idea to precool broccoli immediately after harvest. Precooling removes field heat that would otherwise shorten the shelf life of the crop. When produce is precooled, the temperature of the crop is brought down quickly. The simplest and quickest method of precooling broccoli is to use iced water in a bucket, immersing the broccoli for about 1 hour (Figure 4.3). Alternatively, the broccoli can be put in a string bag (bilum) and immersed in a creek or river (or moving cold water) for an hour or two. Make sure this water is clean and drinkable.

Figure 4.3: Precooling broccoli using iced water.

Trimming

Trim off the leaves but leave two or three leaves to offer protection to the heads during handling and transportation.

Sorting and grading

Remove any diseased and pest-damaged plants. The broccoli may be graded into different head sizes according to market requirements.

Packing

It is important to pack broccoli tightly so that the heads do not move freely and cause damage. Use good cartons that can hold up to 10 kg each (Figure 4.4). Do not use bags or sacks.

For long-distance marketing it is preferable to pack the broccoli with ice in a carton with a plastic liner (see Figure 3.9).

4.2.3 Storage

Broccoli is a highly perishable crop and may not last for more than 1 or 2 days when kept under unfavourable conditions. At 0–4 °C and high humidity, broccoli can be stored for up to 2–3 weeks. Keep broccoli away from ethylene producers during storage and transportation. Ethylene increases respiration in broccoli, which in turn reduces the shelf life of the crop.

Figure 4.4: Well-packed broccoli heads in a carton.

4.2.4 Transportation

During transportation it is important to handle the produce with care. Do not throw the cartons of broccoli during loading and unloading, but lift them and put them down carefully. Do not allow anyone to sit on top of the cartons or allow anything heavy to be placed on them. Transport broccoli in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.3 Cabbage, English

English cabbage has a big, round, strong head that is made up of dark green fleshy leaves tightly bound together. The inside leaves are white. The dark green leaves are high in vitamin C and iron. It may help people suffering from anaemia.

4.3.1 Maturity and harvesting

After transplanting out to the main garden, the cabbages will be ready in 2 months on the lowlands/coast and 3 months in the highlands. The cabbage head must be firm and tight when it is ready to be harvested. Press the head gently to check for firmness (Figure 4.5). If left too long the head will break or become loose.

During harvesting slightly push the head to one side and cut the stem with a clean heavy knife once. Make sure that the heads are not bruised or severed. Harvesting should be done in the cool hours of the day, either late in the afternoon or early in the morning. Leave two or three outer leaves to

Figure 4.5: Check the heads of cabbage for firmness.

offer protection to the heads. Do not remove all the green leaves from the cabbage, because if it is all white it will not look attractive to the buyer.

Quality requirements for market:

- the cabbage head must be of a good size
- the head must be tightly bound and firm
- the head must not show signs of insect or disease damage.

Formal markets prefer to buy cabbages like the one in Figure 4.6.

Figure 4.6: Good-quality cabbage.

4.3.2 Postharvest handling

Precooling

After harvest the cabbages may be put in a cool room for precooling. However, this is not essential since English cabbages are not highly perishable.

Cleaning and trimming

Dirt adhering to the base of the cabbage should be removed. Dry leaves should be trimmed, leaving enough leaves to protect the head.

Packing

The cabbages can be packed either in coffee bags or cartons with holes to allow air to flow through and keep them cool and dry. Do not use flour or stockfeed bags without air holes in the sides as the cabbages will sweat and start to rot. A bag of cabbage may weigh up to 60 kg. Be sure to carry or handle the packed bags with care, and don't sit on them or stack them too high as the cabbages can be damaged easily (Figure 4.7).

4.3.3 Storage

Cabbages can be stored up to 3 months under favourable conditions of 0–4 °C with high humidity. Under highlands conditions (25–27 °C and 60–70% relative humidity) they can be stored for up to 1 week. It is advisable to keep the cabbages under cool conditions for longer storage and away from ethylene producers during storage and transportation. Ethylene increases respiration in cabbages, which in turn reduces the shelf life of the crop.

Figure 4.7: Cabbages well-packed in a coffee bag (left). What is wrong in the photo on the right?

4.3.4 Transportation

During transportation it is advisable to handle the produce with care. Do not throw the bags or cartons of cabbages during loading and unloading, but lift them and put them down carefully. Since a bag of cabbages weighs about 50–60 kg it would be a good idea to have two people carry one bag at a time during loading and unloading. Do not allow anyone to sit on top of the bags or cartons or allow anything heavy to be placed on them. Transport cabbages in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.4 Capsicum

Capsicum is a pepper that is not hot like other peppers but is sweet. It is a fruit vegetable that is usually bell shaped and is used in many dishes to enhance and provide flavour. Green capsicums contain vitamin C and powerful antioxidants, which may protect the body against cancer and heart disease.

4.4.1 Maturity and harvesting

The fruit is ready for harvest when it is a good size and firm, and the skin is clear and shiny. Most are harvested when they are green, but if left longer in the garden some of the fruit will turn red.

Capsicum can be picked by hand, but this needs to be done with care since it has a fleshy stem that can be easily broken. This may cause damage to the plant or the fruit which can lead to infections. It is better to use a clean sharp knife or secateurs and make a clean cut on the stalk just before the fruit.

Quality requirements for market (Figure 4.8):

- Must be a good size (not too small or too big).
- Must have clean skin with no marks, spots or discolouration.
- Skin must be firm with no bruising.
- Must be free from pest and disease damage.

Figure 4.8: Good-quality capsicums.

4.4.2 Postharvest handling

Precooling

It is a good idea to remove field heat immediately after harvest by putting capsicums in a basket and dipping them in cool running water for an hour. Fans can also be used to precool capsicums where electricity is available.

Figure 4.9: Capsicums packed in a collapsible plastic crate.

Cleaning, sorting and grading

All damaged, malformed and bruised capsicums should be removed. Those with dirt adhering to their surface can be cleaned by wiping the surface with a moist soft cloth. The capsicums may be graded into same size and colour lots according to market requirements. Capsicums like those shown in Figure 1.1 should be removed during sorting.

Packing

Pack capsicums in good packaging material such as cartons or plastic crates. Never pack them in bags or bilums as they will break easily. A carton of capsicums should hold about 10 kg. (Figures 3.7, 4.8 and 4.9).

4.4.3 Storage

Capsicums can be stored in a cool room at a temperature of 7–10 °C for up to 3 weeks. For storage purposes, capsicums should be of good quality because quality will decline during storage. Since produce in storage will be competing with newly harvested produce, it is a good idea to try to minimise the amount of time in storage before selling.

4.4.4 Transportation

During transportation it is advisable to handle the produce with care. Do not throw the cartons of capsicums during loading and unloading, but lift them and put them down carefully. Do not allow anyone to sit on top of the cartons or allow anything heavy to be placed on them. Transport capsicums in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.5 Carrots

Carrots belong to the same family as parsley and celery. The edible part of the carrot is the orange coloured root that grows in the soil. Carrots are good for the health as they are high in Vitamin A, which may be good for the eyesight, the skin and the heart, and may also help guard against cancer.

4.5.1 Maturity and harvesting

Carrots are ready for harvest 10–15 weeks after they have been planted. Check the size of the carrots (roots) in the garden—if they are about as long as an average adult human hand, they are ready for harvest.

Carrots are loosened from the soil by inserting a digging tool at an angle and levering it upwards. The roots must be lifted carefully to avoid damage, and shaken to free the soil. The carrots can also be pulled from the soil if they are grown on loose soil. Harvest carrots during the cool hours of the day, either late in the afternoon or early in the morning.

Quality requirements for the market:

- Must be of a good size, about the length of a man's palm (Figure 4.10) and not too big or too small.
- Must not be broken, twisted or have a green colour around the top.
- Must not be dry and rubbery.

Figure 4.10: A good-sized quality carrot.

Figure 4.11: These carrots have been washed and trimmed.

4.5.2 Postharvest handling

Precooling

Carrots are a less perishable crop and may not need precooling.

Cleaning and trimming, sorting and grading

Carrots usually have soil adhered to their surface so it is a good idea to wash them (Figure 3.5) and trim their leaves (Figure 4.11). The carrots are then sorted, removing the deformed and other bad ones (Figures 1.1 and 3.6), and may be graded according to market requirements, especially by size (Figure 3.7).

Figure 4.12: Carrots being packed into a carton.

Packing

Carrots should be packed in cartons (Figure 4.12), special carrot bags or net bags. Pack the carrots neatly and properly so they do not break. A carton or bag should contain 15–20 kg. If you use flour or stockfeed

bags make sure they have air holes in the sides, otherwise the carrots will sweat and start to rot.

4.5.3 Storage

Mature carrots can be stored for a longer period (about 5 months) if kept under favourable conditions of 0–4 °C with high humidity. Immature carrots under the same conditions can be kept for about 1 month.

Carrots intended for storage should be of good quality (i.e. first remove any bruised, damaged and other unwanted ones). Keep carrots away from ethylene-producing produce like ripe tomatoes as this will make the carrots taste bitter.

4.5.4 Transportation

During transportation it is advisable to handle the produce with care because carrots break easily. Do not throw the cartons or bags during loading and unloading, but lift them carefully and put them down carefully. Do not allow anyone to sit on top of the bags or cartons of carrots or allow anything heavy to be placed on them. Transport carrots in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.6 Cauliflower

Cauliflower belongs to the same family as cabbage and broccoli. It has large broad leaves with a white flower head between the leaves. This crop is a good source of vitamin C and may help guard against lung cancer, heart disease, and digestive and kidney disorders.

4.6.1 Maturity and harvesting

Cauliflower is ready for harvest when the head is of a good size (12–18 cm wide), white in colour, tight and compact. When it is ready the leaves covering the head open up, exposing the white head. When the small flower head first appears, cover it with leaves to prevent damage by the sun. Sunlight makes the head turn a yellow colour. When the cauliflower head starts to open it is overmature.

Cauliflower can be cut with a sharp knife and trimmed in the field. Slightly push the plant to one side and slash the main stem once with a clean heavy knife. During the harvesting operation make sure that the heads are not damaged or bruised. Harvesting should be done in the cool hours of the day, either late in the afternoon or early in the morning.

Quality requirements for market (Figure 4.13):

- Should have a white flower head with no marks or spots on it.
- Head must be tight and of a good size.
- Head must still have some leaves to cover it.

4.6.2 Postharvest handling

Precooling

It is a good idea to precool cauliflower immediately after harvest. The simplest and quickest method of precooling is to use iced water. If you have access to ice, break it up, put it in a bucket of water and immerse the cauliflowers. Alternatively, cauliflowers can be put in a string bag (bilum) and immersed in moving cold water (such as a creek or river) for an hour or two. Make sure the moving cold water is clean and drinkable.

Trimming

Trim the head, leaving two or three leaves covering the head to offer protection during handling and transportation (Figure 4.13).

Packing

Pack the cauliflower properly in cartons with holes for airflow. Do not leave spaces between them, so as to avoid movement that will cause damage during transportation (Figure 3.9).

4.6.3 Storage

Cauliflower is a perishable crop. When kept under optimum conditions of 0–4 °C with high humidity, the crop can last for about 3 weeks. For storage purposes collect only the good quality ones. Cauliflower is sensitive to ethylene so keep the crop away from ethylene producers during storage and transportation.

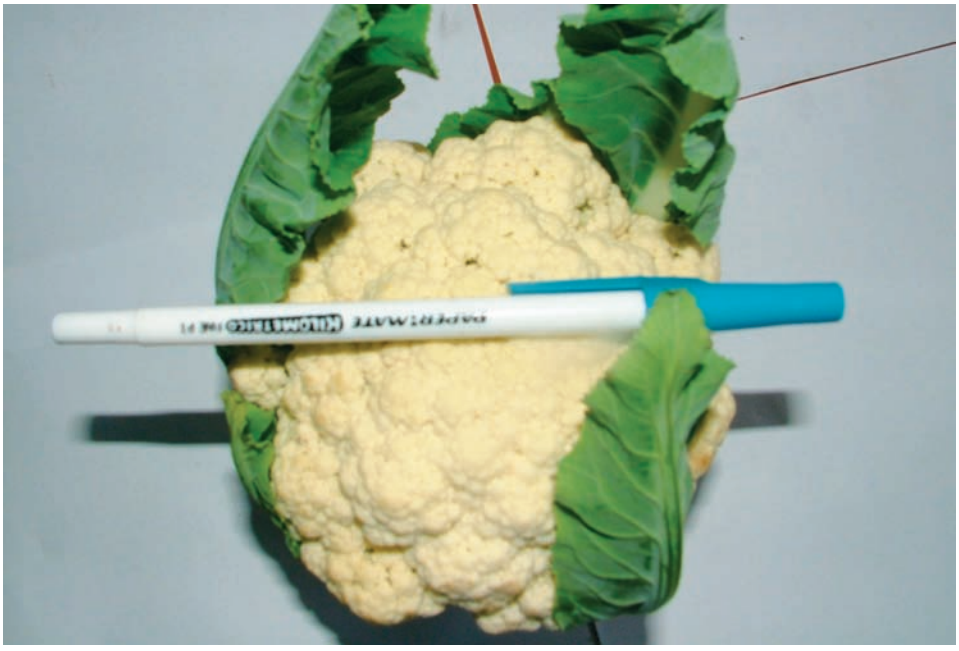


Figure 4.13: Good-quality cauliflower.

4.6.4 Transportation

During transportation it is advisable to handle the produce with care because the heads can be easily damaged. Do not throw the cartons of cauliflower during loading and unloading, but lift them carefully and put them down carefully. Do not allow anyone to sit on top of the cartons or allow anything heavy to be placed on them. Transport cauliflower in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.7 Cucumber

The cucumber is a trailing or climbing plant with hairy, angular stems. It is a popular crop that has been grown for many more years than other introduced produce. It is an important fruit vegetable in the same family group as melons.

4.7.1 Maturity and harvesting

The crop is ready for harvest 60–70 days after planting. Harvest cucumbers when the fruit has grown to a good size but is still young and the seeds inside soft. Always check the garden to make sure the fruit do not become too big and overmature. Overmature fruits turn brownish yellow in colour. Buyers generally prefer green coloured cucumbers about 15–20 cm long. However, some wholesale buyers may prefer yellow or white cucumbers. The fruits are picked by hand by cutting or clipping away the fruit to avoid injury to the vine. Harvest fruit during the cool hours of the day, either early in the morning, late in the afternoon or on a dull day. Make sure that the fruit is not damaged or bruised.

Figure 4.14: A good-sized cucumber.

Quality requirements for market:

- Should be of a good size and shape (Figure 4.14).
- Must show no signs of rotting or insect damage.
- Must be the colour required by the buyer.

4.7.2 Postharvest handling

Precooling

Cucumbers may be precooled by putting them in a cool room where it is well ventilated. Alternatively, they may be hydro-cooled by putting them in a basket and dipping them in cool, moving water (such as a creek or river). However, precooling is not essential for cucumbers; in fact, cucumbers are sensitive to chilling injury at temperatures less than 10 °C.

Figure 4.15: Cucumbers being packed in a lined carton.

Grading

Cucumbers may be graded into same sizes and colours according to market requirements.

Packing

Pack cucumbers neatly in a good carton, preferably of the same size and colour in each carton (Figure 4.15). A carton of cucumbers should hold about 10 kg. Do not pack them in a flour or net bag as they can be easily damaged.

4.7.3 Storage

The optimum storage temperature for cucumbers is 10–13 °C. This crop is sensitive to temperature extremes. Temperatures less than 10 °C can cause chilling injury, while temperatures above 16 °C can cause yellowing of the fruit. Cucumbers are sensitive to ethylene so keep them away from ethylene-producing produce like ripe tomatoes and ripe avocadoes.

4.7.4 Transportation

During transportation it is advisable to handle the produce with care because the fruits can be easily broken and damaged. Do not throw the cartons of cucumber during loading and unloading, but lift them carefully and put them down carefully. Do not allow anyone to sit on top of the cartons or allow anything heavy to be placed on them. Transport cucumber in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.8 Lettuce

The lettuce grown and sold in PNG is head lettuce, which has green leaves with a firm round head. Lettuce may help with nervous, digestive and sleep disorders.

4.8.1 Maturity and harvesting

Lettuce is ready for harvest at 7–12 weeks after planting. At this time the lettuce head will be tight, strong and firm. Before harvesting press the head gently for firmness (Figure 4.16).

To harvest, slightly push the head to one side and slash the main stem once with a clean, heavy, sharp knife. Make sure that the heads are not bruised or damaged as this will lead to a loss in quality. Harvesting should be done in the late afternoon or early in the morning. Do not harvest the lettuce when it is wet as it will heat up quickly and give rise to rotting.

Figure 4.16: Check the lettuce head for firmness and tightness before harvest.

Quality requirements for market:

- should have a strong, tight head
- the head must be of a good size
- the head must not show signs of insect or disease damage.

4.8.2 Postharvest handling

Precooling

Lettuce may be cooled by placing it in a well-ventilated cool room (shed) which should have a temperature 10–15 °C less than the outside temperature. If electricity is available then forced-air cooling would be helpful. Have a fan in a ventilated room/shed blowing across the lettuce.

Trimming and sorting

Leaves that are dry (brown) at the base of the lettuce head should be trimmed off. Those that are damaged or bruised should also be removed.

Packing

Always pack the lettuce in a carton (preferably a special lettuce carton) as shown in Figure 4.17. Pack the lettuce neatly and tightly so that unnecessary movement is restricted during handling and transportation. This will avoid bruising of the heads. Do not pack the lettuce in bags (bilums) as this will cause the leaves to break and the heads to become squeezed (Figures 4.17).

4.8.3 Storage

Lettuce is a perishable crop that needs to be stored under low temperature and high humidity conditions. When stored at the optimum temperature of 0–4 °C and relative humidity of 95–100%, lettuce can be kept for up to 3 weeks. For storage purposes select only good quality lettuce but remember that stored lettuce is never as good as fresh lettuce. On the market stored lettuce will compete with fresh lettuce, so it is advisable to have lettuce stored for only short periods (up to 1 week). Lettuce is sensitive to ethylene so keep it away from ethylene producers during storage and transportation.

4.8.4 Transportation

During transportation it is advisable to handle the produce with care because the heads can be easily damaged. Do not throw the cartons of lettuce during loading and unloading, but lift them carefully and put them down carefully. Do not allow anyone to sit on top of the cartons or allow anything heavy to be placed on them. Transport lettuce in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

Figure 4.17: Lettuce packed in a carton (top) is well protected, unlike in the bilum (bottom).

Figure 4.18: A good-quality bulb onion (45–60 mm diameter).

4.9 Onion, bulb

Bulb onions of different types are grown worldwide for the flavour they contribute to food. They are also commonly regarded as having medicinal properties. In many countries onions are used in the immature green state. In others, where the crop is seasonal, onions are grown that can be stored in a dry state.

4.9.1 Maturity and harvesting

When the bulbs developing from the leaf bases of bulb onions are fully formed, the leafy green tops begin to yellow and eventually collapse to a point a little above the top of the bulb, leaving an upright short neck. When the tops 'go down' in this way the bulbs are ready for harvesting. Because not all the onions in a crop mature at the same time, large-scale commercial growers harvest them when about half the tops have gone down.

Small-scale growers can, if they wish, harvest their crops progressively as the tops go down, especially if they intend to store the dry bulbs for sale or use at a later date. Since onion bulbs are normally formed at the soil surface, it is sometimes possible in sandy soils to pull the mature bulbs out by hand. Where conditions make hand-pulling impossible, harvesting is done by loosening the bulbs with a fork or hoe before lifting them.

It is a good idea to pull each bulb up gently and rest it on its side in the field, exposing the base and the roots to the sun so they can dry out. The bulbs can be left in the field for 3–4 days, turning them to make sure that all the basal parts are exposed to the sun.

It is important that planting of bulb onions should be well planned so that the crops are ready for harvest during dry seasons. If the crops are ready for harvest during wet seasons, curing may not be effective and will result in the crops decaying and losing their quality.

Quality requirements for market:

- must be of a good size (45–60 mm diameter) (Figure 4.18)
- must have a strong, dry outside skin layer with no signs of rotting
- must not be growing new shoots.

4.9.2 Postharvest handling

Sorting

All damaged or decaying onion bulbs should be discarded. Onions with thick necks should be put aside for immediate use because they will not store well.

Curing

Curing is a drying process intended to dry off the necks and outer scale leaves of the bulbs to prevent loss of moisture and attack by decay during storage. The essentials for curing are heat and good ventilation, preferably with low humidity. This dries out the neck and the two or three outer layers of the bulb. The outermost layer, which may be contaminated with soil, usually falls away easily when the bulbs are cured, exposing the dry under-layer which should have an attractive appearance. In dry, sunny weather the harvested crop can be cured by leaving it in windows in the field for a few days until the tops are dry. Where the harvested bulbs are exposed to high-intensity sunlight (e.g. at high altitudes in the tropics), the windrows should be made so that the green tops cover the bulbs to protect them from sunburn.

A length (2.5 cm) of the leaf stalk and some roots should be left attached to the bulbs, and not removed completely. If the bulbs cannot be dried in the field, they can be collected in trays, which are then stacked in a warm covered area with good ventilation (see Figure 3.15). In cool, damp climates the bulbs are cured in bulk-ventilated stores, where they are dried with artificial heat blown through the bulk at a temperature of 30 °C. The storage conditions suitable for curing onions are given in the table below. Onions can also be cured by tying the tops of the bulbs in bunches and hanging them on a horizontal pole in a well-ventilated situation (Figure 4.19).

Temperature (°C)	Humidity (%)	Duration (days)
30–45	60–75	14–21

Figure 4.19: Bulb onions being cured inside on a horizontal pole.

Grading

Market requirements will determine whether onions need to be size graded or not. Retailers in local markets will normally do their own grading when making up lots for sale. If bulb onions are to be made up into strings for storage or sale, it is an advantage to separate them into a more or less uniform size on any string. This makes the stringing operation easier and gives a better appearance to the finished product.

Packing

For bulk marketing the tops of onions are removed when they are thoroughly cured and the necks are quite dry. For small-scale marketing onions may be made up into strings weighing 5–10 kg. This is, however, a labour-intensive operation suited only to small-scale production using family labour. It is not cost-effective on a commercial scale. For larger-scale marketing the onions should be packed into net bags so that the produce stays cool and dry. These bags can weigh about 20 kg (see Figure 3.9).

4.9.3 Storage

The first key to successful storage of dry bulb onions is choosing the right seed variety to plant. It should have a long dormancy period and be able to form a strong outer skin when fully cured. After harvest and curing, bulbs put into storage should be disease free. The most important storage disease is neck rot, which is controlled by dusting the onion seed before planting with a chemical called benomyl fungicide at the rate of 1 g active material per kilogram of seed.

The storage environment must be dry and well ventilated. Optimum (high-temperature) storage is between 25 °C and 30 °C. Outside this range the stored onions will sprout and, if the atmosphere is damp, will develop roots. Onions can also be stored in bulk-insulated stores, with fans for cooling using cold night air. This method is used where large tonnages are stored. Small-scale growers can use naturally ventilated stores made from local materials, where the onions can be stacked in trays or in layers on slatted shelves.

Where small amounts are to be stored, stringing onions in 5 kg or 10 kg lots and hanging the strings in a well-ventilated dry location is a very effective storage method. The tops of the onions should not be cut off, but left so that they can be fixed to a double string by weaving the dried top of each onion through the strings in a figure-8 fashion. Alternatively, onions can be tied by their dried tops in bunches and hung on a horizontal line or pole in the shade.

4.9.4 Transportation

During transportation it is advisable to handle the produce with care because the flesh can be easily damaged. Do not throw the bags of bulb onions during loading and unloading, but lift them carefully and put them down carefully. Do not allow anyone to sit on top of the bags or allow anything heavy to be placed on them. Transport bulb onions in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.10 Potato

These are also called Irish or white potatoes. Although most of the world's potato production is in temperate regions, the crop is becoming more important as a food source in the tropics and subtropics.

4.10.1 Maturity and harvesting

Potatoes are ready for harvest when the stems and leaves dry up and die, about 3–5 months after planting. However, potatoes can be harvested for immediate consumption in an immature state, usually from the time they reach full flowering. At this stage the skin is thin and soft, and the potatoes cannot be stored.

Potatoes which are to be sold but which may need to be stored should not be harvested until at least 2–3 weeks after the plant tops have died off, by which time the skin of the tubers is fully developed and they are mature. They are then less susceptible to damage than immature potatoes. After harvest the potatoes should be cured for about 2 weeks.

Potato harvesting is best done when the soil is slightly moist. Where they are produced on a small scale, harvesting is carried out with handtools. The tubers must be lifted carefully to avoid damage, and shaken free of soil. They are left to dry in the field, after which they are collected in field containers and placed in a cool shady place. Potatoes for food must not be exposed to the light for more than a few hours after harvest or they will turn green, develop an unpleasant taste and may become toxic.

Figure 4.20: Rub the potato with a thumb to see if it is ready for harvest. A strong skin means it is ready, a soft skin that easily rubs away means it is not ready.

To determine if the potato is ready for commercial harvest, the skin should be rubbed with a thumb as shown in Figure 4.20. If the skin is strong, it is ready for harvest, but if it is easily rubbed away then leave the potatoes in the ground for a little while longer.

Quality requirements for market (Figure 4.21):

- Must be dry with a strong outer skin.
- Must be free of soil or dirt.
- Must have no insect or disease damage.
- Must not be green in colour.
- Must be the size of an adult fist.

4.10.2 Postharvest handling

Selection and grading

All potatoes showing greening decay or severe damage owing to harvesting or pest attack should be discarded at harvest. Immature tubers and those wetted by rain or showing minor damage should be put aside for immediate consumption. Potatoes to be stored for food or seed should be fully mature and free from any visible damage or decay. Size-grading requirements will depend on market demand. In most cases there will only be standards for minimum size, but sometimes also for maximum size. Local specialists should be consulted on the subject.

Figure 4.21: Potatoes preferred by markets are free of dirt and the size of an adult fist.

Curing

Potatoes to be stored need curing to repair any skin damage that may be present (Figure 3.14). Curing is best carried out after the potatoes have been placed in store. It involves reducing ventilation to allow an increase in temperature and a build-up of humidity, which are needed to promote curing. The potatoes should be covered with straw and the store well insulated to prevent the condensation of free water on the potatoes. The storage conditions suitable for curing potatoes are given in the table below. The higher the temperature (in the given range), the shorter the time needed for curing. At the end of the curing time full ventilation should be restored to the store.

Temperature (°C)	Humidity (%)	Duration (days)
15–20	85–90	5–15

Packing

Although baskets or wooden boxes may be used to market potatoes, bags are cheaper and more commonly used. They are usually of 50 kg capacity and need to provide good ventilation. Bags include coffee bags, net bags and flour bags (Figure 4.22). The coffee bag is best because:

- It allows air to pass through, keeping the potatoes inside cool.
- It prevents light from entering the bag and turning the potatoes green.

When using net bags to pack potatoes, do not leave them in the sunlight or else the potatoes will turn green. When using flour bags, make holes in the sides for airflow, otherwise the potatoes will sweat and start to rot.

Figure 4.22: From left to right, potatoes packed in a coffee bag, flour bags and net bag.

4.10.3 Storage

Only sound potatoes with no apparent damage or decay should be stored. Potatoes to be used for food or for processing must be kept in the dark to prevent greening. Seed potatoes are stored in diffuse light to promote the development of several strong shoots on each tuber.

On-farm storage can be carried out in low-cost structures employing local skills and using local materials. Where climatic conditions are suitable, potatoes can be left in the field for some weeks after maturity. However, it is generally preferable to collect them for storage in a structure where some measure of control over the storage conditions can be achieved.

Low-cost, small-scale pole and thatch stores holding up to 2 tonnes of potatoes can be constructed in the field. They are particularly suitable for seed potatoes to be held in diffuse light conditions. Potatoes are held in these stores in open trays or on well-ventilated shelves.

Existing buildings may sometimes be modified for storing up to 20 tonnes of potatoes under natural or assisted ventilation. Whatever the type of

store, it is necessary to keep the potatoes dry and as cool as possible by having an insulated structure with good ventilation.

4.10.4 Transportation

During transportation it is advisable to handle the produce with care because the flesh can be easily damaged. Do not throw the bags of potatoes during loading and unloading, but lift them carefully and put them down carefully. Do not allow anyone to sit on top of the bags of potatoes or allow anything heavy to be placed on them. Transport potatoes in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

4.11 Sweet potato (kaukau)

Kaukau is an important crop in PNG. There are many varieties grown, especially in the highlands. It is a good source of carbohydrate and vitamins A and C.

4.11.1 Maturity and harvesting

In the highlands kaukau is ready for harvest 9–12 months after planting, and in the coastal lowlands 4–6 months after planting. When ready for harvest, leaves may start to dry.

Harvesting kaukau is easier if grown on raised beds or mounds. The digging tool can be pushed into the soil under the tubers, which can then be levered upwards, loosening the soil and decreasing the possibility of damage to the crop.

Quality requirements for market (Figure 4.23):

- Must be of a good size.
- Must be fresh.
- Must be free from disease or insect damage.
- The tuber skin must be clean.

Figure 4.23: Kaukau with good size and shape and free from blemishes (suitable for supermarkets).

4.11.2 Postharvest handling

Sorting

Sorting is an activity whereby damaged, bruised, diseased, pest-damaged and deformed kaukau is removed. Figures 4.24 and 1.1 show some examples of kaukau that should be removed from commercial supply.

Cleaning

Most markets require clean produce, so kaukau should be brushed dry using a dry cloth, or washed and then dried to remove excess moisture. Washing plays an important role in removing dirt and other residues (from sprays and dust) and also freshens the produce, making it appealing to the customer.

Curing

Curing is carried out to heal wounds encountered during harvesting and also to harden the skin. It is also effective in reducing decay and water loss during storage or transit. Curing may be done in the field or in curing rooms. The conditions for curing kaukau are summarised in the following table.

Figure 4.24: During sorting, kaukau like these are removed. What can you say about them?

Temperature (°C)	Humidity (%)	Duration (days)
30–32	85–90	4–7

Figure 4.25: Oversized (left) and undersized (right) kaukau. Oversized kaukau are suitable for the institutional markets, while undersized kaukau are more suited to the open market.

Grading

Grading involves sorting the kaukau tubers to ensure uniform size, length, colour and firmness. Grading can be profitable because different customers prefer different grades of kaukau. For example, the tubers in Figures 4.23 and 4.25 could be usefully graded on the basis of size. The tuber in Figure 4.23 is most suited to the supermarkets, while the oversized tuber in Figure 4.25 is most suited to the institutional markets (e.g. hotels, prisons and universities) and the undersized one to the open market.

Packing

Kaukau is packed into bags, cartons or boxes. It is better to pack it into hessian/coffee bags and net bags since they have holes that allow for ventilation (Figure 4.26). It is not a good idea to pack kaukau into flour or stockfeed bags unless holes are made in the sides, as this leads to heat accumulation and eventually to sweating and rotting of the tubers (Figure 4.27). One bag can hold 50 kg of kaukau.

Overpacking and underpacking should be discouraged as either practice greatly increases the risk of damage during storage or transport. When underpacked the kaukau tend to move within the bag, which leads to excessive damage. When overpacked the bags become very heavy and bulge, which can increase the damage from rough handling (e.g. dropping from a height) or breakage of the bag. As with most produce, kaukau should be tightly packed but not overpacked.

Figure 4.26: The coffee bag is good for packing kaukau.

Figure 4.27: The net bag (left) is suitable for packing kaukau but the flour/stockfeed bag without air holes (right) is not.

4.11.3 Storage

Kaukau are often stored after curing and before preparation for marketing. They can be stored for longer periods provided that the storage conditions are right (i.e. ventilated storage in cellars or warehouses or mechanical refrigeration).

Note that, during storage, kaukau should be kept well away from ethylene-producing produce since this gas can cause discolouration and an unpleasant flavour.

4.11.4 Transportation

Several factors reduce quality during transportation including bruising, rough handling, high transit temperature (especially if field heat is not removed before loading), poor or no packaging, and bad roads. Bruising is increased when kaukau is handled repeatedly. Vibration during transport may also cause bruising, and rough handling during loading and unloading of trucks may increase the loss of quality. Heavy piling of bags of produce one on top of the other (deep piling) can cause crushing and heat build-up due to respiration of the produce. High temperature usually develops in transport vehicles due to inadequate ventilation in addition to the high outside temperature and high solar radiation common in the tropics. It is therefore important that kaukau is kept cool with good ventilation as this helps to maintain the quality and reduce wilting and weight loss. Handle the bags with care during transport to prevent bruising and wounding of the kaukau, as this will also cause rot. Do not sit, or place animals or heavy objects, on top of the kaukau bags. Avoid these problems by using crates that can be stacked neatly. Transport kaukau in the early morning, late afternoon or night when it is cool. It is a good idea to use cool containers for long-distance market transportation.

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