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Final report

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1.1 Abbreviations

ACIAR – Australian Centre for International Research.

CPB - Cocoa Pod Borer. Has caused problems for the cocoa industry particularly in East New Britain, Papua New Guinea.

Canarium - *Canarium indicum; C. indicum*, also known as galip nuts, ngali nuts and nangai nuts. Consists of an outer skin (exocarp), flesh (mesocarp), the shell (endocarp), the testa and the edible kernel

ENBP - East New Britain Province, Papua New Guinea (PNG).

FFA - Free Fatty Acids. The chemical test used to test for hydrolytic rancidity in foods

HACCP Hazard Analysis and Critical Control Point

MC - Moisture Content

w.b. - moisture content wet basis

NARI - National Agricultural Research Institute, Keravat, Papua New Guinea (PNG)

NIS - Nut-in-shell

PV - Peroxide Value. The chemical test used to test for oxidative rancidity in foods

USC - University of the Sunshine Coast, Queensland, Australia

2 Executive summary

Canarium indicum (Burseraceae) nuts, known in Papua New Guinea as galip, in the Solomon Islands as ngali and in Vanuatu as nangai, are indigenous to lowland rainforests in Melanesia. Expansion of the *Canarium* nut industry has great potential to improve the livelihoods of rural households in these countries.

A major constraint to commercialisation of the *Canarium* industry has been poor quality of the nuts due to traditional postharvest handling. Nuts are traditionally cracked by hand using stone hammers. The only commercial processing technique available at the start of the project involved freezing of the kernel within 24 hours of processing. This was a major limitation to a commercial industry based on *Canarium*.

This project has identified a range of alternative processing models, methods and techniques based on drying the kernel, including technology adapted from the macadamia industry and traditional techniques used in the Solomon Islands. Highlights of the processing research include:

- A drying regime that results in high quality nuts. Initial drying of nut-in-shell below 40 °C produced whole kernels with good colour and little translucency. A stepwise drying regime of 35°C for 3 days then 38°C for a further 4 days effectively reduces nut-in-shell moisture content from 24% to 6% and enables storage and transport of nut-in-shell without the need for immediate freezing. Storage trials have shown that nut-in-shell dried to 7% moisture content can be stored at low humidity for 11 months without loss of quality.
- Two nut crackers adapted from the macadamia industry are suitable for canarium processing and have created strong interest in PNG
- A mechanical depulper and electric drier adapted from the macadamia industry has been constructed and trialled on canarium fruit
- Protocols for testa removal, roasting and assessing quality at the buying point have been developed
- A HACCP (Hazard Analysis and Critical Control Point) analyses for *Canarium* nuts has been conducted.

This project has also provided capacity exchange via

- Identification and development of industry associations to support the fledgling *Canarium* industry and support stakeholder participation in the industry
- Developing indicators and strategic participatory planning for the *Canarium* nut industry
- Developing awareness-increasing and feedback literature in English and Bislama, distributed at workshops, and through partner agencies in Vanuatu.

The project has been instrumental in building capacity in processing techniques in both Vanuatu and PNG. Although Solomon Islands were not an official partner in this project, representatives of the Solomon Island nut industry have been included in capacity building activities. The project has provided advice, expertise and equipment for a pilot nut processing factory in PNG and provided demonstrations and training on nut processing methods in Vanuatu. One processor in Vanuatu was previously freezing nut products and is now selling canarium nut products based on drying protocols and another is calling for more equipment for drying canarium nuts.

Future work is required to understand the market potential and market segments for canarium nut products and create products to meet the market needs, as well as understanding the drivers, barriers and benefits of stakeholder participation in the canarium industry.

3 Background

Canarium indicum (Burseraceae) is a species used for agroforestry in Melanesia. This species is indigenous to lowland rainforests of Papua New Guinea (PNG), the Solomon Islands and Vanuatu (Nevenimo et al. 2007) and has been important in the diet of the people of PNG for thousands of years (Thomson and Evans 2010). *C. indicum* is a large tree that grows to 40m in height in Melanesia (Thomson and Evans 2006a). The nuts are traditionally consumed or used for ceremonies within the villages or traded in village markets (Thomson and Evans 2006b). In Papua New Guinea, the nuts are known locally as galip, in the Solomon Islands as ngali and in Vanuatu as nangai. In this report the generic term 'canarium' will be used to refer to *Canarium indicum* nuts in industry contexts.

Canarium nuts are marketable products with great potential to improve the livelihoods of rural households in Papua New Guinea and Vanuatu (Nevenimo et al. 2005). In Melanesia, the main canarium species with commercial potential is *C. indicum*. There are also good commercial prospects for a related species, *C. ovatum*, in the Philippines (Coronel 1996). There is strong consumer demand for and acceptance of the product in Papua New Guinea, the Solomon Islands and Vanuatu. In these countries there is great potential to expand the domestic markets and develop an export market. Such expansion could improve the livelihoods of rural households by providing a larger market for nuts in the South Pacific. An improvement in canarium quality will particularly benefit women, who are heavily involved in growing, processing and marketing canarium in Melanesian culture. Deforestation has seen a reduction in the canarium natural resource in rainforests and this provides a strong motive to develop plantations to continue to provide an important traditional food resource (Nevenimo et al. 2007).

Problems for the cocoa industry in PNG make the establishment of alternative primary industries an urgent issue. Many small land-holders in PNG rely on cocoa to provide cash income and the cocoa industry is very important in the PNG economy. In the past decade the Cocoa Pod Borer (CPB) has been detected in different parts of the country including East New Britain in 2006, West Sepik Province in 2006 and Madang Province in 2008 (Curry et al. 2010). There is an urgent need to develop alternative sources of income. Canarium is one crop which offers an alternative source of income from both nuts and timber products. Cocoa trees benefit from some shading. Historically this has been provided by inter-planting with coconut palms. However, as coconut palms grow taller the shading effect diminishes. Canarium trees can be planted under coconut palms and offer the opportunity to provide good shade for cocoa while also producing income (Thomson and Evans 2010).

World trade in tree nuts is in excess of US $2,000 million (USDA, 2008). Currently the market for processed *C. indicum* nuts is small in world terms. Estimates of the market value for packaged nuts in Vanuatu and PNG in 2004 are $1 million per year (Bunt and Leakey 2008). In Vanuatu, demand for processed canarium nuts on the domestic market exceeds supply. Export demands in Vanuatu have not been met for several years, despite prices of around US $25,000 /tonne for processed product. In the next five years, the availability and quality of canarium nuts will increase as a result of more plantings. In addition, selection of superior cultivars as a result of an ACIAR funded project (FST/2004/055) and an EU project in PNG will improve production and supply. To capitalize on this opportunity, markets need guaranteed quality and consistency of packaged canarium nuts.

A major constraint to increased commercialisation of the canarium industry is poor quality of the nuts due to traditional postharvest handling and processing methods (Nevenimo et al. 2007). Nuts are traditionally cracked by hand using stone hammers (Maima 1996;

Roposi 1996; Wissink 1996). Current traditional methods of processing the nuts may be unhygienic and detrimental to kernel quality (Evans 1996a; Nevenimo et al. 2007). A recent ACIAR feasibility study (Maima 1996) concluded that while marketing expertise exists, the nut industry is limited by a lack of knowledge about post-harvest handling and processing techniques. The risk of contamination of food products by toxins can be reduced by better handling practices, proper drying and safe storage (Özilgen and Özdemir 2001). Processing methods need development and promotion at a scale that optimises quality and minimises losses and contaminant risks, and is cognizant of the needs of stakeholders.

Handling and storage are significant impediments to reliable supply. In Vanuatu, for example, a high percentage of potentially marketable canarium nuts are reportedly wasted due to poor postharvest systems. The processor uses a value chain that relies on cracking nuts at high moisture content and freezing the kernels, and reports that nuts deteriorate if they are not processed within 24 hours of cracking. The processor insists on freezing the nuts within 48 hours of cracking, otherwise 50-60% of the nuts can be lost. There is a need to optimise the postharvest chain involving village-level preliminary processing, transport and further centralised processing.

This report presents appropriate postharvest processing practices for canarium, and how this information can be coordinated and disseminated in accessible forms and culturally appropriate ways. This research identifies postharvest handling and processing techniques that are appropriate to and beneficial for producers of canarium nut. Processors from the macadamia industry have provided expertise on processing methods, equipment, Hazard Analysis and Critical Control Point (HACCP) assessment and development of a trial processing plant. The macadamia industry is an excellent model for domestication of a new, indigenous nut crop. In Australia macadamia production has grown from a modest 4400 tonnes nut-in-shell in 1987 to 43000 tonnes in 2005. The Australian industry now leads the world in macadamia production, and exports alone were worth $67 million per annum in 2005. Processing methods have evolved with the industry and there are a range of methods and technologies available for processing of nuts. The fledgling canarium industry can learn from processing expertise in the macadamia industry, and this expertise can be adapted to the new industry. A participatory approach to research has identified methods appropriate to smallholders, block and plantation farmers, and to local conditions in Vanuatu and PNG.

This research aimed for a participatory approach, in which growers and processors in each country identify relevant community and processing issues that might affect processing technology uptake and information dissemination. The research also aimed to increase knowledge of the industry and appropriate processing held by local growers, who may have limited understanding of the potential of one of their subsistence mainstays. Using a participatory approach, the project gathered data from a range of growers and processors about local conditions in Vanuatu and PNG.

Partly this research aimed to optimise the postharvest chain involving village-level preliminary processing, transport, and further centralised processing. There are already many basic methods for value-adding local produce but there are documented aspirations of some Pacific Islanders to have access to more sophisticated technologies and processing methods that will improve product quality and movement through the supply chain.

Lastly, these nuts also contribute to the livelihoods of rural households in the South Pacific. Therefore, the research aimed to increase the earning capacity of rural farmers while improving food security during the off-season and reducing imports.

4 Objectives

The aim of this project was to develop post-harvest processes and techniques for Melanesian C. indicum nuts that can be optimally used by small-scale, block and plantation farmers.

The specific objectives and major activities of each objective were:

1. Adaptively develop and evaluate with relevant stakeholders the appropriateness of different *C. indicum* nut processing techniques. This was addressed by:
    - Develop a participatory model to help implement the project at the local level
    - Establish baseline data about current *C. indicum* processing needs, issues constraints
    - Iteratively evaluate the techniques and the project according to set indicators through regular semi-structured interviews or participant observation during on-farm trials.

2. Identify the most appropriate methods and equipment for pulping, drying, cracking, testa removal, roasting, packaging and storing of *C. indicum* nuts.
    - Examine indices for nut maturity
    - Examine spoilage of nuts with currently used pulping methods.
    - Conduct scientific trials on drying.
    - Identify appropriate technologies for cracking.
    - Examine options for testa removal.
    - Conduct roasting trials of *C. indicum*.
    - Identify technologies for packaging that can maintain quality of nuts.
    - Conduct trials on nuts stored at different temperatures and moisture contents.
    - Identify hazards and critical control points for food safety.

3. Provide training and capacity exchange in optimal *C. indicum* nut processing.
    - Develop awareness-raising material
    - Train local people in the necessary techniques, skills and resource issues.

5 Methodology

This project was carried out in 2 countries, PNG and Vanuatu, with links to research leaders in the Solomon Islands. The project in PNG mainly focused on scientific trials of processing, evaluation of processing technologies, and workshops on industry development. In PNG, the National Agricultural Research Institute (NARI) in Rabaul were best equipped to carry out the scientific research work on nut processing with cool storage facilities, drying equipment and laboratory facilities. Throughout the project, the majority of the scientific trials were carried out at NARI. In the second year, partners in the Department of Forests and private enterprise in Vanuatu were brought into the project with a strong emphasis on the participatory model, training and capacity exchange. Key staff from the Solomon Islands participated in the workshops, although the Solomon Islands was not an official partner on the project.

5.1 Objective 1: To adaptively develop and evaluate with relevant stakeholders the appropriateness of the *C. indicum* nut processing techniques

A content analysis of existing literature about *C. indicum* in PNG, the Solomon Islands, Vanuatu, Tonga, and Samoa was undertaken by the Research Assistant (J. Austin) in Australia in 2008. The literature survey included canarium growing, processing techniques and projects. The analysis also included selected literature from similar industries including Okari nut, cocoa, and palm oil, and relevant aspects of Pacific Island socio-cultural and economic considerations. Much 'grey' literature was gathered from partners and other Pacific researchers by CI Bunt and the Research Assistant in Australia.

This content analysis of literature supplemented the survey of growers in the Papua New Guinea (PNG) province of East New Britain (ENB) conducted by Nevenimo, Johnston and Binifa (in Leakey 2005). That survey revealed that the main grower constraints to commercialisation of the canarium nut industry were land availability, lack of knowledge, fruiting irregularity, and obtaining plant materials. In that survey, respondents from the Duke of York Islands and the Pomio district had no or limited access to major markets, although those in the Gazelle Peninsula did not identify access to markets as a barrier.

All documented issues and barriers were coded, and key themes generated from data gathered for this analysis. The final coding and theming analysis was conducted in Australia by CI Carter. Although many of the themes overlap, they were assigned to only one of the socio-economic themes (Appendix 1, column 1). Colin Bunt also received a copy of the draft literature survey and analysed additional key themes and strategies and considered the survey from a market analysis perspective. A draft participatory model was developed from considering the key themes.

Themes were validated by conducting focus groups with partners and community participants at awareness-raising workshops held in the two Pacific countries in 2009 (one on Gazelle Peninsula in PNG; and on Espiritu Santo and Melakula Islands in Vanuatu). Additional comments were included and a set of key indicators of successful canarium nut processing were proposed that would facilitate a participatory rural development approach to processing the nut (Appendix 1, column 4). The draft participatory model was further developed and endorsed at the awareness-raising workshops in Vanuatu in 2009. Industry development strategies were planned by Vanuatu partners and were developed by PNG partners.

Further data were gathered during focus groups held with participants at a subsequent joint forward planning workshop (referred to as ‘the third workshop’) in Port Vila, Vanuatu, in 2010 (with representatives from PNG, the Solomon Islands and Vanuatu). Participants provided further feedback about analyses, indicators, and progress of the processing trials in an iterative way. Some of these data from workshop discussions were used by the partners to further develop industry development plans.

5.2 Objective 2: To identify most appropriate methods and technologies for pulping, drying, cracking, testa removal, roasting, packaging and storing of *C. indicum* nuts

5.2.1 Examine indices of nut maturity:

Time to maturity of nuts on trees

An experiment was conducted on the Gazelle Peninsula, East New Britain by NARI staff to determine the time taken for green fully sized nuts to turn purple and abscise from the tree. Ten trees were selected from smallholder gardens. On each tree, 6 green bunches were tagged at the top of the tree where they received full sun and 6 green bunches were tagged in the lower part of the tree where they were shaded. Bunches were bagged with plastic mesh bags and observed every week.

At the start of the experiment the numbers of green fruits were counted. These bunches were monitored each week by climbing the tree. Counts were made weekly for each bunch of the number of fruit that were green, the number with a tinge of purple, the number that were half purple and the number that were fully purple. Observations were continued until 8 weeks after the start of the experiment.

Separation of sound and unsound nuts

Floatation of nuts is used in the macadamia industry to separate poor quality nut in shell from good quality nut in shell.

Canarium nut-in-shell (consisting of the kernel-in-testa and the shell [endocarp]) when placed in water can also be separated by floating or sinking. Nut-in-shell that floats generally has no kernels or small, possibly immature kernels and floats because of the air spaces within the nuts. NARI staff in PNG placed 100 nuts in water and the floaters separated from those that did not float. These were cracked to ascertain the difference in kernel size and quality. This technique is only suitable for fresh nuts as when nuts are dried the resultant airspace in dried nut-in-shell can cause some nuts with sound kernels to float. This method is proposed to be used for the pilot EU processing factory as the first control point in the processing quality management chain.

Oil analysis of ripe and semi-ripe Canarium indicum nuts

Full-purple (ripe), half-purple (half ripe) and green (un-ripe) canarium fruit were harvested from the same tree to eliminate any tree variability by NARI staff in PNG. At USC 6 replicate kernels were randomly sampled for each colour for oil extraction.

For each kernel, oil was extracted by diethyl ether with a Soxhlet type apparatus (Fig. 1) operating for a minimum of 16 hours. Ether was stripped from the oil with a Buchi Rotavapor (BÜCHI Labortechnik AG, Switzerland). After drying the nut residue, oil content was calculated as a percentage of total dry weight. Means for oil content for each colour were analysed by one-way ANOVA and Tukey’s test for comparison of means.

Further details on nut maturity index, the methods for assessing these criteria and the results are given in Appendix 2.

Fig. 1. Oil Extraction using a Soxhlet type extraction apparatus

5.2.2 Examine spoilage of nuts with current used pulping methods:

Fruit of *C. indicum* consists of an outer skin (exocarp), flesh (mesocarp), the shell (endocarp), the testa and the edible kernel (Evans 1996a). The edible kernel is enclosed by a tough testa within the endocarp (Leakey et al. 2008). The current common de-pulping method is to allow the outer skin and the flesh to rot from the nut on the ground or in hessian sacks (Roposi 1996). The rotten pulp is then washed from the canarium nuts before storage. A problem with this method is that a food product that has been in contact with soil has a high risk of contamination by bacteria and moulds (Özilgen and Özdemir 2001).

Macadamia nuts are collected from the orchard floor after abscission and delayed harvest reduces the quality of macadamia kernels (Walton and Wallace 2008). One of the risks of harvesting from the ground is from elevated bacterial contamination. Dehusking of Macadamia nuts has been found to reduce the bacterial load (Dommett et al. 1992). Contamination by mycotoxins from fungi has also been reported in peanuts and coconuts (Ismail 2000), leading to loss of quality and increased human health hazards.

Depulping canarium fruit by rotting pulp may present a risk of increased microbial contamination. Tropical climatic conditions in Papua New Guinea and the Solomon Islands also favor rapid mould, fungal and bacterial proliferation. Reducing the hazards from contamination by bacterial and mould toxins after contact with soil can be minimized by harvesting practices, proper drying and safe storage (Özilgen and Özdemir 2001).

An experiment was conducted by NARI staff in PNG to determine the effect of depulping on kernel quality by rotting nuts in hessian sacks for 7 to 14 days, then examining for mouldy or rotten kernels. In a separate experiment, freshly depulped, high moisture content nuts were stored for 14 days, and then examined for mouldy or rotten kernels.

5.2.3 *Conduct scientific trials on drying:*

Drying is a major method for preserving a variety of nuts. Drying reduces the free water required for enzyme activity, chemical reactions and microbial growth. Canarium, like macadamia, has very high oil content, consequently, drying of nuts is critical to ensure quality and increase storage potential by preventing rancidity.

A series of drying trials were undertaken at NARI and USC to identify appropriate drying regimes for canarium. Ease of cracking, percentage wholes, percentage of browning, translucency of kernel and ease of testa removal were assessed following different temperature treatments. Drying experiments at NARI were conducted at 40°C, 60°C, 35°C and 50°C.

Four experiments were conducted at USC, Australia to determine how *Canarium indicum* nuts lost moisture content during drying. Experiments were conducted at USC due to the availability of precision ovens and scientific equipment. A low temperature drying regime (35°C for six days) and a stepped regime similar to drying macadamia nuts (3 days @ 35°C, then 5 days @ 38°C) were used. The moisture content of a subsample of ten nuts were determined each day by weighing and drying nuts at 105°C for 24 hours. Qualities such as size and ripeness were also examined. Moisture loss from large and small nuts from Papua New Guinea and nuts from different provinces in Vanuatu during drying at 35°C was investigated. Moisture losses from very fresh *Canarium indicum* nuts from North Queensland with two stages of ripeness were investigated. *Canarium indicum* nuts from Papua New Guinea were dried using a 10 day drying regime (3 days at 35°C followed by seven days at 38°C) and moisture loss measured.

The full methods for moisture loss during drying and methods for the visual quality assessment of nuts are given in Appendix 3.

Solar dryers were also trialled by NARI staff in PNG for drying canarium nuts. Nuts were placed into the trays for 2 days and temperatures measured. The quality of the nuts after using solar dryers was assessed visually.

5.2.4 Identify options for cracking:

The shell of canarium is hard, similar to macadamia nut, and traditionally has been used as fuel for cooking fires. It has high bulk density (460 kg/m3) and calorific value (20 MJ/kg) (Evans 1991).

There is large variability in nut size; this has even been observed within the same tree (Walter and Sam 1996). In Vanuatu, over 20 different cultivars have been identified with differences in shell sizes and hardness (Walter and Sam 1996). Cracking methods that maximise the percentage of whole kernel are required to optimize financial return.

Two options for cracking canarium were investigated at NARI in PNG and in Australia where the nutcrackers were available. A wide-jawed “TJ” macadamia hand nutcracker to suit various sized nuts, and a larger heavier nut cracker from China have been identified. Rates of cracking and the ability to produce whole kernel were recorded. A journal article on post harvest cracking and testa removal is included in Appendix 4.

5.2.5 Examine options for testa removal:

As canarium nuts dry, the testa adheres to the kernel and becomes more difficult to remove. The moisture content of the kernels affects the ease of testa removal..

Experiments were undertaken to determine the ease of testa removal from canarium kernels after nuts were dried to 6% moisture content at USC due to the ready availability of precision ovens. Initial studies investigated the ease of testa removal following blanching by immersion in freshly boiled water for differing lengths of time. The times were 30 seconds, 60 seconds and 90 seconds. Six replicates of 20 kernels were used for each treatment.

A further trial investigated the ease of testa removal following steaming for differing lengths of time. Times tested were 1; 1.5; 2; 2.5; and 3 minutes. After blanching for the required time with freshly boiled water, free water was dried from the nuts using paper towel. The testa was peeled by removing a small piece of testa from the pointed end and gently squeezing the other end of each nut. The difficulty of removing the testa was recorded on a five point scale (1 = easy to 5 = difficult). The number of whole kernels as well as any discoloured or translucent kernels was also recorded.

More details of testa removal methods are given in Appendix 4.

5.2.6 Conduct roasting trials of *C. indicum*:

Roasting is often employed in nut processing as it enhances texture, flavour, aroma and appearance, for example, in pistachio nuts (Kahyaoglu 2008), hazelnuts (Özdemir and Devres 2000) and macadamia nuts (Leverington 1971). Roasting is also critical for risk management in food safety by reducing aflatoxins (Kahyaoglu 2008) and destroying harmful microorganisms (Özdemir and Devres 2000).

Canarium nuts have a high oil content (>70%) and delicate texture that will make them sensitive to processing techniques (Evans 1996b). There are few reports of roasting regimes for canarium kernels. Evans (1991) dry roasted canarium at 100°C to120°C for one or two hours or 135°C for 55 minutes and Nottingham et al. (2005) dry roasted canarium nuts at 135°C for 50 minutes but found the nuts had uneven appearance and texture. Nottingham et al. (2005) also oil roasted canarium kernels at 125°C and 130°C for 10 minutes.

Four oven roasting trials were undertaken at the University of the Sunshine Coast where precision ovens are available, to determine colour development in canarium nuts during roasting. Treatments in these experiments consisted of roasting nuts for various temperature-time combinations. Experiments were 1) Roasting translucent kernels; 2) Roasting for the same time at different temperatures; 3) Roasting for different times at the same temperature; 4) Roasting for combinations of 4 times and 4 temperatures. For the first 3 experiments, the testa was removed after blanching in boiling water for 90 seconds. In the fourth experiment, the testa was removed after steaming for 2.5 minutes.

1) Roasting translucent kernels: Nuts were sourced from PNG. The treatments were 10 minutes at 115°C, 10 minutes at 120°C, 10 minutes at 125°C and 17 minutes at 120°C using nuts with low, medium and high initial translucency. Each treatment consisted of five replicates each of four kernels.

2) Roasting for the same time at different temperatures: Nuts were sourced from Vanuatu. Treatments were 10 minutes at 115°C, 10 minutes at 120°C and 10 minutes at 125°C. Each treatment consisted of six replicates of six kernels.

3) Roasting for different times at the same temperature: Nuts were sourced from North Queensland. Treatments were 10 minutes at 120°C and 20 minutes at 120°C. Each treatment consisted of six replicates of six kernels.

4) Roasting for combinations of 4 times and 4 temperatures: Nuts were sourced from PNG. There were 12 treatments, each consisting of a temperature-time combination. For each treatment six replicates each of six kernels were roasted for each combination of temperature and time. There were four temperatures, 110°C, 115°C, 120°C and 125°C and nuts were roasted for 10, 15 or 20 minutes at each temperature. Kernels were then re-dried to remove water absorbed during blanching and the moisture content at roasting was 2.1%.

Nuts were assessed for their colour, patchiness, translucency and oiliness at the conclusion of the roasting period. Colour for the majority of the nut was rated from

1(lightest) to 5 (darkest). Mottling was ranked from 1 (colour varied by one shade) to 5 (colour varied by several shades that even varied to black). Oiliness was evaluated from 1(nut was dull), 2 (nut appeared shiny) or 3 (when wiped on clean paper, nut left an oily mark). The full methods for roasting are given in Appendix 5.

5.2.7 Identify technologies for packaging that can improve quality of nuts:

Canarium nuts deteriorate rapidly if they are not processed promptly (Thomson and Evans 2006b). Appropriate packaging to maximise shelf life needs to be developed, to ensure guaranteed quality to the consumer. Shelf life of nuts also depends on their moisture content (Wall and Gentry 2007; Wallace and Walton 2005) and eliminating air to prevent oxidation (Robards et al*.* 1988).

Technologies for packaging nuts have been identified from Australian macadamia nut processors. Oxygen and moisture cause food to degrade, therefore decreasing air content and preventing moisture uptake will extend the shelf life of a food. Both plastic and foil packaging is used for packaging macadamia nuts. There is usually a minimum order of 1,000 and bags can also be customised with the product description. Vacuum packaging with plastic film using a domestic vacuum sealer (Sunbeam foodsaver VAC440) was identified as suitable and affordable for small-scale processing to improve shelf life of canarium and has been used to store nuts for six months without deterioration.

5.2.8 Conduct shelf life trials on nuts stored at different temperatures:

Canarium indicum (Galip) has very high oil content, reportedly from 67.3% to 75.4% (Leakey et al*.* 2008). Rancidity can develop during storage and transportation through the supply chain and causes unpleasant flavours in the packaged product. Rancidity is of two main types, oxidation (oxidative rancidity) and hydrolysis (hydrolytic rancidity). Approximately 55% of Galip oil is unsaturated oils (Leakey et al. 2008), which provide potential for rancidity development (Pike, 1998; Robards et al*.* 1988). Oxidative rancidity generates powerful off-odours and off-flavours and can result in excessive browning during roasting and storage (Nawar 1996).

The chemical tests commonly used to test for rancidity in foods are 1) Peroxide Value (PV) for oxidative rancidity and 2) Free Fatty Acids (FFA) for hydrolytic rancidity. Peroxide values measure the hydroperoxides which are precursors of autoxidation and indicates impending flavour deterioration (Robards et al*.* 1988). Free Fatty Acids measures the breakdown of triacyglycerols into component fatty acids such as oleic, linoleic and linolenic acid as a result of hydrolytic reactions (Robards et al. 1988).

Moisture content of nuts is important in preventing hydrolysis. Hydrolysis of oils can also occur as the result of enzymatic activity in nuts. Hydrolysis also promotes oxidative rancidity as the fatty acids generated are more prone to oxidation than intact triglycerides (Robards et al*.* 1988).

Storage trials of canarium nuts were undertaken at USC, Australia and NARI, PNG, and analysed at USC where the chemical analysis equipment was available. In an initial pilot trial, a small sample of wet nut-in-shell (23.9% MC) was stored in an enclosed container to simulate storage conditions in-country. Treatments consisted of storing nut-in-shell at different moisture levels: moist (16 %), partially dry (9 %) and dry (5 %) for 1, 3 and 6 months. In this experiment, each treatment consisted of five replicates each of 10 kernels for each moisture level. Nuts were visually assessed for colour, patchiness, discolouration and translucency.

Two shelf life studies were conducted to test for development of rancidity of canarium kernels. In one study kernels were stored for nine months under ambient laboratory conditions and under refrigeration at the USC. In the second study kernels were stored for six months under ambient climatic conditions at NARI, PNG. Treatments consisted of storing raw kernel at 6% kernel moisture content in vacuum-sealed plastic bags under refrigeration or at ambient Keravat temperature (Mean maximum 31°C, mean minimum 22°C). Each treatment consisted of five replicates each of 10 kernels for both temperatures. Nuts were visually and chemically assessed to determine quality change and rancidity development during storage.

Full methods are given in Appendix 6.

5.2.9 Analysis of hazards and risk management for food safety:

Canarium is a developing industry with many commercial processes yet to be finalised. The industry has largely existed as a cottage industry at village level. The intention to expand to a full domestic and export market requires stringent food safety protocols.

Food products that have been in contact with soil have a high risk of contamination by toxins. This risk of contamination can be reduced by handling practices, proper drying and safe storage (Özilgen and Özdemir 2001). In the Macadamia industry, dehusking of Macadamia nuts reduces the mean bacterial load (Dommett et al. 1992). Processes of drying and roasting also provide additional protection in eliminating contaminants from the manufactured product.

The HACCP plan (Appendix 8) draws on what is known about the fledgling industry and describes the product, the expected flow of the product, potential threats to food safety and potential critical control points. Recommended control measures for each Critical Control Point (CCP) are provided.

5.3 Objective 3: To provide training and capacity exchange in optimal *C. indicum* nut processing

The literature survey involved a review of canarium growing processing techniques and the Research Assistant (J. Austin) in Australia, used this information to design the initial awareness-raising brochure in 2008. Austin then reviewed this document with partner investigators in Vanuatu who provided further feedback. The final awareness-raising document was collaboratively produced in English and translated into Bislama by partner staff in Vanuatu and was disseminated at the initial workshop (Appendices 9 and 10).

Data from subsequent workshops and trip reports was then used to produce a series of further awareness-raising materials as feedback from the research team after each visit (Appendices 11 -13). Attendees, including staff of regional branches of the partner organisation, disseminated the materials more widely at the community level.

Another literature survey on training and capacity building techniques, development education, and science education was undertaken in 2010 by the Research Assistant (J. Austin) in Australia. This background literature survey and evaluation was used by J. Austin to develop a draft training template.

6 Achievements against activities and outputs/milestones

Objective 1: To adaptively develop and evaluate with relevant stakeholders the appropriateness of the C. indicum nut processing techniques.

no.	Activity	outputs/ milestones	completion date	comments
1.1	Develop a participatory model to help implement the project at the local level	Protocols or strategies that have been adapted for local use	Yr 3 (PNG) Yr2, m3 (Vanuatu) Yr1, m4-6 (PNG) Yr2, m4-6 (Vanuatu)	The participatory model was that of prioritising plantation, regional scale and finally local scale stakeholders in industry development. Partner countries drafted and commenced industry development plans and strategies according to this model of participatory industry development and implementation.
1.2	Establish baseline data about current *C. indicum* processing needs, issues, constraints	A social science analysis of the key issues and barriers to post-harvest processing for different countries and different scales of farming	Yr1, m3 (PNG) Yr2, m3 (Vanuatu) Yr1, m3 (PNG) Yr2, m3 (Vanuatu)	Baseline data established from the social sciences analysis, showed needs, issues and constraints and were grouped into key themes (Appendix 1).
1.3	Iteratively evaluate the techniques and the project according to baseline data	Measures or qualitative themes gathered from stakeholders during workshops (and possibly field days or on-farm trials) that are used to evaluate the technology against pre-set indicators of success.	Yr2, m3 (PNG) Yr3, m1 (Vanuatu) Yr2, m3 (PNG) Yr3, m1 (Vanuatu)	Feedback was gathered during all workshops and used to refine and endorse the themes and indicators (Appendix 1) for a successful canarium industry, and the participatory model. Industry associations were mooted or developed for the two partner countries in light of the key themes and indicators. An industry association was also formed in the Solomon Islands as a result of Dr Pauku's involvement with the Vanuatu workshops. More specific feedback about some of the processing techniques was gathered, particularly in relation to the nutcracker. Feedback was that the nutcracker was useful but some modifications to its design and appropriate users were suggested. This feedback was incorporated into the nutcracker design and industry development strategies.

PC = partner country, A = Australia

Objective 2: To identify most appropriate methods and technologies for pulping, drying, cracking, testa removal, roasting, packaging and storing of C. indicum nuts

no.	Activity	outputs/ milestones	completion date	Comments
2.1	Examine indices for nut maturity	Nuts collected, specific gravity measured, oil extracted and analysed Recommendations for maturity indices developed	Yr 1&2, m6 Yr 3, m6	Indices for nut maturity have been established using colour. Green nuts are immature and purple nuts mature. Chemistry of green and purple nuts: Oil content of green nuts although high (72.8%) was significantly lower than purple nuts (76%). Green nuts also weighed less and were obviously immature. Only purple nuts should be harvested to obtain maximum oil content. Time to maturity: Fruit appears to ripen more quickly at the top of the tree. Most bunches took at least 8 weeks for all fruits to ripen. Nut-in-shell that floats generally has no kernels or small immature kernels with poor kernel recovery. This can be used at buying points to select good quality nut-in-shell and discard immature or poor quality nut-in-shell.
2.2	Examine spoilage of nuts with currently used pulping methods.	Depulping methods to be used for trial decided on Data sets collated for depulping methods. Protocols for pulping developed	Yr 1&2, m3 Yr 1&2, m9 Yr 3, m 6	Rotting on the ground or in hessian sacks is a commonly used depulping method. Trials with rotting pulp in hessian sacs have shown no increase in mouldy or rancid kernels, however the risk of bacterial contamination requires further investigation. Depulping has been identified as a critical control point by the HACCP analysis. A prototype engine operated depulper adapted from the macadamia industry has been constructed and shows promise for large scale mechanical depulping.

2.3	Conduct scientific trials on drying	Drying methods and regimes selected. Nuts collected, trials conducted Data sets of nut quality collated Protocols for drying developed for each country	Yr 1&2, m3 Yr1&2, m6 Yr1&2, m9 Yr 3, m6	Nut-in-shell at a moisture content of approximately 6%-7% is stable and can be stored and transported. High temperature drying, especially of nut-in-shell at over 20% moisture content causes browning and translucency of the kernel. Temperatures below 40°C are required in the early phases of drying. An effective drying regime will require initial low temperature drying to stabilize the nut. Drying at 35°C reduces moisture content from 22% to 7% in 5 days. Drying at 35°Cfor 3 days then 38°C for a further 7 days reduces moisture content from 24% to 6%. Technologies for drying canarium: initial trials with a cocoa solar dryer showed temperatures above 50°C and is likely to damage the nut. A small scale electric dryer has been developed for drying nut-in-shell. Six Bell box dryers have been constructed in PNG for the EU pilot processing factory. These dry the nuts at less than 40°C.
2.4	Identify options for cracking	Cracking methods identified Recommendations for future options for cracking technology.	Yr 2&3, m9 Yr 3, m6	TJ's™ nutcracker used for macadamias has been modified by the manufacturer for use with canarium. These modified TJ's™ nutcracker have created strong interest in Papua New Guinea (Appendix 4 Journal article). Crackers have been supplied to PNG, Solomon Islands and Vanuatu A Heavy duty macadamia cracker purchased from China also shows great promise for larger scale factories. These have been supplied to the pilot EU factory at NARI in PNG.
2.5	Examine options for testa removal	Methods of testa removal identified Recommendations for future options for testa removal developed	Yr 1&2 m3 Yr 3, m6	The testa was easiest to remove prior to the nuts being dried however when dried; the testa could only be effectively removed after blanching. Blanching in hot water for 90 seconds is the best method. Steaming is also an appropriate method for larger scales factories (Appendix 4: Journal article).

2.6	Conduct roasting trials of *C. indicum*	Samples collected Samples imported through quarantine Data sets on roasting collated Protocols for roasting developed	Yr 1&2 m3 Yr 1&2 m6 Yr 1&2 m9 Yr 3 m3	The moisture content and freshness of the nuts prior to roasting may be a contributing factor in the initial results. For example, translucent nuts (an indicator of cell damage) turn very brown when roasted. Roasting for 10 minutes at 115°C produced no colour change to a very light colour, dependent on the age of the nuts. At 120°C light roasted colour developed within 10 minutes and darkened within 20 minutes. These experiments form the basis of a suitable roasting regime; however the acceptable colour and taste for roasted canarium nuts will need to be based on consumer preference.
2.7	Identify technologies for packaging that can improve quality of nuts	Methods of packaging identified and equipment assembled Samples imported through quarantine, Data sets collated Protocols for packaging developed	Yr 1&2, m3 Yr1&2, m12 Yr 3, m6	Suppliers for plastic and foil packaging have been identified. Minimum order is usually 1,000 and bags can also be customised with the product description. A Sunbeam foodsaver VAC440 has been purchased for PNG and subsequently used in storage trials. The plastic packaging has been used to store nuts without deterioration for 6 months.
2.8	Conduct trials on nuts stored at different temperatures	Samples collected Sample imported to Australia, Data sets on quality collated Protocols developed for storage	Yr 2&3, m3 Yr 2&3 m9 Yr 3, m9	Nut-in-shell stored at approx 7 %, low humidity and 25° C moisture content showed no deterioration in rancidity after long term storage. Dried nuts stored for 9 months have shown very little change in rancidity, indicating that dried and vacuum packed kernels can be safely stored for 9 months at 25°C or for 6 months at 30°C. However, free fatty acid levels indicate that further storage is likely to reduce kernel quality.
2.9	Analysis of hazards and risk management for food safety	Document describing processing chain written Critical control points identified and recommend risk management strategies	Yrs 2, m9 Yr 3, m8	Processing chain steps have been identified. Depulping has been identified as a possible source of microbial contamination. The Critical Control Point is at the Kernel In Testa scalding and re-drying stages.

PC = partner country, A = Australia

Objective 3: To provide training and capacity exchange in optimal C. indicum nut processing

no.	Activity	outputs/ milestones	completion date	comments
3.1	Develop awareness-raising material	Various locally-appropriate information packages about the project including the global *C. indicum* nut industry that target a range of numeracy and literacy levels and different scales of industry	Yr1, m1-3 (PNG) Yr2, m1-3 (Vanuatu) Yr1, m3 (PNG) Yr2, m3 (Vanuatu)	Awareness raising was conducted by PNG partners prior to the commencement of this research and no documents are included. Awareness raising was conducted collaboratively by the project team with the Vanuatu Dept of Forests staff prior to, and following, each workshop. Awareness raising material is attached (Appendix 9). Additional newsletters were produced for feedback throughout the research (Appendices 10-13). Further awareness raising was undertaken by Mr Ioan Viji in 2010 after moving to Espiritu Santo to commence industry development on that island.
3.2	Train local people in the necessary techniques, skills and resource issues	Locally appropriate training packages that guide users of the new techniques for a range of different scales of production environment and end users. Trained local staff with expertise in participatory training and in processing *C. indicum* and in training others about the techniques.	Yr 3, m8 Yr 3, m8	Feedback about training gathered during workshops was that it is early to train people while processing techniques are being refined and protocols remain to be refined. This remains a template that can be updated when the processing techniques are finalised.

PC = partner country, A = Australia

7 Key results and discussion

7.1 To adaptively develop and evaluate with relevant stakeholders the appropriateness of the *C. indicum* nut processing techniques

Objective 1 had the following activities: to develop a participatory model to help implement the project at the local level; establish baseline data about *C. indicum* processing needs, issues and constraints; and to iteratively evaluate the techniques and the project according to baseline data.

7.1.1 Develop a participatory model to help implement the project at the local level

For high value export markets, it is not simply *continuity of quality supply* and price competitiveness, but also *market readiness* (Leakey 2005). Market readiness in developed countries, especially for niche products, is likely to be unrealistic in the short term for small Pacific Island producers for a number of socio-economic reasons (reviewed under Activity 2 below) and it can be counterproductive to develop these markets prematurely (McGregor, 1999). Lessons learned about the *commercialisation* aspect of *C. indicum* in Melanesia to date are summarised as to underlying success:

- Whole of supply chain management
- Private sector push
- Strong links between suppliers and producers
- A focus on niche markets to improve returns to growers
- Value-adding based on consumer analysis to improve returns to growers
- Branding
- Promotions

And failure due to:

- High input costs including transport
- High production costs
- Management inexperience
- Market access and regulation
- Reluctance to commit to long-term programs
- Difficulties with transitioning toward mechanisation

Participatory principles need to be adapted to the *commercialisation* context and require consideration of the particular socio-economic context at different scales (reviewed below). The Nevenimo et al. (2005) survey of growers in the Gazelle Peninsula of East New Britain found they were not constrained by access to major markets, probably because of their road network. In comparison, growers from other provinces identified market access as a constraint to their participation in the industry. As such, local areas closest to a regional hub or industrial core will be more easily involved in commercialisation of the industry compared with more distant or remote growers.

A draft participatory model was developed from a literature survey and initial discussions with some partners in the first year of the project (2008). The model was geographic in its nature, with a strong spatial underpinning in that the distance from an urban core is a critical element of the model (Fig. 2). The proposed participatory model required considering stakeholders within their regional contexts e.g. larger scale economic units such as plantations, stakeholders in the region of an urban core such as a large city (e.g. Kokopo, Port Vila, Santo), or smaller economic or familial units within a region. Potential suppliers in the canarium industry were therefore classified within three groups, based on their location, their production capability and their ability to supply. The participatory model required the inclusion of more remote areas and local clans over the longer-term because they face more significant barriers to industry participation. The participatory model was proposed as a guide to a staged approach to development of the industry.

The model exhibits an urban bias, that is, toward involving people from urbanised regions with extant industry infrastructure, markets and supply and communication networks. The model also offers a channel for canarium nut products to piggyback with the trade of other commodities such as copra. Longer-term strategies will be needed to foster expanded industry development with more remote populations by piggybacking raw nut or nuts with minimal processing through existing economic and social infrastructure. It will be critical to determine whether remote growers want to invest their time and resources for potentially lower returns and/or whether they will continue to commit to harvest nuts and undertake processing in terms of available infrastructure, the costs and benefits and other mitigating circumstances, and will probably need to be determined on a case-by-case basis. A majority of future on-ground research at the local scale around industry development was suggested (and is part of a new canarium project funded by ACIAR's PARDI initiative).

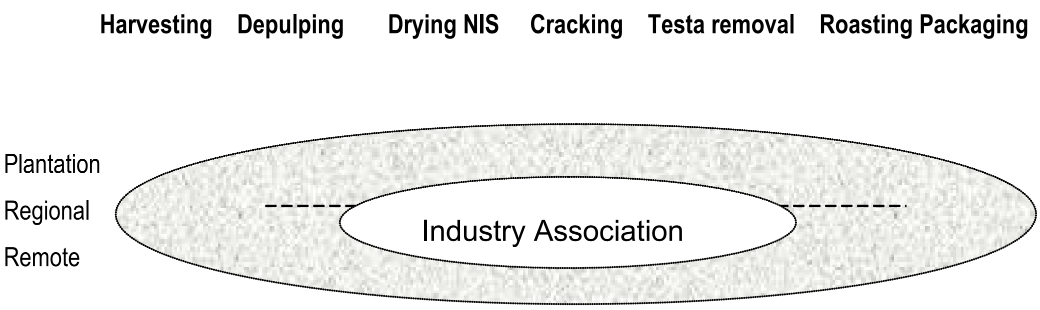

Fig. 2. The draft participatory model proposed in 2008 to ensure quality control of processing stages according to project protocols, and to suit various grower contexts. This model was endorsed as the final participatory model at the awareness raising workshops in 2009. Workshop participants also proposed that an Industry Structure within this participatory model can assist different growers and processors in various ways, according to the scale of production (plantation, regional or local/remote). For example, distant growers may want to only supply Nut-in-shell (NIS) in the short-term, but those closer to a regional centre may wish to supply dried Kernel–in-testa (KIT). The Industry Structure will need to be made aware of, and certified for, quality control of all stages of processing to assist the different groups in their needs. The industry structure also needs to develop strategies to align with marketing needs including product development.

7.1.2 Establish baseline data about current *C. indicum* processing needs, issues, constraints

This activity, undertaken in the first year of the project (2008), established baseline data about *C. indicum* processing needs, issues and constraints from a literature survey (as detailed above). These data were grouped into key socio-economic themes, against which indicators for progress in future research or industry development could be measured. The results of the analysis are shown in Appendix 1 and are elaborated below. (While these indicators were established in year 1 of the project, the three year research activity over the life of the project has meant there has been some progress toward meeting some of these baseline indicators for industry development since then.)

Socio-economic baseline data and key themes arising

1 Employment:

A key social theme in the literature was that of paid and subsistence employment and labour relations. McGregor (1999) distinguishes between labour investment strategies – those that rely on little labour input including the growing and harvesting of nuts versus labour intense aspects of processing, particularly cracking. Gardens are often located some distance from a village and smallholders need to perceive that cash cropping is worth their while, rather than receiving little return for their effort for some crops (Curry et al, 2007). Participation in a large-scale commercialised industry may have limitations for women, as they need to travel from home to centralised cracking units (Wissink 1996), although some literature acknowledges the role of women in commercial industries is changing. Some women's groups may prefer to sell nuts in small, localised markets to retain control over the money received compared with income from large-scale industries. There are also part-time and contractual employment options that might be suitable for canarium nut processing, although legal services for villagers to enforce contracts are required as well as numeracy and literacy for record keeping and management. Centralised processing is the easiest stage to commercial industry roll-out because of ease of access and obtaining labour. Over the longer-term, more remote areas may also develop strategies for their involvement in the industry, depending on their individual circumstances.

2 Infrastructure

The availability of general and processing-specific infrastructure is another key barrier to any Pacific rural development (SPC, undated). Roads, especially secondary roads, are infrequently maintained, and airports periodically closed, and there is a relatively high potential for damage for residents of distant regions wishing to transport produce. There is a high correlation between availability of roads and high income (Allen et al. 2000). Most private motor vehicles are not suitable for transporting processed food as product is damaged and exposed to weather. Advocacy about these issues is needed, possibly through community-based groups or industry associations.

Cold storage, credit facilities, agricultural supplies, quarantine treatment and pilot processing facilities also constrain industry development. Faster hand crackers are desired in some areas, especially where a high volume, plantation type situation may be available to process a range of product forms from damaged kernels such as flakes (Nevenimo et al. 2007). Transport costs are substantially reduced if nuts can be cracked locally (Evans 1994), returning more profits to growers, but suitable shaded, sheltered and accessible places for storage are frequently not available in some villages (Srinivisan 1995). Such facilities need development for larger volumes and enhanced storage technologies including drying regimes and quality packaging will facilitate their storage. Many traditional methods are used for storage including drying, smoking and roasting but on-farm storage technologies need good quality control (Thomson and Evans 2006 a, b). Spare parts and maintenance is needed when introducing technologies to enhance processing, especially if a number of people are using the same piece of equipment (Quirke et al. 2007). Centralised processing of canarium nuts has been attempted in the past (Evans 1991) but the lack of minimum guaranteed supply suggests a participatory model or strategy should coordinate growers and suppliers. Markets are developing in some peri-urban fringe areas. These smaller markets and some domestic institutions might be best for commencing the industry where quality control will be less demanding in the first instance (Brown 1996, McGregor 2003). Following the formation of industry associations or structures, the easiest form of industry roll-out will be to commence high volume processing in urbanised areas where economic and social infrastructure is most readily available. The first technology/infrastructure consideration is access to mechanised nut cracking or development of a low cost, low technology nut cracker. Over the longer-term, advances in processing technologies can be developed for the farm scale/village scale level to complement larger scale plantation or factory scales of production within urbanising regions.

3 Communication and knowledge exchange

In the past, some farmers have not understood all of the costs that accrue through the supply chain, the importance of timing and the need for rapid movement through the supply chain. They may be unwilling to supply nuts on the basis of their perceived low returns (Evans 1996 a, b). Willingness to supply has decreased in some places (Bunt 2005) and sometimes depends on whether growers have immediate cash needs or wish to attempt alternative cash streams that are being promoted such as logging. Extension strategies need to bear in mind these needs and take a holistic approach to training.

Additionally, knowledge may be a source of power and status (Cox et al. 2007) so that formal and informal communication and knowledge transfer is necessary in extension (AusAID 2005). Extension should also involve retailers and buyers so they understand the unique characteristics of different products and their storage, handling and presentation needs.

Branding is not considered a major barrier to the industry (Leakey, 2005) because of the reasonably high domestic and international awareness of canarium potential. However, supermarkets and hotels frequently prefer imported produce because there is a perception that it brings higher quality. A participatory model should include strategies to promote the importance of localised foods in terms of reduced oil/transport costs (especially in light of climate change and peak oil) as well as the economic aspect of supporting income for Pacific Islanders, possibly through marketing coordinated by an Industry body. In the longer-term there may be research or educational campaigns to promote the social and environmental values of local produce through branding products that are particular to Melanesia.

Manuals have been produced in the past (Evans 2003) but training requires integration and coordination, often by a facilitator skilled at networking organisations and groups, and cognisant of village level and gender-sensitive issues. Coutts and Coutts (2003 in Cahn & Liu 2008) suggest follow up activities are also necessary as one-off training is inadequate for significant change. Demonstration plots are useful (Evans 2003) but McGregor (2003) recommends that growers at all scales also need extension services that include entrepreneurial and management experience.

Communication and knowledge can be improved if farmer groups are linked with marketing associations (Curry et al. 2007). Koczberski et al. (2001) recommend that extension services be contracted to the private sector using, for example, the ‘nucleus estate’ model based on estate (public and/or private) or processor services to smallholders. The advantages of these models include access to coordinated transport, product quantities and quality control, credit, extension and price signals. Most costs are met by donors or providers but smallholders are expected to contribute a small amount to training ensuring they are active rather than passive recipients of information (Quirke et al. 2007). Another extension approach groups smallholders on a village or clan base and requires the direct involvement of a village chief or on-ground coordinator. Koczberski et al. (2001) warn that these models may or may not suit geographically dispersed sectors that don’t benefit from the economies of scale offered by the nucleus estate model. Farm management analysis such as that carried out by REDI (Department of Regional Development in Vanuatu) incorporates subsistence production as a value in agriculture. These considerations suggest that in the short term, existing extension or grower networks and trusted intermediaries be important components in communication; and if possible, growers be linked with marketers and distributors through a form of industry association.

4 Economic diversification and specialisation

Regional commercial expansion requires greater economic specialisation because a sound village level economy relies on exchanges that are not constrained by lack of transport outside the village (Power 2001). But there is often little incentive for village level trading because growers usually have their subsistence needs met. Growers may mitigate against risk in any crop by allocating labour between both cash and subsistence needs. Metal workshops have been used to fabricate equipment and generate jobs in various rural hubs for economic diversification but insecurity about spare part availability, repairs, and finances mitigate against accumulating stocks of some supplies. In some regions micro-enterprises struggle to find an adequate market and it is critical to remember the relationship between the primary market chain income stream and knock on effects on the downstream business.

Owners of existing business might allocate money and/or stock to the non-market economy as part of their identity, to build relationships or as gifting (Curry 2005, Curry et al. 2007). Reciprocity is crucial for notions of community, networks and engagement and affects business transactions, loan repayments and whether the business is perceived as 'successful' and by whom. The various clan-based systems may affect the distribution of the proceeds from cash cropping as smallholders may be expected to share earnings within the clan. The lack of banking facilities increases this pressure, making it difficult to save cash to pay for ongoing expenses and future labour requirements (Quirke et al. 2007). Younger generations are sometimes more conducive to cash opportunities as they arise.

5 Economies of scale

Leakey (2005) suggests the ideal industry should blend village based and centralised (urban) activities within an integrated rural-urban supply chain. An integrated chain allows several options for staged processing that include selling to an agent, or directly to a processor, and conducting various components of processing centrally or locally (McGregor 1999). The central unit may provide information on processing such as correct drying procedures, although they may buy poor quality produce to maintain grower interest in supplying nuts. Other equipment that might employ several nut farmers such as village based dryers and oil presses may attract some form of government subsidy, particularly if lobbied for and coordinated by a central representative body. Olsson (1996) operated a two-tier system of participation where village 'representatives' undertook decision making, but on the basis of wider discussion about local knowledge, practices, and access rights and identifying appropriate technology, packaging, transport, drying, storage, contracting arrangements, marketing arrangements, links with transport, storage and supermarkets and distribution among contributing village groups.

6 Industry structures

Kreag (1996) suggests two types of business associations can help improve product quality – product-specific industry associations, and producer owned cooperatives. There is a history of problematic business associations, with some perceived as preserving the profits of members rather than developing their industry. Formalised boards have also been involved in agri-business with little benefit to growers (Cox et al. 2007).

Yet these bodies can provide several important functions. Firstly, they have a critical role in establishing and enforcing quality standards (e.g. grading, health and environmental standards, processing standards), and coordinating different stages of processing and other links (such as transport) between growers, buyers, exporters and marketers in the supply chain. There is only marginal certification of agricultural exports and sub-optimal destination marketing so engaging and supporting smallholders with a link to markets is necessary and potentially a public good (Bazeley & Mullen 2006). There is substantial smallholder participation in the kava industry in Vanuatu (Bazeley & Mullen 2006) or copra, which may offer 'piggybacking' opportunities especially where matched with quality control and/or niche market/organic certification.

Associations also open and promote potential (export) markets or re-open markets that closed due to unreasonable tariffs, quotas, or quarantine standards. Lastly they lobby governments for support in marketing, distribution, enabling legislation, better and cheaper infrastructure, and research to meet industry needs. [On the other hand, lobbying has worked against the public interest, for example, resources may be directed into inefficient industries or subsidies, price supports, tariff and quota barriers, limits to competition and monopolies often produce high costs to local consumers and industries that cannot compete in international markets.] Sometimes associations replace the 'middle-man' and foster genuine price competition that encourages high quality processing.

Nongovernment organisations and agricultural businesses or commodity organisations are currently significant service providers (Caven & McKillop 2001) and governments still invest heavily in the provision of agricultural support services. Alternatively, processors might contract directly with growers to ensure their product maintains consistent high quality, with marketing undertaken by an arm of government (Nongkas & Pasing 1997). Successful produce marketing requires timely communication between growers, traders and buyers (McGregor 2003). There is scope to utilise various Village Extension Worker networks as a communication hub, and ensure these systems are linked with national produce bodies and marketing agents (McGregor 2003) to provide useful marketing information services, or link new producer wholesalers and growers (McGregor 2003) without needing public sector involvement in marketing and export market development. An unintended consequence of the co-operatives organised across PNG in the 1970's was a tendency to neutralise member clan groups in a more distributed structure. Continued formation of commercial farmer groups is anticipated to move the balance of commercial transport power away from PMV drivers who carry produce (McGregor 2003) which may or may not be desirable in a participatory strategy because of the cash losses to rural residents.

There has been a trend towards research that attempts to reorganise industry structures into alternative business models (e.g. transferring nucleus estate or similar grower-trader arrangements between sectors). These models attempt to capture premiums from the value chain and return increased incomes to smallholders. They are criticised by Quirke et al. (2007) for their potential to transfer intellectual property between parts of industry, because they may compel smallholders into cooperatives with poor or corrupt business practices, and because public sector institutions are not committed to the sustainability of these structures or to valued longer-term relationships along highly-competitive value chains.

It was largely the result of this final theme in the literature, its links with the other themes reviewed, and discussions during workshops that led to the proposal to implement participatory strategies with the assistance of various Industry or Grower Associations.

7.1.3 Iteratively refine and evaluate the techniques and the project according to baseline data

1. Participatory model

Workshops were held in Vanuatu and PNG as forums for adaptively refining the participatory model, processing techniques, and indicators for success of research and industry development. The analysis of the draft participatory model and baseline data were discussed at the first workshop in each country. Partners discussed and refined the model and suggested identifying an existing body or forming an industry association to help streamline all industry needs, issues and constraints discussed.

At the first workshop in Vanuatu in April 2009, staff of the Department of Forests proposed a Vanuatu-Solomon Islands Canarium Industry Association, which would be led by the government. Stakeholders suggested the government develop and implement a rural development plan with strategies for progressing linkages between:

- Regions
- Sectors
- Projects
- Persons

Specific strategies that were suggested were:

- Use traditional methods, then over time introduce technology that value adds these techniques, but also that suits each variety and marketing product.
- Target the domestic market firstly with new products as processing systems are put in place to ensure consistency and quality. Use industry champions as the supply chain becomes more complex.
- Ensure the industry body works according to community development principles, that is, build on existing structures, networks, and other projects or opportunities for collaboration.

At the first PNG workshop in November 2009, staff of NARI and industry representatives proposed an industry structure that would take the following form and function:

- be apolitical; led by commercial industries
- lobby government for support and establish priorities
- ensure fair trade for all sectors
- monitor volumes and returns
- coordinate, monitor and enforce quality standards
- coordinate, monitor and enforce domestic and export regulations
- coordinate all marketing activities
- coordinate supply and distribution
- develop branding and trademark strategies
- facilitate training
- establish research and development priorities
- develop networks across Melanesia to coordinate industry functions trans-nationally

A steering committee was formed, comprised of representatives of NARI and the Growers Group. This growers group has a number of smaller, discrete constituent groups who have affiliations with each through this umbrella structure. The role of this committee was to provide input and advice on the industry plan, and progress initial industry establishment. A constitution with rules, such as election to the Board and appropriate representation of the different small growers was an early identified need for the industry body. Under PNG statutory requirements, growers and members pay a levy to run commodity boards, and believe this entitles them to dictate expenditure and allocation of monies.

An industry development plan was also endorsed at the workshop and drafted on the basis of data gathered during this initial workshop in PNG. Participatory strategies were to work with existing commodities networks such as copra and large scale plantation representatives for buying points and industry infrastructure.

At the third workshop, in Vanuatu in April 2010, the Department of Forests and the Department of Agriculture and Rural Development reported on progress with their rural development plan. Rather than an overarching industry body, representatives of existing grower groups were suggested as the industry bodies (e.g. Melakula Growers Association). Farmers reported their priority issues as maintaining organisation and linkages for progressing the industry, a need for common standards, provision of data to avoid boom and bust of canarium harvesting, market analysis, extension, investment and funding, branding and nut collection networks. Processors reported their priority issues as a factory or collection centre that offers training as well as continued processing, marketing, business planning and contact with farmers.

At that workshop Dr Pauku also reported on his establishment of the Nut Grower Association of the Solomon Islands which had just commenced and completed a constitution. His model was collection of nuts according to specifications by local community organisations (with two different methods) and sale to a primary processor who grades, dries, adds value and packages the nut. Freight costs are met when kernels are produced in testa, but without, the farmer meets the freight costs. Nuts are purchased in 20 kg containers that are lined with plastic so the nuts don't generate moisture. From that point the model is producer – distributor – processor – marketer, with criteria for different stages for indigenous methods, new methods etc.

The final participatory model developed in Activity 1 was therefore progressing toward the conceptual model of various scales of stakeholder inclusion (plantation, regional, remote). The model was matched with the baseline data analysis in Activity 2 (reviewed above) and with feedback from stakeholders about indicators for success gathered during this activity (Activity 3). The final model, strategies and indicators for success are presented in Figure 2 and Appendix 1. Lastly, these industry associations will act as a conduit for guiding future research and training and knowledge dissemination about canarium (Objective 3).

2. Processing techniques

At the first workshop in Vanuatu in April 2009, stakeholders stated their preference that the project seek to develop low-cost technology and solutions that do not require high infrastructure costs (e.g. solar powered rather than conventional electricity sources or a cheap electric dehydrator).

Discussions around the nutcracker left people unclear about its use, most participants suggesting it was unnecessary. They reported that they felt traditional methods are fast and easy and previously developed crackers have made no difference to local people. They suggested some modifications if it were to be adopted, commenting that the design enabled it to be used as a left handed cracker if the lever were turned the other way; and that the jaw could be a movable slide jaw for different sized nuts rather than a screwed jaw, it may be more adjustable to different sized nuts. People were concerned that the materials might bend with wear and tear, or that people working under constant pressure might experience fatigue, so a spring loaded lever could be mounted, and the pressure required to crack nuts calculated using an equation, so it released when the nuts start to give (like a torque wrench). They also suggested that new technologies developed for canarium nut might be considered as to their suitability for other species. There was some discussion around whether traditional cracking methods suggest nuts should be stood on their base and cracked at the point, but later comments revealed this did not matter.

Participants felt further trials will be important as there have been crackers developed in the past, one with a longer handle but nobody knows where these are now. Two nutcrackers were left at each island (Santo, Melakula and Efate) for further trial and comment as farmers and government staff interact. Department of Forestry staff developed a questionnaire to gather additional information from farmers who come into their agency. Questions included level of interest in different processing stages, utility of the cracker, comments on its design etc. Some stakeholders in Vanuatu suggest that their traditional cracking methods might be as effective.

Stakeholders in PNG were happy with the nutcracker. Further developments mooted were to note whether the nutcracker developed is most suited to high volume factory processing and traditional methods to smaller scale on farm processing, at least in the short-term. It is likely that these results align with the participatory model developed in that technologies such as the nutcracker will first be adopted at the plantation scale, and possibly later in regional scale units and lastly by more remote areas.

7.2 To identify most appropriate methods and technologies for pulping, drying, cracking, testa removal, roasting, packaging and storing of *C. indicum* nuts.

The traditional way of cracking *C. indicum* is with stone hammers and they are sold in the local markets for immediate consumption (Fig. 3.). In the Solomon Islands, kernel is dried and roasted using hot stones in cooking areas. The only form of commercial value adding at the start of this project was undertaken by the Kava Store, Vanuatu. The kava store processing methods required freezing within 24 hours of cracking fresh nuts. Many nuts were not purchased by the Kava Store due to poor quality.

Fig. 3. Traditional cracking and distrubution of *Canarium indicum*.

This project has identified a range of alternative methods and technologies for processing canarium nuts including pulping, drying, cracking, testa removal, roasting, packaging and storing and has raised awareness of these methods (Table 1).

These alternative methods include (but are not restricted to) the following models of a processing chain:

- Centralised: a totally centralised model where the whole fruit is purchased at processing centres and the fruit is mechanically depulped, dried, cracked, testa removed and value added by processing such as roasting and packaging (Appendix 7). This is modified from the macadamia processing model.
- Village cracking farmers crack the nuts and transport and sell the kernel-in- testa to regionalised purchasing centres;
- Decentralised: farmers in remote locations process the nuts then selling the dried kernel to a centralised processor. This is currently being commercialised by a processor in the Solomon Islands based on traditional village processing techniques

There are advantages and disadvantages with the different models (Table 1). Under the centralised model, quality is controlled throughout the production chain by removal of defective nuts initially and risk management throughout the supply chain. The pulp and shell adds substantially to the weight and transport costs and it may be more efficient to do this primary processing in the production areas and then only transport the kernel-in-testa to the value adding plant. The kernel-in-testa is quite robust for transport with the testa protecting the kernel from damage. Blanching the kernel at the value adding factory to remove the testa would also act as a microbial decontamination process for food safety.

Risk management strategies will need to be re-examined in more detail as the processing models are developed.

Problems with quality of nuts in the Central purchasing model, such as older, yellow nuts, could be minimised by rejection at the collection centres by purchasing only purple nut-in-pulp (to ensure fresh nuts, then depulping at those collection centres (Appendix 7). More detail on the Centralised model is shown in Appendix 7.

Table 1. Alternative canarium nut processing models, with advantages and disadvantages.

A – Centralised	B – Village cracking	C – Decentralised
Grower supplies fresh ripe nut-in-pulp (NIP) to processor at collection centres	Grower harvests nuts and depulps using traditional methods	Grower harvests nuts and depulps using traditional methods
Collection centres De-pulp and Float tests nut-in-shell (NIS) (Unripe and Over-ripe fruit and NIS that floats are rejected)	Dried and Cracked in Village	Crack, remove the testa, dry and roast in Village
Nut-in-shell transfer to Processor	Nut-in-testa transfer to Processor	Package for sale and distribute final product
Processor – NIS dried Cracking Testa removal under hygienic conditions Value adding	Processor – Testa removal Value adding	Processor could further value add and package product
Benefits		
-Quality control throughout process.	Transport costs minimised	Traditional method Low establishment costs Low transport costs
Disadvantages		
High transport costs;	Drying of nuts needed in village; Possible transport damage to kernel; Quality control not as rigorous as centralised	Uneven roasting; Quality control not as rigorous as centralised

Adoption of new processing methods

Since the Vanuatu workshop in 2010, Votausi Mckenzie from the Lapita Café Port Vila, Vanuatu has used a solar drier to stabilize the kernels at the village level. She has then further dried and value added to the product and sold the packaged nuts in supermarkets in Port Vila. The demand for the dried nuts was substantial and all product processed was sold within 2 months. Prior to the workshop she was freezing all product that she purchased. This has highlighted the potential for drying methods as an alternative processing method to freezing. Charles Long Wah, from the Kava Store was also calling for funding for solar driers as a method to stabilize the canarium at the village level. This is a significant change in practice for the Kava Store and highlights a change in practice and capacity as a result of this project.

7.2.1 Examine indices of nut maturity:

This project has identified the time taken for canarium nut-in-pulp to mature on the tree, the chemical characteristics of green and purple nuts and developed a protocol to sort nut-in-shell into mature and immature nuts at buying points (Appendix 2).

Time to maturity of nuts on trees

The experiment undertaken in East New Britain PNG found that trees appear to ripen more quickly at the top of the tree. Most bunches took at least 8 weeks for all fruits to ripen. (Fig. 4.).

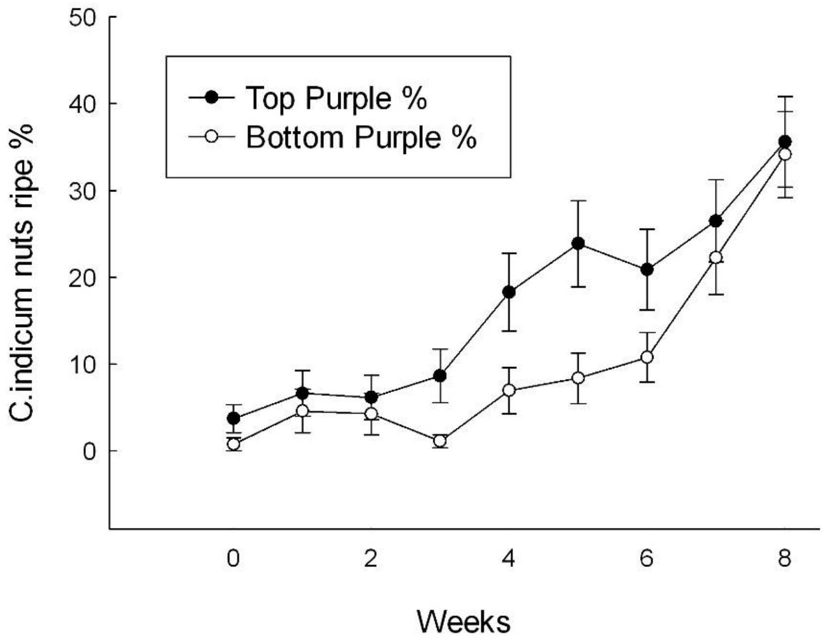

Fig. 4. Maturity of *Canarium indicum* at the upper and lower parts of the tree.

Oil analysis of ripe and semi-ripe nuts

Canarium kernels had high oil content of approximately 76%. Oil content for ripe and half-ripe kernels was not significantly different (76.6% and 76.3% respectively, Table 2). Both ripe and half-ripe kernels had significantly higher oil content ($P = 0.013$) than un-ripe kernels (72.8%). Kernel weight for ripe and half-ripe fruit was not significantly different (c. 1.9 g), but for un-ripe fruit mean kernel weight (0.62 g) was significantly different from both ripe and half ripe kernels ($P < 0.001$).

Oil content for ripe and semi-ripe *Canarium indicum* kernels (76%) was very similar to macadamias (McConachie 1997). Oil content for immature kernels was significantly lower at 72.8%, but this is still a high oil content. These results are similar to 67 – 75% reported by Leakey et al. (2008) for nuts from different regions. Oil content alone could not be considered a reliable indicator of maturity on the basis of these results. The kernels from green fruit had relatively high oil content yet were obviously immature when kernel weight and shrivelled appearance were considered (Table 2). Kernels from green fruit also had an unpleasant odour. This study does show that when hand-harvesting is employed only fruit of full-purple to half-purple colour should be harvested to ensure that kernels are mature with high oil content. Additional information is detailed in Appendix 2.

Water test of nut in shell quality

A new processing protocol has been developed to separate poor quality nut-in-shell from good quality nut-in-shell. Canarium nut-in-shell either floats or sinks in water. Nut-in-shell that floats generally has no kernels or small, possibly immature kernels, and floats because of the air spaces within the nuts. The causes of air spaces include old nuts that have been dried down, rotten kernel, immature nuts with poor kernel recovery, in addition to sterile cells. These conditions combine to produce poor kernel recovery (Table 3). We recommend a processing protocol to separate nuts that float ('floaters') from those that sink ('sinkers') at point of purchase. Floaters will be of lower value and can be discarded or downgraded.

Table 2. Oil content (%) and weight (g) for kernels from ripe (purple), half-ripe) (half-purple) and un-ripe (green) *Canarium indicum* fruit . Values are means (SE) for oil content (Tukey's test) and means for kernel weight (Mann-Whitney *U*-tests). Means in the same column with different superscripts are significantly different.

Fruit Colour	Kernel Oil Content (SE)	Kernel Weight
Purple	76.59 (0.57)[a]	1.89[a]
Half-purple	76.26 (0.68)[a]	1.90[a]
Green	72.29 (1.22)[b]	0.62[b]

Table 3. Kernel recovery of floaters and sinkers. Kernel recovery is the ratio of kernel weight to total nut-in-shell expressed as a percentage.

Colour of sample	Sink kernel recovery (% of kernel to total nut-in-shell)	Float kernel recovery (% of kernel to total nut-in-shell)	% of the sample that sank
Green	19.0	12.9	84.6
Green/purple	21.0	10.5	80.0
Purple	24.7	16.5	76.6

This technique of placing nut in shell in water could be used at buying points to eliminate nuts that are immature, of low kernel recovery, mouldy or old and dry from fresh, high moisture content nut-in-shell. Quality nut-in-shell are those that sink when placed in water and floaters can be either downgraded or rejected at point of purchase.

7.2.2 Examine spoilage of nuts with current used pulping methods:

Spoilage of nuts

Commonly used depulping methods include allowing nut-in-pulp to rot under the tree in a single layer; allowing to rot in piles on the ground; and rotting in hessian sacks. Preliminary trials with rotting nuts in hessian sacks have shown no increase in mouldy or rancid kernels before two weeks. At 14 days, green and half purple nut-in-pulp becomes fully purple allowing easy removal of the softened pulp (Table 4).

Table 4. Percentage of mouldy nuts after 7 and 14 days in hessian sacks.

Nut-in-pulp colour	Day 7 Mouldy nuts (%)		Day 14 mouldy nuts (%)	
Green	15.9	19	0	0
1/2 Purple	5.5	91	0	0
Purple	8.1	8	[illegible]	[illegible]

Depulping canarium by rotting pulp fr … sent an increased risk from elevated bacteria … and increased human health hazards. Tr… d the Solomon Islands favor rapid mould, f… the hazards from contamination by bacte… prompt removal of the fleshy fruit from the nu… extensive trials are needed on the effect of the … of kernel and microbial load of the product. Fu… to be completed.

Mechanical depulper

A mechanical dehusker adapted fron … ped to remove the pulp from the *canarium* n…

Fig. 5. A mechanical dehusker developed to remove the pulp from the canarium nuts.

This machine shows some promise but requires modification before it could be used commercially. Further research and development is required on the following:

- Nut-in-pulp needed to be carefully placed in the hopper one at a time. A modification to the hopper is needed to orient the nut-in-pulp correctly to allow efficient depulping.
- Nut-in-pulp had to be fed in singly and the machine could not depulp large amount of nut-in-pulp quickly. It would need more power and perhaps a second tyre to enable efficient depulping.
- A modification to the tyre could enable more uniform pressure to depulp more nuts. Flaps or grooves cut into the tyre may help to remove the pulp.

- Nut-in-pulp are different sizes and shapes: the nut-in-pulp may need to be graded first.
- The flesh may need to be firm (not soft or rotting) to allow efficient depulping.
- There may be a risk of damaging the kernel if there is too much pressure.
- The depulper removed pulp from 86% of firm, purple nut-in-pulp but only completely removed pulp from 18% of green nut-in-pulp (Fig. 6).

Fig. 6. Purple nut in pulp and green nut in pulp after depulping with mechanical depulping machine designed for this project

Further studies could focus on improving the efficiency of the depulper and comparing the quality of nuts that have been mechanically depulped with those depulped by traditional depulping methods.

7.2.3 Conduct scientific trials on drying:

How drying temperature affects kernel quality

Drying reduces the free water required for enzyme activity, chemical reactions and microbial growth and is a major method for preserving many commercially processed nuts. Without drying, canarium is prone to rancidity because of the very high oil content. The percentage of whole kernels is also an important economic factor in nut processing as whole kernel in other nut industries are a high value product (Wallace and Walton 2005).

We have shown that drying nut-in–shell at temperatures below 40ºC is very important in the initial phase of drying to prevent damage to the kernel. Drying nut-in-shell at 40 ºC increased the percentage of whole kernel compared with drying nuts at 60ºC at days 3, 4, 5, 6 days ($P<0.001$) (Appendix 3). This is a very significant finding, as it means that appropriate drying will improve the percentage of whole nuts and the whole nuts are likely to be the highest value processed product. Our trials also found that nut-in shell dried at 60 ºC showed excessive browning of the kernel compared to nut-in shell dried at 40ºC after 3 days (Fig. 7) and nut-in -shell dried at 40 degrees showed translucence in teh kernel after 3 days. This is also significant as translucence is an indicator of kernel damage.

Fig. 7. Browning and discolouration after 3 days of drying at 40ºC or 60ºC.

Additional drying trials at lower temperatures (detailed in Appendix 3) confirmed these results. Drying at 35^{o}C for 3 days resulted in low levels of translucence compared to, drying at 50^{o}C.The percentage of whole nuts also decreased after 4 days of drying at 50^{o}C. We recommend that nut-in-shell be initially dried at temperatures below 40 ^{o}C to ensure the best quality.

Moisture loss during drying

Canarium nuts have high oil content similar to macadamia nuts; consequently it is expected that they would react similarly in relation to oil chemistry. Canarium nuts dried to 7% nut-in-shell moisture content (approximately 3.7% kernel moisture content) should be stable as they will have reduced water potential and enzymatic and chemical reactions will be reduced.

We examined post harvest processing of canarium nuts by examining moisture loss during drying. Drying at 35^{o}C for 5 days reduced the moisture content to approximately 7% across a range of nut sizes, depending on the initial moisture content (appendix 2). After three days at 35^{o}C the moisture content was stable and there was very little further moisture loss of the nuts. A stepwise drying regime was investigated. Three days at 35^{o}C reduced the moisture content from 23.9% to 12.7%, and after a further 3 days at 38^{o}C the moisture content had decreased to 8.3%. After a further 2 days the nuts dried to 6.2%. Temperature higher than 35^{o}C is needed to dry nuts below 7 %.

Technologies for drying canarium

Several technologies for drying canarium were trialled, developed and adapted in this project. Early trials on a solar drier developed for cocoa drying (Fig. 8(a) showed that nuts were excessively brown and oily, although nuts had been left in the solar drier for 17 days (Fig. 8(b). Temperatures daily reached well above 40^{o}C and were likely to cause translucence and browning of the kernel after only 1 day (Fig.9.).

Fig. 8. (a)Solar dryer used for cocoa drying and (b) Kernel after being dried in the solar drier for 17 days.

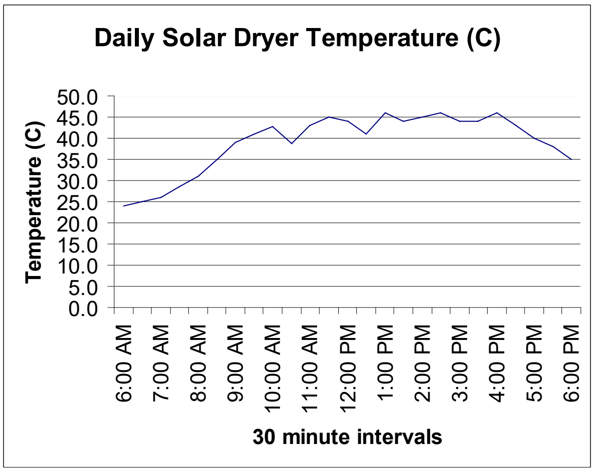

Fig. 9. Daily temperature curve in solar cocoa dryer with canarium nuts.

Box Drier

A small scale drier developed for the macadamia industry has been adapted for canarium drying. The dryer was designed by David Bell of Hidden Valley Plantations (Fig. 10.).

Fig.10. Metal frame and base for Bell box drier.

The drier is cheap and easy to assemble and requires plywood, a steel frame, a fan and a heating element and thermostat in the sheet metal fabricated hood (Fig. 11.). The box can hold up to 1 tonne of canarium nut-in-shell. Six Bell box driers have been assembled at

N ... ssing factory remain to be tested in P...

Fig.11. Bell box drier showing plywood box structure, fan, heating element and hoods.

7.2.4 Identify appropriate technology for cracking:

Two options for cracking canarium have been identified. TJ's™ nutcrackers have been modified to suit various sized nuts. This option is most suitable for small scale or village use. A larger option of a heavier nut cracker from China has been identified and tested, and has been purchased for the pilot processing plant in Kerevat.

TJ's™ nutcracker

A TJ's™ nutcracker used for macadamias has been modified by the manufacturer for use with extra large macadamias, and is suitable for canarium. The jaws of the nutcracker have been made wider to fit larger size nuts, with an adjustable insert for smaller nuts (Fig. 12.) Some smaller nuts can be cracked in the wide jaws end-to-end. The modified TJ's™ nutcracker is most efficient when the flat surface (the 'coffin lid')of the canarium nuts are faced upwards and enables rapid hand cracking of canarium with high whole kernel recovery.

The nutcracker weighs only 1.3 kg, is hand operated, portable and inexpensive ($A50-$A70). It has great potential for use in villages to sell nuts in local markets, especially in remote areas. It is also useful for cracking nutmeg. The crackers have been supplied to Marghoto holdings, SI, Vanuatu Department of Forests, Lapita Café and NARI Kerevat.

The cracker needs slight modification to withstand wear on the bolts at the base of the lever mechanism, and lubricant of the moving jaw. The nutcracker works best when the nut-in-shell is around approximately 10 % moisture content or less to avoid damage to the kernel.

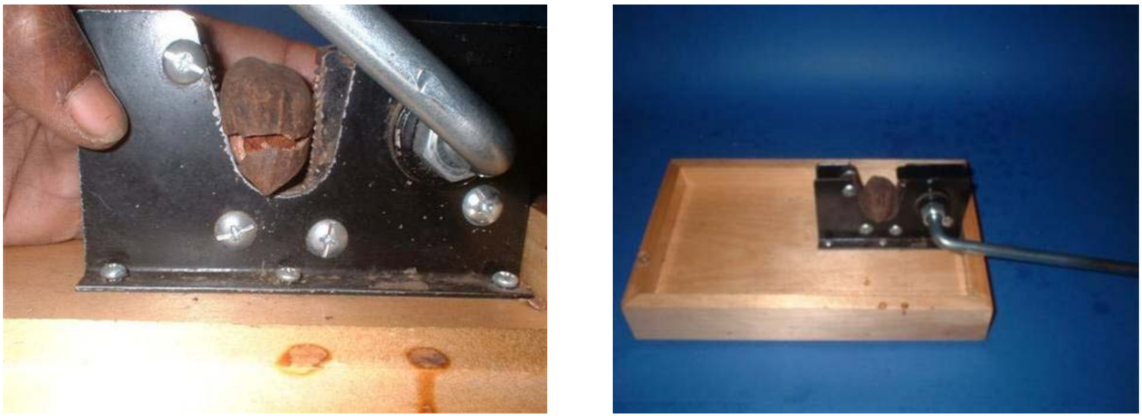

Fig. 12. The modified TJ's ™ nutcracker showing cracking of canarium nuts

The nutcracker has created strong interest from growers in PNG and many have expressed interest in purchasing one. Several Local Level Government women groups with membership of 400-500 members each group have expressed interest. It is estimated that 6,000 nutcrackers could be purchased by women's groups in Kabilomo, Nabual and Kumaina in the Duke of York Island and at Manus Island, where there are 12 women's groups.

Chinese hand cracker

The Chinese hand cracker worked well without any modifications on almost all the different sizes and styles of canarium nut-in-shell provided. The cracker works with a stationary blade at the bottom and a top blade that comes down to cleave the nut. The operator turns a flywheel (Fig. 13.), which brings the top blade down onto the nut, cleaving it in two (Fig. 14.). The flywheel is spring loaded and returns to the ready position automatically. The force applied by the operator determines the force with which the blade strikes the nut. The distance between the blades can be adjusted to suit the size of the nuts and in a factory situation the best efficiency will be achieved by size grading the nuts before cracking. Correctly sized nuts can be cracked by using full force without fear of damaging the kernel.

Large nuts and nuts with twin or triple kernels can be opened on the same machine, but it requires some finesse and usually more than one motion is required and some kernel damage often results. With practice, operators will develop the skill to open these nuts with more speed and minimal kernel damage.

Operators will require safety glasses as sometimes a piece of shell may fly off. Operators will also require a glove on the hand holding the nut to prevent jarring when the shell splits. Alternatively it may be possible to construct a cradle around the bottom blade to hold the nut, or maybe devise some sort of tongs to hold the nut.

Fig. 13. Chinese hand cracker.

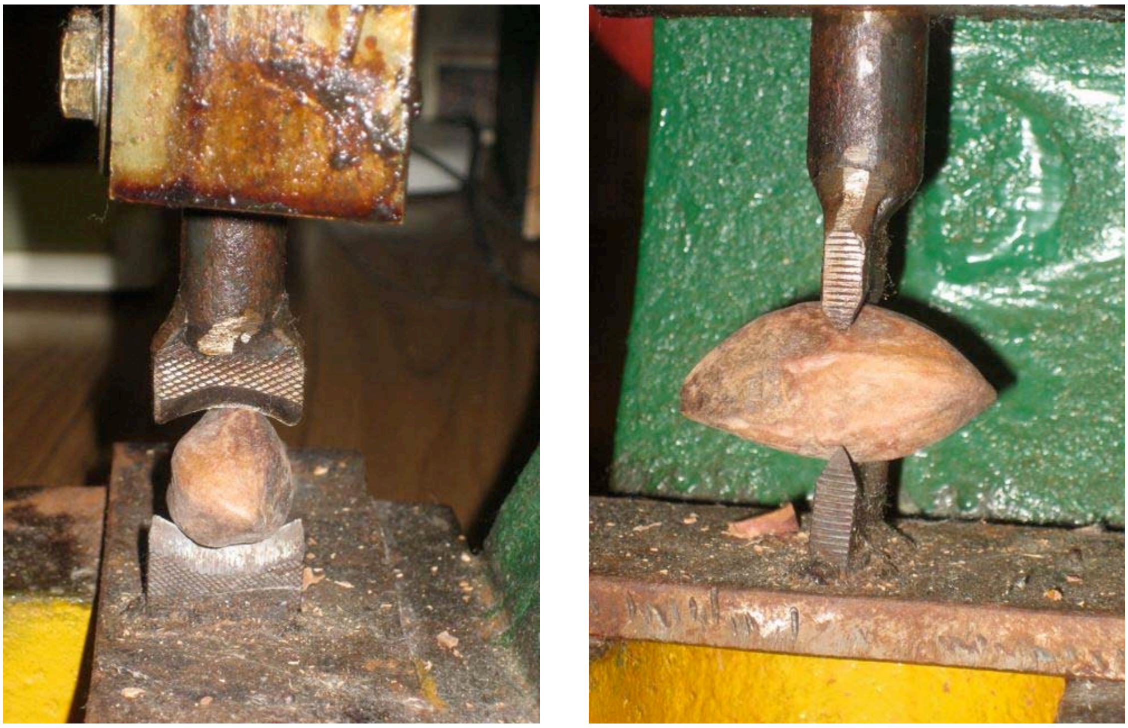

Fig. 14. The canarium nut-in-shell positioned between the two blades on the cracker.

In three speed trials on cracking, canarium, nuts were cracked and kernels removed from 30 nuts in under 5 minutes on average, (Table 5) with an average whole kernel recovery of about 95% (Fig. 15.). With experience, this is likely to improve.

Table 5. Crack out from 30 canarium nuts using the Chinese hand cracker.

Trial	Time	Crack out		
		Whole kernel	Damaged kernel	Mouldy kernel
1	5min 45 secs	29	4	2
3	4min 27 sec	28	1	2
3	4min 35 sec	32	1	0

This cracker has great potential for canarium nut processing. The percentage of whole kernel was about 95%, which is impressive, and is most likely superior to the TJ cracker. The speed of cracking is also probably faster than can be achieved with the TJ cracker. This Chinese cracker is not portable and due to increased cost probably most suitable for larger processing units and small factories, while TJ's is easily portable and cheap and suitable for small scale and village processing.

Fig. 15. Crack-out from 30 canarium nut-in-shell; in most cases the shell is cleaved neatly in two yielding an undamaged whole kernel.

7.2.5 Examine options for testa removal:

As nuts dry, the testa clings to the kernel and becomes more difficult to remove (Fig. 16.). Two options have been developed for testa removal when the testa sticks to the kernel. Blanching in hot (just lower than boiling) water for 90 seconds hydrates the testa and facilities ease of testa removal, without reducing whole kernels (Fig.17.). A publication has been produced from this project describing these methods (Wallace et al. 2010). This is attached in Appendix 4.

Blanching nuts rehydrates the testa and to some extent the kernel and the kernels then need to be redried.

A second treatment identified by this project in a preliminary examination is treating with steam for 2.5 minutes. This treatment softens the testa without moistening the kernel as much as blanching in water. The exact time will depend upon the equipment available, the initial moisture content and the quantity of nuts treated in each batch. The hot water option is most suitable for small scale or village use and the steam option requiring more equipment may be more suitable to commercial use and may be a critical hazard reduction control point.

Fig. 16. *Canarium indicum* showing kernel with and without the testa.

Another option may be to crack and remove the testa at 15% moisture content then dry the kernel to 6% moisture content. This option still requires further study to assess the ability of the kernel to remain whole during handling, and possible limitations in storage capacity.

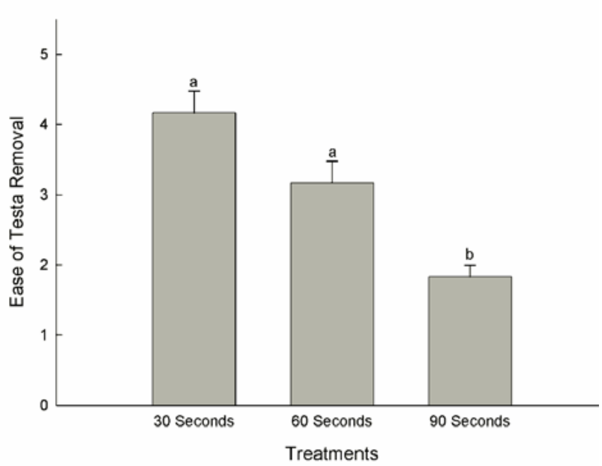

Fig. 17. Ease of testa removal from *Canarium indicum* nuts from PNG using near boiling water. Columns with different letters are significantly different.

7.2.6 Conduct roasting trials of *C. indicum*:

Oven roasting experiments have shown that temperatures less than 125 °C for 20 minutes produce a good colour and that translucent nuts turn excessively brown after roasting. Kernels were assessed for colour and mottling but not taste (Appendix 5).

These experiments indicated that roasting at 120°C for 20 minutes produce a very light colour (Table 6). Dark kernels were not found below temperatures of 125°C (Table 6) and severe mottling did not increase markedly below 120°C for 15 minutes (Table 7). Kernels with increased translucency prior to roasting produced very brown kernel when roasted.

Although Evans (1991) dry roasted canarium kernels at 100°C to120°C for one or two hours or 135°C for 55 minutes, the current experiments suggest that, the result would be an extremely dark roast for those lengths of time.

Table 6. Canarium kernels (%) in each colour category for different roasting regimes (min=minutes). Colour 1 is pale/white colour, colour 4 is very dark brown.

Treatment	*Colour 1*	*Colour 2*	*Colour 3*	*Colour 4*
110°C; 10 min	60.83	38.83	0.00	0.00
110°C; 15 min	69.17	30.50	0.00	0.00
110°C, 20 min	44.17	49.67	0.00	0.00
115°C; 10 min	27.50	71.83	0.00	0.00
115°C; 15 min	5.50	77.33	16.67	0.00
115°C, 20 min	44.17	55.33	0.00	0.00
120°C; 10 min	16.50	63.50	19.33	0.00
120°C; 15 min	0.00	68.83	30.33	0.00
120°C, 20 min	0.00	58.17	41.50	0.00
125°C; 10 min	0.00	47.00	49.83	3.00
125°C; 15 min	0.00	47.00	49.67	3.00
125°C, 20 min	0.00	30.50	63.50	6.00

Table 7. Canarium kernels (%) in each mottled colour category for different roasting regimes (min=minutes). Mottling 1= less than 10% of nut mottled, Mottling 2= less than 50% of nut mottled, Mottling 3= severe mottling with colour differences of several shades.

Treatment	*Mottling 1 %*	*Mottling 2 %*	*Mottling 3 %*
110°C; 10 min	69.00	27.67	3.00
110°C; 15 min	55.33	38.83	6.00
110°C, 20 min	49.83	38.67	11.00
115°C; 10 min	38.67	55.33	6.00
115°C; 15 min	25.00	63.50	11.00
115°C, 20 min	72.00	27.83	0.00
120°C; 10 min	24.83	63.50	11.00
120°C; 15 min	0.00	69.00	31.00
120°C, 20 min	0.00	74.50	25.00
125°C; 10 min	5.67	66.33	25.00
125°C; 15 min	0.00	58.00	42.00
125°C, 20 min	0.00	47.17	53.00

Results from roasting will depend on the freshness, moisture content and post harvest treatment of the nuts. These experiments form the basis of a suitable roasting regime; however no taste testing was undertaken. The acceptable colour, taste and texture for roasted *canarium* nuts and the ultimate roasting regime will need to be based on consumer preference. Additional information on roasting trials is given in Appendix 5.

7.2.7 Identify technologies for packaging that can maintain quality of nuts:

Oxygen and moisture causes food to degrade and the shelf life of food products is extended by decreasing the air content and preventing moisture uptake.

The Macadamia Industry recommends that packaging material have the following water vapour and oxygen transmission properties during 24 hrs at 25^{o}C, 75% Relative Humidity and 1 atm:

1) 3 months maximum storage period: water vapour maximum transmission 1.0g/m^2 and Oxygen maximum transmission1.0cc/m^2
2) 6 months maximum storage period: water vapour maximum transmission 0.3g/m^2 and Oxygen maximum transmission 0.3cc/m^2
3) 12 months maximum storage period: water vapour maximum transmission 0.1g/m^2 and Oxygen maximum transmission 0.1cc/m^2 (Australian Macadamia Society 1994).

Plastic foil bags and cellophane (Fig. 18.) are commonly used in the macadamia industry. Costs range from $30 to $110 in a range of sizes for cellophane bags, with a minimum order of 1,000 bags. Bags can also be customised with the firm's logo and product descriptions. There is also a range of equipment used in the macadamia industry to seal and vacuum pack nuts depending on the volume and speed required (Fig. 19.).

Foil packaging is often preferred commercially because it is a more reliable oxygen and moisture barrier, and provides excellent storage potential. The disadvantages include more expensive equipment required and larger bulk purchase of bags. A more economical alternative is vacuum packaging with plastic film. A Sunbeam foodsaver VAC440 has been purchased for PNG and subsequently used in storage trials (Fig. 20.).

Fig. 18. Macadamia nuts packaged in plastic foil and cellophane bags.

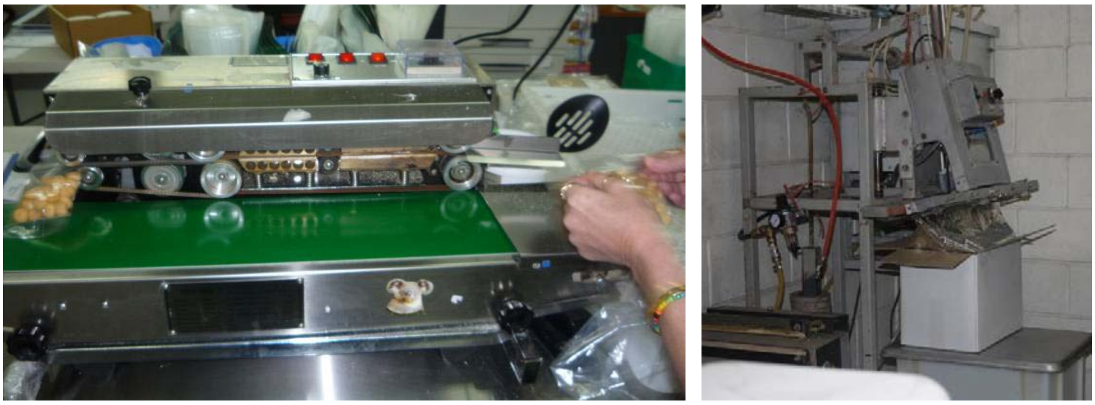

Fig. 19. Sealing Equipment used for Sealing Bulk Macadamia Nuts.

Fig. 20. Vacuum packaging of *Canarium indicum.*

Further study is required to determine moisture content for the best eating qualities and roasting temperature as this will impact on the subsequent shelf life.

7.2.8 Conduct trials on nuts stored at different temperatures and moisture contents:

Wet nut-in-shell (23.9%) became mouldy when stored in an enclosed container for 3 weeks at 25°C as they could not dry. The nut-in-shell dried to 6% at 25°C showed no visible deterioration after 6 months, indicating the need to dry nuts prior to storage.

Canarium kernels did not deteriorate markedly during the 9 months of storage at both USC and NARI (Appendix 6), when the nuts were dried to approximately 6% nut-in-shell moisture content (around 3.5% kernel moisture content). Both peroxide values and free fatty acids were well within acceptable measures of quality. All peroxide values at USC and NARI were very low (≤ 0.39 meq/L) and all values were significantly lower than the control ($P < 0.001$). The highest peroxide value recorded was well below the proposed acceptable upper limit for macadamias nuts. This trial showed that vacuum packaging minimised the amount of oxygen available for peroxidation and canarium kernels can be stored for 9 months at an ambient temperature of 25°C with minimal loss of quality.

Free fatty acid values (FFA) were generally low. At USC there were significant differences ($P < 0.001$) between kernels stored at ambient temperature and controls. The FFA values for ambient storage was significantly higher at 9 months than at 3 months. There was no difference between the ambient and refrigerated treatments at 1 month and at 6 months, but ambient treatment values were significantly higher than those for the refrigerated treatment at the 3 month and 6 month stages. At NARI, FFA increased following storage at ambient temperature for 3 months, and was further increased after 6 months. This may have been due to the higher ambient temperatures (mean maximum 31°C). These kernels were not subjected to a tasting panel, however the highest FFA values indicate reduced shelf life and caution about longer term storage.

Moisture content of the stored kernels may have been a factor in the FFA increases. Kernel moisture content of approximately 2.5% would probably provide some free water for hydrolysis of triglycerides. It is possible that if kernels were stored at lower moisture content, hydrolysis of triglycerides to fatty acids would have been reduced.

Canarium stored under refrigeration resulted in the lowest free fatty acids and peroxide values and had the slowest deterioration. This study also shows that canarium vacuum packed kernels can be safely stored for 9 months at 25°C or for 6 months at 30°C. However, only limited further storage at either temperature may be possible. It is recommended that canarium vacuum packed kernels should be stored under refrigeration to maintain optimum kernel quality.

7.2.9 Identify hazards and critical control points for food safety:

A Hazard Analysis and Critical Control Point Plan for canarium for the pilot canarium processing plant was prepared by Kim Jones from Cropwatch Independent Laboratories (Appendix 8).

Based on the macadamia nut industry, this HACCP plan draws on what is currently known about the fledgling canarium industry and the expected way it will develop, and identifies the need for the industry to expand into the export market. The HACCP plan begins by describing the product (Appendix 8 Table 1), the expected flow of the product (Appendix 8 Table 2), potential threats to food safety and potential critical control points. A draft HACCP plan (Appendix 8 Table 3) describes recommended control measures for each Critical Control Point (CCP).

This is the first hazard analysis for canarium nuts and some of the information on risks is still to be developed. This hazard analysis draws on issues that are common to all tree nuts. Contamination by agricultural chemicals is a low risk as no pesticides are currently used in either wild harvested or plantation grown canarium nut.

The most effective microbial control mechanism is to dry the product to moisture levels that will not support mould growth, which is approximately equal to 7% Nut-in-shell moisture. Nuts stored at high moisture content create an ideal environment for microbial growth. There is a risk that mycotoxins could develop during prolonged on-farm storage. Contamination by human pathogens such as *Escherichia coli* and *Salmonella* spp. could occur if harvested nuts come into contact with animal manures. Aflatoxin and microbial contamination of canarium nuts stored on-farm for extended periods is a high risk. For this reason this HACCP plan focuses specifically on microbial and mycotoxin contamination**.**

During postharvest operations, if safe moisture contents are not achieved quickly and maintained throughout the supply chain, microbial growth and aflatoxin levels will increase rapidly. Sampling and testing needs to be carried out to determine the true extent of the risk that aflatoxins pose to canarium nuts stored at high moisture.

Additional risks during the supply chain include:

- Contamination may spread and aflatoxin levels may increase during delivery to regional collection centres;
- Cracking exposes the kernel to contamination from external sources;
- Blanching or steaming prior to testa removal will act as a sanitiser and kill live microbes, but not remove accumulated aflatoxins;
- Testa removal is a manual process and there is a high risk of re-contaminating the kernel at this step.

A two-stage drying process will allow a primary trader to accumulate product and reduce the moisture content to levels that restrict mould growth and slow enzymatic processes, so maintaining quality (approximately 10% moisture content). Final drying to cracking moisture and to levels that prevent mould growth will occur at the centralised processing plant.

Table 3 in Appendix 8 shows steps and quality control measures. Critical control points include rejection of old or mouldy nuts to prevent contamination. It is important to begin processing the Nut-in-pulp as soon as possible and within 24 hours of delivery. Field moisture needs to be reduced to safe levels to prevent microbial growth and product deterioration. Good storage practice is required to prevent re-wetting of the product and to maintain quality.

Blanching or steaming the product to remove the testa is a critical control point as the hot water or steaming will sanitise the kernel. Throughout the supply chain hygiene standards are important to prevent cross contamination by animal products including manures or workers. Appropriate, regular training to ensure compliance is required. Routine sampling, testing and verification for aflatoxin and microbial contamination needs to be undertaken to prevent any human food safety risk.

7.3 To provide training and capacity exchange in optimal *C. indicum* nut processing

Objective 3 activities were to develop awareness raising material; and to train local people in processing techniques, skills and resource issues.

7.3.1 Develop awareness raising material

PNG staff had undertaken a range of awareness raising activities prior to this research project (see below) and felt that further awareness raising prior to progress in the industry would result in a loss of interest in the industry.
Awareness raising materials were developed and distributed throughout Vanuatu (Appendices 9 - 13). Participants at the first workshop in Vanuatu commented that the information was extremely useful as previous canarium proponents had mentioned the commercialisation potential of the nut but local people had not heard further feedback from them. Stakeholders at the workshop valued the awareness raising newsletters (Appendix 9) as local people are relying on the wild harvest and are unsure whether canarium commercialisation is viable, nor whether marketing problems can be solved. Single issue workshops were valued because they allowed in-depth exploration of the commodity and can be conducted regionally with growers.

Stakeholders agreed that the newsletter should become a regular publication after all workshops to give feedback to all participants and disseminate through their networks. Further newsletters and an updated awareness brochure were published and sent to people after each workshop (Appendices 10-13).

Public interest in commercial canarium activity led to the relocation of the Project Leader, Mr Ioan Viji to Santo in 2010, where he used these materials again to prepare local growers for participation in the industry.

7.3.2 Train local people in the necessary techniques, skills and resource issues

Participants at the first workshop in Vanuatu felt that it was too early to draft training manuals. Once the processing protocols are finalised, a concerted on-ground effort to train people should occur. After that workshop, a training manual was drafted, but, given the processing techniques remain under refinement, the final processing techniques are not detailed. Final documentation will need to clearly articulate the processes and standards for certification for the various stakeholders in the supply chain (on-farm, factory, consumer etc.), and may need to link to other agencies who provide broader training requirements such as licensing or business acumen. Public, private and non-government organisations are now specialising in extension and may be useful partners in future research for extension and training.

Training was discussed at the workshop in PNG and a range of training recommendations given. Participants suggested that training be given both as codes of practice and as training devices. They felt that a range of written and applied formats in combination was the most effective extension strategy, emphasising that on-farm demonstration is the most time-consuming and resource intensive, but critical for skills development. However, regular visits are needed, albeit less frequently, to continue to support farmer and processor efforts, understand concerns, and introduce new technologies and developments. Participants suggested funding applications must build in appropriate estimates for such expert extension. In particular, they suggested specialised extension experts who understand different types of information, mediums, and methods of extension be used, partly because of their training in the use of appropriate language and its application across differing scales of production. These extension requirements were used to inform the industry development plan that NARI commenced.

At the third workshop in Vanuatu, the Department of Agriculture and Rural Development representative, with staff of the Department of Forestry, had drafted a canarium development plan. That plan detailed targets of training including short-term strategies in more remote parts of Vanuatu to raise awareness and interview farmers about an appropriate nut collection system; and to conduct training in nursery and production in Mota Lava, Maewo, Santo, Malekula and Efate. A processing manager trained in the operation of primary processing centres on Efate, Santo and Malekula was also planned, as was a partnership with the Kava store to train people with government-produced information booklets accompanying the applied demonstration.

At that workshop, a representative of a Solomon Islands NGO gave an applied demonstration of different traditional methods of processing. The first depends on how nuts are collected and produces kernel in testa and the second is labour intensive requiring all processing stages to occur simultaneously. He also demonstrated different traditional cracking methods, oven construction and cooking.

It will be critical to ensure the industry associations are involved in the future participatory industry development strategies developed by partners, and build linkages with growers once the training protocols are developed. These associations might link with existing facilities e.g. the agricultural college in Santo might be a regional centre. At the moment canarium nuts are used as in-kind payment for school fees and trained students might undertake appropriate tests with equipment while the college would eventually have the ability to process the nuts used in payment. Students can also raise seedlings, and take their technical knowledge back to the villages.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project has produced new scientific knowledge on processing of canarium nuts. A scientific publication has been produced on cracking and testa removal (Appendix 4) and further publications are expected. These include articles on Nut Maturity, Drying, Roasting and Storage of canarium based on Appendices 2, 3, 5 and 6 of this report.

This project has improved scientific capacity in Papua New Guinea by supplying data loggers, cameras and ovens to NARI for scientific experiments to be undertaken in Papua New Guinea. Staff at NARI were trained in experimental design, operating equipment such as data loggers, experimental protocols, and data analysis. As a result, this project has increased scientific capacity in the NARI beyond the life of the project and will provide strong benefits for the forthcoming canarium marketing and product development project.

The project has provided a range of scientific and processing equipment for the pilot factory including TJ's hand nut crackers and commercial mechanical Chinese nut-in-shell cracker, small scale depulper machine, vacuum packer and scientific ovens (Memmert laboratory fan-forced oven (Memmert Gmbh & Co. KG, Schwabach, Germany) (Fig. 21a.). A small scale drying silo (Nut-in-shell [NIS] Bell box drier system) used in macadamias has been built in PNG using local and imported materials (Fig. 21b.). Tinytag temperature and humidity sensors obtained by the project have been utilized to monitor drying temperature and humidity during processing. These will enable further drying trials with more accurate data for the project at NARI and to facilitate canarium processing for the pilot factory.

Fig. 21. (a) Scientific ovens and (b) NIS bell box drier system showing fan and hood

Visits by Dr John Moxon and Mr Matthew Poienou from NARI Papua New Guinea and Mr Charles Long Wah from Vanuatu to macadamia processors in Australia have deepened their understanding of the value adding potential for the canarium nut industry. Visits by Mr. Kim Jones, Professor Helen Wallace, Dr. David Walton, Mr. Bruce Randall, Dr. Jen Carter, Mr. Colin Bunt, and Dr. Richard Pauku to both PNG and Vanuatu have also increased the scientific and research capacity of both countries by training, experimental planning and information sharing.

8.2 Capacity impacts – now and in 5 years

At the commencement of the project, the traditional way of cracking *Canarium indicum* was with stone hammers and they were sold in the local markets for immediate consumption. The only form of value-adding was undertaken by the Kava Store, Vanuatu. This process required freezing, which was not widely available, and resulted in a large percentage of the crop being rejected due to poor quality. Since the Vanuatu workshop, Votausi McKenzie from the Lapita Café, Port Villa, Vanuatu has utilised a solar drier to dry and process canarium nuts. The demand for the dried nuts was substantial and all product processed was sold within 2 months. The Kava store has also called for more access to solar dryers to dry canarium kernel. This project has built nut processing capacity in Pacific Island countries and has enabled processing techniques to be used that do not require immediate freezing of nuts.

This project provided expertise, advice and equipment to setup a pilot canarium processing plant at NARI, Kerevat, funded by the EU. In particular, much equipment from the macadamia industry was able to be adapted for canarium, and the macadamia experts involved in this project have been instrumental in guiding the sourcing and purchase of equipment.

The major achievements in building capacity include:

- developing alternative processing methods including drying protocols. These have been modified and adopted in Vanuatu and will be used in the pilot factory in PNG
- trialling and sourcing nutcrackers for village scale and factory scale processing
- recommending and sourcing equipment for the pilot factory at Kerevat

The project has helped provide knowledge about the canarium industry to all partners and has directed strategic development for canarium nut industry by modelling on the Australian macadamia industry. In Vanuatu the Department of Agriculture and Rural Development and the Department of Forestry are producing a whole-of-government development plan for implementing canarium industry development.

Department of Forestry staff have continued to work with growers to gather their feedback over other technical concerns such as the ease of cracking with different moisture content of the kernel, and with different sized nut-in-shell. Capacity improvement is being addressed by regular stakeholder input in processing trials and improved equipment. The TJ's nutcracker was initially felt to be a slow cracking method, although they acknowledged the cracker was safer and easier than using stone and had potential to produced undamaged kernel-in-testa. A strategy to increase capacity in the future might involve training younger people (who don't have the cracking skill of older people) in using the cracker.

Staff at NARI in Papua New Guinea have received training on research activities, including building links with government and non-government organisations for sustainable canarium postharvest handling and processing. They have utilised this knowledge to supervise and train PNG University of Goroka students on developing skills in nut drying and nut cracking using TJ’s nut cracker and writing reports as minor components of the project.

The PNG project has provided in-depth insight on capacity building for the partner countries like Vanuatu and Solomon Islands where all partners are willing to share development and research results for the benefit of the Melanesian canarium industry development funded by the ACIAR.

Participants at the second workshop in Vanuatu (Fig. 22.) expressed their thanks to ACIAR and USC for coordinating and providing updates on progress in the canarium nut industry. They were particularly thankful for the new knowledge they acquired on canarium postharvest handling and processing provided at PNG (through the involvement of Dr. John Moxon) and the complexities of marketing (through the involvement of Mr Colin Bunt).

Fig. 22. Participants at canarium workshop in Vanuatu.

The workshop also gave Mr. Matthew Poienou (NARI) the opportunity to visit a small-scale canarium nut processing unit in the Solomon Islands (led by Dr. Richard Pauku), where he was able to view the facility and equipment, and ask questions about the processing methods.

Other capacity impacts include:

- The participatory model for development
- An initial awareness raising brochure was collaboratively produced and translated into Bislama by partner staff in Vanuatu. Information has been presented at workshops, and then disseminated by delegates at a wider community level.
- A draft training template has been prepared
- Involvement in the various stages of information exchange
- Gathering data involved growers and processors
- Adoption of appropriate technologies at the village scale
- Awareness raising material and training manuals in PNG and Vanuatu has increased local capacity
- An industry association was also formed in the Solomon Islands

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

The ACIAR and EU projects have served to promote widespread interest and ownership of the new emerging canarium nut industry in PNG. The interest of the cocoa industry in planting canarium as a dual purpose shade/cash crop with cocoa is of great significance. A steering committee has been formed to establish a PNG Canarium Nut Association currently working out of the PNG Growers Association. The canarium nut industry is seen as having the potential to generate income at local level.

This project has facilitated the emergence of additional processors of canarium nuts in the Solomon Islands and Vanuatu. Since the start of the project, Lapita Cafe has started purchasing and processing canarium nuts. The packaged product is sold in the supermarkets in Port Vila. Currently product is sourced from Luganville and previously product has been sourced from other islands. In the Solomon Island, Maraghoto holdings has emerged as a buyer and processor of canarium nuts from community based organisations such as the Tetepare Descendants Organisation in Western Province. Both processors have been active participants in the information exchange and workshops in this project. Both have trialled drying methods rather than freezing to process the nuts. While it is hard to estimate the economic effects of the growth in the industry, there are clear economic benefits for Pacific Island communities such as the Tetepare Descendants Organisation and suppliers of Lapita Cafe having access to markets that they did not previously. Interest in canarium buying and processing has been expressed by large organisations such as Agmark in PNG,and in planting Canarium by the East New Britain Development Corporation.

A critical economic impact is expected with the development of an informal trans-national Melanesian network that has emerged from this research. Each of the two partner countries as well as the Solomon Islands have identified the bodies that will be used to help progress industry development. Partly these bodies will be able to more efficiently lobby for pricing, market access, consumer needs, promote a unified image through branding and lobby for research and infrastructure development needs. In turn these bodies will help to pass on benefits through the supply chain.

The longer term impacts of this research will help to engage smallholders and processors in cash or salaried employment opportunities and develop alternative crops to the cocoa industry. First, the domestic market potential is being reached and product for the export market is anticipated to have impacts at a later stage. In the long-term, rural-urban migration which is causing labour shortages in some rural areas may be addressed by developing village-level processing techniques that can optimise village-level returns.

8.3.2 Social impacts

A key impact from this research has been the progress in planning of industry development in both countries. As mentioned, each of the two partner countries have commenced a number of strategies that will help to expand benefits of the industry. For example, the project leader in Vanuatu has been moved to Santo Island to start building regional capacity for canarium processing there to complement work in Port Vila. The buying points in the cocoa supply chain will be used in Papua New Guinea meaning that people in more remote areas can piggyback their produce through these supply chains.

The PNG Canarium Association, led by Dr. John Moxon, has already developed a long term canarium Business Plan in preparation for the established plantings (phase one over 100, 000, phase two 70,000, phase three 1 million canarium trees) for establishment in East New Britain, West New Britain, New Ireland, Madang, Sepik, Autonomous Bougainville and Manus.

Another social impact is the increase in locally-grown and locally-produced commercial foodstuffs. Developing these commodities helps to retain employment for people in regional areas and to reduce the prices of healthy, nutritious foods for people in marginal areas.

8.3.3 Environmental impacts

This project will have positive environmental outcomes. Canarium trees have potential in a sustainable integrated agricultural system to provide shade for cocoa production.
The project will help to convince farmers of the importance of retaining native species and that value-adding their produce can provide economic gain. Retaining the species maintains a range of environmental services that the trees provide. Additionally, reduced costs of locally produced commercial foodstuffs will reduce transport and associated peak oil concerns.

Currently, the demand for increased planting has increased in ENBP from 100,000 to 1 million trees, with similar interest expressed from New Ireland as a result of awareness-raising and improved processing opportunities.

8.4 Communication and dissemination activities

A range of feedback materials were presented, as detailed in Section 11. Firstly an analysis of all previous canarium research and development activity was presented as an introduction to this research. This first newsletter was also translated into Bislama and copies given out at the initial awareness raising workshop in Vanuatu. Participants commented on its value and took copies back to their communities to disseminate and discuss with other community members.

Based on the success of this community dissemination format, further update newsletters were provided following workshops and other significant activity in the research. An updated awareness raising brochure was also produced and staff of the Vanuatu Department of Forests are working with community representatives on Santo Island to engage people in the potential of the industry.

Applied demonstration is a critical element of training and was built into the third workshop so that participants acquired some initial practical experience of traditional processing used by Dr Pauku in the Solomon Islands. Most participants welcomed the low-technology demonstration and believed that their own techniques or similar techniques might be used to progress their engagement in the supply chain when finalised.

NARI has undertaken extension about domesticating the most suitable canarium trees in 5 provinces, mostly through field days, held at local, ward and village level and using extension bulletins and posters. Some awareness raising about other donor-funded activities (e.g. an EU nut development project and the processing facility in East New Britain) have been undertaken and further extension was not taken to reduce community consultation fatigue.

Around 50 participants (including researchers) attended all Vanuatu workshops and 35 (including researchers) attended the PNG workshop.

Protocols and recommendations for processing have been developed but theses need to be trialled and adapted by processors in each country. While training in processing techniques was too early, further NGOs will be engaged in training in follow-on projects when protocols are tested and adapted to each country's needs, helping to extend the reach of the project outcomes.

9 Conclusions and recommendations

9.1 Conclusions

This project has identified a range of models for processing canarium nuts and developed methods and technologies to support these. These models include (but are not restricted to) centralised processing, village cracking and decentralised processing. Each of these have advantages and disadvantages and can be tailored and modified to produce products suited to particular markets.

Methods and technologies have been developed for pulping, drying, cracking, testa removal, roasting, packaging and storing of *C. indicum* nuts. In particular, drying methods have been developed to enable storage of the nut without the need for freezing. Drying methods as an alternative to freezing will allow more stakeholders to participate and enable expansion of the industry. The scientific trials have demonstrated that canarium nut-in-shell can be dried at temperatures less that 40°C without compromising the quality of the product. Nut-in-shell is stable once it is dried to 7% moisture content. Drying at 35°C for 5 days reduced the moisture content of the nut-in-shell to approximately 7% across a range of nut sizes, depending on the initial moisture content. Drying as an alternative processing technique to freezing has been adopted very quickly in Vanuatu by one processor Votausi Mckenzie from the Lapita Café Port Villa, Vanuatu, who is now buying kernel from the villages that has been dried in solar dryers. Traditional processing techniques from the Solomon Islands using hot stones also created interest in Vanuatu.

Two crackers adapted from the macadamia industry are suitable for commercial nut cracking, the TJ's™ nutcracker is suitable for small scale village level cracking and the macadamia nut chinese cracker is suitable for larger factory cracking. Nutcrackers have been provided to stakeholders in PNG, Vanuatu and the Solomon Islands and will be used in the pilot EU nut processing factory at NARI. There is a need for a distribution network for village level nutcracking equipment, especially in PNG where the TJ's™ nutcracker has created strong interest,

Colour development of canarium during roasting depends on the quality, moisture content and age of the nuts and consumer preferences will determine what is an acceptable colour. Further taste testing and consumer preference surveys are needed on roasted and raw canarium products.

Stakeholders' in the Papua New Guinea and Vanuatu have demonstrated their interest in developing the necessary industry body to promote the development of the *Canarium* industry and develop strategic plans. Examples such as, the demand for TJ's™ nutcrackers and Votausi Mckenzie from the Lapita Café Port Villa, Vanuatu using a solar drier to dry and store *C. indicum* nuts have demonstrates a willingness to take up this information.

Feedback during workshops was that it is too early to train people until processing techniques and protocols were refined. Once these are refined, dissemination of information and training will be required to increase strategic awareness and tailored to different target groups (i.e. farmers perception of appropriateness is different from commercial operators point of view on storage techniques; food security priorities during droughts versus commercial return etc.)

9.2 Recommendations

This project has identified and developed processing techniques for the Pacific canarium industry. There is now an urgent need for further industry development to maintain the momentum and realize the potential of canarium to improve the livelihoods of stakeholders across the Pacific. In particular the next phase of industry development requires:

- market analysis and understanding market segments. In particular the PNG industry needs to identify export markets for commercial manufactured Canarium products and verify the best market opportunities.
- consumer and customer research. In all countries, consumer surveys are needed to understand product preferences in the domestic and export markets.
- products need to be developed to meet consumer preferences. This will require further processing research targeted to value added opportunities for *Canarium indicium* (e.g. roasted, salted, honey coated, nut-meal, oil by-products). Future processing research will also need to target whole kernel, high value products suitable for export markets.
- food safety and quality control in processing. Manufacturing and storage protocols will be needed to minimise rancidity and microbial contamination in the final products by strict adherence to food safety standards. Training in techniques and processing skills will be required to ensure consistent quality control once the pilot processing plant at NARI is operational.

Stakeholder analysis is also needed to understand the broader social and cultural constraints to the industry.

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11 Appendixes

11.1 Appendix 1: Summary of needs, issues and constraints for canarium industry processing linked with participatory model (plantation scale, regional scale, local scale).

Social issues and barriers.

THEME	NEEDS AND OTHER ISSUES	CONSTRAINTS	INDICATORS OF SUCCESS
		Plantation scale	
Paid employment and subsistence labour Availability of Infrastructure	Current success of Balsa Wood Factory in Kokopo. Offers a model for high wage for skilled workers	Social and cultural obligations of women restricts their availability to work Distance between place of residence (esp. women) and CPU	Centralised processing in the short-term, longer-term strategy to involve remote areas Commence processing in urbanised areas

Communication and knowledge exchange	Growing PNG middle class increasingly desire higher quality	Unless nuts were prepacked, staff and customers tended to eat nuts from store or refrigerator	Campaign to change consumer preferences toward local produce
Regional clans and stakeholders			
Paid employment and subsistence labour		Availability of labour	Centralised processing in the short-term, longer-term strategy to involve remote areas
Infrastructure	Existing factory e.g. at Kandrian and possibly other parts of regions Existing shade and storage facilities at different points in supply chains	Current use of Public Motor Vehicles for transporting produce – drivers encourage passengers to use polypropylene bags that are not rigid, but don't breathe. Produce is sometimes left on side of road	Commence processing in urbanised areas
Communication and knowledge exchange	Radio Networks, some attempts to bring farmers and wholesalers together and encourage the entry of new producer wholesalers	Lack of knowledge Timely and improved communication needed between growers, processors and buyers (otherwise growers tend to do the marketing) Some evidence of wariness of government and NGO projects.	Utilise existing networks or associations as a communication hub e.g. FPDC's village Extension Worker (VEW) network, FPDC, marketing agents etc.
Local clans and smallholders			
Paid employment and	Communal labour and gifts of capital strengthen social bonds within and between communities	Availability of labour Extra labourers may be	Commence processing in urbanised

subsistence labour	– meets their moral obligations, raises social status (no desire for consumption or profit) Part-time employment looked on favourably	needed for different steps in processing Possibility for outsourcing cracking	areas
Infrastructure	Traditional cracking is cheap and effective	Nut cracking without hand cracker is time consuming and hard work and in the past has been underpaid in the opinion of the people involved. Transport to regions or CPU is costly Lack of on-farm storage technologies	Nut cracker developed for optional use at the village level Advancements in processing technologies especially drying regimes
Communication and knowledge exchange	Experience with Land Trusts as legally recognised bodies to make decisions on behalf of customary land owners (some problems may emerge) Agricultural Colleges, vocational centres and NGO's offer education in some technologies	Need for trust in representative bodies Extension negligible, technology adoption rare, practical training for young farmers has lapsed due to lack of funding, farm management skills decreased in some places	Use of existing organisations and trusted intermediaries to set up participatory model

Economic issues and barriers

THEME	NEEDS AND OTHER ISSUES	CONSTRAINTS	INDICATORS OF SUCCESS
Plantation scale			
Diversification and specialisation	Availability of equipment and facilities trained	More resources needed to upgrade and expand	Guaranteeing quality and quantity for business

	personnel, good quality control, workshops and short courses run by organisations	activities Better employment in urban centres negates people's desire to establish small businesses in small villages	
Economies of scale	Middleman marketing model seen by some as the best option (see McGregor) The operation in Port Vila has been sustained for 15 years Possibility for other uses of canarium (i.e. oil from pulp, or ground flour, or bits for baking industry.	Middleman tend to be opportunistic and take highest price	Direct linkages and marketing nodes between grower and processor, possibly through a coordinating body or association
Industry structures		Lack of faith in the sustainability of the industry discourages private investment IP not protected in the past on some products (e.g. oil)	
Regional clans and stakeholders			
Diversification and specialisation	Some potential for diversification		Needs a coordinated rural development approach
Economies of scale	Systems of village collectors has been tried	Some poor quality nuts, although kava Store buys them to encourage the growers.	Collection points needed and coordinated
Industry structures	Institutions have been major buyers of local produce (schools, unis, prisons, military,	Middleman tend to be opportunistic and take highest price Some local people	Set up direct linkages between grower and processor through association

	specialist caterers) – can source from smaller wholesalers and less demanding with grading and packing requirements. Micro-Credit opportunities Potential for by-products of shells, bbq fuels, horticultural bedding, firewood	willing to invest but these people/groups were not interested in managing the processing themselves	Linkages or co-ordination between for collecting & processing
Local clans and smallholders			
Diversification and specialisation		Logging seen as higher return than processing the nuts Copra seen as a higher return than canarium but this does not take account of subsidies for Copra nor the time involved in producing the same volume	Education and training around long term versus short term sustainability, labour, time and costs when assessing a fair price during training Set up direct linkages between grower and processor
Economies of scale		Middleman tend to be opportunistic and take highest price Lack of circulating cash Lack of on-farm storage for NIS Subsistence economy (esp. women's duties e.g. garden, child care) and cultural obligations (example kinship, reciprocity) often have priority over commercial activity	Representative body for sale from villages to coordinate and distribute proceeds Drying regimes to address Complementarity of processing strategies with existing livelihood strategies and social well being
Industry structures	A scheme introduced separate		Coordinating body

	"guaranteed" payments to women – improved income distribution and labour arrangements in households – reduced reliance on garden marketing income Younger people often looking for cash generation opportunities		needed.

11.2 Appendix 2: Indicators of Fruit and Nut Maturity

This project has identified the time taken for fruit to mature on the tree, the chemical characteristics of green and purple fruits and developed a protocol to sort nut-in-shell into mature and immature nuts at buying points.

Methods Time to maturity of fruit on trees

An experiment was conducted in East New Britain, PNG to determine the time taken of green fully sized fruit to turn purple and abscise from the tree. On each of 10 trees, 6 green bunches were tagged at the top of the tree where they received full sun and 6 green bunches were tagged in the lower part of the tree where they were shaded. Bunches were bagged with plastic mesh bags and observed weekly for eight weeks.

At the start of the experiment the numbers of green fruits were counted. Each week, counts were taken of the number of fruit that were green, the number with a tinge of purple, the number that were half purple and the number that were fully purple in each bunch.

Methods Oil analysis of kernels from ripe and semi-ripe Canarium indicum fruit

Materials and methods fruit source and experimental design

Fruit of full-purple (ripe), half-purple (half ripe) and green (un-ripe) colour *Canarium indicum* fruit (Fig. 2.1) were harvested from the same tree at Vimy plantation, Rabaul area, East New Britain, PNG to eliminate any tree variability. At USC 6 replicate kernels from each fruit colour were sampled for oil extraction (one kernel per oil extraction). Fruit were depulped to obtain the nut-in-shell.

Fig. 2.1. Colour of *Canarium indicum* green to purple (ripe) fruit.

Nut processing and oil extraction

Nuts were dried for 4 days at 35°C followed by 2 days at 40-45°C to achieve nut-in-shell moisture content of 10% (wet basis), equivalent to kernel moisture content of approximately 4.8%. Nuts were cracked at NARI using a TJ's nutcracker. At USC kernels were blanched then redried to remove water absorbed during blanching. For each extraction one kernel was crushed in a garlic press to yield approximately 2 g of kernel for analysis for ripe and half ripe kernels. For each kernel sample oil was extracted by diethyl ether with a Soxhlet type apparatus operating for 16 hours (Fig 2. 2). Ether was stripped from the oil with a Buchi Rotavapor (BÜCHI Labortechnik AG, Switzerland). The oil obtained and the nut residue were dried to constant weight at 95°C.

Statistical analysis

Oil content was calculated as a percentage of total dry weight. Means for oil content for each colour were analysed for significant difference by one-way ANOVA with two degrees of freedom and Tukey's test for comparison of means. Mean kernel weight was calculated for 27 kernels from each fruit colour category. Fruit weight data were non-parametric and data were analysed by a Kruskall Wallis test and Mann-Whitney *U*-tests, with a Bonferroni correction factor for comparison of means.

Fig. 2.2. Oil Extraction

Separation of sound and unsound nuts

Floatation of nuts is used in the macadamia industry to separate immature nuts with low oil content from ripe high quality nuts. This occurs because of the specific gravity of the oil content.

Canarium indicum nut-in-shell (the kernel-in-testa and the shell [endocarp]) when placed in water can also be separated by floating or sinking. Nut-in-shell that floats generally has no kernels or small, possibly immature kernels and floats because of the air spaces within the nuts. 100 nuts were placed in water and the floaters separated from those that did not float. These were cracked to ascertain the difference in kernel size and quality. This technique is only suitable for fresh nuts as the resultant airspace in the dried nut-in-shell causes nuts with even sound kernels to float. This method is proposed to be used for the pilot EU processing factory as the first control point in the processing quality management chain.

Results and Discussion

This project has identified the time taken for fruit to mature on the tree, the chemical characteristics of green and purple nuts and developed a protocol to sort nut in shell into mature and immature nuts at buying points.

Time to maturity of fruit on trees

Canarium fruits turn from green to purple over a period of 8 weeks and fall from the tree. Around 20% of fruit were only tinted purple and had not turned fully purple at the end of the 8 week observation period (Fig. 2.3).

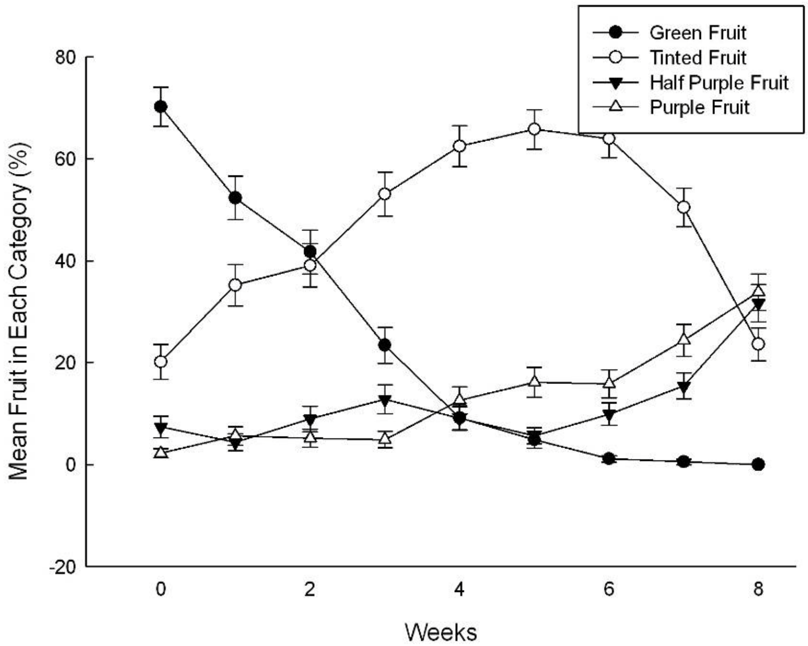

Fig. 2.3. Maturity of *Canarium indicum* while on the tree from green to ripe fruit.

Fruit at the top of the tree ripen faster than fruit at the bottom (Fig. 2.4.).

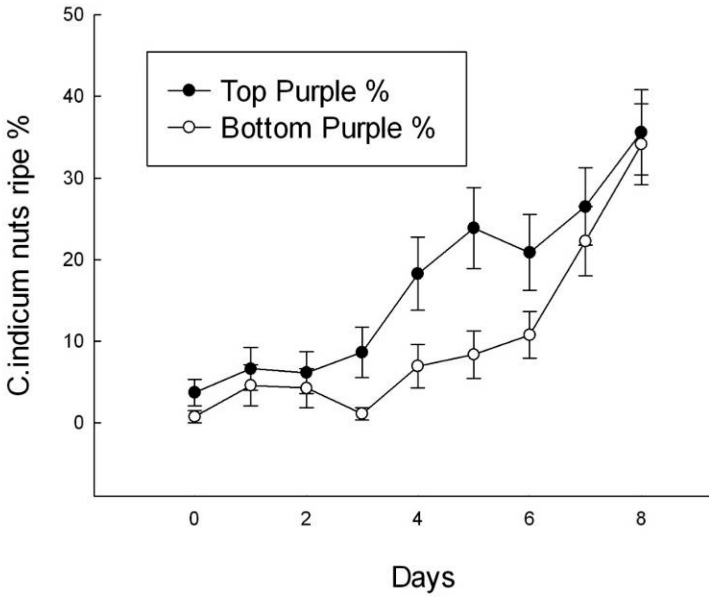

Fig. 2.4. Maturity of *Canarium indicum* fruit at the bottom and the top of the tree.

Separation of floating and sinking nuts

A new processing protocol has been developed. *Canarium indicum* nut-in-shell of all colours either float or sink. Nut-in-shell that floats generally has no kernels or small, possibly immature kernels and floats because of the air spaces within the nuts. The causes of air spaces include old nuts that have been dried down, rotten kernel, and immature nuts with poor kernel recovery. This results in poor kernel recovery (Table 2.1).

Table 2.1. Kernel recovery of floaters and sinkers. Kernel recovery is the ratio of kernel to total nut in shell, measured by weight and expressed as a percentage.

Colour of sample	Sink kernel recovery (% of kernel to total nut-in-shell)	Float kernel recovery (% of kernel to total nut-in-shell)	% of the sample that sank
Green	19.0	12.9	84.6
Green/purple	21.0	10.5	80.0
Purple	24.7	16.5	76.6

This technique of placing nut-in-shell in water could be used at buying points to separate out immature, low kernel recovery, mouldy and old dried nuts from fresh high moisture content nut-in-shell. Quality nut in shell are those that sink when placed in water and floaters can be either down graded or rejected at point of purchase. The recommended processing protocol is to separate floaters and sinkers at point of purchase. Floaters will be of lower value and can be discarded or downgraded.

Oil analysis of kernels of ripe and semi-ripe Canarium indicum *fruit*

Canarium indicum kernels had high oil content of approximately 76%. Oil content for purple and half-purple kernels was not different (76.6% and 76.3% respectively, Table 2.2). Both purple and half-purple kernels had significantly higher oil content ($P = 0.013$) than green kernels (72.8%). Kernel weight for purple and half-purple fruit was not different (c. 1.9 g), but for green fruit mean kernels weight (0.62 g) was significantly different from both purple and half purple kernels ($P < 0.001$).

Oil content for purple and half-purple *Canarium indicum* kernels (76%) was very similar to macadamias (McConachie 1997). Oil content for immature kernels was significantly lower at 72.8%, but this is still high oil content. These results compare with 67 – 75% reported by Leakey et al. (2008) when oil content varied for nuts from different regions. Oil content alone could not be considered a reliable indicator of maturity on the basis of the current study. The kernels from green fruit had relatively high oil content yet were obviously immature when kernel weight and shrivelled appearance were considered (Table 2.2). This study does show that when hand-harvesting is employed only purple and half-purple fruit should be harvested to ensure that kernels are mature with maximal oil content.

Table 2.2. Oil content (%) and weight (g) for kernels from purple, half-purple and green *Canarium indicum* fruit. Values are means (SE) for oil content (Tukey's test) and means for kernel weight (Mann-Whitney *U*-tests). Means in the same column with different superscripts are significantly different.

Fruit Colour	Kernel Oil Content (SE)	Kernel Weight
Purple	76.59 (0.57)^{a}	1.89^{a}
Half-purple	76.26 (0.68)^{a}	1.90^{a}
Green	72.29 (1.22)^{b}	0.62^{b}

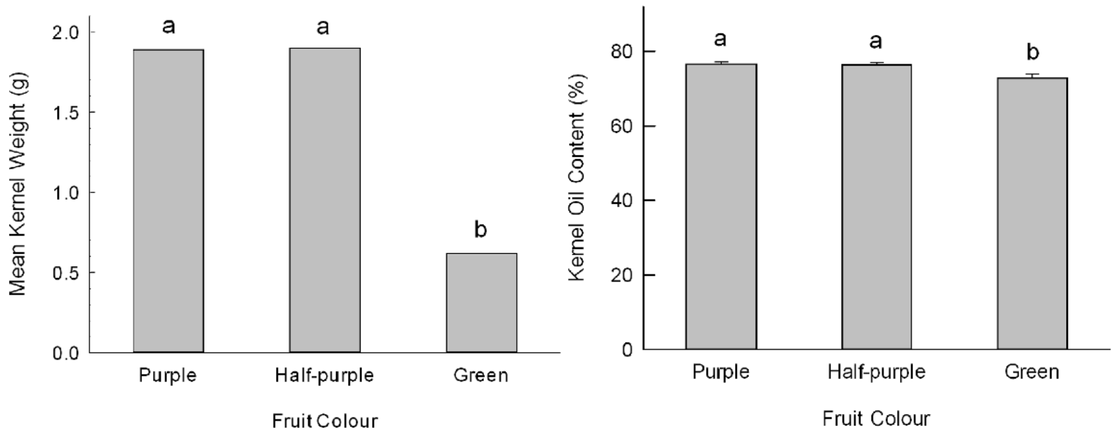

Fig. 2.6 a) Mean Kernel weight for Purple, Half Purple and Green (*Canarium indicum* nuts; b) Mean Oil Content % for Purple Half Purple and Green *Canarium indicum* nuts. Different letters denote significance (P<0.001) differences in Kernel Weight and Oil Content.

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11.3 Appendix 3: Scientific Drying Trials – Moisture Loss and Quality assessment of *C. indicum* during drying

Introduction

Drying is the primary preservation technique for some nuts as drying reduces the free water available for enzyme activity, chemical reactions and microbial growth (Wall and Gentry 2007). Water Activity (a_w) is a measure of free water held in extracellular spaces by week attractive and capillary forces (Coultate 2002). Free water can be removed by the drying process without inducing chemical changes and loss of quality (Mason et al. 1998). Appropriate drying and storage at low moisture content are critical to prevent rancidity and off flavours in nuts (Wallace and Walton 2005). Optimum Water Activity (a_w) for dry food to maximise the shelf life is usually around 0.2 to 0.3 for most foods (Coultate 2002). Macadamia kernels with a moisture content of 1.5% have a_w about 0.3 *(Beuchat 1978). C. indicum*, like macadamia has very high oil content, so similar problems are likely.

Canarium seeds are also recalcitrant (Evans 1996) necessitating prompt drying to reduce enzyme activity. Temperatures greater than 50°C are required during the drying period to completely deactivate enzymes that cause browning reaction in many foods (Saltveit 2000).

The critical factors for ensuring high quality and storage potential of nuts are appropriate drying regimes, so that nuts are stored at low moisture content (Kowitz and Mason 2001). Macadamia nuts-in-shell needs to be dried to ~ 7.5% (Kowitz et al. 1998). Nut-in-shell needs to be dried on farm prior to storage but the optimum moisture content for canarium nuts is not known (Evans 1996). Quality of stored nuts will depend on their original maturity, moisture content and storage conditions (Nevemino et al. 2007).

Drying on farm typically involves passing ambient air through a bed of nut-in-shell. This depends on the ambient air temperature and relative humidity. When relative humidity is high, ambient air may cause insufficient drying and result in nuts with moisture content above the critical level resulting in increased unsound nuts due to mould. Consequently the use of supplementary heating to decrease the relative humidity may be required. Temperatures in excess of 40°C have been found to decrease the quality of the roasted macadamia nuts (Kowitz and Mason 2003).

The aim of this study was to determine drying regimes for *C. indicum* that produce high quality whole nuts without browning. A series of drying trials were undertaken at NARI and USC on *Canarium indicum* to determine the effect of different drying temperatures on quality parameters such as whole kernels, percentage of browning and translucency of the kernel The moisture content as well as ease of cracking, percentage wholes, percentage of browning, translucency of kernel and ease of testa removal were assessed following drying at 40°C; 60°C; 35°C and 50°C.

Methods: Moisture Loss

We examined moisture loss of *Canarium indicum* nuts by oven drying in four experiments. Samples were weighed prior to initial drying, prior to drying at 105°C and after final drying to determine the moisture content as the initial drying regime progressed. Tinytag data loggers were also placed in the ovens during these experiments to recorded temperature and humidity.

Experiment A: Drying different sized Canarium indicum nuts

We used nuts from Papua New Guinea that had been harvested two weeks prior. Canarium nut in shell were dried in a Memmert (model 700) oven at 35°C for six days. The effect of genetic variability and the differing sizes (large and small classes) on drying rates was investigated. Each day for 6 days the moisture content of 10 nut samples was determined by drying at 105°C for 24 hours. Each day new nut samples after being weighed at the commencement of the experiment to determine the moisture content

Experiment B: Drying different province nuts from Vanuatu

We investigated the moisture loss from *C. indicum* nuts from different provinces (Santo and Aerotap provinces). These nuts were one week since harvest then were stored in air-conditioned environment for three days. Nuts were dried for 5 days as described in experiment A above. Each day changes in weight of 10 nut subsamples following drying at 105°C for 24 hours was used to determine the moisture content.

Experiment C: Drying nuts from North Queensland

We investigated how extremely fresh ripe (fruit just commencing to turn purple) and extremely ripe (fruit purple and soft) *C. indicum* nuts from Daintree in North Queensland lost moisture content during drying for three days at 35°C, then three days at 38°C. These nuts were three days since harvest and collected as nut-in-pulp. They were de-pulped by hand and dried immediately after removal from the fruit. Six nuts (three ripe & three very ripe) were assessed for each treatment. They were also much smaller than the nuts from PNG and Vanuatu.

Experiment D. Moisture loss from stepwise drying

The two temperature drying regime investigated how *C. indicum* nuts from Papua New Guinea lost moisture content during drying for three days at 35°C, then seven days at 38°C. These nuts were treated six days after harvest in Papua New Guinea then refrigerated at 5^0C for nine days. Each day the moisture content of ten nut subsamples were assessed.

Methods: Drying temperature affects on quality

Two drying trials were undertaken at NARI to compare drying temperatures for *Canarium indicum.* Trials were conducted in drying ovens at 40°C and 60°C; and 35°C and 50°C for 6 days. In the trials at NARI, 5 replicates of 50 nuts were assessed each day. Quality characteristics of kernels such as colour and translucency, the percentage of wholes, ease of cracking and ease of testa removal were assessed. Colour was assessed on a 5 point scale from (1) white to (5) dark brown. Translucency was assessed from (1) no translucency to (5) more than 50% of nut translucent. Ease of cracking and ease of testa removal were assessed on a five point scale from (1) easy to (5) very difficult to crack or remove kernel.

Drying trials undertaken at the University of the Sunshine Coast also assessed changes to the nuts while drying at 35°C for 6 days. In conjunction with experiment B above, the quality of nuts were also assessed for the ease of testa removal, their ability to remain whole, their colour of the kernels and patchiness of the kernels throughout the 6 day drying period. Six replicates of 5 nuts were assessed daily.

Colour for the majority of the nut was rated from 1(lightest) to 5 (darkest). Mottling was ranked from 1 (colour varied by one shade) to 5 (colour varied by several shades that even varied to black). Oiliness was evaluated from 1(nut was dull), 2 (nut appeared shiny) or 3 (when wiped on clean paper, nut left an oily mark).

Results: Moisture Loss

Experiment A: Drying different sized Canarium indicum nuts

The moisture contents prior to drying different sized *Canarium indicum* nuts were: large nuts 14.4% (SE 0.43), small nuts 13.3% (SE 0.58) and combined average 13.9% (SE 0.38). During the drying period, there was no significant difference in moisture content between small and large sized nuts (P=0.124).

At 35°C during the drying period, the nuts dried from 13.86% to 6.42%. There were highly significant differences in moisture content caused by time (P≤ 0.0001). Significant differences in drying rates are indicated (Fig.3.1). At the conclusion of the drying period, there was no significant difference in moisture content between small and large sized nuts (P=0.156). Most days throughout the period differences were not significant.

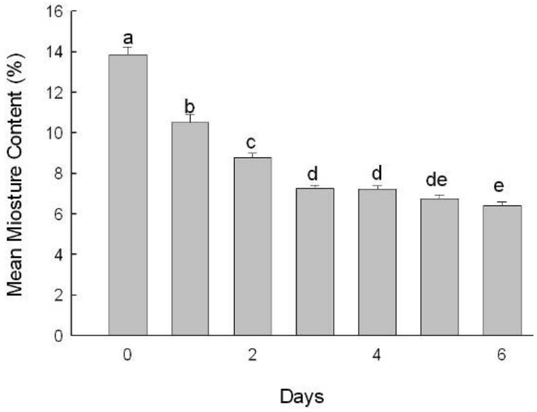

Fig. 3.1. Moisture content during drying different sized *Canarium indicum* nuts at 35°C for 6 days. Different letters denote significance (P<0.001) differences in moisture content.

Experiment B: Drying different province nuts from Vanuatu

There was no significant difference in moisture content between provinces overall (P=0.448) nor daily. The nuts from different provinces had an initial moisture content of 20.5% (SE 2.46). They dried to 6.9% after 5 days. There were highly significant differences in moisture content throughout the drying period (P≤ 0.0001). There was a large difference in the initial moisture of the nuts as signified by the large standard error on day 0 (2.459) (Fig. 3.2a).

Experiment C: Drying fresh nuts from North Queensland

The nuts from North Queensland had an average initial moisture content of 22.4% (SE 0.36). They dried to 7.1% (SE 0.10) after 5 days. There were significant differences in moisture content on different days due to drying (P=0.001) (Fig. 3.2b). There were also significant daily differences between ripe and very ripe nuts after day 2 (Fig. 3.3a & b).

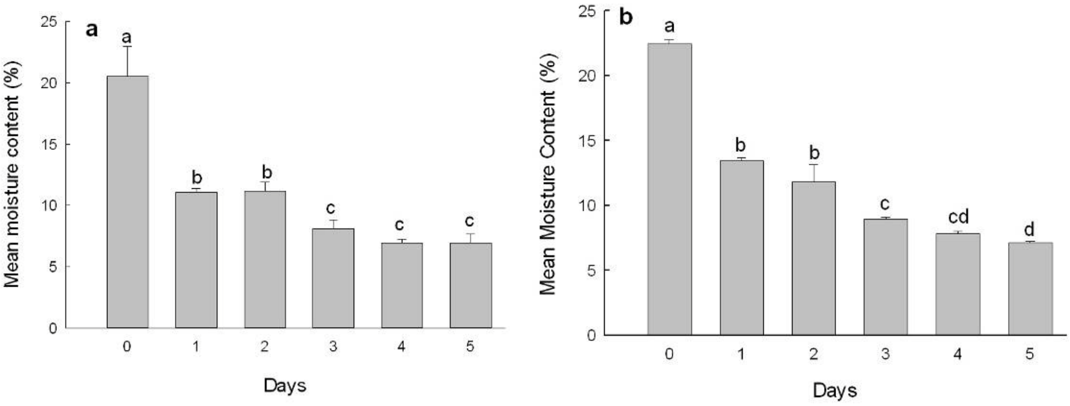

Fig.3.2. Moisture content during drying (a) different province *Canarium indicum* nuts from Vanuatu at 35°C for 5 days (b) fresh North Queensland *Canarium indicum* nuts at 35°C for 5 days. Different letters denote significance (P<0.001) differences in moisture content.

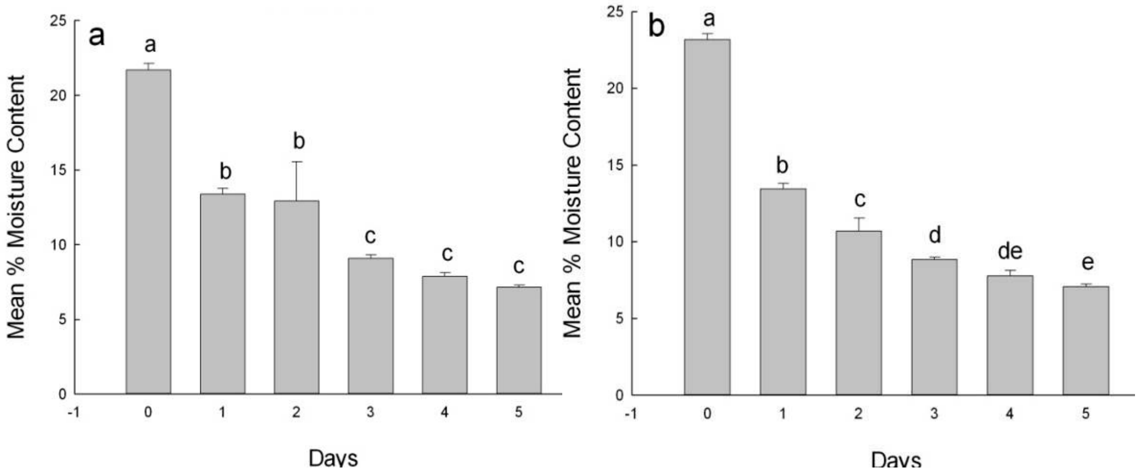

Fig. 3.3. Moisture content of (a) ripe and (b) very ripe North Queensland *Canarium indicum* during drying at 35°C for 5 days. Different letters denote significance (P<0.001) differences in Kernel Weight and Oil Content.

Experiment D. Moisture loss from stepwise drying

The nuts used for the two temperature drying regime had an initial moisture content of 24.98% (SE 1.262). They dried to 12.67% after 3 days at 35°C then to 8.26% after a further 3 days at 38°C, and to 6.28°C after 7 days at 38°C. There were highly significant differences in moisture content on different days due to drying (P ≤0.000) (Fig. 3.4).

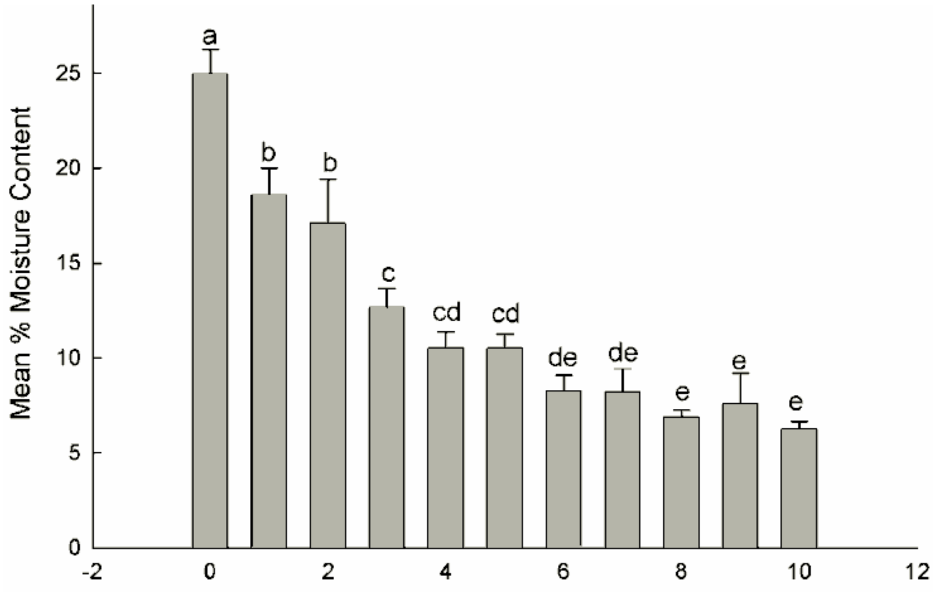

Fig. 3.4. Moisture content of *Canarium indicum* during two temperature drying regime (3 days at 35°C, then 7 days at 38°C). Different letters denote significance (P<0.001) differences in moisture content.

Results: Quality assessments

Drying nuts at 40 ºC increased the percentage of whole kernel compared with drying nuts at 60 ºC at days 3, 4, 5, 6 days (p<0.001, Fig 3.5a). This is a very significant finding, as it means that appropriate drying will improve the percentage of whole nuts and the whole nuts are likely to be the highest value processed product. Drying nuts at 40 ºC increased the percentage of translucency compared with drying nuts at 40 ºC after 2 days (p<0.001, Fig 3.5b). Nuts dried at 60°C showed no translucence after 3 days; however the darker colour of the nuts at 60°C masked any translucency. Translucence may be an indicator of nut damage. As the nuts dry testa removal becomes more difficult (Fig 3.6).

Nuts dried at 60 ºC showed excessive browning compared to nuts dried at 40ºC after 3 days (Figs. 3.7; 3.8).

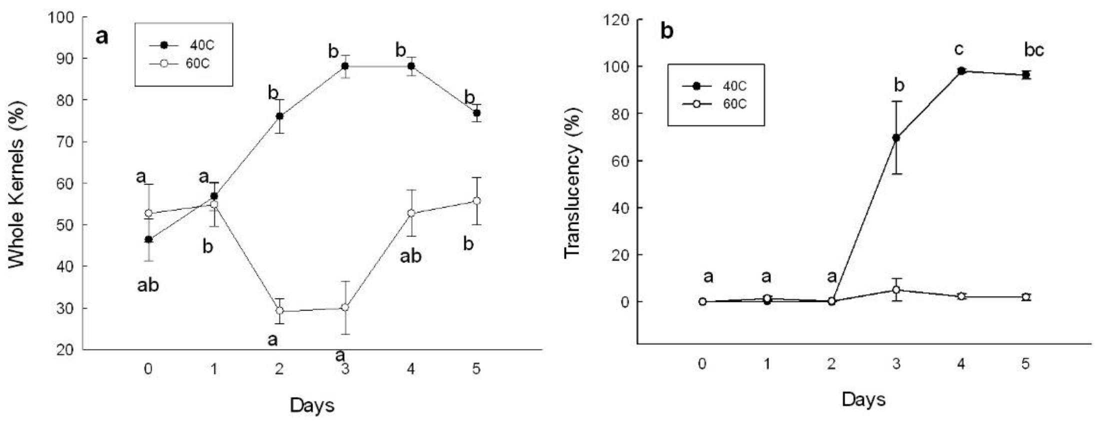

Fig. 3.5. (a) Percentage of whole kernels; (b) Percentage of translucent kernels; after drying for 5 days at 40ºC and 60ºC.

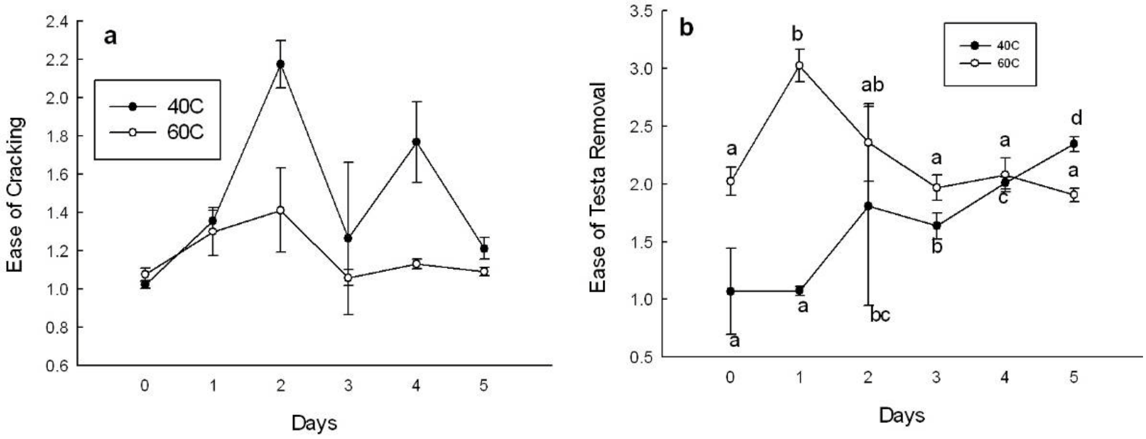

Fig. 3.6. Ease of cracking; Ease of testa removal after drying for 5 days at 35ºC and 50ºC. 1 is easy, 5 is difficult.

Fig. 3.7. Discolouration after 3 days of drying at 40ºC and 60ºC.

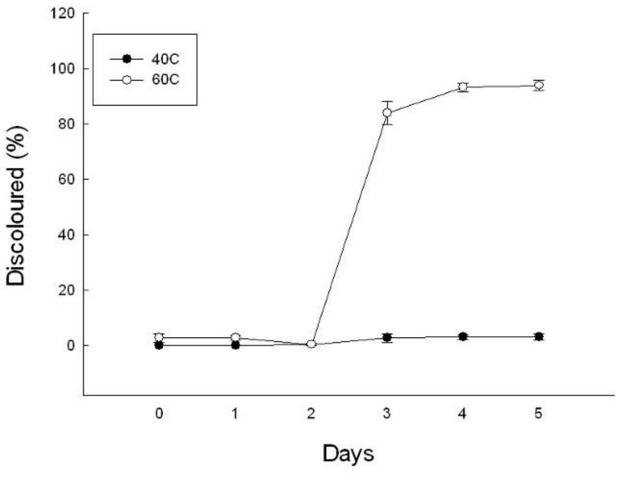

Fig. 3.8. Mean discolouration after drying for 5 days at 40ºC and 60ºC.

Drying nuts at 35ºC increased the percentage of whole kernel compared with drying nuts at 50 ºC after the third day (Fig. 3.9).

Nuts dried at 50ºC showed increased translucency compared to nuts dried at 35ºC after 3 days (Fig. 3.8) and this may indicate damage to the nuts with decreased storage potential.

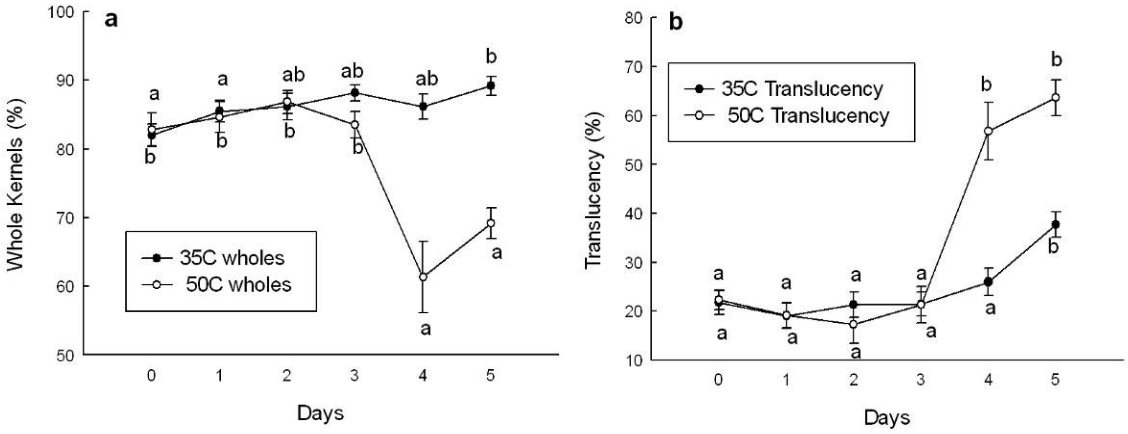

Fig. 3.9. (a) Percentage of whole kernels; (b) Percentage of translucent kernels; during drying for 5 days at 35ºC and 50ºC.

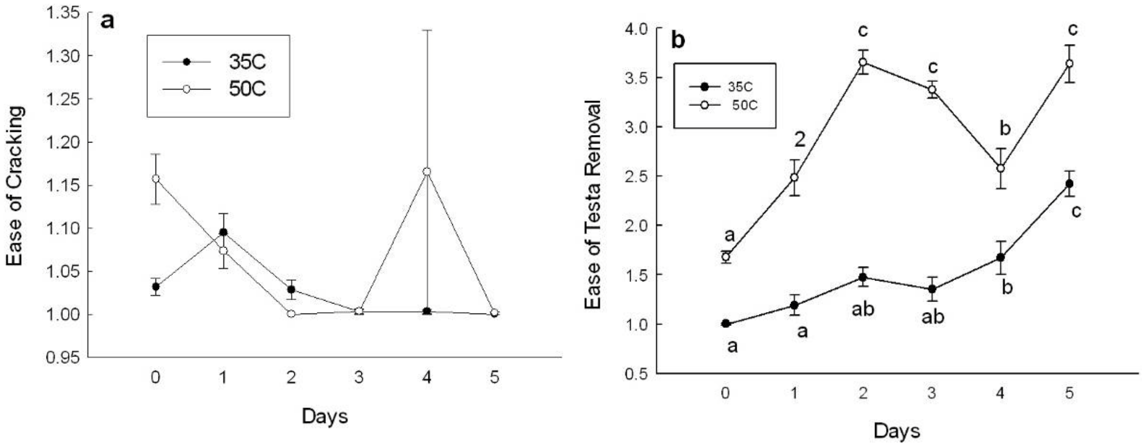

Fig. 3.10. (a) Ease of cracking; (b) Ease of testa removal during drying for 5 days at 35ºC and 50ºC. 1 is easy, 5 is difficult.

Experiment B showed that ease of testa removal only changed significantly between day 0 and all the other days ($P \leq 0.0001$) (Fig. 3.11). The testa was easiest to remove on day 0 and became more difficult throughout the experiment. After day 4, the testa could only be removed satisfactorily following blanching. The kernel became darker during the drying period. There was no significant difference for the first 4 days but colour was different on the final 2 days (Fig. 3.12). The number of wholes was not significantly different ($P= 0.371$) during the drying period. The nuts were significantly easier to crack on day 0 ($P= 0.016$) but not significantly different during the remaining period.

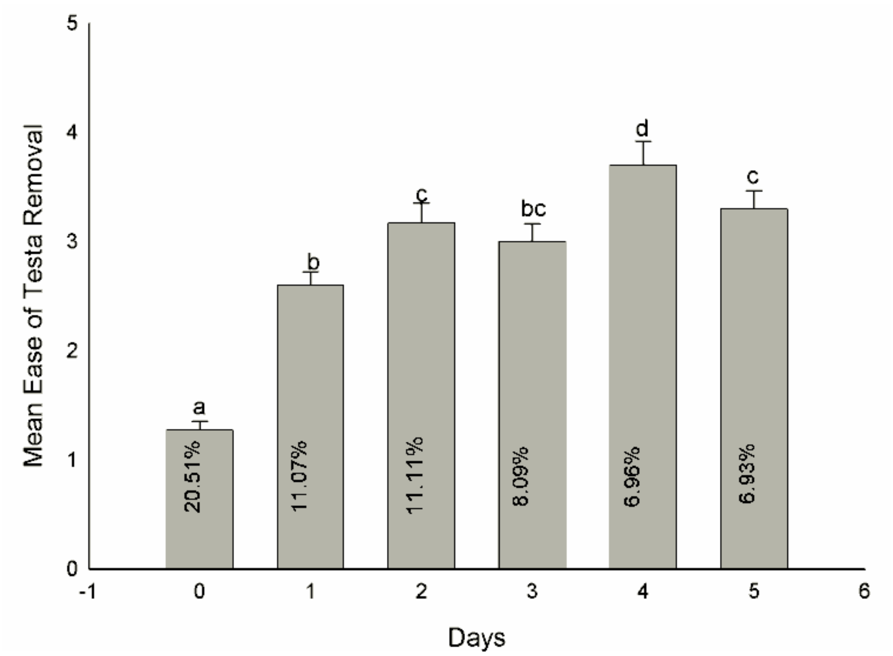

Fig. 3.11. Ease of testa removal from *Canarium indicum* during drying different province Vanuatu nuts at 35°C for 5 days. Moisture content (%) for each day is indicated. Different letters denote significant (P<0.001) differences in Kernel Weight and Oil Content.

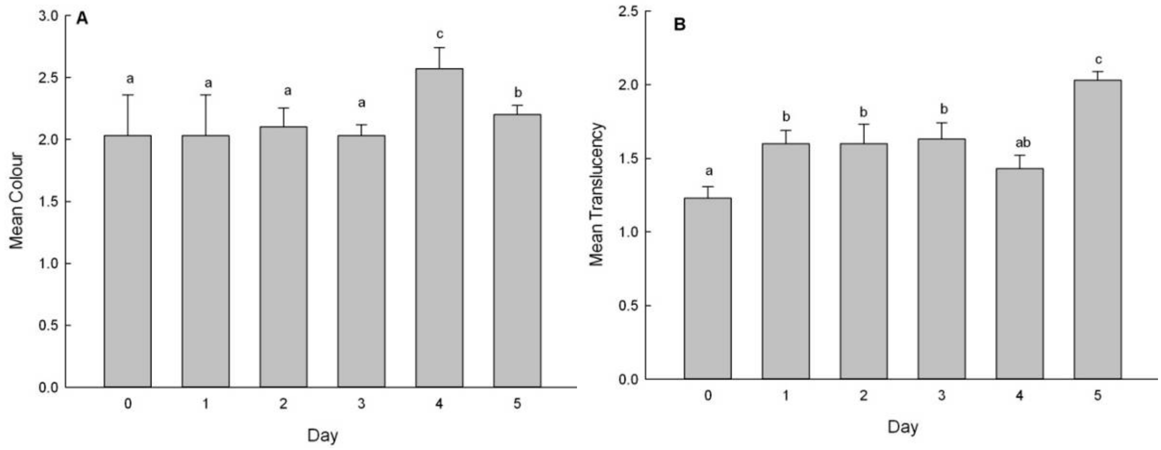

Fig.3.12. (A) colour change and (B) increase of translucency during drying different province nuts from Vanuatu at 35°C for 5 days. Different letters denote significant (P<0.001) differences in Kernel Weight and Oil Content.

Solar dryers have been trialled for drying canarium nuts. Nuts were placed into the trays for 2 days and temperatures measured. The solar dryer was an adapted cocoa dryer using a fuel source (Fig. 3.13a). The temperatures based on sun heating alone were quite high, above 47ºC (Fig. 3.13b). The polycarbonate sheeting material usually requires regular cleaning as it builds up moisture and mould grows.

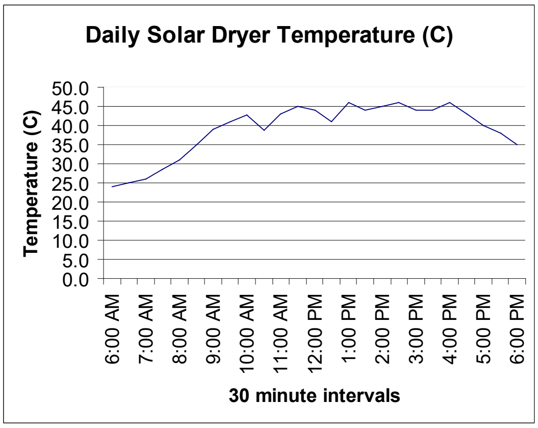

Fig. 3.13. a) Cocoa drier used to trial drying canarium nuts; b) Daily temperature curve in solar cocoa dryer with canarium nuts.

Conclusion

This study has shown that canarium nuts can be dried to a moisture content where they are stable without loss of quality. Drying nut-in-shell initially at temperatures lower than 40 ^{o}C for 3 days produces a high percentage of whole kernels, and does not result in translucency or browning of the kernel. We recommend a drying regime of three days at 35^{o}C then 4 days at 38^{o}C. This regime will produce good quality nuts, maximise the percentage of whole nuts and produce nuts with excellent keeping potential. Drying at higher initial temperatures is detrimental to quality.

The nuts dried at 35^{o}C for the first 3 days reached equilibrium at 6 – 7%. In the two temperature drying regime, the nuts reached equilibrium after 3 days at 10% then with a 3^{o}C increase in temperature the moisture content decreased to 6% in an additional 5 days. The initial moisture content between these experiments indicates that the nuts used in the Vanuatu drying were fresher those used when drying different sized nuts however both were less fresh than the nuts from North Queensland or the nuts used in the two temperature drying regime. Drying for 6 days at 35^{o}C reduced the moisture content to less than 7% regardless of size or province. However this may be still too moist to prevent bacterial or fungal infection during long term storage.

Morphological traits of *C. indicum* vary considerably within populations (Leakey et al. 2008). This was demonstrated in the large degree of variability of nuts and kernels within the small sample of nuts used in drying different sized nuts from Papua New Guinea. While this may pose problems for cracking, the drying regime of 6 days at 35^{o}C, reduced the moisture content to 6% for both large and small nuts within 6 days. Similarly, drying different province nuts from Vanuatu also reduced nuts from initial higher moisture content to less than 7% within 5 days.

When the nuts have dried, blanching is required to satisfactorily remove the testa. Wallace et al. (2010) established that blanching for 90 seconds was best, but this period may be dependent on the moisture content. While the testa was easier to remove while the nuts are not dried, drying is essential to stabilise the produce and delay spoilage. Drying for 5 or 6 days at 35^{o}C has so far proved satisfactory, however the stepped regime will reduce the time required to achieve lower moisture content. The time required will depend on initial moisture content of the nut-in-shell and relative humidity.

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11.4 Appendix 4: Journal Article Postharvest Cracking and Testa Removal

Wallace, H. Poienou, M., Randall, B., and Moxon, J. 2010. Postharvest Cracking and Testa Removal Methods for *Canarium indicum* Nuts in the Pacific, International symposium Postharvest Pacifica 2009, International Society for Horticultural Science ACTA Horticulture 880 pp 499-502.

Postharvest Cracking and Testa Removal Methods for *Canarium indicum* Nuts in the Pacific

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Keywords: nut processing, nutcracker, whole kernels, galip nuts, kernel-to-nut ratio, discolouration

Abstract

The genus *Canarium* (Burseraceae) contains approximately 100 species, mostly found in tropical Asia and the Pacific. In the Pacific, *C. indicum* is widely utilized for its edible nuts. Nuts are mostly traded fresh in roadside and village markets, in Papua New Guinea, the Solomon Islands and Vanuatu either as nut-in-shell or as kernels. The *Canarium* industry, based on processed kernels, is in its infancy and has huge potential to improve the livelihood of the rural poor in these countries. We are investigating postharvest processing methods for *C. indicum* that are appropriate to Pacific Island countries. Our research is examining depulping, drying, cracking, testa removal, roasting and packaging methods. We have found that a 90 second hot water dip removes the testa on 85.8% of nuts without loss of whole kernels or increase in discolouration. We are also evaluating technology adapted from the macadamia industry for processing *C. indicum* and have found that a modified TJ's™ nutcracker has potential for efficient cracking of nuts. The cracker is portable, hand operated and suitable for use in Pacific Island countries for both small scale and commercial processing. Further research will examine processing technologies for larger scale processing such as mechanical depulpers, dryers and vacuum packaging.

INTRODUCTION

World trade in tree nuts is in excess of $US2 billion and just four species, walnuts, hazelnuts, pistachios, and almonds, make up more than 80 % of this trade (USDA, 2008). Many other species of edible nuts have potential to be processed and sold commercially. One genus of rainforest tree, *Canarium* has been the focus of efforts to create new nut industries in the South Pacific.

The genus *Canarium* (Burseraceae) contains approximately 100 species, mostly found in tropical Asia and the Pacific. Eight species in southeast Asia, Australia and the Pacific have edible kernels. *C. indicum* is the most widely utilized for its edible nuts and timber in the Pacific (Nevenimo et al., 2007). Fruit of *C. indicum* contains an endocarp with an edible kernel and testa, and the kernel has an oil content of 67 – 75 % (Leakey et al., 2008). In Melanesian society, trees are selected, tended and cultivated around coastal villages and *C. indicum* is a very important food and ceremonial tree (Thomson and Evans, 2006). The tree has been used for over 6000 years in Papua New Guinea (Matthews and Gosden, 1997).

Canarium nuts are mostly traded fresh in roadside and village markets, either as nut-in-shell or as dried kernels. There is huge potential for expansion of the domestic and export market in Pacific Island countries, and a strong industry based on processed kernel would improve the livelihoods of rural households (Nevenimo et al., 2007). However, there is a need for more information on appropriate processing methods such as testa removal (Maima, 1996). There is also a need for a mechanical cracker as most nuts are still cracked traditionally using stone hammers (Maima, 1996: Wissink, 1996).

We are investigating postharvest processing methods for *C. indicum* that are appropriate to Pacific Island countries. Our research is examining depulping, drying, cracking, testa removal, roasting and packaging methods. Here we report on cracking and testa removal methods and technologies for *C. indicum*.

Materials and Methods

Cracking methods. A TJ's™ nutcracker used for macadamias has been modified by the manufacturer for use with *Canarium*. Jaws of the nutcracker have been made wider to fit larger size nuts, with an adjustable insert for smaller nuts. Nut-in–shell was dried in an oven for six days at 40ºC. Five samples each containing 50 nuts of variable size were cracked with a TJ's™ cracker by an operator. Whole kernel percent and kernel-to-nut ratio were measured. Whole kernels were those where the cotyledons remained together after the testa had been removed. Kernel-to-nut ratio was measured as weight of kernel-in-testa to weight of nut-in-shell and converted to a percentage.

Testa removal. *Canarium indicum* nuts were harvested in East New Britain, Papua New Guinea. They were de-pulped by hand, cracked using a TJ's™ cracker and the nut-in-testa shipped to the University of the Sunshine Coast, Queensland, Australia for a testa removal (blanching) experiment. Boiling water was poured over the samples until they were covered. There were three treatments: blanched in hot water for 30 seconds; 60 seconds or 90 seconds. Each treatment had 6 replicates, each replicate with 20 kernels-in-testa. The testa was then peeled off by removing a small piece of testa at the pointed end and gently squeezing the nut from the testa. Ease of testa removal for each replicate was recorded on a scale of 1-5 (where 1 is easy to remove), the number of whole kernels for each replicate and their colour and translucency were recorded. Whole kernels were those where the cotyledons remained together after the testa had been removed. The criteria for evaluating colour and quantifying discolouration was based on comparison to Taubmans Paints colour swatch No.44 (Walton and Wallace, 2009). Kernels were considered discoloured if more than 50 % of the kernel corresponded with the 2 darkest colours on the swatch. Medium translucency described nuts where 25% to 50% of the nut appeared shiny and transparent and high translucency described nuts where more than 75% of the nut appeared shiny and transparent.

Statistical analysis. Parametric data were analyzed with a One-way Analysis of Variance. Rank data (ease of testa removal) were analyzed with Kruskal-Wallis and Mann-Whitney U- tests and a Bonferroni correction was applied to determine the appropriate level of significance.

Results and discussion

Cracking methods. The modified TJ's™ nutcracker was most efficient when nut-in-shell were placed into the nutcracker with the long axis at right angles to the jaws and the flat surface of the *C. indicum* nuts faced upwards (Fig. 1a). When pressure was applied to the shell, the nut fractured around the germination suture (Fig. 1b). This method enabled rapid hand cracking of *C. indicum* nuts with little damage to the kernel. Kernel- to- nut ratios from the nutcracker ranged from 15.3.0% to 16.6 % with a mean of 16.0%. This is higher than other studies, e.g. Wissink (1996) reported 1.2-2.7 kg per 20 kg (6%-13.5%). Whole kernel percentage from the nutcracker was also high, with a mean of 76.8 % and a range of 72-82 %.

The nutcracker has created strong interest from growers in PNG and many have expressed interest in purchasing one. It has great potential for use in villages to prepare nuts for sale in local markets. It also has potential for larger scale commercial processing, if nuts are graded according to size and matched with the appropriate jaw size of the cracker.

Testa removal. Our results show that the 90 second hot water dip was significantly better than the other two shorter treatments for testa removal (Table 1). Other quality parameters such as percentage of whole kernels, percentage of kernels with testa remaining, percentage of discoloured kernels, and percentage of translucent kernels were not significantly different between the treatments (Table 1).

In other established nut industries, the premium high value product is whole kernel free of defects such as excessive browning (Walton and Wallace, 2005; 2008; 2009). In *C. indicum*, 66-86% of kernels remained whole after testa removal, irrespective of treatment. However around 12.5-15.8 % showed some discolouration. Translucency is a significant issue, and preliminary trials have show that translucent nuts have increased browning when roasted (H.M Wallace and B. Randall unpublished results). This was not related to testa removal methods but may have been a result of extended storage.

CONCLUSION

Canarium indicum has potential for a viable nut industry in Pacific island countries but needs appropriate processing methods to produce a high quality product. The testa removal methods described here and the modified TJ's™ have potential to improve processing of *C. indicum* without causing loss of quality. Further research will focus on drying methods, pulp removal, storage, and packaging technologies appropriate for *C. indicum*.

Acknowledgements

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Table 1. Ease of testa removal, and quality attributes for kernels of *Canarium indicum*, with 3 blanching treatments. Kernels-in-testa were placed in hot water for 30, 60 or 90 second treatments.

Treatment	30 seconds	60 seconds	90 seconds	P-value
Mean Ease of Testa Removal (out of 5 where 1 is easy) 1	4.17 a	3.17 a	1.83 b	0.002
Kernels with all testa removed (%)	65.8 (7.5)	74.2 (5.5)	85.8 (4.0)	0.082
Discoloured kernel (%)	15.8 (1.5)	12.5 (2.8)	15.0 (3.2)	0.649
Whole kernel (%)	55.8 (3.7)	65.8 (4.0)	66.7 (5.6)	0.2
Kernels with medium translucency (%)	4.2 (2.4)	15.0 (2.2)	13.3 (4.9)	0.086

Kernels with high translucency (%)	51.7 (3.3)	50.8 (4.5)	54.1 (4.9)	0.852

1 Means with different letters are significantly different (Mann-Whitney U- test with Bonferroni correction, P<0.017).

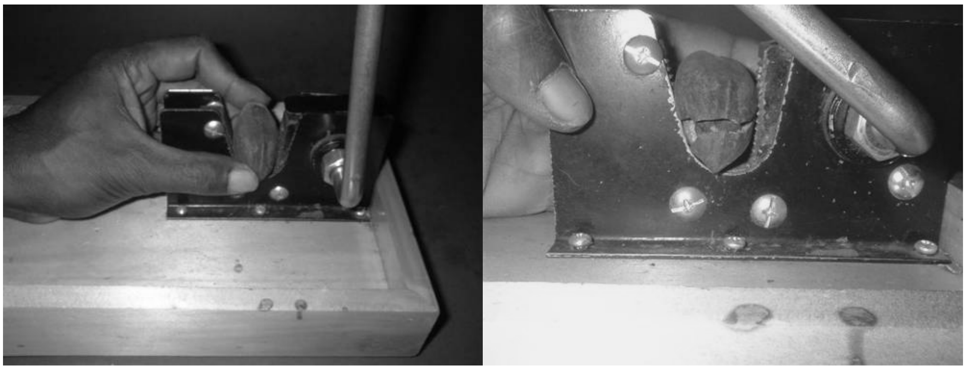

Figure 1.A) The modified TJ's™ nutcracker showing the orientation of the *Canarium indicum* nut flat side up and B) the fracture along the germination suture when pressure is applied from the jaws of the cracker.

11.5 Appendix 5: Roasting canarium

Nuts are often roasted before sale, e.g., a high proportion of macadamias are marketed at the retail level as a roasted product (Mason et al. 1995) and roasting is the main step in hazelnut processing (Özdemir et al. 2001). Roasting macadamias has been reported to improve palatibility and increase shelf life (Leverington, 1971) and to significantly enhance flavour, colour, texture and appearance of hazelnuts and pistachios (Özdemir et al. 2001; Kahyaoglu 2008). Improved shelf life is thought to be due to the fact that roasting reduces the binding sites for water in the kernel (Martinez-Navarrete and Chiralte, 1996). However, some have found that roasted macadamias have reduced shelf life (Isaacs et al., 1991).

Roasting is also critical for risk management in food safety for reducing aflatoxins (Kahyaoglu 2008) and by destroying harmful microorganisms (Özdemir and Devres 2000). *C. indicum* nuts have a high oil content (>70%) and delicate texture that will make them sensitive to processing techniques (Evans 1996b). There are few reports of roasting regimes for canarium nuts. Evans (1991) dry roasted canarium nuts at 100°C to120°C for one or two hours or 135°C for 55 minutes and Nottingham et al. (2005) dry roasted canarium nuts at135°C for 50 minutes but found the nuts had uneven appearance and texture. Nottingham et al. (2005) also oil roasted canarium nuts at125°C and 130°C for 10 minutes.

Roasting sometimes causes kernels to appear less attractive, e.g., a condition known as After Roast Darkening occurs in macadamias where some kernels are excessively coloured (Albertson et al., 2005, 2006; Walton and Wallace, 2008, 2010). Roasting hazelnuts produces some kernels with internal browning, a condition known as brown centres (Özdemir et al., 2001).

Brown centres are also a concern in macadamias although the causes are unclear (Wall and Gentry, 2007; Le Lagadec, 2009). Appearance is very important to consumers and unevenly coloured kernels raise suspicions about eating quality or spoilage (Clydesdale, 1976). There is little information available on roasting canarium, both in relation to methods and desirability.

Several factors affect quality of roasted product, such as temperature and duration of roasting, and the moisture content of kernels at roasting. Macadamias should be at no more than 1.5% moisture content wet basis (w.b.) at roasting to avoid excessive browning (Prichavudhi and Yamomoto, 1965), but the correct moisture content for roasting canarium is unknown. The time/temperature relationship is proposed as the most important factor in the prevention of rancidity in roasted nuts (Leverington, 1962). An excessively high temperature will not cook the kernels through to the centre by the time a desirable colour is obtained (Leverington, 1962). When this happens, the binding sites for water in the centre of the kernels are not reduced effectively by roasting (Martinez-Navarrete and Chiralte, 1996). The temperature and time length for roasting should be set to achieve the desired colour. The length of time required to roast canarium could be expected to be less than for macadamias because of the different shape of the canarium kernel.

Macadamias can be roasted in vegetable oil or dry roasted in air. An advantage of oil roasting is a more evenly coloured product than for air roasting (Grimwood, 1971). However, degradation of roasting oil from heating can lead to peroxidant contamination of kernels (Winterton, 1966; Grimwood, 1971). Another problem with oil roasting is that nuts can lose substantial quantities of endogenous oils to the frying oil (Cavaletto and Yamomoto, 1971). Most roasted macadamias produced in Australia at present are air roasted (Burton, pers. comm.) Different air roasting regimes used by macadamia researchers are listed in Table 5.1. An example of a roasting regime used by a macadamia processor is presented in Table 5.2.

Table 5.1. Roasting regimes used for roasting macadamias in air

In-shell or shelled	Cultivar or species	Temperature (ºC)	Duration (min)	Author
Shelled	*M. integrifolia* *M. tetraphylla*	135 127	25	Leverington & Winterton, 1963
Shelled	*M. integrifolia* *M. tetraphylla*	163-190	12-15	Grimwood, 1971
In-shell	Yonik	110	60-75	Rosenthal *et al*., 1984
In-shell	Beaumont (695)	102	70-75	Basker and Kadman, 1986
Shelled	Yonik	104	16	Basker and Kadman, 1986
Shelled	Hybrids* HAES 791, HAES 741, HAES 788, HAES 508, HAES 246	127 127	12 25	Lemmer *et al*., 1998
Shelled	HAES 344, HAES 741	130°	20	Walton and Wallace, 2010

* Nelmak 1, Nelmak 2, Nelmak 26, Beaumont (695)

Table 5.2. Example of a roasting regime for a batch roaster used by an anonymous commercial macadamia processor

Roast colour	Nut style	Temperature (ºC)	Duration (min)
Light	Large, style 0-4	125	26
	Small, 5 - fine	130	40
Medium	Large, style 0-4	130	50 (25x2)*
	Small, 5 - fine	135	50 (25x2)*
Dark	Small, 5 – fine#	138	40

* Trays mixed after 25 min
# Roasted for biscuits, confectionery

There is little information about roasting canarium. In one study kernels were roasted in vegetable oil at 125°C and 135°C for 10 mins (Nottingham et al., 2005). We conducted a series of experiments to devise a suitable regime for air roasting canarium nuts.

Materials and Methods

Four oven roasting experiments were undertaken at the University of the Sunshine Coast on canarium nuts, to determine colour development in *C. indicum* nuts during roasting. One experiment examined the effect of roasting on translucent (oily) kernels, and the three other experiments investigated the effect of various temperature-time roasting combinations. For the first 3 experiments, prior to roasting the testa was removed by blanching in boiling water for 90 seconds. A Memmert laboratory fan-forced oven (Memmert Gmbh & Co. KG, Schwabach, Germany) was preheated to the desired temperature, nuts were placed in the oven and the time for roasting was counted from when the set temperature was regained (Fig. 1.). When the time had elapsed, nuts were allowed to cool at ambient temperature.

A) Roasting translucent kernels

Nuts were sourced from PNG. The treatments were 10 minutes at 115°C, 10 minutes at 120°C, 10 minutes at 125°C and 17 minutes at 120°C. In addition to comparing the effect of roasting for the same time at different temperatures, this experiment compared the effect of initial translucency on nuts roasting capabilities using nuts with low, medium and high initial translucency. Each treatment consisted of five replicates each of four kernels.

B) Roasting for the same time at different temperatures

Nuts were sourced from Vanuatu. The treatments were 10 minutes at 115°C, 10 minutes at 120°C and 10 minutes at 125°C. Each treatment consisted of six replicates of six kernels.

C) Roasting for different times at the same temperature

Nuts were sourced from North Queensland. Treatments were 10 minutes at 120°C and 20 minutes at 120°C. Each treatment consisted of six replicates of six kernels.

D) Roasting for combinations of 3 times and 4 temperatures

Nuts were sourced from PNG. Testas were removed by blanching kernels with steam for 2.5 minutes. There were 12 treatments, each consisting of a temperature-time combination. For each treatment six replicates each of six kernels were roasted for each combination of temperature and time. There were four temperatures, 110°C, 115°C, 120°C and 125°C and nuts were roasted for 10, 15 or 20 minutes at each temperature. Kernels were then re-dried to remove water absorbed during blanching and the moisture content at roasting was 2.1%.

Kernel assessment

Kernels were assessed for colour and mottled colour. As a standard for colour evaluation, a Taubmans Paints (Regents Park, Sydney, Australia) Colour Concepts® colour swatch No.44 was employed. Kernels were ranked from 1 to 5 according to the five darkest colours on the swatch with 1 for the lightest colour and 5 for the darkest colour: 1, pale; 2, lightly coloured; 3, moderately dark; 4, very dark. Kernels in categories 3, 4 and 5 were considered too dark for consumer acceptance. Mottling was ranked from 1 (colour varied by one shade) to 5 (colour varied by several shades that even varied to black). Translucency (oiliness) was evaluated from 1(kernel was dull), 2 (kernel appeared shiny) or 3 (when wiped on clean paper, kernel left an oily mark). The nuts for the first experiment were the least fresh and had high levels of translucency.

Mottled colour was ranked as 1 for slightly mottled, 2 for moderately mottled and 3 for severely mottled. Mottled colour was classified severe if approximately 20% or more of the surface examined had a mottled, brown appearance.

Results and discussion

Roasting for 10 minutes at 115°C produced no colour change to a very light colour, dependent on the age of the nuts. At 120°C light roasted colour developed within 10 minutes and darkened within 20 minutes. Roasting will be dependent on the freshness, moisture content and post harvest treatment of the nuts. The final roasting regime will depend on an acceptable colour and texture. This acceptable colour and taste for roasted canarium kernels will need to be based on consumer preference.

In experiment A, roasting for 17 minutes at 120°C, produced dark brown kernels (Fig. 5.1a).Nuts were also darker after roasting for 17 minutes than for 10 minutes at 120°C (Fig. 5.1b). Kernels with low initial translucency produced a lighter colour than kernels with high initial translucency (Fig. 5.2.). Roasting translucent kernels showed that 10 minutes at 115°C produced a more even light colour than 10 minutes at 120°C or 125°C. Kernels with high translucency will produce dark kernels when roasted. The level of translucency may be an indicator of deteriorated quality. Poor quality kernels are not suitable for roasting.

In Experiment B, kernels developed colour after the 10 minutes at 125°C (Fig. 5.3.), Experiment C found no significant differences between treatments.

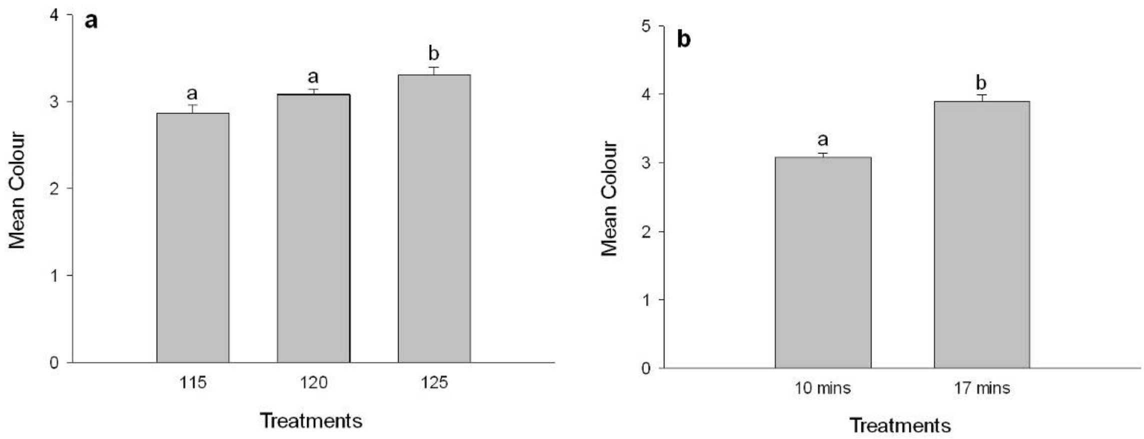

Fig 5.1. In experiment A; a) the colour of roasted nuts after roasting for 10 minutes was darker above 120°C; b) nuts were darker after 17 minutes than for 10 minutes at 120°C.

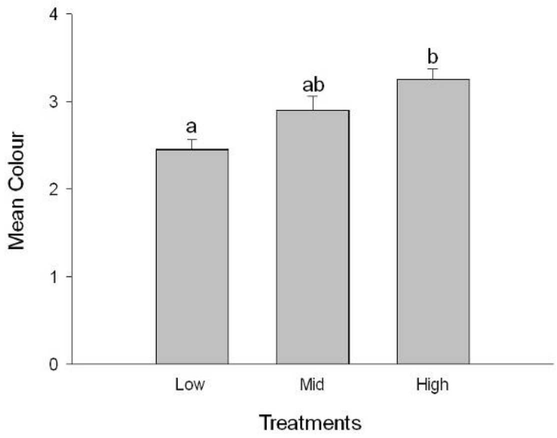

Fig. 5.2. In experiment A; nuts that were very translucent prior to roasting developed a darker colour during roasting for 10 minutes at 115°C. low= low translucency, medium= medium translucency, high= high translucency

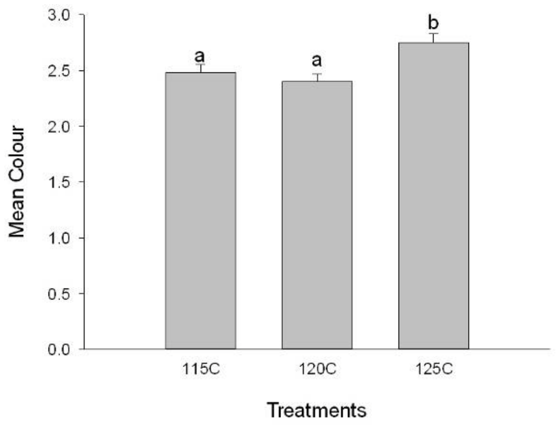

Fig. 5.3. In experiment B, kernels were darker after 10 minutes at 125°C.

Experiment D produced no significant difference in colour development when roasted at 120°C for 20 minutes compared to roasting at 120°C for 10 minutes. Dark kernels (rank 4) were not found until temperatures of 125°C were used (Table 5.3). All dark kernels in the experiment were found in the treatments roasted at 125°C. Dark kernels were few (from 3 – 6%). Severe mottled colour occurred in all the roasting treatments, but did not begin to increase markedly until the120°C treatments, when it rose from 11% of the 10 minute treatment to 31% of the 15 minute treatment (Table 5.4).

Although Evans (1991) dry roasted canarium nuts at100°C to120°C for one or two hours or 135°C for 55 minutes, the current experiments suggest that for those lengths of time, the result would be extremely dark roast. The suitable degree of roasting and associated temperature/time requirement will ultimately depend on consumer acceptability.

The roasting regimes used in the final experiment proved very suitable for *Canarium indicum.* The most important element of roasting is temperature. Very low levels of dark kernels were found at roasting, but because of consumer resistance to dark colours these low percentages are considered sufficient reason for rejection of roasting temperature of 125°C. However, some consumers prefer roasted kernels of a darker colour, and as the industry develops roasting for a darker colour may be useful. If roasting canarium becomes common practice acceptable roasting colour may ultimately be decided by tasting panels. High levels of severe mottled colour of kernels occurred at lower temperature (120°C). *Canarium indicum* kernels should probably not be roasted at a temperature of above 115°C to ensure quality.

These experiments form the basis of a suitable roasting regime. The acceptable colour and taste for roasted canarium nuts will need to be based on consumer preference. These findings also indicate the results from roasting are dependent on the age, moisture content, original condition and post harvest treatment of the nuts. Firm recommendations on roasting cannot be made until consumer preferences have been established by sensory tasting panels.

Table 5.3. Canarium kernels (%) in each colour category for different roasting regimes. Colour was ranked from 1 (lightest) to 5 (darkest) according to Taubmans Colour Concepts® colour swatch No.44. (min = minutes).

Treatment	Colour_1	Colour_2	Colour_3	Colour_4
110°C; 10 min	60.83	38.83	0.00	0.00
110°C; 15 min	69.17	30.50	0.00	0.00
110°C, 20min	44.17	49.67	0.00	0.00
115°C; 10 min	27.50	71.83	0.00	0.00
115°C; 15 min	5.50	77.33	16.67	0.00
115°C, 20min	44.17	55.33	0.00	0.00
120°C; 10 min	16.50	63.50	19.33	0.00
120°C; 15 min	0.00	68.83	30.33	0.00
120°C, 20min	0.00	58.17	41.50	0.00
125°C; 10 min	0.00	47.00	49.83	3.00
125°C; 15 min	0.00	47.00	49.67	3.00
125°C, 20min	0.00	30.50	63.50	6.00

Table 5.4. Canarium kernels (%) in each mottled colour category for different roasting regimes. Mottled colour was ranked as 1 for slightly mottled, 2 for moderately mottled and 3 for severely mottled (approximately 20% or more of the surface). (min = minutes)

Treatment	Mottling_1	Mottling_2	Mottling_3
110°C; 10 min	69.00	27.67	3.00
110°C; 15 min	55.33	38.83	6.00
110°C, 20min	49.83	38.67	11.00
115°C; 10 min	38.67	55.33	6.00
115°C; 15 min	25.00	63.50	11.00
115°C, 20min	72.00	27.83	0.00
120°C; 10 min	24.83	63.50	11.00
120°C; 15 min	0.00	69.00	31.00
120°C, 20min	0.00	74.50	25.00
125°C; 10 min	5.67	66.33	25.00
125°C; 15 min	0.00	58.00	42.00
125°C, 20min	0.00	47.17	53.00

Numbers of translucent kernels were very low in all treatments (data not presented).

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11.6 Appendix 6: Storage Trials on *Canarium indicum* nuts:

Introduction

Canarium indicum (Galip) has very high oil content, reportedly from 67.3 to 75.4% (Evans 1996; Leakey *et al.*, 2008). Development of rancidity during nut storage is an important quality consideration. Rancidity is of two main types, oxidation (oxidative rancidity) and lipolysis (hydrolytic rancidity). A typical analysis of Galip oil is 40% oleic acid (mono-unsaturated, with one double bond) and 14% linoleic acid (poly-unsaturated, with three double bonds) (Leakey *et al.*, 2008). The high degree of unsaturation of Galip oil means that there is potential for oxidative rancidity development (Robards *et al.*, 1988). Once begun, oxidation can proceed in the nature of a self-sustaining free radical chain reaction known as autoxidation without additional oxygen (de Man, 1990). In particular, linoleic acid is very prone to oxidation. This type of rancidity generates volatile by-products which are powerful off-flavour compounds. Apart from causing rancid flavours, lipid oxidation products can react with amino acid residues, causing excessive browning (Nawar, 1996).

Lipolysis or hydrolytic rancidity is the hydrolysis of fatty acids from the glyceride molecule. Because of their volatility, hydrolysis of short-chain fatty acids can result in off-odours and off-flavours (Pike, 1998). Moisture content of nuts is important in preventing hydrolysis. Free fatty acids are produced in raw macadamia kernels at higher moisture content, e.g., 4.3% (Cavaletto *et al.*, 1966). Hydrolysis of oils can also occur as the result of enzymatic activity in nuts. Only small differences in free fatty acids were reported for roasted macadamias at higher moisture content, probably because enzymes were inactivated by the roasting temperature (Dela Cruz *et al.*, 1966). The effect of hydrolytic activity extends beyond free fatty acid production. Hydrolysis also favours oxidative rancidity as the fatty acids generated are more prone to oxidation than intact triglycerides (Robards *et al.*, 1988).

The chemical tests commonly used to test for rancidity in foods are 1) Peroxide Value (PV) for oxidative rancidity and 2) Free Fatty Acids (FFA) for hydrolytic rancidity. Peroxide values are determined by measuring the hydroperoxides which are precursors of autoxidation (Robards *et al.*, 1988). Thus PV is an indication of impending flavour deterioration (Robards *et al.*, 1988). Free Fatty Acids are a measure of the breakdown of triacyglycerols into component fatty acids such as oleic, linoleic and linolenic acid as a result of hydrolytic reactions (Robards *et al.*, 1988).

Methods

Packaging and storage trials of *C. indicum* nuts were undertaken at the University of the Sunshine Coast, Queensland, Australia, to examine storage keeping ability. In an initial pilot trial, a small sample of wet nut-in-shell (23.9% MC) was stored in an enclosed container to simulate storage conditions in-country.

In a nut-in-shell storage experiment, treatments consisted of storing nut-in-shell at different moisture levels: moist (16 %), partially dry (9 %) and dry (5 %). In this experiment, each treatment consisted of five replicates each of 10 kernels for each moisture level. Nuts were visually assessed for colour, patchiness, discolouration and translucency.

Treatments in the vacuum sealed experiment consisted of storing raw kernel at 6% moisture content in vacuum sealed plastic bags under refrigerated or 25^{o}C. Each treatment consisted of five replicates each of 10 kernels for both temperatures. Nuts were visually and chemically assessed.

Two shelf-life studies were conducted to test for development of rancidity of canarium kernels. In one study kernels were stored for nine months under ambient laboratory conditions and under refrigeration at the University of the Sunshine Coast (USC). In the second study kernels were stored for six months under ambient climatic conditions and under refrigeration at the National Agricultural Research Institute at Keravat, East New Britain. The aims were to determine the development of rancidity during storage as measured by peroxide values and free fatty acids.

Canarium indicum nuts for these experiments were obtained by depulping fruit using a traditional method of rotting the fruit prior to removal of the nut. For the vacuum sealed study, kernels were packed in vacuum packs using a Foodsaver Vac 440 domestic vacuum sealer (Sunbeam Corporation, Botany, NSW) in polyethylene packaging film (Foodsaver VSO520, Sunbeam Corporation, Botany, NSW). Kernels were stored in an air conditioned laboratory at 25°C, or a refrigerator at 4°C. Peroxide Values and Free Fatty Acid analyses were conducted at the start of the trial, after one month, after three months, after six months and nine months of storage. For the Keravat study, kernels were packed using the same model machine and packaging film and stored at ambient temperature (maximum of °C minimum of °C) or in a refrigerator at 4°C. Peroxide Values and Free Fatty Acid analyses were conducted at the start of the trial, after one month, after three months and after six months of storage.

Oil extraction
Kernels were blanched to remove the testa. A sample of 10 kernels was crushed twice in a garlic press and mashed in a mortar and pestle with pentane. The sample was then stirred in a covered beaker with pentane for half to one hour. The liquid was then transferred to test tubes and centrifuged at 3000 rpm for 3 minutes to separate the dissolved oil from the nut residue. The liquid was then decanted and the pentane stripped from the oil in a Buchi Rotavapor (BÜCHI Labortechnik AG, Switzerland).

Peroxide values
Peroxide values were determined according to AOAC Official Method 965.33 modified as follows: smaller samples of oil were used (1 g instead of 5 g); 0.01N $Na_2S_2O_3$ was used instead of 0.1 N $Na_2S_2O_3$; and $Na_2S_2O_3$ titration was accomplished with a 100 µL HPLC syringe instead of a burette. Peroxide Value (expressed as milliequivalents of peroxide per kilogram of sample) was calculated according to the formula:

$$PV = \frac{(S-B) x N x 1000}{sample\ wt\ (g) x\ 1000} \qquad \text{equation (1)}$$

Where:
S = sample titration (µL)
B = Blank titration
N = normality of $Na_2S_2O_3$

Free Fatty Acids
Free Fatty Acids were determined using AOAC method 940.28, modified as follows: smaller samples of oil were used (1 g instead of 5 g); 0.1 N NaOH was used instead of 0.25 N; and NaOH titration was accomplished with a 100 µL HPLC syringe instead of a burette. Free Fatty Acids were calculated as follows:

$$\%\ FFA\ (as\ oleic) = \frac{(\mu L) alkali\ x\ N\ of\ alkali\ x\ 28.2\ mg}{sample\ wt\ (g)\ x\ 1000} \qquad \text{equation (2)}$$

Results
In the initial pilot trial, nuts that were stored at 20% moisture content all went mouldy within 14 days. Nut in shell that were stored at the thee different moisture contents (MC) (Dry - 5% MC; Partly dry – 9% MC; and Moist 16% MC); equilibrated to 7.28-7.40% moisture content by six weeks under storage conditions of 25^{o}C and low humidity. No significant differences were found visually between any treatments for colour, patchiness, mould and oiliness (P>0.05). After 11 months the Peroxide Values and Free Fatty Acid values of these nut-in-shells were very low (Table 6.1).

Table 6.1. Peroxide Values for *Canarium indicum* nut-in-shell stored at ambient temperatures at the University of the Sunshine Coast for 11 months. Peroxide value (PV) and free fatty acid values (FFA) are means and standard error (SE).

Treatment	Mean Peroxide Value (SE)	Mean Free Fatty Acid (SE)
Baseline value	1.36 (0.171)	0.11 (0.003)
Nut-in-shell after 11 months storage at 25°C	0.31 (0.032)	0.31 (0.29)

Canarium kernels did not deteriorate markedly during the 9 months of storage and both peroxide values and free fatty acids were well within acceptable measures of quality. Peroxide values after one month storage are not presented because subsequent to analyses, the chloroform used was found to be oxidised. The baseline value was1.36, but this was also likely to be artificially elevated due to oxidised chloroform (Table 6.2). There were no significant differences between the 3, 6 and 9 month treatments and all values were very low (≤ 0.39 meq/L) and all values were significantly lower than the control ($P < 0.001$).

Table 6.2. Peroxide Values for *Canarium indicum* kernels stored at ambient or refrigerated temperatures at the University of the Sunshine Coast for 9 months. Peroxide values are means and standard error (SE).

Treatment	Peroxide Value	S E
Baseline	1.36[a]	0.171
Ambient 3 months	0.38[b]	0.06
Refrigerated 3 months	0.29[b]	0.03
Ambient 6 months	0.25[b]	0.03
Refrigerated 6 months	0.26[b]	0.02
Ambient 9 months	0.23[b]	0.01
Refrigerated 9 months	0.19[b]	0.03

Free fatty acid values were generally low, however, there were significant differences ($P < 0.001$) between kernels stored at ambient temperature and controls. All ambient FFA values were significantly different from the control (Fig. 6.1.).There was no difference between the ambient and refrigerated treatments at 1 month and at 6 months, but ambient treatment values were significantly higher than those for the refrigerated treatment at the 3 month and 6 month stages (Fig. 2.). The only significant difference between ambient treatments was that FFA values at 9 months were higher than at 3 months (Fig. 6.1.).

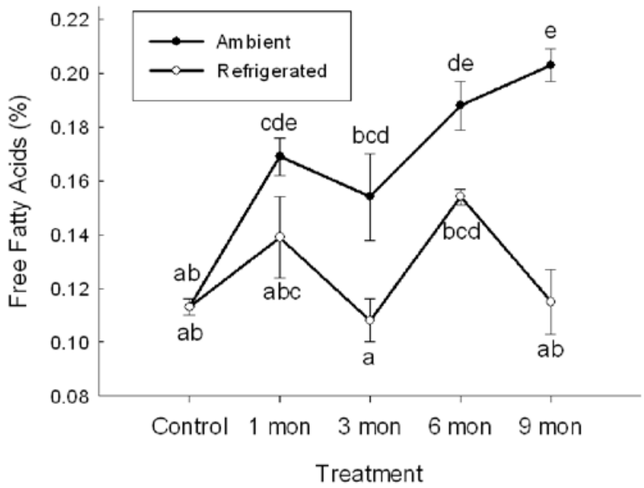

Fig. 6.1. Free Fatty Acids for canarium kernels stored at ambient laboratory and refrigerated temperatures for 9 months at the University of the Sunshine Coast. Values are means (SE), columns with different letters are significantly different.

Peroxide values for kernels stored in PNG were also low and there were no significant differences during the storage period (Table 6.3). Free fatty acids were also at low levels, but were increased following storage at ambient temperature for 3 months, and were further increased after 6 months (Fig. 6.2). Kernels stored under refrigeration showed no increase in FFA levels (Fig. 6.2.).

Table 6.3. Peroxide Values for *Canarium indicum* kernels stored at ambient or refrigerated temperatures for 6 months at Keravat, PNG. Values are means (SE).

Treatment	PV	S.E.
Control	0.45	0.02
Refrigerated 1 month	0.61	0.03
Ambient 1 months	0.41	0.07
Refrigerated 3 months	0.42	0.04
Ambient 3 months	0.40	0.04
Refrigerated 6 months	0.38	0.03
Ambient 6 months	0.48	0.07

Peroxide values

This trial showed that vacuum packed canarium kernels can be stored for 9 months at an ambient temperature of 25°C with minimal loss of quality. The highest value recorded (1.36 meq/L for the control) was well below the proposed acceptable upper limit for PV of macadamias of 6.0 meg/L (McConachie, 1996; Mason et al. 2003). This significantly elevated PV for the control can probably be attributed to oxidised chloroform used in analysis and does not appear to be typical of overall oxidative quality, as the determined values at 3 months, 6 months and 9 months were very low. Similarly, PVs at Keravat were low and there was no increase in values. The results indicate that the packaging system used was effective in minimizing the amount of oxygen available for peroxidation.

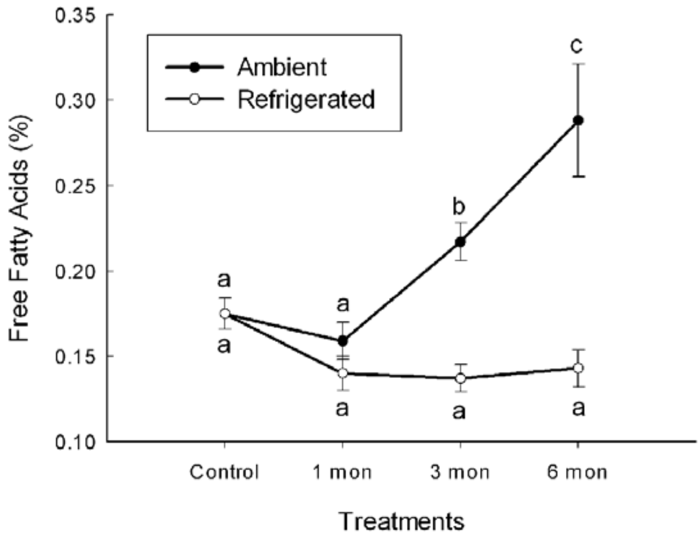

Fig. 6.2. Free Fatty Acids for *Canarium indicum* kernels stored at ambient laboratory and refrigerated temperatures for 6 months at Keravat, PNG. Values are means (SE), columns with different letters are significantly different.

Free Fatty Acids

Free fatty acid values also indicated minimal loss of quality over 9 months of storage at USC at 25°C. The highest value recorded, 0.203% for the ambient treatment at 6 months, was well within the acceptable range proposed for macadamias of 0.1 - 3.0% (McConachie, 1996). However, there are some qualifications to this evaluation of quality. The ultimate test of quality is taste (Robards et al., 1988), and these kernels were not subjected to a tasting panel. The highest FFA values indicate caution about longer term storage. Values for all ambient temperature treatments and the 6 month refrigerated treatment increased to over 0.15%, and this indicates caution. If macadamia kernels develop FFA over 0.15% in 12 weeks of storage they are considered to have a dramatically reduced shelf life (Mason et al. 2003). This suggests that these canarium kernels may have a limited further shelf life at 25°C or higher temperatures. However, the duration of safe storage could only be determined by further study.

At Keravat after 6 months storage FFA levels were almost 0.3% and were higher than reached at USC. This may have been due to the higher ambient temperatures.

Moisture content of the stored kernels may have been a factor in the FFA increases. It is possible that if kernels were stored at lower moisture content hydrolysis of triglycerides to fatty acids would have been reduced. The nut-in-shell moisture content of the kernels at the beginning of storage was 5.4%, which equates to a kernel moisture content of approximately 2.5%. Kernel moisture content of 2.5% would probably provide some free water for hydrolysis of triglycerides. At ambient temperatures at both locations hydrolysis of oils increased as time elapsed. However, under refrigeration hydrolysis was not sufficient to significantly increase FFAs at either location. This agrees with Cavaletto (1983) that lipolysis appears to be related to storage at excessively high temperature. Free fatty acids are very important for nuts because even differences in FFA values for macadamias were highly correlated with differences in flavour scores (Dela Cruz et al., 1966).

Discussion and Conclusion

Growing location and variety affect composition, total oil content and shelf life of macadamias (Mason et al. 2003). Macadamias cultivars varied in total oil content and fatty acid profiles. As total oil content increased, linoleic acid also increased, increasing the susceptibility to oxidation. Bundaberg nuts contained more oil than those from the Lismore area and different fatty acid profiles were found for different varieties (Mason et al. 2003). It is recommended that, if possible, nuts from different varieties and different regions should be processed separately.

This study shows that *Canarium indicum* vacuum packed kernels can be safely stored for 9 months at 25°C or for 6 months at 30°C. However, free fatty acid levels indicate that only limited further storage at either temperature may be possible. *Canarium indicum* vacuum packed kernels should be stored under refrigeration to maintain optimum kernel quality. Depulping by a traditional method for these shelf life experiments did not appear to affect kernel quality, perhaps because the nuts were processed promptly within a week of harvest.

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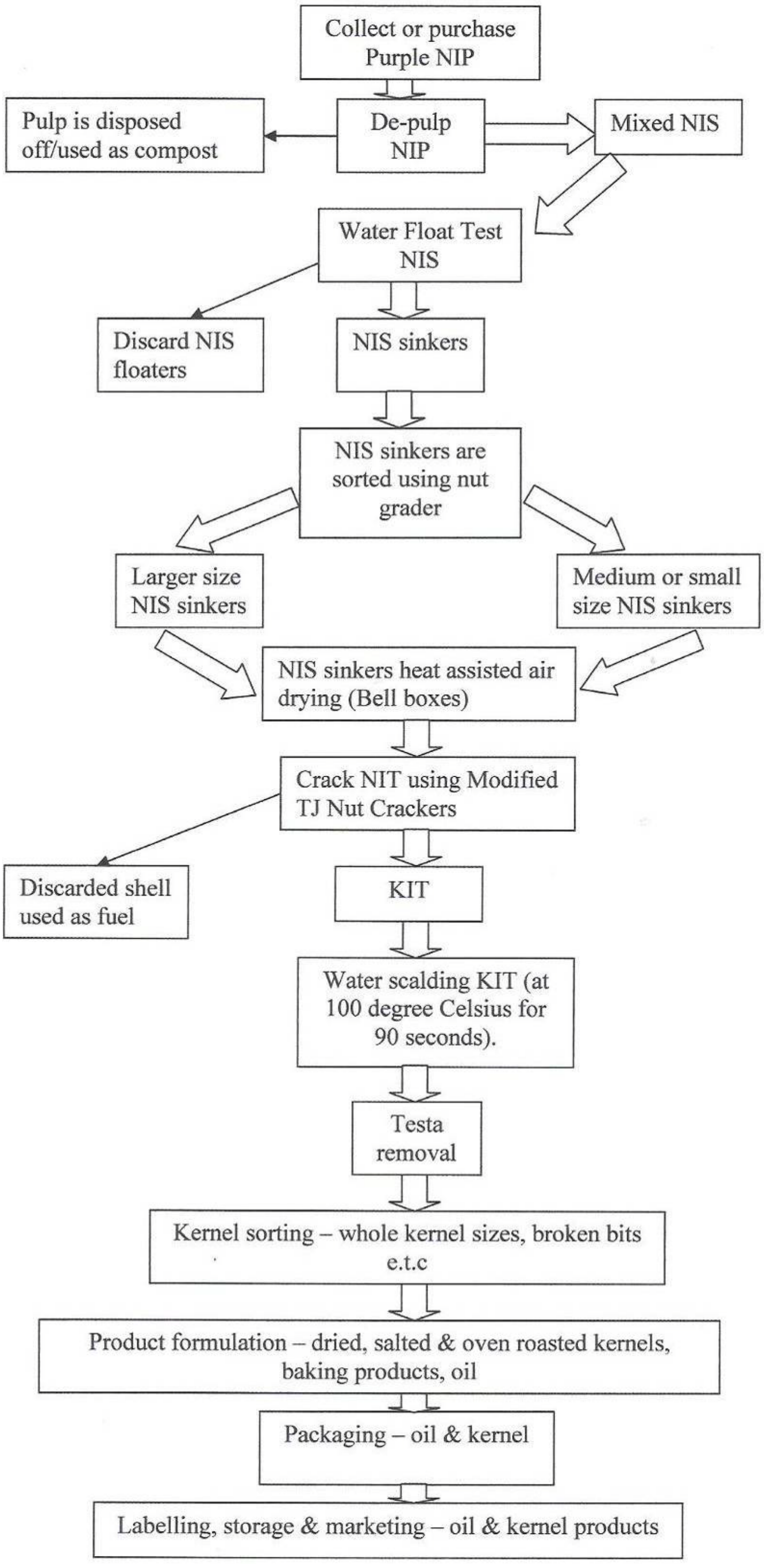
11.7 Appendix 7: Centralised Processing model for canarium nuts

The flow chart below details a canarium nut processing methods based on macadamia nut processing techniques. This is a centralised nut processing model where all nuts are brought to a centralised facility for processing.



11.8 Appendix 8: HACCP Plan

Analysis of hazards and risk management for food safety:
Hazard analysis and critical control point Plan for *Canarium indicum* (Galip Nut) for the pilot canarium processing plant.

Prepared by Kim Jones from Cropwatch Independent Laboratories .

Galip nut is a developing industry with many commercial processes yet to be finalised. The industry has largely existed as a cottage industry at village level. The intention to expand to a full domestic and export market requires stringent food safety protocols. This HACCP plan draws on what is known about the fledgling industry and the expected way it will develop.

The HACCP plan begins by describing the product (table 8.1), the expected flow of the product (table 8.2), potential threats to food safety and potential critical control points.

A draft HACCP plan is described in table 8.3 along with recommended control measures for each Critical Control Point (CCP).

All nuts are susceptible to contamination with human pathogens such as E. coli and Salmonella and mycotoxins including aflatoxins. This is the first hazard analysis for galip nuts and some of the information on risks is still to be developed. This hazard analysis draws on issues that are common to all tree nuts.

Contamination by agricultural chemicals is a low risk as no pesticides are currently used in either wild harvested or plantation grown galip nut. For this reason this HACCP plan focuses specifically on microbial and mycotoxin contamination**.**

Table 8.1. Product description and intended use of Galip nut.

Name of Product	**Galip Nut, *Canarium indicum,* for human consumption**
Description	Raw and roasted kernels
Customer specification	Domestic: graded for Fair Average Quality Export: graded with aflatoxin limits of importer e.g. 20 µg/kg for the EU and Japan, and microbial levels defined by food standards
Conditions of storage	Nut-in-shell in bulk silos and /or bins and after drying airtight containers or relative humidity below 40%, kernel dried and vacuumed packed and cool stored
Shelf Life	Yet to be determined
Intended use	Snack products, ingredients
Packaging	Foil laminate bags
Target Consumer	Both domestic and Export

Table 8.2. Product flow, GAP= Good agricultural practice, GMP=Good manufacturing practice, GSP= Good storage practice.

Product flow		
Step	**Activity**	**Classification**
1	**Farm/forest** Growing	**GAP**
2	**Farm/forest** Harvest and accumulation	**GAP**
3	**Farm** Inspection	**CCP1**
4	**Regional trader** Accumulation of nuts and Quality check	**CCP2**
5	**Depulping**	**GMP**
6	**Drying/storage**	**GMP/GSP**
7	**Transport to factory**	**GMP**
8	**Factory** Drying nut-in-shell	**GMP**
9	**Factory** Cracking	**GMP**
10	**Factory** Blanching and testa removal	**CCP3**
11	**Factory** drying kernel	**CCP4**
12	**Factory** Packaging	**GMP**

HACCP Plan

Step 1

Pre-harvest microbial contamination is associated with insect damage and other forms of damage that penetrates the shell. Galip has a very thick shell surrounded by a fleshy pulp. No known insects attack the developing nut.

It is concluded that the risk of pre-harvest microbial contamination is low.

Steps 2 and 3

Nuts stored at high moisture content creates an ideal environment for microbial growth. There is a risk that mycotoxins could developing during prolonged on farm storage. Sampling and testing needs to be carried out to determine the true extent of the risk that aflatoxins pose to galip nuts stored at high moisture. Contamination by human pathogens such as E. coli and Salmonella sp could occur if harvested nuts come into contact with animal manures.

It is concluded that aflatoxin and microbial contamination of galip nuts stored on-farm for extended periods is a high risk.

Step 4

It is likely that wild-harvested nuts and nuts from plantations will be delivered to a regional collection centre for depulping and accumulation of commercial “lots”.

Contamination may spread and aflatoxin levels increase above acceptable levels at this step.

Steps 5 and 6

Microbial growth and aflatoxin levels will increase rapidly if safe moisture contents are not achieved quickly.

Step 7

Transportation of NIS to a centralised factory has low risk of contamination provided the transportation vessels are clean and free from foreign matter.

Step 8.

Drying nut-in-shell (NIS) to cracking moisture has low risk of contamination, however aflatoxins and microbial contamination produced at earlier steps will persist through this step.

Step 9

Factory cracking exposes the kernel to contamination from external sources. There is a high risk that kernel could become contaminated at this step.

Step 10

Blanching or steaming prior to testa removal will act as a sanitiser and kill live microbes. Blanching or steaming will not remove aflatoxins that have accumulated prior to this step. Testa removal is a manual process and there is a high risk of re-contaminating the kernel at this step.

Step 11

Microbial contamination will increase rapidly if safe moisture contents are not achieved quickly.

Step 12

There is a low risk of microbial contamination of the finished dry kernel at this step.

Possible food safety control measures

The most effective microbial control mechanism is to dry the product to moisture levels that will not support mould growth. Growth of Moulds and yeast cease at water activities below about a_w 0.7 (Figure 1) (Labuza, 1979), which is approximately equal to 7% NIS moisture.

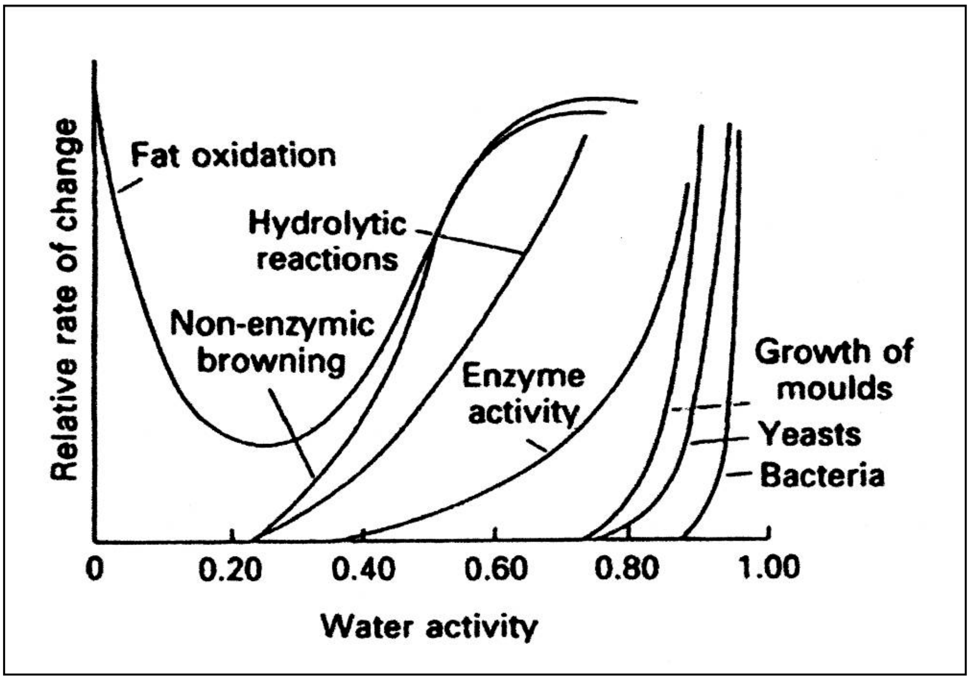


Figure 1. The relationship between the activity of: enzymatic or non-enzymatic reactions and growth of mould, yeast or bacteria to water activity (from Labuza, 1979).

A two stage drying process will allow a primary trader to accumulate product and reduce the moisture content to levels that restrict mould growth and slow the enzymatic processes to maintain quality. Final drying to cracking moisture and to levels that prevent mould growth will occur at the centralised processing plant.

Initial drying at step 6 should aim to reduce the NIS moisture content below 10%, which will slow the growth of any microbes and help to maintain nut quality. Further drying and storage trials are needed to confirm the optimum moisture content for short-term storage.

Blanching or steaming at step 10 is a sanitising step that should kill pathogens such as Salmonella or E. coli. As well, the drying step 11 will also help reduce any microbial load. Good manufacturing processes from this stage will prevent re-contamination. It should be remembered that the temperatures used for testa removal and subsequent re-drying of the kernel will not destroy aflatoxins.

Segregation of acceptable from unacceptable batches on farm (step 3), and at regional trader (step 4) is a useful control measure to avoid product that is susceptible to aflatoxin accumulation.

Table 8.3. HACCP plan worksheet: Food safety for Galip nut domestic and export industries.

HACCP Plan worksheet: Food safety in Galip nuts for domestic and export markets.		
Process Step	**Description of Hazard**	**Control Measures**
1 & 2 Farm/forest Growing Harvest and accumulation	Microbial contamination, mould, aflatoxin	**GAP** Harvest regularly at least every two weeks. Once the NIP has been harvested it must be delivered to the regional trader within 24 hours of collection. If delivery is not possible within 24hours the NIP should be placed on wire racks, undercover, where air can circulate freely.
3 Farm Inspection	Mould	**CCP1** Discard any mouldy NIP or old nuts.
4 Regional trader Accumulation of nuts and Quality check	Mould and aflatoxin	**CCP2** Inspect and document every delivery. Reject batches with mouldy NIP or old nuts, collect sample for quality analysis. Reject deliveries that do not comply with specification. Reject nuts if the supplier cannot provide information on harvest date and post harvest treatment. Reject any product if contaminated with foreign material.
5 & 6 Depulping Drying/storage	Mould and aflatoxin Increased heat from respiration of product	**GMP/GSP** Depulp within 24 hours of delivery and begin controlled drying immediately following depulping.

7 Transport to factory	Contamination from transport vessels	**GMP** Inspect transport vessel to ensure good hygiene. Reject deliveries that do not comply with specification. Reject any product if contaminated with foreign material.
8 Factory Drying nut-in-shell	Mould/ aflatoxin	**GMP** Continue controlled drying and reduce the water activity below A_w 0.4 to stop all microbial growth and enzymic processes.
9 Factory Cracking	Contamination with human pathogens	**GMP** Ensure an effective cleaning schedule is developed and implemented. Ensure staff have the required cleaning knowledge and skills.
10 Factory Blanching and testa removal	Biological, chemical and physical cross contamination by staff, equipment, cleaning agents and pests	**CCP3** Monitor temperature of blanching water/steam and ensure it is maintained at 100°C. Ensure appropriate hygiene practices are being carried out by staff
11 Factory drying kernel	Biological, chemical and physical cross contamination by staff, equipment, cleaning agents and pests	**CCP4** Monitor temperature of the driers and maintain at 45°C. Monitor and measure water activity or kernel moisture %. Ensure kernel moisture is at optimum levels for quality and food safety. Sample and test product for microbial load and aflatoxin levels before packaging.

12 Factory Packaging	Biological, chemical and physical cross contamination by staff, equipment, cleaning agents and pests	**GMP** Ensure appropriate hygiene practices are being carried out by staff

Development of the HACCP Plan

The worksheet summarising the HACCP plan is given in table 8.3. Each step in the development of the plan is given below.

Step 1 and 2: GAP

Pre-harvest mould contamination is a relatively low risk as a fleshy pulp surrounding a very thick and hard shell protects the nuts. No known insects or other pests attack the nuts while they are on the trees.

Step 3. CCP

This step is identified as a critical control point with rejecting and discarding obviously mouldy, or old nuts, as the control measure. Mouldy and old nuts aggregated with fresh nuts have the potential to contaminate the whole batch. Inspection on farm should be carried out to ensure that old and mouldy nuts are discarded at this point. While this step has been identified as a critical control point it is acknowledged that some harvesters and forest collectors may not have the training and understanding to meet these measures. It will take training and explanation to ensure a good compliance. As a back up measure the next step has also been determined as a CCP.

Step 4. CCP

This step is identified as a critical control point with rejection of obviously contaminated consignments as the control measure.

Accumulation of nut will most likely occur on a regional basis through a common collection point or regional trader. It is at this point that the risk of greater contamination may occur if contaminated nuts are combined with acceptable product from other farmers or collectors. The regional trader must inspect every delivery and collect a sample for quality assessment. Any suspect or contaminated consignments should be segregated or rejected at this stage.

Documents should be kept for every delivery and should record: The name of the farmer/collector, harvest date, delivery date, weight of product, and quality.

Step 5&6. GMP/GSP

It is important to begin processing the NIP as soon as possible and within 24 hours of delivery. Field moisture needs to be reduced to safe levels to prevent microbial growth and product deterioration.

Regional traders will most likely store product for short periods to allow them to accumulate enough product to transport to the central factory. Good storage practice is required to prevent re-wetting of the product and to maintain quality.

Step 7 GMP

Contamination by pathogens may occur if the NIS is transported in containers that have previously been used to transport animals or animal products including manures. All vessels should be thoroughly cleaned and inspected before loading with NIS.

Step 8 GMP

Further drying at the factory is required to reduce the water activity below the level that will support microbial growth. This is also an important quality step so moisture must be removed in a controlled and continuous process. Drying temperatures and moisture levels should be monitored and recorded.

Step 9 GMP

Factory hygiene protocols should be developed to avoid cross contamination from workers or pests. Appropriate training needs to be conducted on a regular basis.

Step 10 CCP

Blanching or steaming the product to remove the testa also doubles as a critical control point. The hot water or steaming will sanitise the kernel at this point. Temperature of the blanch bath and steam room need to be monitored and recorded.

Step 11 CCP

This has been determined as a critical control point where routine sampling and testing for aflatoxin and microbial contamination. The control measure is laboratory report which must meet specification. Any product that falls outside specifications at this stage must be reprocessed or discarded as a human food safety risk. This is the last point on the production line where contaminated product can be easily identified and treated appropriately. Past this point any contamination may result in product recalls or threats to human health.

Step 12 GMP

Factory hygiene protocols should be developed to avoid cross contamination from workers or pests. Appropriate training needs to be conducted on a regular basis.

Verification procedures:

All critical control points (Table 8.4) must be verified and documented.

Table 8.4 Critical Control points in the canarium HACCP Plan

CCP	What To check	What to Record	How often
CCP 1	All NIP harvested	Harvest record form: Date of harvest, farm or forest harvested	Every harvest
CCP2	All deliveries	Record 2: Goods receiving form: Name, date of delivery, weight of delivery, date of harvest, quality assessment	Record all deliveries
CCP 3	Blanching or steam temperature	Process control form: Date, time, batch number being processed, temperature	Every batch or at least daily
CCP4	Microbial load and aflatoxin levels	Micro test form: Microbial and aflatoxin levels as determined by food safety organisations of importing countries.	Every batch

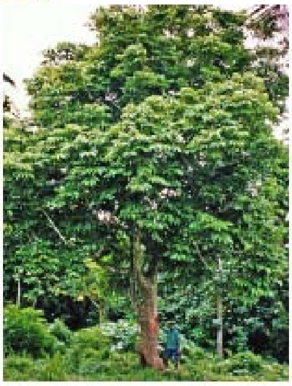
References:

Anon: Manual on the application of the HACCP system in Mycotoxin prevention. FAO Corporate Document. www.fao.org/005/y1390e0j.htm

Labuza TP (1979). “Water activity: Physical and Chemical Properties.” In “Food Process Engineering. Volume 1. Food Processing Systems”. Eds. P. Linko, Y. Malkki, J. Olkku and Larinkari, J. Applied Science Publishers; New York.

11.9 Appendix 9: Initial awareness raising brochure (Newsletter 1) English version.

GALIP NIUS
May 2008



Pictures taken by Russell Haines (ACIAR) and David Walton (USC)

Source of Canarium tree photo: Thompson & Evans *Species Profiles for Pacific Island Agroforestry*, www.traditionaltree.org

Information on new research for processing Galip Nut

Market Opportunities for Galip

There is strong increasing demand for Galip in Melanesia and export markets.

Buyers in distant markets require good quality nuts

If farmers and processors in Niugini want to sell Galip market products, they will need to consistently produce quality nuts that have been packed and processed to meet market standards.

It will be important to handle nuts-in-shell carefully after picking or they will not be suitable for sale. Dried nuts-in-shell must be packed carefully so they do not break while being stored or transported. Roasting nuts for sale for different markets will also need to be done differently to suit these markets.

Processing good quality nuts for sale

The Food Preservation and Processing Unit of the University of Technology, in Lae, has worked out that nuts-in-shell should be dried and stored as quickly as possible after harvest. This reduces the high moisture content of the nuts that makes the nuts spoil.

There are other reasons why nuts-in-shell spoil before cracking, and why cracked nuts spoil during processing and packaging. A research project has been funded by ACIAR (Australian Centre for International Agricultural Research) to work out the best way to fix these problems.

1

Packaged Ngali and Ngali mixes, produced and marketed by Resource Management Trust, Honiara

Parisian hand made chocolate with Canarium toppings sourced from the Kava Store in Vanuatu

2

Details of new processing research project

The research project has started this year. It will explore whether the processing methods used for other nut industries in Australia can be used in Niugini.

Trials of cracking, drying, roasting and packaging will be run in Australia and at NARI to see how well these methods suit Galip nuts.

The project, *Processing of Canarium indicum nuts: adapting and refining techniques to benefit farmers in the South Pacific*, is in partnership with ACIAR, NARI (National Agricultural Research Institute), and USC (University of the Sunshine Coast), Australia.

Over the next 3 years Dr John Moxon and Dr Guinivere Ortiz and other staff from NARI will work with the research team from USC.

The researchers from USC are Dr Helen Wallace, Dr David Walton, Dr Jennifer Carter and Ms Jenny Austin, from USC, and Mr Colin Bunt, who has worked with NARI and James Cook University (JCU) on Galip marketing.

Different members of the research team will talk with local farmers and processors in Niugini from time to time to let them know what is happening with the trials.

3

Processing Methods to be investigated

1. De-pulping

What we know now

Past research has shown that is better to remove the flesh from the outside of the nuts-in-shell as soon as can be done after harvesting the fruits. Leaving pulp on for too long can cause quality problems in both the raw and processed nuts.

There are many ways of removing the nuts-in-shell, but some of these methods can introduce microbial contaminants. If this happens, nuts-in-shell or processed nuts will not be accepted by buyers in distant markets.

2. Drying nuts-in-shell

What we know now

Sun-drying the nuts can reduce kernel moisture which makes the nuts less likely to spoil. Usually de-pulped nuts in their shell are dried in the sun or over low heat from a kitchen fire. The kernels are usually completely dry in the shell if they rattle when shaken. When the shell is removed there is a clean white-coloured nut inside.

4

Other ways of drying nuts-in-shell

Tests by the Kandrian Gloucester Integrated Development Project (KGIDP) in West New Britain province, showed flue pipe drying was faster than sun drying, and with less spoilage, but this process costs much more.

What this project will be doing

In Australia and at NARI, Helen Wallace and Dave Walton will try out different technologies and methods for drying Galip nuts-in-shell that might possibly be suitable for commercial processing.

Some of these methods and technologies include solar dryers (used in Niugini to dry cocoa), copra driers or coconut dryers, and portable electric driers. These might be suitable for Galip in some areas of Niugini.

3. Storing

What we know now

If nuts-in-shell are not intended to be sold within a short time of drying, it is best if they can be cracked as soon as they have finished drying.

The quality of stored nuts-in-shell depends on the moisture content of the nuts, the age of the nuts when picked, and the way they are stored.

5

4. Cracking Nuts

What we know now

Cracking shells by hand, or using a hand operated nutcracker, is very slow. A mechanical cracking device is faster, but the kernels shatter very easily, and this also slows production. Both ways of cracking have problems at the moment.

What this project will be doing

Helen Wallace and David Walton will have a look at this cracking technology, and assess which method might be possible to use in villages or limited factory processing.

Manual nutcracker For Macadamia nuts

Mechanical cracker – Kava Store, Port Vila May 2005

6

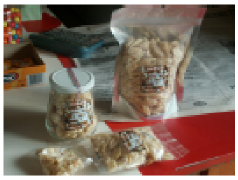
Roasting (value adding)

Once the shell is removed, the nut kernel can be eaten with or without the testa (the bitter outside skin). Kernels can be salted or roasted for a different flavour, and there are many ways to do this.

Helen Wallace and David Walton will trial different ways of roasting kernels in Australia using an electric drier/roaster used for Macadamias. Other roasting methods will be trialed on site at NARI.

5. Packaging

Helen Wallace and David Walton will also look at the different ways of packaging processed nuts that could be used in Niugini. The photos above and below show how processed Galip (Nangai) nuts are packaged for sale in Vanuatu.



7

Sharing knowledge about the processing trials

Jennifer Carter and Colin Bunt will hold workshops at NARI to talk about the processing methods with farmers and processors. They would also like to hear about any needs or problems in using the methods developed by the scientists.

Discussing these methods with you can help them sort out problems along the way, or hear about other suggestions and ideas. It will also help to make sure that the researchers work in a way that suits your business, local village or culture.

The information farmers and processors tell us will also help Jennifer Carter and Jenny Austin to develop a training manual that will help you learn how to use the new processing methods.

NARI staff will also be able to provide training to local staff, with hands-on examples of the methods Helen Wallace and Dave Walton have developed. The people who have been trained will be able to train others in their villages or workplaces in using the new methods.

8

Contact details of the project teams are provided below, should you require any further information or additional copies of this information booklet.

Project team at NARI, Keravat, ENBP, Papua New Guinea:

Research Programme Leader:
Dr John Moxon Ph: + 675 983 9189

Outreach Officer: Gadi Ling gadi.ling@nari.org.pg

NARI Head Office, Lae, Papua New Guinea:

Dr Guinivere Ortiz Ph: +675 475-1033
Fax: +675 475-1034

Project team at USC, Australia

- **Faculty of Science, Health and Education:**

Project Leader: Dr Helen Wallace Ph +61 7 5430 1228
Research Officer: Dr David Walton Ph +61 7 5459 4519

- **Faculty of Arts and Social Sciences:**

Project Leader: Dr Jennifer Carter Ph +61 7 5459 4496
Research Officer: Ms Jenny Austin Ph +61 7 5459 4857

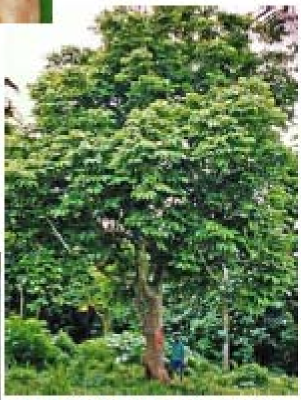
Postal Address:
University of the Sunshine Coast
Locked Bag 4,
MAROOCHYDORE DC, Qld 4558
AUSTRALIA

9

11.10 Appendix 10: Initial awareness raising brochure (Newsletter 1) Bislama Version.

News blong Nangai

May 2008



Man we I tekem picture ia hemi Russell Haines(ACIAR) mo David Walton(USC)

Oli tekem aot photo long:Thompson & Evans *Profile blong ol species blong Pacific Island Agroforestry, www.traditionaltree.org*

Information blong ol niufala - stadi long saed blong Processem ol frut blong Nangai Nuts

Ol Market opportunities blong Nangai

I kat bigfala Janis blong yumi exportem Nangai (Galip) mo demand blong hem i bikwan insaed long ol kaontri blong Melanesia mo ol narafala export markets.

Olgeta buyers blong yumi long ol Market we I stap aotsaed mo longwei oli wantem yumi blong exportem gudfala quality blong kakai blong Nangai(nuts)

Sipos ol farmer mo ol processor(olsem olgeta industri blong Nangai) insaed long Vanuatu mo Papua New Guinea (PNG) oli wantem salem ol products blong Nangai iko long ol kaen market olsem ia, bambai oli mas kohed oltaem blong producem ol quality nuts we oli processem mo packagem long wan stret fasin we I save mitim olgeta standards blong Market.

Hemia I minim se bambae hemi important tumas blong handelem Shell blong nangai we Kakai I stap insaed yet long wan stret fasin taem we yumi jes pickimap olgeta nomo long tri blong olgeta. Sipos yumi no handelem gud olgeta,samtaem bambai yumi nomo save salem olgeta from quality blong olgeta I no gud. Yumi mas pakemap gud ol shell blong Nangai we oli drae finis blong oli no save brok taem we yumi storemap olgeta or taem yumi stap transportem olgeta. Nangai we oli rusum mo salem long ol diferen market olgeta tu oli nidim special fasin we yumi mas handelem gud olgeta blong oli mitim standard blong market blong olgeta.

Processem ol gudfala quality nuts blong salem

Food Preservation and Processing Unit we I stap long University of Technology,long Lae,PNG hemi bin faenem aot se taem yu harvestem ol Nangai,yumi shud hariap blong driemap mo storem Shell blong Nangai we kakai I stap insaed (Nuts-in-shell).

Hemia I blong tekemaot wota long kakai blong Nangai or kernal we plante taem I spoilem quality blong Nangai

1

Nangai we oli packagem mo sam narafala samting(kakai) we oli mixim wetem Nangai we Resource Management Trust long Honiara oli producem mo marketem.

2

Details blong project we I lukluk long niufala research or stadi blong processem Nangai

Project blong Processem Canarium indicum nuts (Nangai): Tis yia, project hemi lukluk blong follem wan niufala teknik we bambae hemi save benefitim ol farmers blong South Pacific. Hemia emi stap long partnership wetem ACIAR, Department blong Forests blong Vanuatu (DFV), National Agriculture Research Institute, PNG (NARI) mo The University of the Sunshine Coast, Australia (USC).

Long next 3 yias mo I ko bambai I kat Dr John Moxin wetem ol narafala staff blong NARI bambai oli wok wetem research team blong USC. Long team ia I kat Dr Hellen Wallace, Dr David Walton, Mr Bruce Randall, Dr Jennifer Carter mo Ms Jenny Austin we oli kamaot long USC, mo Mr Colin Bunt we hemi bin wok wetem NARI mo James Cook University(JCU) long saed blong Marketem Nangai long PNG.

Project ia bambae hemi traem faenem aot sipos method we olgeta long Australia oli usum blong processem ol narafala nuts oli save usum long Vanuatu mo PNG. Mr David Bell hemi wan advisor blong Industry long Australia. Mr Charles Long Wah long Pacific Nuts Company hemi wan advisor long saed blong industry blong Nangai long Vanuatu. Klosap plante long ol scientific trials blong fasin blong kilim shell blong Nangi I brok,driemap Nangai, roastem mo packagem Nangai bambae USC long Australia nao hemi ranem mo NARI long PNG.

Sipos ol trials ia oli successful, bambae oli jes save mekem ol smol smol trial we bai I stap long Vanuatu mo PNG blong mekem sua se olgeta processing techniques ia oli stret blong Yumi save usum long Vanuatu.

Bambai I kat ol diferen memba blong team blong research ia we bambai oli stap visitim ol famas mo ol processors long Vanuatu mo PNG blong tokabaot wanem nao I stap happen wetem olgeta trials ia.

3

Wan method blong processem Nangai we I kat nid blong yumi mas faenem aot

1. De-pulping or fasin blong tekem aotsaed skin or mit we I kaveremap shell blong Nangai

Wanem we yumi save naoia -

Ol stadi blong bifo oli faenem aot se I moa gud blong yumi tekemaot pulp or skin or mit aotsaed we I kaveremap shell blong Nangai quick taem nomo taem we yumi jes arvestem olgeta fruits. Taem yumi lego pulp istap long taem, hemi save mekem problem long quality blong Nangai nut we I green mo hemia we oli processem. I kat plante kaen fasin blong kilim Nangai,sam long ol fasin ia I save spoilem kakai blong Nangai or nut. Sipos olgeta nuts ia oli nogud hemi minim se bambae olgeta market we I stap long wei oli no save acceptem ol kaen Nangai olsem ia.

2. Wanem save I stap naoia long saed blong fasin blong draemap Nuts blong Nangai wetem Shell blong hem

Wanem we yumi save naoia - Fasin blong draemap Nangai nuts long san hemi save mekem se kakai blong Nangai or kernal hemi drae, Mo hemi I mekem se emi no save spoilem tumas quality blong hem. Taem yumi tekem aot pulp long Shell blong Nangai, yumi draemap long sun or draemap long faea we I laet smol or ases blong faea. Taem yumi seksekem shell blong nangai, bambai kakai blong Nangai insaed long shell I muvmuv mo I mekem noise. Hemia I minim se Kakai blong Nangai insaed long shell hemi dry. Sipos yumi tekem aot shell blong Nangai bambai yumi save faenem white kakai blong Nangai Or kernal we I stap insaed.

Ol narafala wei blong draemap Nangai

Olgeta long Kandrian Gloucester intergrated Development Project (KGIDP) long Province blong West New Britain,Papua New Guinea, oli testem mo fanemaot se taem yumi draemap Nangai long fasin blong flu long Pipe hemi drae hariap bitim fasin blong draemap Nangai direct long sun. Fasin blong flu long pipe hemi no mekem bigfala damage long Nangai,be hemia nomo hemi kostem bigfala mane blong follem fasin ia.

Wanem nao bambae project ia hemi mekem?

Long Australia mo NARI,Helen Wallace, mo Dave Walton bambae oli traem usum ol difdiferen idea(technology) mo follem wan method blong draemap Nangai we ating bambae I stret blong yumi follem blong winim mane.

Some long olgeta methods mo technologies we bambae yumi usum ikat solar dryer olsem fasin blong usum san(Yumi usum fasin ia blong draemap kakao), hot air blong kopra,mo ol smol machine we I usum electricity. Ol samting ia yumi save usum tu blong draemap Nangai long sam aelan or area blong yumi long Vanuatu mo PNG.

3. Fasin blong Storem gud Nangai

Wanem we yumi save finis

Sipos yumi no tingting blong salem hariap Nangai within wan short taem,taem we yumi draemap nangai long sun finis,yumi mas hariap kilim brekem shell blong Nangai mo karem out kakai blong nangai or kernel blong hem

Hemia emi from se quality blong Nangai we yumi storem bambai hemi depend tumas long hamas wota we I stap insaed long kakai blong nangai ia,hamas dei yumi kaontem taem we yumi pikimap ol Nangai long bush mo fasin we oli storem ol nangai ia.

4. Fasin blong kilim brekem ol Shell blong Nangai

Wanem we yumi save finis

Taem yumi kilim brokem shell blong Nangai wetem hand blong yumi nomo or taem yumi usum sam samting blong kilim brekem, hemi slow tumas. I kat wan machine we oli usum blong brekem shell blong Nangai,we hemi mo hariap,be hemia nomo hemi save mekem Kakai blong Nangai hemi brokbrok wan wan afta I minim se hemi save slowem daon wok or production blong yumi.Tufala fasin blong kilim brekem shell blong Nangai ia I still kat problems naoia we I save affectem quality blong nangai.

Wanem we bambae project ia I mekem

Helen Wallace mo David Walton mo Bruce Randall bambai oli lukluk gud mo stadi gud long wan stret fasin blong olgeta fama long village oli save usum blong brekem shell blong Nangai or olgeta long factory oli save usum.

Wan machine blong brekem shell blong Nangai we hemi usum electricity-kava store, Port Vila

Wan manual machine blong brekem shell blong nangai we oli stap usum blong brekem shell blong Macadamia

Rusum Nangai (addemap Value I ko long Nangai)

Taem yumi tekemaot shell long nangai, yumi save kakai nangai(kernel) wetem skin blong hem testa) or sipos no yumi tekem aot skin we I kaveremap hem (testa) mo kakai.Yumi save sakem salt long Nangai mo yumi save rusum blong kivim wan diferen flava mo I kat plante moa wei we yumi save follem blong givim flavour long nangai.

Helen Wallace, Dave Walton mo Bruce Randall bambae oli traem usum ol difdiferen electric drier or machin blong rus we oli stap usum long ol diferen nuts olsem nut blong Macademia. Bambai I kat ol narafala method blong rusum nuts tu we bambae oli mekem trials. long hem long NARI research station.

5. Fasin blong packagem Nangai or fulumap Nangai

Helen Wallace, Dave Walton mo Bruce Randall bambae oli lukluk tu long ol diferen kaen we we yumi save packagem ol processed Nangai long Papua New Guinea mo Vanuatu.

Photo we I stap antap mo daon hemi shoem fasin we yumi long Vanuatu yumi stap fulumap or packagem ol processed nuts mo ready blong salem.

Seremaot save long saed blong ol trials blong processing

Dr Jennifer Carter mo Colin Bunt bambai oli holem ol wokshops long Vanuatu mo long NARI long Papua New Guinea blong toktok long ol famas mo ol processors long saed blong sam fasin blong follem blong processem Nangai.

Bambai oli glad blong harem ol storian mo ol tingting blong ol famas mo ol processors long ol needs blong olgeta mo semtaem harem tingting blong olgeta long olgeta problems we I stap abaot method we ol scientists oli developem blong yumi usum.

Discussion blong ol methods ia bambae hemi helpem yumi bigwan blong sortem aot ol problem we might yumi save kasem taem yumi stap kohed blong usum ol methods ia mo discussion ia bambae hemi save helpem yumi blong givim sam narafala suggestions or ideas long method we yumi ting se I gud blong follem.

Bambai hemi helpem ol researchers tu blong oli fainem mo follem wan rod we I stret long tingting blong ol bisnis man, ol local village or fasin blong yumi

Ol staff blong Department blong forestry long Vanuatu mo NARI long PNG bambai oli save providem training iko long ol local staff, wetem sam smol trening long ol examples long ol processing methods we Helen Wallace, Dave Walton mo Bruce Randall oli developem.

Bambai behaen olgeta we oli kasem ol trening ia bambai oli save ko trenem ol narafala man long ol vilij or narafala ples blong wok mo usum ol niufala methods ia.

8

Contact details blong olgeta man we yu save contactem olgeta blong kasem sam moa information abaot project blong Nangai:

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11.11 Appendix 11: Awareness raising brochure (Newsletter 2)

Newsletter 2 - September 2009

Workshop discussions:

- Mr Ioan Viji (DOFV) - canarium plantings
- Dr Jennifer Carter (USC Research Co-investigator) - update on processing research
- Mr Colin Bunt (USC Consultant) - marketing potential for Nangai
- Richard Pauku (USC Consultant) - growing and marketing canarium in the Solomons
- Rural development and local supply chain - co-ordinating rural industry planning and strategy development
- Formation of Vanuatu-Solomon Islands Canarium Industry Association

Workshops to raise awareness about the ACIAR research project: *Processing of Canarium indicum nuts: adapting and refining techniques to benefit farmers in the South Pacific,* were held on Santo and Malekula from 31st March to 3rd April 2009. Participants included representatives of Vanuatu Department of Forests and Department of Agriculture, Chief Executive Officer of Vanuatu Agricultural College, local councillors, growers, processors, and ACIAR research team from the University of Sunshine Coast, Australia.

Graham Sele (from Tangoa Island, South Santo), Litu Sikala (from Narango) and Joseph Tungon (Department of Forests, Port Vila)

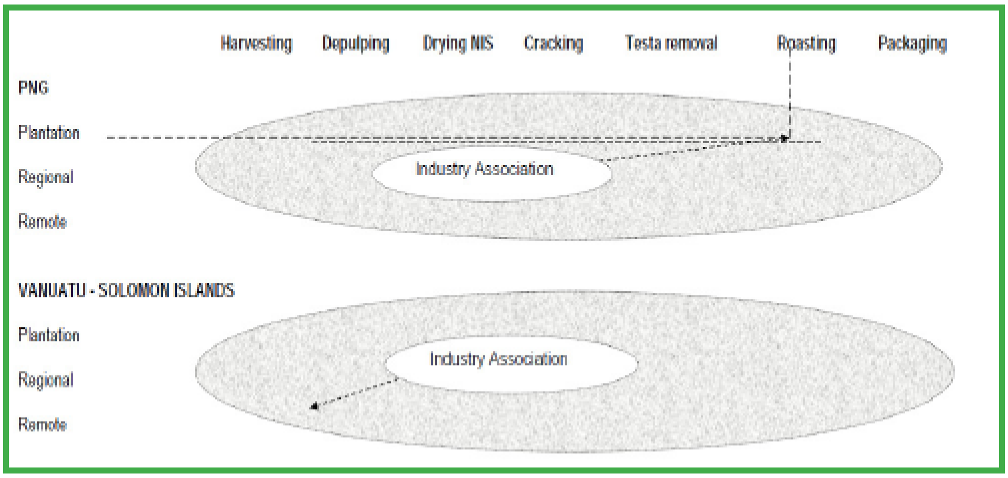
Mrs. Wendy Tomker (Secretary, Department of Forests) and Mrs. Glera Toa (Secretary, Santo Agriculture College) helped with workshop arrangements.

Kilbert Nangri (Farmer, Labultamata, North Pencecost) and Peter Napuat (Vanuatu Agricultural College) discuss marketing with Colin Bunt (USC Consultant)

Alan Vira (Forest officer, Santo) Ioan Viji (PFO Technical), Godfrey Daruhi (Social and Economic Planner, Penama province) Peter Kumi (Tasiriki farmer, SW Santo), Kasen Alick (Forest officer, Sola Vanualava), Rexon Vira (Representative of farmers West Ambae) Dr Jennifer Carter (USC project leader)

Dr Jennifer Carter (USC project co-investigator) talked about post harvest processing of Canarium (Nangai) within the wider social context in which industry development is taking place. On the basis of her analysis, Dr Carter suggested that a governance structure was necessary to co-ordinate further development.

Finally, a conceptual model of a staged approach to processing that might be coordinated by an agent (see below) was presented for discussion.



The key points when implementing community participation in processing according to this model are to:

- consider which stages of the processing will work best in what context (e.g. central or plantation scale, regional scale, or local scale).
- consider the need for a middleman/agent or structure who can coordinate stages of the processing at these different locales and scales, and, with training and certification, can ultimately monitor and control quality, ensuring consistency of product.

Some low-cost technology and solutions that do not require high infrastructure costs were discussed (e.g. solar powered rather than conventional electricity sources or a cheap electric dehydrator).

Santo Workshop participants inspect an electric dehydrator during the lunch break.

Page 2

Other processing issues discussed included:

- Cracking methods (reported as causing injuries and damaging nuts)
- The need for cracked nuts to be processed within 24 hrs (nuts received at central processing units are sometimes rejected because they are too wet or too dry)
- Driers (these are seen as expensive to buy and not able to be maintained due to lack of spare parts)

A low cost hand operated nutcracker developed for the plantation industry in PNG was demonstrated. Some of these crackers have been left at DOFV offices on Efate, Malakula and Espiritu Santo for further trial and comment as growers and government staff interact.

The TJ nutcracker (pictured above)

A wide jaw version of the TJ nutcracker (pictured above) can be used for different sizes of Nangai (another piece of jaw can be screwed in for smaller nuts)

Christian Frank (Farmer, Port Olry East Santo), Ken Selerong (Farmer, Nambauk, South East Santo) and Willie Johnson (Farmer, Pelmoli, South West Santo) talking about the potential for using the TJ nutcracker in Vanuatu.

Comments on TJ nutcracker

Cracking is not a problem in Vanuatu.

Traditional methods are fast and easy.

Previously developed crackers have made no difference.

The design of the TJ Nutcracker enabled it to be used as a left handed cracker if the lever were turned the other way.

If either sized jaw was a movable slide jaw rather than a screwed jaw, it could be more adjustable for different sized nuts.

There was concern that the materials it was made of might bend with wear and tear, or that people working under constant pressure might experience fatigue. To avoid this, if a spring loaded lever could be mounted, and the pressure required to crack nuts calculated using an equation, the lever would release when the shell starts to give.

Any new technologies developed for Canarium indicum chould have their use for other species considered.

There was some discussion around whether traditional cracking methods suggest nuts should be stood on their base and cracked at the point, but later comments revealed this did not matter.

By working with and learning from growers in this way, the USC research team will refine post harvest technology to suit local conditions that will meet quality standards important for building the Nangai Industry. It will also be important to build strong links and trust between growers, processors and buyers as part of industry development.

In the past, growers sending Nangai to Pt Vila from Santo, Malakula or other islands have found that transport between the islands is expensive and not always reliable. The USC research team will develop different participatory models for processing and marketing that will suit growers and local conditions. However, the success of any of these models will require co-operation between growers, processors, institutions and the private sector at every step of the way.

Mr Colin Bunt (USC marketing consultant) discussed these and many other issues that affect marketing at a local and export scale. Charles Long Wah has already established a strong market demand for Nangai in Pt Vila linked to tourism. Colin suggested that growers had a lot to gain if they could fine tune domestic industry linkages before looking to markets overseas.

To compete with other nut industries that are already well established in the international market place, the Nangai industry could develop a niche marketing advantage of being a soft nut.

The industry could also look at other ways to process Nangai to increase marketing opportunities.

Canarium oil in cosmetics

Value added Canarium (Pili) in Asia

Nangai as a food ingredient

Colin Bunt's advice was appreciated by the growers as past experiences with marketing had left some growers concerned about the most suitable market for their Nangai.

Dr Richard Pauku from the Solomon Islands has been developing his own small scale Canarium (Ngali) business. Richard shared his experiences in doing this and explained the different ways he purchases, processes and market nuts locally in the Solomons.

Richard's buyers are community based officers (CBO's) who are already known to the growers. These CBO's only buy nuts that meet a quality standard required for the local market in the Solomons.

Richard Pauku (Solomons) and Toufau Kalsakau (Forest Officer, Malekula) compare packaged Ngali nuts to Nangai packaged at the factory.

At the Malekula workshop, Mr Bruce Hannent spoke about his experiences in his first season in 2008 as a buyer and processor based on Malekula. In particular he found that inconsistent information about marketing and processing made it difficult for him and the growers. His comments showed the importance of processors working together so that they and growers can both benefit.

Malekula workshop participants acepted Mr Bruce Hannent's invitation to find out more about his methods of processing Nangai at his "nuts n' oils" factory at Lakatoro.

If purchasing, processing standards and supply arrangements can be co-ordinated Nangai oil can be used in soap products, and the shell waste bagged for sale.

Key needs and recommendations from the workshops

1. Establish a Vanuatu-Solomon Islands Canarium Industry Association. The government is currently writing a rural planning strategy and this multi-pronged industry/product structure will be part of that initiative, particularly to coordinate quality control and marketing.

2. Continue with rural planning, through representatives of government and international partners to commence planning the Industry Association and Canarium Industry Development Strategy.

3. Include an emphasis on education and training. All participants stressed the importance of regularly receiving information, the role of the newsletter, and the importance of continuing to work together across sectors and regions.

4. Strategies might include some ideas from this meeting, including:

☐ Use dualistic processing – hybrids of traditional and technological processing. Use traditional methods, and introduce technology that value adds these but that also suits each variety and different marketing products .

☐ Target the domestic market firstly, with new products, as processing systems are put in place over the long term to ensure consistency and quality.

☐ Explore links between the Vanuatu Agricultural College and other educators e.g. USP, USC and/or FAO for curriculum design with Dr Pauku as a trainer.

☐ Explore appropriate training for community based officers or associations in quality control, but there may be no single training manual suitable.

☐ Use case study learning of other industries and other regions, e.g. vanilla, pine nuts, Australian Native foods and CEMA (learn from the successes - prevent the mistakes).

☐ Consider current nucleus estate models of participation and extension.

☐ Have multiple products and piggyback these for transport and other economies of scale.

☐ Maintain crop diversity.

☐ Develop regulations, conduct inspections and monitoring.

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Ioan Viji provided an update of the progress made with plantings by the Department of Forests. In 2000, DOFV distributed and planted 8000 selected Nangai seedlings in Vanuatu. An average of 1000 more seedlings per year were planted between 2001 and 2008. All this work has been done to establish a good supply of quality trees so the Nangai Industry can grow.

Growers can also add to their number of trees by learning how to produce plants that are genetically identical to their selected parent plant. Some of these methods include: grafting, budding, cuttings, air-layering and micropropagation. In his talk to the workshop Dr Richard Pauku spoke about how he and others are training growers to do this in the Solomons. Growers have also been shown how to build and use a low cost poly-propagator that provides a protective environment to grow the new plants. The photos below show these activities in the Solomons.

Building the frame for the poly-propagator.

Being shown how to marcot.

Page 7

Canarium germination bed with newly germinated plants

Agroforestry farming (Canarium & Sandalwood) Efate - woodlot training for trainers

Page 8

Santo Agricultural College

The University of the Sunshine Coast researchers wish to thank the workshop hosts on Santo and Malekula, the Department of Forestry officers, and participants at the workshops. Your hospitality and willingness to share ideas created a pleasant and collaborative environment. By joining hands together we are hopeful for a brighter future for the Nangai industry.

Lakatoro Community Centre, Malekula

For more information:

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University of Sunshine Coast:

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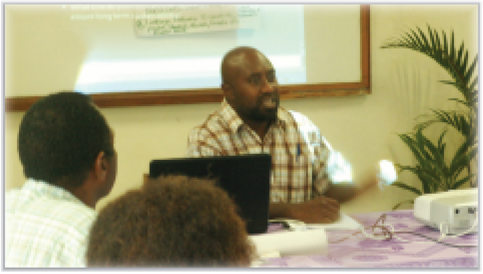
11.12 Appendix 12: Awareness raising brochure (Newsletter 3)

NANGAI NEWS

Newsletter 3 - April 2010



Summary of Canarium Industry development workshop activities at Tagabe Agricultural College, Port Vila, Vanuatu 7th - 9th April, 2010. Participants included growers, processors, government and researchers from Vanuatu, Australia, Papua New Guinea and Solomon Islands.

FORMAL PRESENTATIONS

Dr Helen Wallace and Dr Jennifer Carter, University of Sunshine Coast (USC) - Update on progress on Canarium processing project

Dr Wallace described 3 different processing methods used in Vanuatu, the Solomons and Papua New Guinea (PNG). She explained how important it is to make sure quality of the nut is not lost in the processing chain (when depulping, drying, cracking, removing testa, roasting and packaging).

Dr Carter spoke about the first Canarium Industry awareness raising workshop in Vanuatu in 2009, where delegates discussed a staged processing model. This model suggests different steps of processing occur in different locations. An industry body could use this processing model and co-ordinate the quality of the product, training and certification, and other aspects of the industry.

Dr John Moxon & Mr Matthew Poineau, National Agricultural Research Institute (NARI) PNG

Dr Moxon explained that Canarium nut has been chosen as an alternative cash crop to Cocoa in PNG. Canarium can be grown for shade along with other crops such as cocoa, coffee, pepper, vanilla, and kava. He explained NARI's tree domestication and grower extension programs and talked about the processing methods they are developing. He is testing whether it is possible for buyers to purchase nuts in pulp, which will make it easier for buyers to collect from farmers at remote localities. An interim Canarium Association has been set up in PNG.

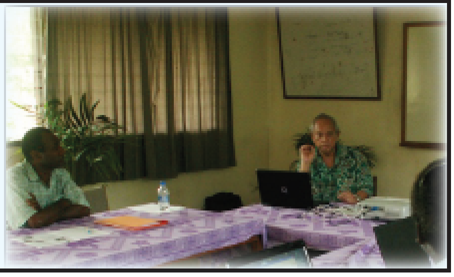
Mr Matthew Poineau explained that the drying temperature is not easily controlled in solar technologies so they are trialling other drying methods and hope to have some ideas and low cost technology available shortly.

FORMAL PRESENTATIONS

Mr Charles Long Wah - Canarium Industry update

Mr Long Wah explained his processing method and his desire for more processing centres throughout Vanuatu.

He wants to buy more product from growers, but he understands they can't always get their produce to him for many reasons. He suggested transporting their produce with other products to make it worthwhile.



Mr Ioan Viji - Department of Forests (DoF) - Nangai Development in Vanuatu

Mr Viji raised the idea of using a brand or label such as Charles Long Wah's claim that Nangai is "the softest nut in the world". He spoke about institutional interest in a centre to help farmers, but this would need help from the private sector. This centre might provide equipment such as freezers for storage prior to shipment of nuts to Port Vila. He suggested a program for buying and selling products be developed and DoF nominate officers responsible for Canarium.

Mr Joseph Tungon - Department of Forests

Mr Tungon discussed growers' comments about using the manual nut cracker. People were happy that there might be less damage to their fingers, but thought traditional methods were more cost effective and preferred by the older people.

Mr Tungon also reported on some new Nangai products appearing in the market, and there were further discussions around improving the cracking technique.

Mrs Votausi Mackenzie-Reur - Local processing experience

Mrs Mackenzie-Reur described the Lapita Cafe's experiences with product development. She has developed gluten free products made with Nangai nut for particular markets. She is also working on a recipe book to promote and sell the kernel.

She explained that food certification is difficult for small businesses with limited resources. The export market is difficult to predict because of currency fluctuation. A useful strategy is exchange visits between growers and processors so each can better understand the needs of the other.

Mr Kim Jones - Establishing a Rural Farmers Network in Macadamia Nuts

Mr Jones explained that the Macadamia Association in Australia is paid for by a levy on growers, matched dollar for dollar by the government, plus income from advertising in the association newsletter and an annual conference. The levies pay for market research.

Their association, rather than processors, developed industry standards with different grades to pay growers. Soon they will have an international body to deal with food standards.

Mr Colin Bunt - Processing and marketing in the region

Mr Bunt reminded participants that industry organisations need to have good links with nut importers in other countries because the global food industry is dominated by a few very large companies. A marketing strategy shows an importer why your product is better than another.

Fair Trade is one growing market to think about. Importing countries have tariffs and legislation that must be taken into account.

FORMAL PRESENTATIONS

Mr Francois Japiot - Department of Agriculture and Rural Development (DARD)

Mr Japiot spoke about the Canarium development plan drafted by DARD. Part of this plan is that the Department of Forests (DOF) and DARD will help to raise industry awareness and run training workshops in nursery and production.

The Vanuatu government would like to have primary processing centres operating on Efate, Santo and Malkekula, but will need to do this in partnership with non government investors.

Mr Joel Kalpal - Malekula Farmers' Cooperative Association - Experience with Canarium Marketing

Mr Kalpal explained that the Malekula Farmers' Cooperative Association is linked with local growers, as a larger scale operation is risky at the start. The association needs help with equipment, labelling and packaging nuts within the domestic market to make sure it is operating smoothly. Government assistance to set up trading agreements between governments will be needed later.

TRAINING

Dr Richard Pauku - Traditional processing

Dr Richard Pauku talked about traditional ways of processing used in the Solomon Islands, and demonstrated one of these (see photo).

In the Solomon Islands, Nangai (Ngali) nuts are purchased by community groups who sell them to Dr Pauku to process.

Processing depends on the way nuts are purchased (depulped, or as fruit which is depulped later).

The second way takes a lot of work as all stages of processing must occur on the same day.

SMALL GROUP DISCUSSIONS

GROWERS SAID THEY NEEDED:

1. Organisation of growers
2. Collection of data such as tree numbers
3. Development of common standards between growers & processors
4. Markets for different products
5. More extension support
6. Close supervision when planting to maintain quality before harvest
7. Production of information leaflets & posters on pre-harvest standards
8. Development of a concept proposal
9. Help for small growers to brand products
10. National collection networks
11. Cost of equipment in project proposals

PROCESSORS SAID THEY NEEDED:

1. A factory or collection centre
2. Training at the centre
3. Product development
4. Processing, packaging and branding to meet market requirements
5. Marketing assessment
6. Business plan
7. More contact with growers
8. Involvement with suppliers
9. Use PNG technology packages
10. Nangai available all year round
11. A high commodity market
12. Links between Vanuatu, PNG & Solomons

ACTION PLAN

1. **Support and co-ordinate growers organisations.**
2. **Seek funding from donors e.g. Vanuatu Government, PARDI etc.**
3. **Talk to Intellectual property specialist.**
4. **Continue processing standards work in PNG and work with Vanuatu participants about these.**

For Further Information:

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Mr Joseph Tungon, Project officer:	678 23856	Dr Jennifer Carter, Project Leader	61 (7) 54 594496

11.13 Appendix 13: Canarium Processing Research Poster

11.14 Appendix 14: Update on Research Progress

Processing of Canarium indicum nuts: adapting and refining techniques to benefit farmers in the South Pacific

An Australian Centre for International Agriculture Research project
in partnership with Department of Forests, Vanuatu,
National Agricultural Research Institute, Papua New Guinea,
and the University of the Sunshine Coast, Australia

MARCH 2009 UPDATE ON PROGRESS ON RESEARCH

University of Sunshine Coast Research Team:

Faculty of Science, Health and Education:

Dr Helen Wallace, Project Leader

Mr Bruce Randall, Research Officer

Nangai (Canarium) nuts have great potential to be processed and sold in Vanuatu and overseas.

Processing canarium nuts involves removing the pulp, drying, cracking, removing the testa, roasting, packing and storing canarium nuts.

The canarium processing research teams at USC and NARI have been working on finding the best ways to do these steps.

So far, trials have found a very promising hand cracker, and found that canarium nuts are damaged by heat.

When the nut is placed flat-side up the lid pops off the nut easily

Faculty of Arts and Social Sciences

Dr Jennifer Carter, Project Leader

Ms Jenny Austin, Research Officer

PULPING (removing the flesh)

Trials for the best way to do this are still in progress.

We are trying two methods to remove the pulp from the nut in shell.

1. Allowing fruit to rot in piles on the ground
2. Allowing fruit to rot in hessian sacks

Removal of pulp with a knife

Trials conducted at NARI, PNG
Pictured: Matthew Poienou, Research officer, NARI

DRYING NUTS IN SHELL

We have been trialing drying the nuts in shell to reduce moisture content – (When this is done for other types of NIS we know that this helps to stop them spoiling

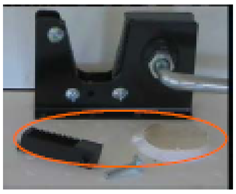
Early results show:

- Nut in shell dried at 60 degrees for 3 days is very brown.
- Nut in shell dried at 40 degrees for 3 days becomes translucent.
- Excessive heat may damage canarium nuts.

Experiments are continuing on heating and drying at NARI and USC.

CRACKING

We have been trialing a TJ's macadamia nut cracker for cracking Canarium at NARI in PNG and at USC in Australia. This cracker comes in two sizes. Early trials show that this is much faster than traditional methods.



The larger-jawed cracker can be made smaller to suit small nuts, with screw and extra Piece for jaw (as pictured)

REMOVING THE TESTA FROM THE KERNEL

Blanching (immersing the Kernel-in-testa in boiling water) for 90 seconds was found to make the testa easier to remove than blanching for 30 or 60 seconds.

11.15 Appendix 15: Galip Information Poster