
Appendix 8.24

**This case study forms part of the overarching
2017–19 ACIAR Mango Agribusiness Research Program**

Project: Agribusiness research and development opportunities for tropical fruit processing in the Asia-Pacific region

Project number: AGB/2016/010

Date: 30 October 2019

Prepared by: Robin Roberts, Richard Beyer
Griffith University



Australian Government
**Australian Centre for
International Agricultural Research**



Contents

1	Acknowledgements	1
2	Case summary	1
3	Introduction	3
3.1	Project background	4
3.2	Study objectives	5
3.3	Study methodology	5
4	Tropical fruit processing in the Asia-Pacific region	7
4.1	Asia-Pacific	7
4.2	Australia	13
5	Opportunities and constraints	17
5.1	Cross-cutting issues	17
5.2	Challenges for the tropical fruit processing sector	19
6	Conclusion and recommendations	20
6.1	Conclusion	20
6.2	Recommendations	20
7	References	21

Disclaimer

This publication is published by ACIAR and Griffith University. Care is taken to ensure the accuracy of the information contained in this publication. However, ACIAR cannot accept responsibility for the accuracy or completeness of the information or opinions contained in this publication. You should make your own enquiries before making decisions concerning your interests.

© Australian Centre for International Agricultural Research (ACIAR) and Griffith University 2019. This work is copyright. Apart from any use permitted under the *Copyright Act 1968*, no part may be reproduced by any process without prior written permission from Griffith University, 170 Kessels Road, Nathan Qld 4111.

1 Acknowledgements

This study report for the Tropical Fruit Processing project was prepared by Richard Beyer, and Robin Roberts, Griffith University. The information and recommendations provided in this study inform ACIAR in order to direct longer-term research and development programs for processing of tropical fruit, principally mangoes in Australia and selected South-East Asian countries. Thanks to the members of the reference group – Evi Iriani, Suliyanti Hakim, Ahmad Dimiyati, and Samantha Frolov (Australian Mango Industry Association) – for your assistance.

2 Case summary

Market success depends on quality, safety, consistency and value for money. Within the fruit and vegetable industries, fresh produce is always the coveted outcome; however, quality maintenance is not always possible. Processing enables quality to be stabilised and, with appropriate manufacturing procedures, product consistency can be assured. This study recognises that processing can protect and enhance market demand by meeting quality expectations and consistency, and that other issues can be addressed, including the use of substandard fruit, trimmings, and waste. Processing has a major influence on return for effort for chain members, which, in turn, delivers significant benefit to the sector and to mango fruit growers.

Of all candidate crops for fruit research, mangoes are among the most promising. This is due to their unique flavour characteristics and the fact that growing conditions in Australia and South-East Asia make these regions suitable locations for efficient cultivation. In addition, there is an assured and expanding market for mango and mango products. However, the short season hinders profitable processing because expensive equipment may lie idle for much of the year, which threatens financial viability. Other ACIAR projects have identified market trends and have also centred on season extension through flower induction and raw material stabilisation at harvest. Such projects contribute to the overall effort to enhance this sector.

Fresh mangoes continue to dominate the market, given that processed products cannot match their flavour and texture. However, cuts of high-quality mangoes (including cheeks, cubes and spears) command high prices when correctly frozen, particularly in temperate country markets. Processing can be based on substandard fruit and blemishes can be removed by trimming and sorting – a strategy that can lessen wastage. The resulting range of mango-based products now has a regular presence in the processed-fruit industry. Aligned to this opportunity, the objectives of this project were to identify the market situations and trends where possible, and to identify issues, innovations, constraints and opportunities in selected South-East Asian countries and Australia.

Two workshops were conducted in order to gain insight into these objectives. The first was held in Bali, Indonesia, and was attended by processors, researchers and marketers from Indonesia, the Philippines, Vietnam, Pakistan, China and Australia. The second workshop was held in Brisbane, Australia, and included 34 delegates from around Australia who discussed issues relating to fruit processing.

Successful processing is predicated on the adequate supply of raw materials of the appropriate quality, as well as technology to effect necessary product changes to attract markets. A continuum of research and development is imperative to maintain market edge and production efficiency. The workshops were designed to facilitate sharing of recent advances in product innovation as well as institutional research, which, in some cases, was supported by government policies.

Study themes

Mango supply and the value chain

An understanding of the value chain emerged as an important issue for all sectors of the industry. Processors are hindered by seasonality and limited supplies, and a full understanding of supply overabundance and scarcity is essential for efficient use of equipment. Good communication is imperative in this endeavour. At the same time, an in-depth understanding of market preferences and a detailed awareness of the constraints and successes of chain partners are essential.

Optimising value

The use of substandard fruit for the processing of products based on comminuted mango flesh such as pulp, puree, juices, fruit leather and jams is well known. Several novel products (not necessarily using modern techniques) and innovations have emerged from micro-operators.

Waste

Waste occurs prior to harvest as well as throughout the chain, all the way to the consumer. Waste figures are difficult to quantify, but estimates put them at between 18% and 40%. In some cases, underdeveloped fruit on the tree may be utilised for local products but may not be extended to larger markets.

New technologies

Food processing techniques are constantly evolving. Low-temperature, high-pressure pasteurisation for improved flavour and vitamin retention are favoured by nutrition-conscious markets and sectors such as fruit snack food products.

Nutritional advantages

Many target markets are focusing on healthy food and drink options and avoiding the use of sugary drinks (in which large quantities of sugar are commonly added). Mango is a naturally sweet food with a wide range of saccharides, which contributes to its moderate glycaemic index ranking (50%). The spectrum of nutrients found in mangoes is consistent with modern views on healthy eating.

By-products

During the processing of mangoes, peel and stone are generated as waste (40–50% of total fruit weight). Oil from mangoes is now finding a place in the cosmetic industry, alongside stones and skins.

Standards and specifications

Participants at both workshops voiced concerns in relation to sourcing market intelligence, appropriate technologies, and standards and specifications. Safety management techniques are now entrenched; however, opportunities to improve information highways have emerged and are recommended.

3 Introduction

Australia has partnered international mango research with industry development since 1982. ACIAR has supported almost 40 mango studies in 11 countries, including Cambodia, China, Fiji, Indonesia, Laos, Malaysia, Pakistan, Papua New Guinea, the Philippines, Thailand and Vietnam. ACIAR responds to national priorities identified using in-country consultations and this approach has confirmed the importance of mango as a source of livelihoods, especially for smallholder farmers. This project differs from previous strategies in that it focuses on the role processing can play to maximise return for effort for smallholder farmers and multinational companies. The setting for both workshops was conducive to interaction between participants, whereby successes and concerns could be shared. Increased dialogue between value chain participants in this project has enabled common obstacles to be identified; further research and investigation may provide a pathway to overcoming productivity impediments.

Marketing of fresh fruits and vegetables is the aim of all horticultural industries, and value chains are constructed in order to achieve this objective. Geographic location, suboptimal infrastructure and extended distribution lines throughout Australia and many South-East Asian countries require that value chains consider delays that threaten fresh fruit quality. For this reason, chains that specifically include processing are now commonplace within Australia and South-East Asian countries. Processing usually in-builds preservation; hence, the pressure associated with moving fresh products quickly is avoided.

Fruit processing has numerous important roles. Many of the attractive qualities of fruits can be conserved using modern, sophisticated preserving techniques such as individual quick freezing (IQF). At the same time, many products that are processed in depth are now institutionalised and enjoy enduring markets.

Mangoes are particularly good candidates for processing since the characteristic flavour withstands the steps associated with preservation. As such, processed mango products retain their appeal. IQF cheeks, spears and cubes produced using high-quality fresh mangoes can command high prices in temperate country markets.

In order for mango processing to be sustainable, three elements are essential:

1. Adequate supply of (quality) raw material

Mangoes are a seasonal crop, although recent interventions directed at out-of-season flowering may help to alleviate the seasonality issue. Many gains have been reported with regard to tackling losses by retarding spoilage through crop stabilisation and correct handling; however, until flowering has been perfected farmers will generally be reluctant to rely on mangoes alone for their income and food security because they do not want expensive facilities and equipment to lie idle. In some countries, mango varieties mature sequentially over several months thereby extending availability. In regions where mango variety selection is more conservative, processors often rely on alternative fruits for continuous operation.

Farms in more developed nations such as the Philippines, Indonesia and Australia are larger and supply pathways are well established, which ensures minimal delays where infrastructure permits.

2. Technology to build features that appeal to consumers

Many processed mango products are well known. Frozen cubes and cheeks, jams, juices, purees and confections are now commonplace in product development programs. This is a safe strategy given this technology is widely known and consumers are familiar with these products.

The emergence of newer technologies such as high-pressure food-preservation (HHP, high hydrostatics pressure) are delivering an exciting new range of products in both Australia and throughout Asia. Consumers are attracted to these products for their

novelty, but health-conscious consumers are also attracted by the maintenance of nutrient levels that modern techniques ensure.

3. Markets

When considering the food category relevant to mangoes (i.e. guava, mango and mangosteen), global production of this fruit has grown in recent years. In 2013, 43,300,000 tonnes of mangoes were produced, which is 24% more than the total for 2009. International trade in fresh mangoes will amount to an estimated USD1.8 million in 2029, representing a moderate but constant growth in worldwide trade in mangoes (UN Comtrade, 2014). Processing is linked to total production because return for effort provides chain partners with income-generating opportunities through loss reduction and access to lucrative remote markets.

Markets awareness has been the subject of many ACIAR projects (ACIAR AGB/2015/015) for standard products that are well understood. Findings indicate the new market-based products that are prepared using new technologies or new varieties that have clearly differentiated features require significant support to encourage consumer awareness.

3.1 Project background

The global competitiveness of agricultural produce can be considerably enhanced by utilising appropriate technologies to produce high-quality processed foods. Research that focuses particularly on processing equipment, product design and packaging has informed the development of new food products. Typically, tropical fruits have had an excellent record of introduction to the world market because of their exotic flavours. When processed into puree, juice, nectar or dried fruit slices, they can be shipped long distances with only minimal changes in quality. IQF cuts of fruits that have excellent quality features on thawing are now commonplace among online marketers.

The popularity of fruit can be attributed, in part, to consumer perception of their health benefits. Many consumers are now looking for healthy alternatives to carbonated beverages and fruit-flavoured drinks prepared from fruit syrups, which are so refined that the all micronutrients have been removed prior to blending. The availability of natural fruit juices derived from fresh fruits is a welcome alternative to synthetic compounded beverages that are marketed as fruit juices. Most fruits (including mango) are rich in dietary fibre and phytonutrients (especially antioxidants) and have no cholesterol. Mangoes are sufficiently sweet that they do not require additional sugar in the final formulations. This is especially relevant given that 21 locations (of which 14 are countries, including Australia) have now imposed a sugar or sugary drinks tax (Malik et al., 2016). Mango drinks can compete without the need for sweetening additives.

Mangoes are now well established as a highly desirable fruit for consumption in both fresh and processed forms (ACIAR AGB/2015/015). The commercial prospects were reported as being favourable since Australia and most South-East Asian countries have indicated a commitment to increased planting and to addressing value adding and waste mitigation through processing, (Pacific ACIAR: AGB/2015/015 (2016); Future Mango Insights: REP-GB-5695 (2017)). This trend was confirmed at the country level by delegates at the processing workshops. This project provided a forum that enabled participants and ACIAR to assess the prospects for the industry. At the same time, the project recognises that the setting in which processors operate throughout Australia and the represented South-East Asian nations are diverse and are influenced by a wide variety of impediments and restrictions.

3.2 Study objectives

The aim of this project was to identify the latest issues, constraints and opportunities influencing the viability and profitability of mango fruit processing in Australia and selected South-East Asian countries. By organising two stakeholder workshops, the SRA sought to garner ideas from as wide a range of processors as possible, especially those with proven track records in technological innovation and market acceptance.

The objectives of the SRA were to:

1. Identify the current market situation and trends affecting the fruit processing sector across selected case study countries in South-East Asia, with a specific emphasis on issues, innovations, constraints and opportunities relevant to the mango sector.
2. Identify the current market situation and trends affecting the fruit processing sector across selected case study countries in Australia, with a specific emphasis on issues, innovations, constraints and opportunities relevant to the mango sector.
3. Identify research and innovation opportunities (in either basic or applied research) for development that would deliver significant benefits to the mango processing sector and mango fruit growers.

3.3 Study methodology

The approach adopted was to draw together a range of stakeholders with the widest possible span of practices relevant to all stages in the mango supply chain and to encourage dialogue and cross-referencing of experiences. This dialogue took the form of two workshops: one held in Indonesia and the other in Australia. The two workshops encouraged information sharing that was facilitated by carefully selected presenters who were representative of the range of disciplines and locations.

The first workshop was held in Sanur, Indonesia, in November 2018 and was attended by 45 delegates from Pakistan, China, the Philippines, Vietnam, Indonesia and Australia. The second workshop was held in Brisbane, Australia, in February 2019 and was attended by 37 delegates. During this workshop, 14 presentations covering supply, processing, marketing and product development were given.

Prior to the workshops, participants' preferred topics were established through online discussion. During the workshops, along with formal presentations, participants were asked to highlight the most important tropical fruit processing issues in their regions by participating in table-talk activities and facilitator-led discussions. Case studies, panel discussions and working groups served to gather contributions from all participants. The presentation results were reviewed and are presented within this report, along with conclusions and recommendations.

Research design

This SRA centred on the collection of data that could be used to inform a strategy to advance the sector in the selected South-East Asian countries and Australia. Participant experiences were captured and discussed during the workshop sessions. Within the constraints of commercial confidentiality, private sector organisations were able to share their knowledge, ranging from meeting consumer expectations to improving profitability of their operations.

During the workshops, enterprises were given a forum to share operational constraints, which ranged from raw material supply to situational issues such as government involvement and infrastructural shortcomings, access to market intelligence, and research and development. Working groups in both workshops were used to garner collective views from all corners of the mango industry across country borders, technologies and markets. The issues were ranked according to delegates' priorities. The workshop environments encouraged dialogue about experiences that had been used to increase returns

throughout supply chains in all participating nations. Constraints to growth and sustainability were logged and assembled, and future directions were planned.

Data collection

The success of this SRA depended on the effective collection of data and marshalling of this information to determine the direction of future effort. All presentations were recorded and the overall themes established. The workshops encouraged comprehensive information exchange in an informal setting, with nominated spokespersons who distilled and recorded the deliberations of each working group.

The frequency with which some matters were discussed during the two workshops was noted (see Table 1). This data represents the scope of the issues but not necessarily the gravity of each topic. All presentations given at the workshops have been recorded on the Asia Pacific Mango Network website for use as ongoing reference material.

Table 1. Common issues in Australia and South-East Asian countries

Issues raised in both workshops Topic	Number of mentions	
	Australia	South-East Asian countries
Collaboration with similar organisations for synergy in processing development	17	4
Assistance meeting standards for local and international trade	16	5
Market intelligence	29	16
Assistance with research and development	38	21
Raw material sourcing	9	10
Assistance with appropriate government policies development	7	14
Awareness of the value chain	10	12
Raw material varieties and availability	6	12
Extension support	1	8
Packaging design and functionality and labelling	7	1
Access to finance	10	

Source: *author's analysis*

Study limitations

Every effort was made to ensure that key researchers, policy-makers and processing professionals were included in the workshops in order to attain representative views. While it is accepted that these views may not represent the entire sector, overall the workshops were a valuable illustration of practical progressions.

The workshops were limited to a day and a half, and discussion length was restrained due to time allocations. The round-table sessions and the conversation groups were excellent forums for exchange of ideas. Although every effort was made to ensure that views were comprehensive, limits to resources meant that the selection of participants was constrained, with the inescapable possibility that some ideas may have been missed. The experiences of many of the Australian representatives related to fruits similar to mangoes rather than specifically to mango. However, given that there was continuity in the views

and experiences, the workshop findings can be extrapolated to the mango sector with some confidence.

4 Tropical fruit processing in the Asia-Pacific region

Fresh mango supply chains suffer high losses, not only at farm level but also during distribution and marketing. Processing in one form or another is an important tactic for optimising return for effort for all chain partners, especially farmers. In the Asia-Pacific region, there is a wide spectrum of processing activities driven by supply and consumer preferences. Large mango-producing nations such as India, Thailand and the Philippines have many options for processing. For instance, multinational companies can invest in multi-use technologies to stabilise fruit quality during a seasonal glut and make optimum use of equipment by processing a number of different fruits. Juices, purees, canned mangoes in syrup, and frozen cheeks, cubes and spears make up over 90% of the total range of processed mango products.

The influence of Thailand as the third-largest mango producer in the world cannot be overlooked. In 2016, Thailand produced 3.4 million tonnes of mangoes. Although the production volumes are large, only about 2% of the fresh fruit is exported to the regional countries of South Korea, China, Japan, Malaysia and Singapore. However, recent Thai government initiatives to increase processing are likely to affect the world's processed mango industry (Chan, 2015).

With the exception of Indonesia, mango processing is much smaller among participating nations in comparison to India. However, globally the problem of losses due to spoilage and pre- and post-harvest practices encourages maximisation of product value through processing. The workshops highlighted some exciting novel products and techniques that warrant exposure for adaptation throughout the sector.

4.1 Asia-Pacific

From the presentations and dialogue at the workshops, it is apparent that the processing imperative for South-East Asian nations and Australia are nation-specific and are driven by the relative size of each mango industry and their markets; the returns for inputs; and specific, overarching policy frameworks and markets. This section makes general observations based on the cross-cutting themes, but also summarises country reports for completeness.

China

The China delegate reported that Chinese agriculture focuses on investment in grain and animal production, with increases in fruits and vegetables mirroring the rise in GDP and living standards. In 2012, 148,400 ha were devoted to mango production, which represented a year-on-year increase of approximately 6% (2009–12) (China Agriculture Year Book, 2015). China (including Taiwan) is the second-largest mango producer in the world, with a total crop of 4.77 million tonnes per annum. Major importers of Chinese mangoes include Russia, Japan and South Korea.

Indonesia

Indonesia is currently ranked fifth among mango producers; however, mangoes are not a priority crop for the Indonesian government at present. Most of the produce is consumed fresh by the local population, which restricts supplies for processing. Processing activity is emerging slowly but is further hampered by minimal processing expertise. It was reported that there is currently very little institutional support for processing mangoes. However, under the auspices of the International Conference on Agricultural Policies and Rural

Development (ICAPRD), laboratory-scale samples of mango puree, juice, vacuum-fried snacks, dodol and freeze-dried products have been prepared. Furthermore, at the workshop it was evident small enterprises have begun to engage with modern techniques, and there were displays of low-pressure fried mango snacks of international quality and air-dried mango of desirable quality. Low labour costs and extensive land availability provide opportunities for expansion of the industry.

The Philippines

The Philippines is currently ranked seventh among world producers of mango, with an annual production of 827,075 tonnes. World ranking has dropped from fifth in 2015 due, in part, to dated production and harvesting techniques, as well as poor orchard management leading to a decline in farm yields. Fresh mango exports have also been constrained by the failure to meet strict sanitary and phytosanitary (SPS) requirements in key markets. Among the leading importers of fresh and processed Philippine mangoes are Japan, Hong Kong, Singapore, Canada and the United States. Globally, Philippine mango exports of fresh and processed products ranked eleventh, with a value of USD91 million; this is equivalent to 4% share of the global market, with exports destined for 48 countries (UN Comtrade, 2014). Commercially, important processing techniques include canning in syrup (22%), dehydration (16%), puree (18%) and mango puree (6%) which are championed by the large multinational corporations Dole and Del Monte. However, a plethora of small to medium sized enterprises (SMEs) exist, located principally around metro Manila and Cebu. The processing sector is underpinned by active product development programs both from the private sector and the government through the Food and Processing Innovation Centre within the Department of Science and Technology.

Pakistan

Pakistan is the sixth largest mango-producing country, with a production of 1,606,091 tonnes in 2018. Mango losses of 40% caused by poor farming practices, poor post-harvest handling and distribution delays due to modest infrastructure handicap the industry. Technology development has been slow. The private sector accounts for all processing activity, ranging from producing standard lines from IQF cheeks and cubes through to chutneys, jams and dried strips. The significant processors – for example, Shezan International Ltd., Benz Industries Ltd., Mitchells Fruit Farms, Indus Fruit Products, Ahmad Food Industries Ltd. – account for approximately 16,000 tonnes annually.

A great deal of effort is directed towards addressing waste. In rural areas, underripe fruit has been a significant target because it can be harvested before it is completely ripe, and thus prior to infestation and further harvesting and transport losses. Products gaining prominence (particularly arising from SMEs) include unripe mango slices, dried peel slices and powder from unripe fruit, mango pickle and chutneys, and salted underripe mango for further processing at the end of the fresh season. Recent efforts have been directed towards using stones for oil extraction, fermented products (including fermented alcoholic and yoghurt-type products, or lactic fermentation), and using substandard and underripe fruit, and flesh adhering to stones after mainstream processing.

Vietnam

Fruit and vegetable production is undergoing a significant growth phase, as evidenced by export values in the sector increasing by approximately 15% over the past four years. During 2017, the total area devoted to mango production was 84,500 ha, which produced 929,300 tonnes per annum – mainly in the south-east of the country, including the Mekong Delta. In 2012, Vietnam's official exports were 4,870 tonnes, which is equivalent to just 0.3% of national production. A more realistic estimate suggests that exports are in the order of 30,000 to 50,000 tonnes per year, mostly as informal exports overland to China. At these levels, exports account for 4–6% of production. This also implies that China imports about 90–95% of Vietnam's mango exports. Other markets include South Korea, Hong Kong, Canada and the United Arab Emirates.

There is government optimism about the mango processing activity in Vietnam based on a tangible investment in facilities, including previously single-product factories such as a water-bottling factory that has recently increased market scope to use its full range of technologies to expand to mango juice, purees and preserves. The benefit of the industry in terms of improving farmer livelihoods is the subject of ACIAR Project: 'Improving smallholder farmer incomes through strategic market development in mango supply chains in southern Vietnam' (AGB/2012/061).

4.1.1 Consumer preferences and trends

Although no specific data was provided by delegates, Transparency Market Research (2018) predicts that there will be a steady increase in mango consumption and growth of the mango industry. The penetration of products into new markets, the appetite for novel products and the nutritional advantages of mangoes are significant market advantages. It is predicted that efforts to add value and to mitigate losses, as well as the introduction of new technologies, will increase concomitantly. Governments and industry are optimistic about the future for processed mango and the consumer trends for the sector. Workshop participants thought that, with appropriate assistance in product development, innovations at farm level and a greater understanding of manufacturing, the anticipated increases in processing innovation will be fully realised.

The keynote address at the Indonesian workshop used honey as an illustrative tool to discuss the necessary match between any agricultural product and the market demand, and the importance of a clear understanding of consumer preferences. Quality consistency is of paramount importance; consumers' previous experiences play a major role in product selection because it is not possible to assess quality through impervious packaging at the point of sale. Furthermore, quality features including appearance, taste, colour, aroma and texture must meet market requirements; however, but market preferences for these features can be influenced by style and brand. Novelty innovations such as convenient package design and single-serve dispensers are strategies aimed at increasing brand competitiveness, particularly where quality features between commodities may be minute. With respect to mangoes, the South-East Asian representatives reported that preferred varieties tend to be country- and even locale-specific, particularly for the sector that relies on fresh, local sales.

China

Approximately 10% of Chinese mangoes are consumed fresh. The net profit from processed mango is estimated to be 30% of the total, compared to 70% from the fresh product. Exports are somewhat hampered by a lack of awareness of international standards and how to best achieve them. The processing sector is bound by such standards as Codex, USFDA, UN Commission for Food Standards, and FSANZ (Australia and New Zealand) and ASEAN (GCP/RAS/280/JPN).

Processing is the solution to losses and the problems associated with long distribution lines and rural infrastructure. Production of mangoes is expected to rise from 214,000 tonnes in 2018 to 277,000 tonnes in 2022, and it is anticipated that the processing sector will rise concurrently. Many processed products (such as juices) are prepared from imported pulp (from Vietnam and Thailand); however, there are more than 50 products that are made from mangoes in China. Freeze-drying is emerging as an important technology, and resulted in CNY1.2 billion in sales in 2017 despite the inherent processing costs. A large proportion of processed exports are offered for sale online. Alibaba.com offers 4,834 processed mango products. Of these, 95% are manufactured in China. About 1% of this is fresh mango; approximately 40% is IQF mango; and 1% is dried fruit. The remaining products consist of juices, preserves and canned mango in syrup.

Indonesia

Although it is the world's fifth largest producer, Indonesia's mango processing activity has been slow to emerge, with most effort directed towards exports of fresh mangoes. The annual production of mango in Indonesia is steady; however, there has been a slight increase over the past three years, rising from 1,814,540 tonnes in 2016 to 2,203,789 tonnes in 2017. In 2011, a protocol for the export of fresh mango by sea was developed with support from ACIAR. This culminated in a second research program (ACIAR, 2013) that focused on exports to Hong Kong.

Processing has been largely stimulated by threats to income due to losses. A further advantage of processing is that problems with biosecurity, as well as SPS imperatives and long distribution lines, are sidestepped. Research and development trials on puree and juice production, freeze-drying and low-pressure frying have been conducted at the Centre for Tropical Fruit Tree Studies (CETROFS). Feedback from ICAPRD reveals these products are emerging in domestic markets for both local consumers and tourists.

The Philippines

The Philippines accounts for an average of 10% of fresh and dried mango exports worldwide (FAO, 2016). In 2015, the major export destinations were the US (24%), Hong Kong (17%), Republic of Korea (13%) and Japan (12%) (UN Comtrade, 2014). The Philippine government has put in place a 'Five-year Mango Industry Road Map' to address policy-, production- and processing-related issues. The initiative is ably supported by the Food Processing Innovation Centre under the Department of Science and Technology, Agriculture, and Trade and Industry. The Mango Industry Foundation, Inc. (comprising mango exporters and growers) has allocated PHP10 million to help boost mango production in the country.

Agencies such as the Food and Processing Innovation Centre have focused their attention on producing prototype products such as mango leather, mango balls, green mango chips and mango powder. SMEs and start-up companies are driving the commercialization process for local and export markets. The lack of effective post-harvest management and SPS control has prompted research and development, resulting in a program of process upgrading and certification for farms and packhouses to meet hazards analysis and critical control points (HACCPs), minimum residue levels, phytosanitary and other quality requirements in order to enter new target markets.

Vietnam

A group of highly sophisticated processors is emerging in the Dong Thap and Ben Tre provinces in the Mekong Delta. These businesses have been stimulated by the identification of lucrative markets, the effort to address seasonality and the constant drive to stabilise quality at the point of harvest. Leading finished products are pulps, purees and IQF cubes and cheeks, and there has been a significant growth in the dried slice and snack food markets.

A prime-ministerial decision to restructure the agriculture sector to increase value-adding and sustainability, and to reduce waste, has boosted activity in southern Vietnam. There is strong evidence that the sector is expanding in the Mekong Delta provinces and Ho Chi Minh. Factories that previously produced only bottled water are now including fruit products in their portfolios. In addition, attention has turned to waste and the value that can be added by processing. The sector is ably supported in product development innovation by the Sub-Institute for Agricultural Engineering and Post-Harvest Technology (SIAEP), and at mango-production level by the Southern Horticultural Research Institute (SOFRI). Support is also being directed towards SMEs by means of the southern Vietnam project 'Improving smallholder farmer incomes through strategic market development in mango supply chains' (ACIAR AGB/2012/061).

4.1.2 Innovation and technologies

Many value-added items produced throughout Australia and South-East Asia are now considered to be standardised and are based on largely familiar products such as IQF cheeks, cubes and spears from high-quality fruit, as well as juices, purees and pastes, and jams, chutneys and comminuted products and snacks.

Freezing

The quality of IQF products depends on the efficiency with which the freezing temperature of the fruit is reduced to between -0.5°C to -5.5°C. This temperature range causes the least amount of damage to the fruit and, after thawing, the fruit is still close to fresh quality. Most IQF mango processors are now using techniques such as continuous fluidised bed freezers.

Most puree and paste manufacturers are using multi-effect evaporators that remove moisture from the comminuted fresh fruit under vacuum so that heat damage is minimal. Juices must be pasteurised as a final step in their preservation and are aseptically packed for retail sale. During the manufacture of soft dried mango snacks, texture-modifying components and sugar are added to mango pulp and the product is pasteurised before setting in a mold to form the confection. Preservative is usually added to ensure adequate shelf life.

Freeze-drying

Freeze-drying involves freezing fruit to -18°C and placing it under vacuum conditions (less than 4.58 mm mercury). The product is heated at this low pressure, which causes ice in the product to change directly into steam (sublimation), leaving small channels as it escapes from the food. These channels aid reconstitution when the product is rehydrated. Both texture and flavour are largely undamaged for consumption purposes. The crisp, open texture is also attractive in snacks. Although there were several references to freeze-drying among the South-East Asian and Australian delegates, they reported that this technology is the domain of the larger processors. Capital costs and running costs are high (approximately 100,000 kW are required to freeze-dry 100 kg of soft fruit). The SMEs that work with freeze-drying products rely on larger processors to complete contracts.

Vacuum frying

Of increasing interest is vacuum frying. At a pressure of 2.7 kPa (equivalent to 0.39 psi), fruits can be fried to crispness at 90°C, which is low enough to prevent browning. After frying, products are centrifuged to remove excess oil. One delegate from Indonesia reported on his home-constructed vacuum fryer; he was able to produce vacuum-fried mango with an excellent colour and flavour retention and a crisp texture.

Pressure processing

Increasingly, juices and pulps are being pasteurised under pressure to prevent heat damage to flavour, colour and labile nutrients. Details were not provided at the Indonesian workshop, although a Philippine delegate alluded to the technique. More detailed information was made available at the Australian workshop.

By-products

Mango has a relatively high sugar content and a moderate glycemic index. Mango juice is sufficiently sweet that sugar addition is not required – a significant advantage over other fruit juices, which often require fruit-derived syrup or sugar addition for palatability.

The mango stone is approximately 8% oil and, in the Philippines, it is being extracted for use – but this is currently confined to cosmetics. The global mango butter market was valued at USD28 million in 2018. It is envisaged this market will reach USD36 million by the end of 2025, growing at a compound annual growth rate of 3.4% from 2019 to 2025.

Several delegates reported that the mango stone with its adhering flesh was used in yeast fermentation for wine and, subsequently, brandy production. Lactic-acid-producing organisms can be added to mango flesh that has either been extracted or left on the stone for the production of a yoghurt analogue. Volume sales of such products are not available at this stage. Additionally, many delegates reported that vinegar was being produced from waste mango. (Vinegar is usually produced from wine by allowing the alcohol to oxidise to acetic acid.)

4.1.3 Processing standards

Standards are generally set by the market, and full compliance is imperative for international trade. All nations in the region are members of the World Trade Organization (WTO). WTO mandates Codex and the quality maintenance system, HACCP. The larger companies with a history of international trade reported that they were familiar with the processing standards required in their target markets. The SMEs called for governments to become involved in assisting with standards-awareness programs in the form of training with regard to requirements for modern standards, particularly HACCP certification.

In the case of exporting mangoes, some importing countries and their retail markets require good agricultural practice (GAP) certification of suppliers of raw mango and other treatment regimens such as irradiation, vapour heat treatment (VHT) or hot water treatment (HWT) in order to meet requirements. GAP certification by farmers is a significant advantage for processors, as it significantly reduces the risk of crop hazards (such as pesticide residue levels).

The larger private sector companies in the Philippines and China reported that they were aware of the United Nations Food and Agriculture Organization initiative – ‘Support for Capacity Building for International Food Safety Standard Development and Implementation in ASEAN Countries’ (GCP/RAS/295/JPN) – that was launched in 2016. Member nations of ASEAN (which include the Philippines, Indonesia, Vietnam and Pakistan, and Australia as a contributor to the East Asia Summit) are committed to the ASEAN Food Safety Regulatory Framework (AFSRF). This framework is intended to facilitate the free flow of safe food between ASEAN countries by enhancing SPS measures, minimising technical barriers to trade (TBTs) and reducing discrepancies in national food-control systems. Awareness of AFSRF was scant among the workshop delegates; better education and conformation may be a useful means of facilitating regional international trade. Concerns about standards were expressed at both workshops (see Table 1), and delegates requested future workshops that specifically focus on the mango processing industry.

Sector sustainability and waste and loss determinants

Sustainability depends on an adequate return for effort for all partners in the value chain. Many delegates referred to their lack of understanding about the chain and, in some cases, highlighted the resentment of chain partners. Increased knowledge about the priorities of agribusiness chain partners emerged as a topic for future analysis. Cases within the agribusiness sector have been reported in which the mutual understanding of chain partner prerogatives that result in synergies within chains and economic benefits ensue (ACIAR: PARDI Phase I; Participatory guarantee scheme – helping farmers reach high-value market: ACIAR HORT/2014/080). Similar strategies would be appropriate for the mango sector.

Among all representative countries, losses were considered to be the major impediment to value optimisation. The figures for losses were variable and depended on the point in the supply chain at which the occurrence was monitored. In some cases, losses on the tree were included in statistics. However, the discussions primarily centred on the post-harvest losses at points along the supply chain. Most delegates reported that losses varied between 30% and 50% and that these predominantly arose from incautious handling and

from delivery delays throughout regions where infrastructure is inadequate and transport is unreliable.

The delegates universally agreed that processing is key to increasing return for effort at all stages along the value chain. The larger processors graded incoming mango crops according to quality on receipt. High-quality fruit was destined for the IQF process where returns are highest. Lower-quality fruit was streamed for other products where it is possible to overcome texture and flavour defects by comminuting (reduce to small particles) and blending. The SME delegates, on the other hand, underlined the difficulties of processing when faced with costs associated with acquiring equipment and technology. Financial recovery of investment is difficult for a highly seasonal crop such as mango. Discussions took place regarding assistance with training in relation to product development, and the requirements for entry to and advancement of the processing sector. This suggests that there may be a lack of connection between the research institutions and practitioners.

Oil extraction

Oil is extracted after drying and milling the stones to expose surface area. To prepare the oil for consumption, the broken dried stones are pressed. Where the oil is to be used for cosmetics, it is extracted using a harmless, easily removed solvent called hexane.

4.2 Australia

The mango industry in Australia is small by world standards. The total volume of fruit sold fluctuates from year to year due to seasonal conditions and the irregular bearing nature of the crop. In the past five years, the average mango crop has been approximately 60,000 tonnes. The gross value of production (GVP) at the farm gate is approximately AUD180 million per annum. Production is spread over a large area of the north of the country and, hence, availability is sequential. Production starts in the Northern Territory (Darwin and Kununurra) in September, and the last crop is available in northern New South Wales as late as January. These areas are widely dispersed and losses (reportedly up to 30%) are incurred as a consequence of long supply chains. Season extension is the subject of extensive research that is supported by ACIAR (AGB-2012-061). Out-of-season flowering and fruit stabilisation through partial processing are recommended strategies to be adopted in light of work by CSIRO, which was reported during the Brisbane workshop.

Ninety-five per cent of Australia's crop is sold through the fresh supply chain, of which 10% is exported. However, some large processing operations are producing familiar products such as purees and frozen or freeze-dried products – in some cases using highly sophisticated technologies such as high-pressure pasteurisation and IQF cubes and cheeks. Operating alongside these processors are many SMEs, and they report difficulties commonly experienced by small-scale manufacturers. In many instances, the constraints have been overcome by generating excellent returns on highly regarded merchandise such as convenient frozen confections and unique sauces and chutneys.

4.2.1 Demand trends

Although a wide range of mango varieties are grown in Australia, delegates from the larger processors stressed the importance of single-variety supply. However, finished product quality features are dictated by the preferred mango varieties, of which Kensington Pride is the most common (52%), followed by Calypso (22%), R2E2 (13%), Honey Gold (7%) and Keitt (2%). Processors commonly source a single variety of mango to ensure all-important consistency in finished products; for example, some firms process only the Calypso variety.

Delegates likened the demand changes in processed mangoes to that of avocado. In recent years, the mango industry has achieved similar success to that enjoyed by avocado growers, who have managed to change consumer opinions of the avocado fruit

from a luxury product to a household staple. Seventy-six per cent of the population now buy mangoes compared to 66% in 2014, as reported by the Australian mango industry representative at the workshop.

The round-table discussions at the workshop included comments that the federal government should be involved in facilitating international trade. It was recommended that the role of government be the subject of further enquiry, given that issues such as commitment to policies, AFSRF, bilateral quarantine agreements (BQAs) and free-trade agreements (FTAs) are not currently widely understood by the sector.

4.2.2 Innovation and technology

The fruit processing industry in Australia is mature. As mango production has increased and the imperative for processing to reduce losses has evolved, new technology has been adopted and adapted as necessary. During the workshop, many case studies were presented, which had relevance to the mango sector, highlighted the technologies and product development strategies associated with other fruits such as plums strawberries, custard apples and avocados. A number of mango processing businesses were born out of existing mango farming enterprises. An example is the Zingo frozen mango confection that relies on freezing fresh mango for its innovative retail products (see Figure 1).



Figure 1. Zingo Mango, North Queensland

Source: Processing Workshop, February 2019

Simpson Farms has invested in the development of high-pressure pasteurisation capabilities at their processing facility in Bundaberg, Queensland. High-pressure pasteurisation (up to 87,000 psi or approximately 6,000 atms) is applied to food to achieve microbial inactivation or to alter the food attributes in order to produce consumer-desired qualities. This is sufficient to inactivate yeasts and moulds, which are the organisms that are most likely to cause spoilage. Simpson Farms promotes the use of pasteurisation in their advertising copy (as seen in Figure 2).



Figure 2. Simpson Farms, high-pressure pasteurisation

Source: *Processing Workshop, February 2019*

Pressure pasteurising at low temperature retains the nutrients of foods (see Figure 2). Cold-processed mango products are good candidates for the health food sector since all known nutrients are retained. Furthermore, results show, the effect of this technique on other fruit biochemicals (for which the health benefits are yet to be determined) would indicate that they are likely to be retained.

Freeze-drying

High capital costs are associated with freeze-drying equipment. In the workshops, the SMEs noted that they used larger companies to freeze-dry on a contract basis. Running costs are dependent on local power costs. For this reason, cost–benefit analysis is critical to ensure that the processing costs can be recovered from sales.

Fundamental processing technologies

Basic technologies are used from the household level and throughout the entire fruit processing industry. Jams, sauces and chutneys are simple products that can add to the family income and utilise substandard fruit. Micro-enterprises could use simple interventions consistent with safety requirements in group settings to improve product features thereby ensuring the sustainability of the product through operational approaches. Assistance at this level for farmers and farmer groups can become the wellspring of truly commercial operations, especially if supported by appropriate training in small-scale food processing.

4.2.3 Research and development institutions

Several innovations have captured the attention of the Australian government science organisation, CSIRO, including the use of mobile stabilisation units involving ultraviolet light to surface-sterilise fruits and vegetables at harvest. Another is integrated mobile juicing plants which are currently only available overseas. Whether this method is

appropriate for Australia in overcoming the difficulties of extended distribution lines is unknown; however, in the workshops their use was suggested.

4.2.4 Processing standards

As a member of the WTO, Australian processors are committed to Codex and FSANZ standards. HACCP is widely accepted as the minimum standard for both domestic and international trade. Larger exporting companies were familiar with the food standards required by their markets, for instance: exporting to China requires adherence to guidelines for the People's Republic of China Food Safety Law; for the United States of America, the Food and Drug Administration in the US; to the European Union, the European Food Safety Authority; and to the United Kingdom, the Food Standards Agency of UK.

Australia is a participant in the ASEAN East Asia Summit and is committed to the ASEAN Food Safety Regulatory Framework (AFSRF). SMEs are required to obtain certification to practice and this criterion is based on HACCP principles and FSANZ standards. Food standards were a topic for discussion at the workshop and it was recommended that standards implementation should be totally inclusive throughout Australia and its trading partners. This indicated a perception that commitment to AFSRF is not universal in Australia.

4.2.5 Sector sustainability and waste, and loss determination

Throughout the industry, mango processing is now considered to be institutionalised within Australia and investment in technology and market research are considered essential for the future of the industry. Discussions at the workshop indicated a desire to understand the supply chain in more detail which could result in greater identification of points for loss mitigation. Increased awareness of supply chain functions also assists in understanding consumer demands and purchasing motivations.

Losses currently occur at all stages in the supply chain, but while infrastructure in Australia is protracted, it is more advanced than sister nations in South-East Asia.

5 Opportunities and constraints

Processing inevitably involves investment, whether in the form of expensive high-pressure pasteurising systems or simple jam-making facilities. Whether through outright purchase of equipment, lease or a loan facility, financial outlay for equipment is required by all fruit processors – a financial burden that can only be recovered from product sales. Obviously, the more frequently facilities/equipment are used, the quicker the financial outlay can be recouped. However, supply of raw material and market accessibility are other constraints that determine income levels, and delegates at both workshops indicated that seasonality and quantities available for processing are a significant factor in determining profitability and sustainability.

5.1 Cross-cutting issues

Raw material supply

The unique quality of fresh mango has been the driving force behind the decision to process the fruit. All processors attained their current status through growth. It is an economic imperative to increase the rate at which these products are processed. Irrespective of the size of the processing organisation, an investment has been made in premises, equipment, transport and at least some aspect of the value chain. To achieve profitability, fixed-cost elements of each mango or mango product sold must be minimised; hence, the throughput rate must be as high as possible. For this reason, producers are constantly driving to process as much raw material as possible.

Delegates reported that, as a result of judicious selection of varieties from a wide range of location, and with supplementation by imports, China was able to maintain a mostly year-round supply.

Indonesia is dominated by the local demand for fresh product, but processing is gaining momentum using novel processing techniques. Government intention is for tourism to deliver a significant economic benefit. In turn, tourists are a ready market for indigenous products of all kinds, including local fruits. The opportunity in Indonesia is therefore to expand processed fruit production to deliver a unique regional product for tourists.

To cater to seasonality, Vietnam intersperses mango processing with other fruits. A state-owned processing company, Long Yuen, for example, produces more than 60 products based on freezing technology, while production scheduling maintains a throughput rate with 22 different raw materials. This strategy is typical of several processors in the Mekong Delta provinces.

Pakistan's current strategy to reduce losses (which are estimated to be at least 40% of the total fruit crop) is to base a wide range of products on immature fruit that is harvested before infestation by pests and disease. The consumer acceptance rate of these products was not reported, and it is suggested that Pakistan research the topic to define market acceptance of this range of products.

There is considerable marketing and technical support for the mango industry in Australia. Supply is seasonal, and the preferred growing areas are widely dispersed. This accounts for the large number of processors whose main raw materials are mango alternatives. One highly successful mango processor has aligned mango processing with established avocado processing so that factory continuity is assured. Others have dovetailed mango supplies with other fruits. A number of SMEs have stabilised fruit at harvest by using techniques such as freezing for later processing, with one reporting to have contracted out freeze-drying of products for later production of freeze-dried snacks and powder.

Losses

High-quality mango suitable for IQF processing into cheeks, cubes and spears demands that processing is undertaken as soon as possible after harvest. Substandard fruit is processed as capacity and seasonal flow permits. Copious supplies can be frozen in bulk in consignments that suit later batch processing. This technique is due for refinement and application for mangoes in ACIAR Project AGB/2012/061.

Propositions in relation to mobile processing units which are available internationally, have been mooted. These could find application within isolated locations of production areas, or where infrastructure prevents rapid distribution to full-scale processing centres.

Other techniques available include the addition of preservatives. Sodium metabisulphite is commonly used because it can be removed during a subsequent heating process. Other substances such as glycerol effectively inhibit spoilage and are used in the manufacture of soft slice mango confections products now more commonly available in the retail sector. However, since these cannot be removed during later processing, they must be compatible with final product features.

Sequential seasonality

Several workshop delegates discussed the availability of numerous varieties of mangoes. For instance, an Indonesian delegate listed 17 different varieties with wide-ranging colour, texture and flavour characteristics. Although this offers choice options for fresh mango consumers, there is still staggering despite the variety. However, for the processor, consistency of finished product is paramount. An item that is favoured by consumers must be identical to its predecessor. Wide variations in raw material features (such as colour) may serve to prevent finished product uniformity.

Standards

HACCP and ASEAN are the established standards to which, through the WTO, governments are committed to conforming. Standards are institutionalised within the nations that were represented at the workshops. Adherence and observance are of paramount importance to international traders, who are obliged to meet not only international standards but also extra demands imposed by retailers who seek quality advantages over their competitors. The SMEs throughout the Asia-Pacific region have a mixed understanding of quality standards and, in some cases, do not comply with these standards. Delegates in Australia and throughout South-East Asia expressed the desire to assist in awareness programs. Ensuring those processors who are unfamiliar with standards receive assistance can help the industry to gain a universal reputation for quality. The quest for quality acceptance should include farming practices (possibly through GAP certification) and continue through the entire chain, and should also consider retailers' commitments such as rotating stock. While, maximum residue levels are assuming greater importance among Western clients as well as processors, the ultimate determinant of quality standards outside the mandated national obligations is that imposed by markets.

Markets

By 2026, the global processed mango product market is expected to reach USD2.043 billion for primary processed mango product and USD31.67 billion for secondary processed mango product—expanding at a compound annual growth rate of 6.1% and 7% respectively from 2018 to 2026 (Transparency Market Research, 2018). Asia-Pacific held the dominant market share of the processed mango product market in 2017. This was driven by increasing penetration into markets where mangoes are considered to be a novelty, as well as the more permanent markets (especially beverages) where the attractive natural sweetness of mangoes appeals to nutritionally conscious consumers. Delegates (especially those from the smaller enterprises) were consistent in their call for more market intelligence. Larger processors have established relationships with clients,

whereas the SMEs rely on intermittent trade. Confidence and reliability play a big part in repeat purchases.

5.2 Challenges for the tropical fruit processing sector

Fresh mango quality stabilisation

Preventing deterioration at harvest will reduce losses. A few techniques are available for extending shelf life of mangoes using cool temperatures (13–18°C), with reduced oxygen (<2%) and increased carbon dioxide levels (~6%) increasing the fresh shelf life of Kensington Pride up to six weeks (Singh, 2015). Processors can use this data to extend growing seasons or for shipment of fresh mangoes. An alternative technique is to freeze the product in bulk with minimum prior handling (washing and peeling); the frozen product can then be used as the raw material for jams, juices and purees.

Information exchange

All processors have expressed an interest in greater information exchange in relation to standards, including Codex standards, emerging technologies and process and product development. Most countries have research institutions that may be able to provide timely advice to all levels of the sector about the various aspects of processing. Furthermore, previous examples of the use of social media to develop formal networks for market intelligence can be used to develop new channels of exchange.

Process management

It may be appropriate to accommodate all issues noted in Table 1 by means of a carefully constructed Code of Practice to record aspects of processing, including:

- specifications for incoming mangoes and responsibilities of suppliers, and standards at the point of transaction
- minimum hygiene standards for premises
- elements of HACCP
- clean-down and hygiene procedures
- Codex and other standards for processed mango products
- obligations to immediate (chain) collaborators – both suppliers and markets.

Networking

In some countries, existing networking channels are present. For instance, the Australian Mango Industry Association would be able to operate as an information exchange hub. In the Philippines, the Philippine Mango Exporters Foundation Inc. assumes similar responsibilities; it would be useful if the Philippine Mango Exporters Foundation could:

- establish opportunities for collaboration
- gather information on emerging processing techniques
- gather information on markets and threats to supply
- be a conduit for interested parties to discuss policy.

6 Conclusion and recommendations

6.1 Conclusion

Across both workshops, there was wide variation in the importance accorded to mangoes and mango processing in terms of national development strategies within the five Asian nations and Australia.

The key points arising from the workshop discussions are summarised below.

- The volume supply of mangoes rarely meets that required by the market.
- Intermittent supply due to the seasonal nature of mangoes is a significant threat to optimum use of expensive processing facilities.
- Losses between production and market are high, although there is inconsistency in monitoring methods.
- Producers are aware of the potential of off-season flowering as a solution the problems associated with seasonality; however, processors do not view this as an opportunity for improved supply at present.
- The vulnerable points along the value chain where losses are high vary throughout the industry and are dependent on infrastructure and financial resources.
- There is disparity in understanding among processors about standards, including the obligations they impose and the ability to conform to those required by the market and those responsible for public health.
- Comprehensive compliance is necessary to maintain the integrity of the industry.
- SMEs do not have available personnel to commit to research and product development, and in many nations and cases processors are unaware of the facilities available to provide assistance in-country.
- Mangoes are a good option for the most advanced processing techniques, which result in extremely high-quality products that can secure a premium price.
- There is widespread unawareness of the plight of chain partners, which is prevalent between producers (and middlemen) and processors.
- Processors are unaware of farming practices that may impinge on the quality of their finished products and their access to demanding markets.
- Collaboration between value chain partners is considered to have benefits for information exchange and for lobbying for more favourable government support.
- Small-scale processing at farmer level is common not only in the mango industry but throughout the fruit farming sector. Targets for assistance in progressing toward SME status that includes safety and shelf life should be investigated in order to ensure that their market reach becomes greater.

6.2 Recommendations

It is recommended that a review be undertaken to determine the feasibility of establishing a forum for regular national and international exchange of ideas and discussion about impediments, remedies and successes between mango processors. This initiative should also include considering the compilation of a processing handbook that contains topics that are relevant to mango processors. These topics may include:

- hygienic design of a food processing facility
- institutionalised techniques used to preserve mango, including freezing, dehydration, sugar preserves and chutneys suitable for processors from SMEs and multinational companies
- international standards and how to best meet them
- modern processing techniques. including freeze-drying, low-pressure frying, high-pressure pasteurisation and ultrasonics

- indicative costs of processing regimens
- obligations to immediate chain partners.

A directory of institutions has been compiled of relevant South-East Asian and Australian organisations that offer services such as:

- process and product development and evaluation methods
- hazard analyses, including GAP, that are relevant to processors.

It is recommended that the following institutions be approached for research collaboration opportunities:

- Commonwealth Scientific and Industrial Research Organisation, Australia
- Conference on Agricultural Policies and Rural Development, Indonesia
- Food Processing Innovation Centre under the Department of Science and Technology with the Departments of Science and Technology, Agriculture and Trade and Industry, the Philippines
- Centre for Tropical Fruit Tree Studies, Indonesia
- Agricultural Engineering & Postharvest Technology, Vietnam
- Southern Horticultural Research Institute, Vietnam
- Philippine Mango Exporters Foundation Inc., the Philippines
- Mango Research Institute for Multan, Pakistan.

Wherever there is evidence of farmer-level processing, these farmers should be targeted for training in food handling, preservation and product development, and safety at the SME level. Wherever commercial confidence permits, an analysis will be undertaken of the Australian commercial organisation that established processing in Laos to determine if this is a viable option for increasing profitability levels for other processors.

7 References

Bung, P (2015) 'Challenges facing mango cultivators of India', *International Journal of Management and Development Studies*. ISSN 2320 0685.

Chan, H (2015) Mango Processing and products, viewed <https://scholarspace.manoa.hawaii.edu/bitstream/10125/16479/HITAHR_04-06-93_51-53.pdf>

China Agriculture Year Book (2015), viewed <<http://english.agri.gov.cn/service/ayb/>>

FAO (2016) Support for Capacity Building for International Food Safety, Standards Development in ASEAN Countries. GCP/RAS/295.

Future Market Insights (2017) Mango Puree Market: Beverages End Use Segment to Hold More Than Half the Global Market Share Throughout the Forecast Period: Global Industry Analysis (2012–2016) and Opportunity Assessment (2017–2027) (*REP-GB-5695*)

Malik, VS; Schulze, MB; Hu, FB (2016) 'Intake of sugar-sweetened beverages and weight gain: a systematic review' *The American Journal of Clinical Nutrition* 84(2): 274–288

Singh, Z. (2015) Controlled Atmosphere Storage of Mango Fruits, *Acta Horticulturae*, 1066: 179–191.

Transparency Market Research (2018) 'Processed Mango Product Market– Global Industry Analysis, Size, Share, Growth, Trends, and Forecast, 2018–2026.'

UN Comtrade. (2014) International Trade Statistics Database. UN Comtrade, viewed <<https://comtrade.un.org/pb/>>