Collation of Health Literature for Tropical Fruits and Extracts
Collation of health literature for tropical exotic fruits and extracts

by Kent Fanning and Yan Diczbalis

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In this report the nutrient and phytochemical composition of a range of tropical exotic plants has been detailed, with literature summaries of the bioactivity and health properties of whole fruit consumption. The bioactivity of non-edible fruit and plant part extracts has also been reviewed.

This data could be used to promote the consumption of tropical exotic plants.

There is very little data for Australian grown tropical exotic fruits compared with fruit grown overseas. However, there are Australian research groups now undertaking work in the area of phytochemical profiling and bioactivity testing of Australian grown fruits.

Achachairu appears to be the best opportunity for developing extracts for use in food and nutraceutical applications.

This report is an addition to RIRDC’s diverse range of over 2000 research publications and it forms part of our New and Developing Plant Industries R&D Program, which aims to facilitate projects/industries that advance import replacement and export creation/expansion, and identify opportunities for, and facilitate the development of, new industries that are well placed to make a substantial contribution to rural and regional development in the future.

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About the Author

Dr Kent Fanning has been involved in researching the composition and potential health benefits of tropical fruits since he began with DAFF in July 2007. He has written two publications reviewing tropical fruits. He is currently working on a range of projects examining the phytochemical content of temperate, sub tropical and tropical horticultural produce and associated processed products.

Yan Diczbalis is in the Horticulture & Forestry Science division of DAFF. He has thirty years experience working with tropical and exotic fruits and has contributed to relevant promotional materials including ‘Tropical Tastes’ (DEEDI). He has also plays a very significant role in promoting tropical and exotic fruit at the annual ‘Feast of the Senses’ event in Innisfail.

Abbreviations

LDL – low density lipoprotein

HDL – high density lipoprotein
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Executive Summary

What the report is about

In this project we have collated data on the nutrient and phytochemical content of tropical exotic fruits, the evidence for health effects from consumption of these fruit and the use of extracts from edible and non-edible parts of these plants. The knowledge of Australian fruit compared with that grown overseas is presented together with opportunities for future work by Australian researchers. Opportunities for developing commercial extracts for use as food or nutraceutical uses are also presented.

Who is the report targeted at?

- Tropical exotic fruit growers and marketers.
- Researchers who are involved and/or interested in tropical exotics research.

Where are the relevant industries located in Australia?

The tropical exotic fruit industry is based predominantly in north Queensland and the Northern Territory. Some fruit is also grown near the coast in central Queensland, south east Queensland and northern New South Wales.

Background

Research into nutrient content, phytochemical content and potential health benefits of tropical exotics has traditionally been far less than the work done on temperate fruits. There is also little known about how Australian grown fruit compare with that of fruit grown overseas. Furthermore, both edible and non-edible fruit and plant parts used in traditional medicine may have commercial opportunities for Australian producers.

Aims/objectives

The four objectives of this project were

- To collate compositional and health literature for tropical and exotic fruits, with a focus on information from Australian grown produce.
- To highlight where cultivars, growing practices and supply chain handling may differentiate Australian grown fruits from fruit from other countries.
- To identify opportunities for extracts to be developed from fruit or non-edible parts of fruit trees to be used in food and/or nutraceutical and/or pharmaceutical products.
- To recommend further research and development activity that would help support further knowledge of the compositional and health benefits of Australian grown tropical fruit.

Methods used

Extensive literature searches together with detailed analysis of the tropical exotics industry in Australia in comparison with the industry in other countries.
Results/key findings

There is an accumulating body of literature detailing the nutrient and phytochemical content of tropical exotics. However, there is very little data available for fruit grown in Australia. No specific advantages were identified for Australian grown fruit on the basis of cultivar difference or growing/handling practices. There is evidence from animal and/or human feeding trials for the health benefits of fruit consumption of some of the studied fruits from the literature. The best opportunities for developing extracts for use in food or in nutraceutical applications exist for achachairu, due to the significant volume of fruit being grown in a single location with no apparent import competition. The use of extracts in improving health and well being from several other fruits have ranging levels of scientific evidence, with commercial products from other countries available internationally. However, the economic viability for production of the extracts from Australian grown fruit is still unclear from this study.

Implications for relevant stakeholders

• The information in this report on the nutrient content and benefits of fruit consumption could be developed into promotional and/or educational materials.

• Waste fruit (including seeds, peels etc) may be able to be utilised in food or nutraceutical applications. Achachairu has the most potential, of the fruits studied, due to the relatively high production volume, single growing location and lack of international competition.

Recommendations

• Undertake work to put the nutritional and health benefit information for these fruits into suitable formats (web based etc) for promotional and/or educational purposes.

• Develop and present a proposal to FSANZ to develop NUTTAB records for the fruits that do not currently have one.

• Develop a suitable forum to keep a connected and coordinated approach for tropical fruit research in Australia, following on from the 2008 Tropical fruits in human nutrition and health conference. It is anticipated that research will continue through relatively small student projects.

• Develop a plan to investigate opportunities for utilisation of retail-rejected Achachairu fruit as flesh/peel/seed products/extracts for food and nutraceutical uses.
Introduction

The increasing epidemiological evidence for the health benefits of fruit and vegetable consumption is attracting great interest. There is burgeoning research into unearthing the mechanisms behind these observed benefits. However, knowledge on the health properties of tropical exotic fruit products appears to lag behind that of temperate crops such as apples, pears, plums and berry fruit as well as crops grown in warm dry climates such as citrus, olives and pomegranate. This is despite most tropical exotics being recognised for health or medicinal properties by populations indigenous to the areas where they are customarily grown. Some of this traditional knowledge has stimulated health research. This combined with nutritional compositional analysis, is indicating which properties of tropical exotics can contribute to the health and well-being of consumers.

More knowledge of the nutrient and phytochemical composition data and specific health effects of Australian grown fruit may provide a useful tool for promoting consumption of this fruit. This knowledge may also position Australian grown fruit favourably versus imported product.

Other non-edible parts of many fruit trees have been used in traditional practices. Often the non-edible parts of plants have specific phytochemicals not found in the fruit itself or a higher content than in the fruit.

In preparing for the Tropical fruits in human nutrition and health conference in 2008 (held at Couran Cove, South Stradbroke Island) a review of the traditional uses, nutritional content, antioxidant activity and health literature for 28 tropical fruits currently grown in Queensland was undertaken. This was entitled The health benefits of tropical fruit grown in Queensland, Australia (Fanning, Murray et al. 2009) and was published in the conference proceedings. This work did not focus on data specifically for Australian grown fruit, or the phytochemical content of the edible, specific fruit extracts or non-edible parts. A much smaller consumer-friendly booklet was also published and released at the conference, Queensland tropical fruit – The healthy flavours of North Queensland (2008). This booklet was designed to accompany the previously published book Tropical Tastes – Fruit, foods and flavours of north Queensland. Tropical Tastes content has been used to educate and promote tropical exotic fruits and also received wider publicity through the RACQ’s Road Ahead magazine last year.

The first aim of this project was to gather useful information on the nutrient and phytochemical content and health attributes of tropical exotic fruits relevant to the Australian industry. Where there was the data, this report makes a comparison of data for Australian grown versus fruit grown in other countries, with the influence of cultivar differences also considered.

The second aim of this project was to review the literature and identify possible opportunities for developing extracts from the edible fruit or other parts of the plant for use in food and/or nutraceutical and/or pharmaceutical products.
Objectives

- To collate compositional and health literature for tropical and exotic fruits, with a focus on information from Australian grown produce.

- To highlight where cultivars, growing practices and supply chain handling may differentiate Australian grown fruits from fruit from other countries.

- To identify opportunities for extracts to be developed from fruit or non-edible parts of fruit trees to be used in food and/or nutraceutical and/or pharmaceutical products.

- To recommend further research and development activity that would help support further knowledge of the compositional and health benefits of Australian grown tropical fruit.
Methodology

The fruit list for this project was based upon the RIRDC report by Yan Diczbalis titled Tropical exotic fruit industry strategic direction setting 2010-2015 (Diczbalis 2010). Pertinent background information was extracted from this publication for this report and formed part of the basis for consideration of cultivar, agronomic and post harvest practices between Australia and fruit grown overseas.

The content of two previously published documents examining the nutrient content and health benefits of tropical fruit consumption (The health benefits of tropical fruit grown in Queensland, Australia (Fanning, Murray et al. 2009), Queensland tropical fruit – The healthy flavours of north Queensland (2008)) were used as the starting basis for the collation of information.

In examining the recent literature for nutrient composition, phytochemical composition and bioactivities of the various fruits the following literature databases were searched using the listed terms.

- Science Direct
- Web of Knowledge
- Scirus

Terms:

- abiu OR (Pouteria caimito) OR caimito OR luma OR aboi OR pouteria
- Achachairu OR (Garcinia humilis)
- black sapote OR (Diospyros digyna)
- breadfruit OR (Artocarpus altilis)
- carambola OR (Averrhoa carambola)
- (Duku-langsat) OR (Langsium domesticum)
- durian OR (Durio zibethinus)
- guava OR (Psidium guajava)
- hog plum OR (Spondias cythera) OR fiji apple OR amarella OR vi apple OR otaheite apple
- jaboticaba OR (Myrciaria cauliflora)
- jackfruit OR (Artocarpus heterophyllus) OR jackfruit
- longan OR (Dimocarpus longan)
- mamey sapote OR (Pouteria sapota)
- mangosteen OR (Garcinia mangostana)
• pitaya OR (dragon fruit) OR *(Hylocereus undatus)* OR *(Hylocereus costaricensis)* OR *(Selenicereus megalanthus)*

• pomelo OR pummelo OR *(Citrus grandis)*

• rambutan OR *(Nephelium lappaceum)*

• rollinia OR *(Rollinia deliciosa)* OR biriba

• sapodilla OR *(Manilkara zapota)* OR chico

• soursop OR *(Annona muricata)* OR guanabana

• star apple OR *(Chrysophyllum cainito)*

The United States Department of Agriculture (USDA) online nutrient reference database (http://ndb.nal.usda.gov/ndb/foods/list) and the Australian equivalent, NUTTAB (administered by Food Standards Australia New Zealand, http://www.foodstandards.gov.au/consumerinformation/nuttab2010/nuttab2010onlinesearchabledatabase/onlineversion.cfm) were searched for entries of nutritional information of each fruit. In regards to the results reported, if there was suitable data indicating that the edible part of the fruit contained vitamin content ≥10% of recommended dietary intake, or fibre content ≥10% of daily intake, per 100g (as described in the Australian and New Zealand Food Standards (ANZFS 2008)), than this was specifically included under the heading ‘Nutrient and phytochemical composition’.
Results

Nutrient composition data for breadfruit, carambola, durian, guava, jackfruit, longan, mamey sapote, mangosteen, pummelo, rambutan, sapodilla, soursop and star apple were present in the USDA nutrient database. There were only entries for three of the studied fruit, guava, jackfruit and rambutan, in the NUTTAB nutrient database.

A recent review on the phytochemical contents and bioactivity of fruits including breadfruit, mangosteen, guava, soursop and pummelo (Pierson, Dietzgen et al.), and the Food Research International special issue on exotic fruits (Exotic Fruits: Their Composition, Nutraceutical and Agroindustrial Potential, Volume 44, Issue 7, August 2011), are valuable background reading.

Abiu (*Pouteria caimito*)

Background and growing situation in Australia

Abiu originates from South America in the tropical regions of Peru and Brazil. The yellow fruit is round to oval in shape and some varieties have a nipple like protrusion at the end of the fruit. The fruit is best eaten fresh to reveal the subtle caramel flavoured flesh. There are a number of selections which include Gray, Z2, Z4 and E4. There are a total of 610 trees with 73.8% (450 trees) in north Queensland and 122 trees in the NT. Abiu was regarded as an exotic fruit with potential (Ross 1997). Production is generally not a problem. The fruit bruises easily and the major challenge is getting unbruised fruit to market.

Nutrient and phytochemical content

Abiu is a good source of Niacin and an excellent source of Vitamin C. One hundred grams of the fruit contains 34% of the RDI for Niacin (Morton 1987) and 122% of the RDI for Vitamin C (Morton 1987).

The total phenolic content of fruit flesh and seed have been determined with seed content higher than flesh (Contreras-Calderon, Calderon-Jaines et al. 2011). Phenolic acid profile (Fukuji, Tonin et al.), elemental analysis (Oliveira, Almeida et al. 2006) and volatile profile of flesh (Maia, Andrade et al. 2003) have all been undertaken. Several triterpenes from the bark have been isolated (Ardon and Nakano 1973).
Achachairu (*Garcinia humilis*)

**Background and growing situation in Australia**

Achachairu is a fruit recently introduced from Bolivia. It is related to mangosteen and is borne on a tree similar in appearance but with smaller lancolate leaves and more sun tolerant. The trees of the variety “A-SE” (17,000 trees) are owned (under plant variety rights) by one company and planted in an area south of Townsville. The fruit is bright yellow in colour and egg shaped. The white crisp flesh, surrounding a single seed is slightly acidic in nature and is delicious fresh. The skin can be used to make a refreshing drink and the flesh also lends itself to being used in purees and juices.

**Potential as a food ingredient**

There is interest to develop processed food products utilising retail rejected fruit in Australia.

**Nutrient and phytochemical content**

The achacha website (http://www.achacha.com.au/) has comments regarding the content of potassium, vitamin C, folate and sugar content of fruit flesh, as well as the presence of hydroxycitrate in the skin. However there was no data found in the literature search.

**Bioactivity and health properties**

Seed extracts have shown pain reducing ability in several rodent pain models (Dal Molin, Silva *et al*.). A polyisoprenylated benzophenone identified as guttiferone was isolated and seen to be more potent than the crude seed extract (Dal Molin, Silva *et al*.). This compound has also been identified in bark and stem extracts and has been shown to bind to liver X receptors as an agonist (Herath, Jayasuriya *et al*. 2005). Agonists of these receptors may mediate increased cholesterol efflux, reduced plasma LDL content and increased plasma HDL content.
Black Sapote (*Diospyros digyna*)

**Background and growing situation in Australia**

Black Sapote or chocolate pudding fruit is native to Mexico and a close relative of persimmon. The fruit is easily produced in the tropics from a variety of seedling selections. Large squat fruit are preferred to the smaller oval types. The fruit is a culinary fruit because it is best used in recipes where it is used in association with chocolate or as a replacement for chocolate colouration. The fruit are climacteric and can be picked green mature. They are best to consume when fully softened. The tree is hardy and is used successfully as a windbreak. The tree is well adapted to warmer sub tropical areas as well as the wet coast of north Queensland. There are an unquantified number of trees in northern Australia. Market demand is increasing due to interest in the fruit from chefs.

**Nutrient and phytochemical content**

The black sapote is an exceptional source of vitamin C with one hundred grams of fruit containing 4.8 times the RDI (Morton 1987).

The total phenolic content (Yahia, Gutierrez-Orozco *et al.*; Arellano-Gomez, Saucedo-Veloz *et al.* 2005), phenolic profile (Yahia, Gutierrez-Orozco *et al*), carotenoid profile and content (Yahia, Gutierrez-Orozco *et al.*; Arellano-Gomez, Saucedo-Veloz *et al.* 2005), and vitamin E content have been described for the fruit (Yahia, Gutierrez-Orozco *et al.*).

Breadfruit (*Artocarpus altilis*)

**Background and growing situation in Australia**

Breadfruit is native to the Pacific islands and is inexorably connected to Captain Bligh who was responsible for transporting the trees from Tahiti to the West Indies. The fruit is an important staple food in the Pacific and can be used for making crisps and chips. The tree is truly tropical in its requirements and is ideally suited to NT. In Queensland its range is currently restricted to areas north of Cairns or elevated areas, free of the influence of cold air drainage, south of Cairns. The survey suggests there are nearly 500 trees with 350 trees (74.2%) located in north Queensland. The remaining 120 trees are planted in the rural areas adjacent to Darwin.
Potential in other uses

Breadfruit is used as a whole and pulp flour (Adepeju, Gbadamosi et al.), however there are opportunities for its use as a starch in applications such as use as a dusting starch (Nwokocha and Williams) and tablet disintegrant (Adebayo, Brown-Myrie et al. 2008).

Nutrient and phytochemical content

Breadfruit is an excellent source of vitamin C (USDA). One hundred grams of fruit contains 72% of the RDI.

Several studies have compared nutrient and phytochemical content across cultivars, comparing tannins (Appiah, Odoro et al.), mineral content (Jones, Ragone et al.) and carotenoid content (Englberger, Alfred et al. 2007). The large variation in these components indicates the opportunities to select for nutritionally superior varieties (Jones, Ragone et al.; Englberger, Alfred et al. 2007). Stilbenes, arylenzofuran, flavanone, flavones and sterols have been characterized in the fruit (Amarasinghe, Jayasinghe et al. 2008).

Bioactivity and health properties

In vitro anticancer activity has been shown by extracts from different parts of the plant. Wood extract has shown apoptotic inducing ability in breast cancer cell line (Arung, Wicaksono et al. 2009). Geranyl chalcone derivatives from leaves have shown moderate cytotoxicity to a range of human cancer cells (Wang, Xu et al. 2007). Arcommunol A has also shown chemoprotective properties in a range of cancer cell lines (Hsu, Shyu et al.).

An extract from heartwood of the breadfruit tree has been shown to give fibroblast lattices of wrinkled skin the ability to contract (which was lost without treatment in the studied in vitro system) (Viyoch, Buranajaree et al.). The authors proposed that this ability to rejuvenate the metabolism and reorganisation of collagen may underlie a wrinkle treatment.

Lectins extracted from seeds, frutackin, inhibit fungal growth and development (Badrie, Broomes et al.).

Leaf extracts have shown ACE-inhibitory activity with the high content of glycosidic and phenolic compounds being implicated as responsible, at least partly, for the activity (Siddesha, Angaswamy et al.). The authors stated that this work supported the traditional use of leaf material for the treatment of hypertension. The authors proposed that further studies that looked to isolate and better determine which phytochemicals were most responsible for these effects should be undertaken.

The inclusion of breadfruit in the diet of residents of the Caribbean has been promoted by certain health professionals for its potential usefulness in aiding the management of conditions such as diabetes and hypertension (Badrie, Broomes et al.).
Carambola (*Averrhoa carambola*)

**Background and growing situation in Australia**

Carambola or star fruit has been widely grown as a back yard fruit tree along the SE coast of Queensland and northern Australia. Commercial plantings exist from northern NSW, southern and central Queensland and the rural regions surrounding Darwin. The main commercial cultivars are B2, B10, B17, Arkin, Fwang Tung and Giant Siam (Diczbalis and McMahon 2004). The fruit is primarily grown for the food service market where it is used as a garnish surrounding fruit platters. The survey indicates there are 2,200 trees (65.7%) planted in Queensland with the bulk of commercial trees in regional areas surrounding Rockhampton and Bundaberg. The remaining 1,150 trees are grown in the Darwin rural area. The estimated production potential of carambola, at a yield of 45 kg/tree is 150 tonnes valued at $1.21M. Opportunities exist for industry expansion if the fruit can be introduced to the larger Australian market. The fruit is highly versatile as a fresh fruit and a refreshing juice.

**Potential as a food ingredient**

Esterified insoluble fibres from starfruit may have opportunities as carriers of nutrients in food systems to deliver certain vitamins/phydrochemicals (Hsu, Lin et al. 2009).

**Nutrient and phytochemical content**

Carambola is an excellent source of Vitamin C, with a typical large fruit (124g) containing 107% of the RDI (USDA).

The flavonoid (Liu, Zhang et al. 2009) and phenolic (Yap, Ho et al. 2009) contents of the fruit have been defined. Alkyl phenols and benzoquinones have been identified in wood samples (Chakthong, Chiraphan et al.). Leaves have been shown to contain - beta-sitosterol, apigenin-6-C-beta-L-fucopyranoside and -apigenin-6-C-(2"-O-alpha-L-rhamnopyranosyl)-beta-L-fucopyranoside (Moresco, Queiroz et al.).

**Bioactivity and health properties**

Topically applied extracts of the leaves have significantly reduced edema and myeloperoxidase activity in a croton oil-induced ear edema model of inflammation in mice (Cabrini, Moresco et al.). Isolated compounds, from the extracts, apigenin-6-C-beta-L-fucopyranoside and apigenin-6-C-(2"-O-alpha-L-rhamnopyranosyl)-beta-L-fucopyranoside, were much less effective than the whole extracts in reducing edema.

Leaf extracts have shown induction of hypoglycaemia in normal mice (Shejuty, Joyanta et al.) and rats (Ferreira, Fernandes et al. 2008), and lowered fasting blood glucose levels in hyperglycaemic rats (Cazarolli, Folador et al. 2009). Apigenin-6-C- -1-fucopyranoside was seen to lower blood glucose
and stimulate glucose-induced section in hyperglycaemic rats (Cazarolli, Folador et al. 2009). The mechanism for the activity is increased muscle glycogen synthesis (Cazarolli, Folador et al. 2009) and not a result of hepatic gluconeogenesis and/or increased uptake of glucose by muscle tissue (Ferreira, Fernandes et al. 2008).

Leaf extracts have also caused hypotension in normal rats (Soncini, Santiago et al.; Vasconcelos, Gondim et al. 2008).

Extracts of the fruit have shown the ability to restore hepatic disturbances induced by carbon tetrachloride in mice (Azeem, Mathew et al.) and rats (Padhy, Yedukondalu et al. 2008). A range of effects have been seen with reduction of liver function enzymes, increased reduced glutathione levels, improvement of other biochemical indices and corresponding improvements in hepatic structure (Azeem, Mathew et al.; Padhy, Yedukondalu et al. 2008).

Carambola pomace, when included in hamsters’ diets as a source of dietary fibre, has shown potential benefits to gut health (Chau, Chien et al. 2005; Chau and Chen 2006). However consumption of carambola and carambola juice has resulted in neural and renal damage in people with kidney problems (Neto, Robl et al. 1998; Chang, Hwang et al. 2000; Chen, Fang et al. 2001; Fang, Chen et al. 2001; Chang, Chen et al. 2002; Chen, Chou et al. 2002; Neto, da Costa et al. 2003; Tse, Yip et al. 2003; Andersson and Sundh 2004; Chang and Yeh 2004; Chen, Fang et al. 2005; Tsai, Chang et al. 2005; Niticharoenpong, Chalermsanyakorn et al. 2006; Wang, Liu et al. 2006; Fang, Chen et al. 2007; Cassinotto, Mejdoubi et al. 2008; Fang, Lee et al. 2008; Marin-Restrepo and Rosselli 2008). Both the fruit and juice also inhibit liver enzyme activity, which can alter prescription drug pharmacokinetics (Hidaka, Fujita et al. 2004; Hosoi, Shimizu et al. 2008).

**Duku–Langsat (Langsium domesticum)**

**Background and growing situation in Australia**

Duku–Langsat is a relatively unknown fruit in Australia although well known in Thailand, Malay Peninsula and the Indonesian islands. The fruit are borne in grape like clusters on the trunk and main branches of the tree. The fruit is covered in a leathery skin which is easily peeled to reveal two to three translucent flesh segments. Immature fruit produce latex at the edge of the broken skin. Fruit may contain one greenish seed similar in size to a pumpkin seed. In most cases the seeds are aborted. The flesh has a refreshing flavour with a hint of acidity. The survey revealed a surprising number of trees in northern Queensland and the NT. There are 1200 trees planted in north Queensland (68.7%) with a further 550 trees (31%) in the NT.

**Nutrient and phytochemical content**

Total phenolic content, vitamin C, carotenoid content and vitamin E content have been described in fruit flesh (Isabelle, Lee et al.).
**Bioactivity and health properties**

Extracts of fruit skin and leaf have reduced parasite populations of two strains of falciparum in vitro (Yapp and Yap 2003). Similarly, three tetranortripernoids and five triterpenoids, extracted from seeds, were shown to have antimalarial activity (Saewan, Sutherland et al. 2006).

**Durian **(*Durio zibethinus*)

**Background and growing situation in Australia**

Durian, the “King” of tropical fruit, perfectly represents the term “exotic fruit”. A fruit armoured with spines and a pungent odour when ripe. The creamy edible flesh surrounding the seeds has a flavour similar to garlic custard. The bulk of trees accounted for in the survey are in the NT (3,107 or 62.2% of total). The remaining 1,888 trees in Queensland are the survivors following cyclone Larry. Pre Larry stock-take suggested that there were up to 13,000 durian trees planted in north Queensland. The estimated production potential of durian, at a yield of 12 kg/tree is 60 tonnes valued at $0.48M.

**Nutrient and phytochemical content**

Durian is an excellent source of vitamin C (49% RDI/100g) and thiamin (34% RDI/100g) (USDA).

Flesh content of phenolic acids, flavonoids, flavonols and anthocyanins have been studied (Haruenkit, Poovarodom et al. 2007; Toledo, Arancibia-Avila et al. 2008). Varietal differences have been observed for phenolics, carotenoids and vitamin C content (Ashraf, Maah et al.; Ashraf, Maah et al.) (Leontowicz, Leontowicz et al. 2008; Toledo, Arancibia-Avila et al. 2008).

**Bioactivity and health properties**

Durian in the diets of rats has shown the ability to inhibit rises in total cholesterol and LDL that result from high cholesterol feeding regimes (Haruenkit, Poovarodom et al. 2007; Leontowicz, Leontowicz et al. 2007; Leontowicz, Leontowicz et al. 2008; Leontowicz, Leontowicz et al. 2008). Other effects observed in these studies include increased plasma antioxidant activity (Haruenkit, Poovarodom et al. 2007; Leontowicz, Leontowicz et al. 2007; Leontowicz, Leontowicz et al. 2008), restoration of normal blood glucose levels (Leontowicz, Leontowicz et al. 2007), reduced histopathology in liver and aorta (Leontowicz, Leontowicz et al.) and altered plasma fibrinogen composition (Leontowicz, Leontowicz et al. 2008).

An ethanol extract of durian fruit was seen to show gastro-protective effects in rats, with inhibition of gastric lesion development, decreased pyloric-ligation induced basal gastric secretion, and reduced gastric mucosal injury observed (Paulsi and Dhasarathan).

A durian shell extract was seen to reduce ammonia and S02 induced coughing in mice, as well as mediating a pain relieving effect in an acetic acid induced pain model (Wu, Xie et al.).
Polysaccharide gels from shell/husk have shown immune stimulating effects in shrimp (Pholdaeng and Pongsamart) and chickens (Chua, Nurhaslina et al. 2008), wound healing ability when used as a film dressing in dogs (Chansiripornchai and Pongsamart 2008), and have been tested for use in cosmetic applications showing positive in vitro effects on facial skin capacitance and firmness (Futrakul, Kanlayavattanakul et al.).

**Guava (Psidium guajava)**

Background and growing situation in Australia

Guava is well known for its use as an ingredient in tropical juices. The skin and interior flesh containing small seeds are edible when immature as a crisp fruit or as a mature soft fruit. Flesh colour varies with variety from white to salmon pink. The white fleshed fruit are supplied to the market as mature unripe for fresh fruit consumption. The pink fruit are supplied for fresh fruit consumption as ripe fruit. The fruit, in particular the pink fleshed varieties, have recently gained notoriety with exposure on Master Chef®. Guava is an underrated fruit with major plantings in The NT (3,290 trees or 86.2% of total production). The remaining 525 trees are grown in north Queensland. The estimated production potential of guava, at a yield of 30 kg/tree is 114 tonnes valued at $0.5M.

Nutrient and phytochemical content

A typical guava (55g) is an exceptional source of vitamin C, providing over 3 times the RDI, and provides 10% DI of fibre (USDA).

Phytochemical content of many parts of the plant have been described including the fruit (Oliveira, Lobato et al.; Pierson, Dietzgen et al.; Thuaytong and Anprung; Chandrika, Fernando et al. 2009) and leaves (Metwally, Omar et al.; Oloyede; Peng, Peng et al.; Pierson, Dietzgen et al.; Witayapan, Songwut et al.; Yang, Hsieh et al. 2008; El Sohafy, Metwalli et al. 2009; Fu, Luo et al. 2009; Kuan-Chou, Chiu-Lan et al. 2009).

Bioactivity and health properties

The health benefits of guava, particularly leaf extracts, have received more attention than most other tropical exotics, which is evidenced by a number of recent reviews (Gupta, Jagbir et al.; Metwally, Omar et al.; Milind and Ekta; Payal, Vikas et al.; Pierson, Dietzgen et al.; Sanda, Grema et al.; Gutiérrez, Mitchell et al. 2008).

Anti-diabetic

A specific, commercially available guava leaf tea, marketed in Japan, was recently reviewed which detailed the benefits of its anti-hyperglycaemic and anti-hyperlipidemic activity in human trials (Deguchi and Miyazaki). A number of studies have reported the effects of guava leaf extracts in diabetic rats with reduced blood glucose (Shen, Cheng et al. 2008), increased plasma insulin level (Shen, Cheng et al. 2008), increased glucose utilisation (Prasad, Alka et al. 2008; Shen, Cheng et al.)
2008), reduced serum triglyceride (Chuang, Shen et al. 2008), reduced LDL (Chuang, Shen et al. 2008), reduced lipid per oxidation (Soman, Rauf et al.) and reduced glycated haemoglobin (Soman, Rauf et al.) (Soman, Rajamanickam et al.). Various flavonoids from the leaf (quercetin, kaempferol, apigenin) have shown high inhibitory activities of alpha-glucosidase and alpha-amylase in vitro (Wang, Du et al.), with quercetin shown to be the major compound, in guava leaf tea, that enhances glucose uptake in rat hepatocytes (Cheng, Shen et al. 2009).

Extracts from fruit peel have shown similar effects in diabetic rodents with reduced blood glucose levels (Rai, Mehta et al.; Rai, Jaiswal et al. 2009), reduced urine glucose levels (Rai, Jaiswal et al. 2009), increased haemoglobin levels (Rai, Jaiswal et al. 2009), increased body weight (Rai, Jaiswal et al. 2009), decreased triglyceride (Rai, Mehta et al.), decreased total cholesterol (Rai, Mehta et al.), decreased LDL (Rai, Mehta et al.), as well as reversal of smooth muscle response impairment (Liu, Peng et al.).

Bark extracts have also lowered blood glucose levels in mice with induced hyperglycaemia (Prasad, Qureshi et al. 2008).

In rats injected with streptozotocin, a compound that induces diabetes by damaging pancreatic beta-cells, fruit extracts have also shown the ability to reduce loss of islet beta-cells (Huang, Yin et al.).

Intake of guava bud in PNG residents may help to ameliorate the diabetic effect of chewing betel quid (Owen, Martineau et al. 2008).

**Anti-cancer**

The relative in vitro activity and different mechanisms of pulp, peel and seed fractions in mediating observed anticancer effects has recently been described (Bontempo, Doto et al.).

Guava leaf extracts have shown cytotoxicity to a range of human cancer cells including prostate (Ryu, Park et al.), ovarian and leukaemia (Levy and Carley). Leaf extracts have also shown the ability to reduce tumour size in a xenograft mouse tumour model (Chen, Peng et al.). Guava branch extract has shown cytotoxic effect on colon carcinoma cells (Lee and Park).

**Anti-hypertensive**

Guava puree fed to spontaneously hypertensive rats has lowered body weight and systolic blood pressure (Ayub, Norazmir et al.). When guava was included as a dietary intervention for selected hypertensive patients, vitamin C intake was massively increased and a significant lowering of total cholesterol, triglycerides and blood pressure was observed and an increased HDL cholesterol, was observed over those patients not receiving guava (Singh, Rastogi et al. 1992; Singh, Rastogi et al. 1993; Singh and Rastogi 1997). A recent study in young men has shown increases in serum antioxidant status and HDL-cholesterol from guava consumption over a 4 week period (Rahmat, Abu-Bakar et al. 2006).

**Cytoprotective**

Leaf extracts have shown liver protective effects against erythromycin (Sambo, Garba et al. 2009), paracetamol (Priscilla and Milan; Roy and Das; Taju, Jayanthi et al.) and carbon tetrachloride (Roy and Das) induced liver damage. The extracts have reduced elevated serum levels of aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase and bilirubin, whilst also protecting tissue structure. Similarly leaf extracts have shown protective effects against kidney damage induced by arsenic (Manju and Sushovan). Administration of leaf extracts have led to significant reduction in aortic atherogenic lesion area in apoE-knock out mice (Kawakami, Hosokawa et al.), with ethyl gallate and quercetin were seen to be the main compounds inhibiting leucocyte-type 12-lipoxygenase and LDL oxidation in vitro.
Anti-diarrheal and gastro-protective

Leaf extracts have shown in vitro ability to control infectious diarrhoea, with the full scope of its antidiarrhoeal activity not due to quercetin alone (Birdi, Daswani et al.). Leaf extracts have shown protection to rats and mice from castor oil-induced diarrhoea, with inhibition of intestinal transit and delay of gastric emptying (Ojewole, Awe et al. 2008) (Shah, Begum et al.).

In rats with induced colitis, leaf extracts have shown decreased disease activity index, decreased macroscopic and microscopic lesion score, showing similar effects to aspirin (Sarmistha and Swarnamoni). In induced-ulcer animal models, guava leaf extracts have inhibited gastric lesions, reduced gastric secretory volume, acid secretion and increased gastric pH (Livingston Raja and Sundar).

Anti-inflammatory

Leaf extracts have shown the ability to reduce paw edema, inhibit exudate formation, inhibit weight reduction and downregulate arthritis index in a number of rat inflammation models (Dhiman, Nanda et al.; Dutta and Das).

Anti-parasitic

In rats infected with Trypanosoma brucei brucei, leaf extracts have resulted in removed or lowered parasite load, extended life span, reduced serum MDA and reduce lipid peroxidation (Adeyemi, Akanji et al. 2009; Akanji, Adeyemi et al. 2009).

Immune stimulating

Guava leaf - The levels of IFN-gamma and IL-2 in the salivary juice in the patients with Norovirus diarrhoea were higher than the normal healthy patients. Guava leaf has the effect of raising the levels of IFN-gamma and IL-2 in the salivary juice on Norovirus diarrhoea patients, so it can regulate the cellular immune function and promote the T helper cell 1 immunity. (Zhou, Huang et al. 2008)

Women’s health

Guava leaf inhibited spontaneous phasic rat uterine horn preparations of female rats. – this supports its use in the traditional practice of African women in treating primary dysmenorrhoea. (Chiwororo and Ojewole 2009)

Memory

Guava fruit have shown memory improving effects in mice and rats, reversing the effects of scopolamine and diazepam-induced amnesia (Milind and Ekta).

Hog Plum (Spondias cytherea)

![Hog Plum Image]
Background and growing situation in Australia

Also known as Fiji Apple, Ambarella, Vi Apple or Otaheite Apple is a member of the mango and cashew family. The fruit, dark green in colour, is plum shaped sweet-sour to taste and is eaten at all stages of ripeness. The fruits have a distinct spiny seed that hardens as the fruits mature thus requiring care when the flesh is sucked from the seed. Although the fruit is native to the Pacific it is now commonly grown and eaten throughout SE Asia and Central America. The fruit is grown commercially in the NT with 890 trees representing 97.3% of total plantings. Fruit is produced from two major selections a large tree and a dwarf variety.

Nutrient and phytochemical content

Provides 12% of RDI for vitamin C (Ishak, Ismail et al. 2005). Total phenolic content of fruit flesh has been described (Ishak, Ismail et al. 2005). The structure of polysaccharide isolated from pulp has been determined (Iacomini, Serrato et al. 2005).

Jaboticaba (*Myrciaria cauliflora*)

Background and growing situation in Australia

Jaboticaba is native to southern Brazil. The fruit are produced directly on the main trunk and branches and are similar in appearance to a large black skinned grape. The skin of jaboticaba is relatively thick and contains a translucent flesh similar to a grape. The fruit are delicious when eaten fresh and would lend themselves to being presented in a punnet similar to temperate berries. The survey suggests there are 441 commercial trees with all of them present in north Queensland. Jaboticaba will also grow successfully in sub tropical areas such as SE Queensland.

Nutrient and phytochemical content

Jaboticaba is an excellent source of vitamin C. One hundred grams of the fruit contains 57% of the RDI for Vitamin C (Morton 1987).

Various phytochemical contents of the fruit flesh (citric acid, oxalic acid, phenolic compounds) (Abe, Lajolo et al.; Trevisan, Bobbio et al. 1972; Einbond, Reynertson et al. 2004), skin (anthocyanins and phenolic compounds) (Einbond, Reynertson et al. 2004; Reynertson, Yang et al. 2008) (Abe, Lajolo et al.) and seed (fatty acids) have been determined (Jorge, Bertanha et al.).

Bioactivity and health properties

Jaboticaba leaf extracts have shown anti-bacterial activity, which may be useful in treating dental plaque (Carvalho, Macedo-Costa et al. 2009; Macedo-Costa, Diniz et al. 2009).

Freeze-dried, anthocyanin rich, peel powder has been shown to inhibit lipid oxidation in vitro and when fed to rats has increased plasma antioxidant capacity (Leite, Malta et al.).
Jackfruit (*Artocarpus heterophyllus*)

**Background and growing situation in Australia**

Jackfruit is a relative of breadfruit and mulberry and is chiefly grown for its ripe fruit that is eaten fresh or used in desserts and sweet drinks. Green fruit is also commonly used in vegetable curries and the seed of ripe fruit can be eaten after being boiled or roasted. Jackfruit is an increasingly important fruit with major plantings in The NT (7,240 trees, 78.1% of total production). The remaining 2,031 trees are grown in north Queensland. Fruit are supplied as immature green for use in curries or as whole mature fruit. The fruit also has an important profile in farmers markets in the NT. The estimated production potential of Jackfruit, at a yield of 80 kg/tree is 741 tonnes valued at $2.6M. Selected varieties of Jackfruit are assumed to have potential for the fresh cut market. This would allow the fruit to be introduced to a new market.

**Nutrient and phytochemical content**

Jackfruit is a good source of vitamin A (19% RDI/100g) (Chandrika, Jansz *et al.* 2005) and also contains other carotenoids including lutein, neoxanthin and violaxanthin (de Faria, de Rosso *et al.* 2009).

Recent reviews provide a good summary of the many compounds found in the jackfruit plant together with details of cultivar variation (Baliga, Shivashankara *et al.*; Om, Rajesh *et al.* 2009).

**Bioactivity and health properties**

Extracts of the plant have shown a large range of effects including anti-inflammatory, anti-fungal, immunomodulatory, anti-diabetic and anti-bacterial activities (Om, Rajesh *et al.* 2009).

The fibre from jackfruit was seen to inhibit the effects of insecticide on beta-glucuronidase activity (a weak marker of colon cancer) in the gut of rats (Serji and Devi 1993).

Cycloheterophyllin and artronin A and artonin B have shown *in vitro* inhibition of LDL oxidation and lipid peroxidation in rat brain homogenate (Baliga, Shivashankara *et al.*).

Artocarpesin, norartocarpesin, oxyresveratrol from leaves have shown *in vitro* anti-inflammatory activity with artocarpesin being heralded as potentially beneficial in treating inflammatory disorders (Fang, Hsu *et al.* 2008). A bark extract has shown anti-inflammatory activity in carrageenan-induced inflammatory rat model (Sandhya, Roopam *et al.*).

Leaf extracts have shown the ability to improve glucose tolerance in diabetic patients (Fernando, Wickramasinghe *et al.* 1991). In diabetic rats leaf extracts have lowered blood glucose, cholesterol and triglyceride levels, in a similar fashion to clinically used drug glibenclamide (Chackrewarthy, Thabrew *et al.*), as well as decreasing lipid peroxides, glycosylated hemoglobin, triglycerides, total cholesterol, LDL and VLDL, but increasing HDL levels (with the high flavonoid content thought to be responsible for the effects) (Omar, El-Beshbishy *et al.*). A fruit extract showed similar
improvements to blood glucose and blood lipid profiles in diabetic rats (Sanjay, Rajani et al.). Both plant seed powder and bark extract have also significantly lowered blood glucose in diabetic rats (Osmani, Sekar et al. 2009), with the bark extract also seen to reduce serum cholesterol and restore body weight (Priya, Gothandam et al.).

Various parts of the plant have shown promise as sources of anti-cancer compounds with a range of compounds showing *in vitro* antitumor activity, including dihydromorin, steppogenin, norartocarpetin, artocarpanone, artocarpesin albanin A and 3-prenyl luteolin, being extracted from twigs, wood and tegmen (Zheng, Chen et al. 2009) (Arung, Shimizu et al.; Arung, Shimizu et al.; Arung, Yoshikawa et al.). Jacalin, a lectin from latex, has been shown to inhibit colon cancer cell proliferation (Ajayi).

Jacalin and ArtinM (another lectin) have shown adjuvant and immune stimulating activities against several parasites (Cardoso, Mota et al.).

Glycoproteins isolated from latex have shown in vitro anti-thrombotic activity (Siritapetawee and Thammasirirak; Siritapetawee, Thumanu et al.).

**Longan (*Dimocarpus longan*)**

**Nutrient and phytochemical content**

Longans are an excellent source of vitamin C with one hundred grams of the fruit containing over 2 times the RDI (USDA).

Several recent review articles have compiled excellent summaries of the compounds identified and quantified in pericarp, seed and fruit flesh of longan with detailed cultivar comparisons (Wang, Liang et al.; Yang, Jiang et al. 2011). Interestingly the aim of elevated polysaccharide content has become the target of Chinese breeding programs (Zheng, Jiang et al. 2008).

**Bioactivity and health properties**

Polysaccharides from pericarp have shown neuroprotective ability in rats with ischemia/reperfusion injury, with polysaccharide administration reducing the neurological score, infarct volume, brain water content, and a range of oxidative stress and inflammatory response markers (Chen, Chen et al.; Chen, Sun et al.).

Longan flower extracts have shown *in vitro* delay of LDL oxidation with epicatechin and proanthocyanidin A2 thought to be mediate the effect (Hsieh, Shen et al. 2008).

Longan seed powder has shown antifungal activity, which was superior to that of pulp and whole fruit, being heralded as a suitable antifungal agent in mouthwash products (Rangkadilok, Tongchusak et al.).

Fruit extracts and polysaccharide-protein complexes from pulp have shown immune stimulating effects in both in vitro systems (Yang, Sen Tai et al.) and immunosuppressed mice (Kui, Qiang et al.) (Yi, Liao et al.) (Su, Zhang et al.).

Polysaccarhides from pulp have shown *in vitro* inhibition of tyrosinase activity, which may be suggestive of potential benefits in skin cancer therapy (Yang et al, FRI 2011) as well as antitumor effects in mice (Kui, Qiang et al.). Longan flower extract has also showed *in vitro* chemoprotective activity against colon cancer cell lines (Chih-Ping, Ying-Hsi et al.).

In rodents, extracts of fruit peel have ameliorated the effects of kainic acid (which induces seizures) with increased survival rate and latency of convulsion onset, as well as decreased seizure scores and
weight loss (Jo, Eun et al.). Both seed and fruit extracts have shown memory enhancing effects in mice (Park, Park et al.; Losuwannarak, Pasadhika et al. 2009).

Polyphenol-rich longan seed extract, polysaccarhides from pulp, and twig extract have all showed in vitro anticancer activity against cancer cell lines (Chung, Lin et al.; Wang, Tang et al.; Yang, Jiang et al. 2011).

Polysaccarhides have also shown in vitro anti-glycation activity, which may indicate potential benefits for diabetics (Yang et al, FRI 2011).

In hypercaloric rat models longan flower water extracts have shown the ability to decrease body weight, size of epididymal fat, serum triglyceride level, atherogenic index, hepatic lipids, insulin resistance, systolic blood pressure, and improved liver function and tissue structure (Deng-Jye, Yuan-Yen et al.; Liu, Yang et al.; Tsai, Wu et al. 2008).

Seed extracts have shown anti-fatigue properties in mice with extended swimming time, increased hepatic glycogen, reduced blood urea nitrogen and decreased lactic acid observed (Zheng, Jiang et al.).

**Mamey sapote (Pouteria sapota)**

**Nutrient and phytochemical content**

Mamey Sapote is a good source of fibre (10% RDI/100g) and niacin (20% RDI/100g), and an excellent source of vitamin C (60% RDI/100g) (Morton 1987).

The phenolic (Torres-Rodriguez, Salinas-Moreno et al.; Ma, Yang et al. 2004; Li, Xie et al. 2008), carotenoid (Murillo, McLean et al.; Yahia, Gutierrez-Orozco et al.; Alia-Tejacal, Villanueva-Arce et al. 2007) and vitamin E (Yahia, Gutierrez-Orozco et al.) Composition of the fruit flesh have all been examined recently.

**Mangosteen (Garcinia mangostana)**

**Background and growing situation in Australia**

Mangosteen is considered the “Queen” of tropical fruit. The thick purple skin surrounds a number of white fleshed citrus like segments which may contain one or two seeds. Mangosteen is primarily grown in north Queensland (11,606 trees or 98.6% of total plantings). The remaining 163 trees are recorded in the NT. This is not unexpected given that mangosteen is not ideally suited to the monsoonal tropics. The production potential of mangosteen, at a modest yield of 15 kg per tree is 176 tonnes valued at $1.77M. Mangosteen production is dependent on ideal environmental conditions. Hence yearly production is highly variable.
Nutrient and phytochemical content

A range of studies have isolated, identified and quantified a variety of phytochemicals in various parts of the plant, including pericarp procyanidins (Zhou, Lin et al.), phenolic acids in flesh and pericarp (Zadernowski, Czaplicki et al. 2009), anthocyanins in pericarp (Zarena and Udaya Sankar), and xanthones and benzophones present in fruit and pericarp (Jiang, Quan et al.; Wittenauer, Falk et al.).

Bioactivity and health properties

In rats fed 5% powdered mangosteen together with 1% cholesterol rats showed significantly lower total cholesterol, LDL-cholesterol and triglycerides, than 1% cholesterol rats without mangosteen (Leontowicz, Leontowicz et al. 2006; Leontowicz, Leontowicz et al. 2007).

The various bioactivities of the pericarp extracts have created much interest with several review articles examining the effects of extracts and isolated compounds (Lobb; Shan, Ma et al.; Akao, Nakagawa et al. 2008; Chin and Kinghorn 2008; Obolskiy, Pischel et al. 2009).

Anticancer

Whole extracts of pericarp as well as the isolated xanthones, alpha- and gamma-mangostin, have shown anti-cancer activity in a range of human cancer cell lines, including breast (Balunas, Su et al. 2008), colon (Zhou, Huang et al.), colo-rectal (Ramida, Faongchat et al.), leukemia (Ong, Ling et al. 2009), melanoma (Han, Kim et al. 2009), brain (Hui-Fang, Wen-Tsung et al.), prostate (Johnson, Petiwala et al.), mammary carcinoma (Shibata, Iinuma et al.) and gastric adenocarcinoma (Kikuchi, Ohtsuki et al.). Stem bark extracts have also shown cytotoxicity to colon cancer cells (Han, Kim et al. 2009).

Studies in animal models have also shown promising results. Intratumoral administration of xanthones in mice has repressed, reduced size and caused disappearance of tumors of implanted human colorectal adenocarcinoma cells (Ramida, Faongchat et al.). In mouse models of mammary cancer, alpha-mangostin administration has significantly increased survival rate, reduced tumor volume and suppressed lymph node metastases multiplication (Shibata, Iinuma et al.), and panaxanthone (80% alpha-mangostin and 20% gamma-mangostin) significantly suppressed tumor volumes (Doi, Shibata et al. 2009). Alpha-mangostin administration in mice implanted with pancreatic cancer cells also caused a significant reduction in tumor volume (Johnson, Petiwala et al.).

Cytoprotective/anti-oxidative stress

Xanthones have shown in vitro inhibition of lipid peroxidation (Zarena and Sankar 2009). Alpha-mangostin has shown in vitro attenuation of neurotoxicity induced by amyloid oligomers in rat cortical neurons (Wang, Xia et al.). As Alzheimer’s Disease is associated with accumulation of these oligomers, the authors proposed that alpha-mangostin may be a candidate for treatment. Pretreatment of mice with xanthone fraction has shown protection from doxorubicin-induced central nervous system toxicity (Tangpong, Miriyala et al.). Pretreatment with alpha-mangostin showed protective effects against isoproterenol-induced myocardial necrosis in rats (Cui, Hu et al.). Alpha-mangostin has shown the ability to ameliorate the harmful effects of cisplatin (apoptotic cell death and oxidative stress) to the kidneys of rats (Sanchez-Perez, Morales-Barcenas et al. 2010).

Alpha and gamma-mangostin have also showed potent in vitro ability to inhibit hepatic stellate cells, which may indicate a possible role in the treatment of liver fibrosis (Chin, Shin et al.; Akao, Nakagawa et al. 2008).
**Anti-bacterial**

Pericarp extracts have shown in vitro activity against bacteria that cause acne (Propionibacterium acnes and Staphylococcus epidermidis), with alpha-mangostin a major active component (Pothitirat, Chomnawang *et al.*). When formulated into a gel system the extract had better activity than commercial clindamycin phosphate gel (Bhaskar, Arshia *et al.* 2009). A gel formulation containing pericarp extract has also shown promise as a topical anti-bacterial assisting in periodontal treatment (Rassameemasmaung, Sirikulsathean *et al.* 2008).

Pericarp extracts and isolated alpha and gamma-mangostin have shown in vitro ability to reduce inflammation including insulin resistance in adipocytes (Bumrungpert, Kalpravidh *et al.* 2009), allergic responses in mast cells (Hee-Sung, Sei-Ryang *et al.*) and basophils (Itoh, Ohguchi *et al.* 2008), and nitric oxide and prostaglandin E-2 release from macrophages (Tewtrakul, Wattanapiromsakul *et al.* 2009). Furthermore, in animal studies, extracts as well as the individual compounds have exhibited pain relieving effects (Cui, Hu *et al.*) and inhibited carrageenan-induced paw edema (Chen, Yang *et al.* 2008). In obese patients mangosteen juice has shown the ability to reduced elevated high-sensitivity C-reactive protein levels (Udani, Singh *et al.* 2009). However there was no change in other markers of inflammation or lipid peroxidation. Similarly in a study in healthy adults, participants receiving mangosteen juice had decreased serum C-reactive protein levels (Tang, Li *et al.* 2009). This was accompanied by increased concentrations of various markers of immune function.

Leaf extract has shown in vitro ability to enhance tyrosinase activity, which indicates a potential use is self-tanning cosmetic products (Hamid, Sarmidi *et al.*).

**Pitaya (Hylocereus undatus, Hylocereus polyrhizus, Selenicereus megalanthus)**

Background and growing situation in Australia

Pitaya is also known as dragon fruit. There are normally grown and marketed as *Hylocersus undatus* (red skin white flesh), *Hylocerus polyrhizus* (red skin red flesh) and *Selenicereus megalanathus* (yellow skin with white flesh). The fruits are members of the cactus family. They are popular among immigrants of Vietnamese decent. The fruit are an attractive addition to a fruit platter. Some consider the flesh bland. The red fleshed species lends itself to be used as a base for exotic spiced or sweet sauces. Dragon fruit is currently the most prolific species recorded in the survey with 50,100 planting sites. The bulk of the plantings are in the NT (34,150 sites or 62.2% of total plantings). The survey did not distinguish between the three species but experience suggests that the bulk of the plantings in the NT are based on *Hylocersus undatus* while Queensland produces a high proportion of *Hylocerus polyrhizus*. The third species (S. megalanthus) is usually grown in small quantities. The farmgate value of the pitaya industry, based on the survey data, is $2.25M from a production of 750 tonnes.
Nutrient and phytochemical content

Pitaya is an excellent source of vitamin C, with a 100 gram serving of the white and red fleshed fruits containing 33% and 140%, respectively, of the RDI (Mahattanatawee, Manthey et al. 2006).

The betalain (Wybraniec and Mizrahi 2002; Yi-Zhong, Jie et al. 2006; Wybraniec, Nowak-Wydra et al. 2007) (Jamilah, Shu et al.; Phebe, Chew et al. 2009) and phenolic content (Vaillant, Perez et al. 2005; Mahattanatawee, Manthey et al. 2006; Wu, Hsu et al. 2006; Esquivel, Stintzing et al. 2007) of both flesh and peels has been determined, as well as the structures of the oligosaccarhides in the flesh (Wichienchot, Jatupornpipat et al.). Identification of major flavanoids (Yi, Zhang et al.) and new glycosides, termed undatusides (Wu, Wang et al.), in flowers of Hylocereus undatus, as well as seed composition (Adnan, Osman et al.; Chemah, Aminah et al.; Villalobos-Gutierrez, Schweiggert et al.) have also been undertaken.

Bioactivity and health properties

The fruit pulp when applied topically showed wound healing ability in diabetic rats (Perez, Vargas et al. 2005). There was decreased edema, increased collagen and tensile strength of the wound site, a shortened period of epithelialisation, and increased hexosamine, total proteins and DNA.

Extracts of fruit have shown in vitro inhibition of breast cancer cells (Jayakumar and Kanthimathi), while peel extracts had greater inhibitory activity on melanoma cancer cell growth than flesh (Dembitsky, Poovarodom et al. 2011).

Both peel (Nurmahani, Osman et al.) and flesh (Tenore, Novellino et al.) fractions have shown antibacterial properties in vitro.

When fed to hypercholesterolemia rats, fresh pitaya reduced total and LDL cholesterol and blood glucose but increased serum antioxidant activity (Omidizadeh, Yusof et al.). Similarly in diabetic rats fruit pulp reduced fasting blood glucose, as well as reducing systolic blood pressure, malondialdehyde levels and aortic stiffness but increased superoxide dismutase and total antioxidant capacity (Anand Swarup, Sattar et al.).

Oligosaccharides from both white and red fleshed fruit have shown in vitro stimulation of the growth of lactobacilli and bifidobacteria (Wichienchot, Jatupornpipat et al.).

Oral administration of fruit extract to male rats has shown increased sperm count, sperm viability and sperm production, with histology of the testis showing a high density of sperm in seminiferous tubules (Aziz and Noor).
Pomelo (*Citrus grandis*)

**Background and growing situation in Australia**

This citrus best suited to the hot humid tropics, is the largest of the citrus fruits with specimens recorded up to 6 kg in weight. Pomelos are round or pear shaped depending on cultivar and tend to have relatively thick rind. Skin colour is generally light green, yellow or light pink. The flesh varies in colour from pale yellow to pink. The juice sacks are large and lightly crunchy containing a mildly sweet acidic juice. The fruit is a favourite among Chinese people, particularly during festivals such as Chinese New Year and the Moon Festival. Pomelo is grown widely in tropical north Australia with major plantings in the NT (4,100 trees or 76.7% of total). The fruit are growing in acceptability in the market and are being increasingly utilised by high-end restaurants in fusion style salads. The estimated production potential of pomelo, at a yield of 60 kg/tree is 321 tonnes valued at $0.96M.

**Nutrient and phytochemical content**

Pomelo is an excellent source of vitamin C with one hundred grams of the fruit containing 1.5 times the RDI (UDSA).

A range of studies have identified and examined the carotenoids (Tao, Gao *et al.*; Xu, Fraser *et al.* 2006; Wang, Chuang *et al.* 2008), limonoids (Tian, Dai *et al.* 2000), polysaccharides (Mokbel 2005), furocoumarins (Girennavar, Jayaprakasha *et al.* 2008), flavonoids (Wang, Chuang *et al.* 2008), and essential oil (Neng-Guo and Yue-Jin) content of different parts of the fruit including flesh, juice, peel and seeds. Several studies have examined cultivar variation in limonin and naringin (Zhang, Duan *et al.*; Dan, Sheng *et al.* 2008; Pichaiyongvongdee and Haruenkit 2009), total phenolic content (Ramful, Tarnus *et al.*), total flavonoid content (Ramful, Tarnus *et al.*) and ascorbic acid content (Ramful, Tarnus *et al.*).

**Bioactivity and health properties**

The juice affects the pharmacokinetics of certain prescription drugs (Lin, Chao *et al.*; Grenier, Fradette *et al.* 2006; Guo, Chen *et al.* 2007; Farkas and Greenblatt 2008).

Peel extracts have shown in vitro antimicrobial activity (Neng-Guo and Yue-Jin).

Leaf extracts have shown a range of *in vitro* activities including anti-inflammatory effects (Yang, Kang *et al.* 2008; Yang, Kang *et al.* 2008; Yang, Lee *et al.* 2009), cytoprotective effects to induced oxidative stress (Lim, Yoo *et al.* 2006; Kim, Cho *et al.* 2008), anti-cancer properties with antiproliferative effects on human prostate cancer cells (Chiang, Kim *et al.*) and apoptotic inducing effects on human cervical carcinoma cells (extract was identified as rich in polymethoxylated flavones) (Kim, Moon *et al.*), as well as insulin-like activity of two isolated compounds, rhoifolin and cosmosiin (Rao, Lee *et al.*). Further anticancer activity has been shown by peel (Jae-Seok, Sung-Myung *et al.* 2009) and fruit (Lim, Moon *et al.* 2009) extracts, mediating in vitro apoptosis of human cancer cells.
Flavanone extracts have shown *in vitro* inhibitory effects on the activity of intestinal alpha-glucosidase and pancreatic alpha-amylase inhibition, which may indicate a role for these compounds in controlling blood glucose level in diabetics (Gyo-Nam, Jung-Geun *et al*. 2009).

**Rambutan (Nephelium lappaceum)**

![Rambutan](image)

**Background and growing situation in Australia**

This fruit has been the mainstay of the tropical exotic fruit industry. The fruit is the “tropical” cousin of lychee and longan. The attractive soft spined exterior skin surrounds the sweet translucent to white flesh containing one seed. Rambutan’s are best eaten as a fresh fruit. The majority of trees are located in north Queensland (approx 20,000 or 79.7% of total plantings) with approximately 5000 trees recorded in the NT. The production potential of rambutan, at a modest yield of 25 kg per tree, is 627 tonnes valued at $3.76M. Rambutan production is dependent on ideal environmental conditions. Hence yearly production is highly variable.

**Nutrient and phytochemical content**

Rambutan is an excellent source of vitamin C with one hundred grams of the fruit containing 75% of the RDI (Morton 1987).

Total phenolic content (Gorinstein, Zemser *et al*. 1999) and major phenolic compounds of flesh (Thitilertdecha and Rakariyatham ; Thitilertdecha, Teerawutgulrag *et al*. ; Gorinstein, Zemser *et al*. 1999) and pericarp (Liping, Huilin *et al*. ) have been recorded including anthocyanins (Jian, Hongxiang *et al*.).

**Bioactivity and health properties**

Pericarp extracts have shown a range of activities in vitro including antimicrobial activity (Nont, Aphiwat *et al*. 2008), cytoprotective activity (Ling, Saito *et al*. ) and fatty synthase inhibition (Zhao, Liang *et al*.), as well as inhibition of alpha-glucosidase, alpha amylase, aldol reductase and prevention of advanced glycation end product formation, which may translate to benefits for diabetic patients (Palanisamy, Thamilvaani *et al*.). The high content of phenolic compounds in rind extracts, in particular ellagic acid, corilagin and geraniin, have been identified as the key compounds in mediating many of these effects (Dembitsky, Poovarodom *et al*. 2011).
Rollinia (*Rollinia deliciosa*)

**Background and growing situation in Australia**

Also known as Biriba, this fruit is a relative of custard apple native to tropical central America and south America. The fruit is a yellow and heart shaped with a bumpy surface of soft leathery spines. The soft white tasty flesh is interspersed with black seeds which are not eaten. The tree is commonly propagated by seed and no varieties exist in commercial production. The fruit is challenging to move when ripe but a number of specialist growers are managing to get the fruit to southern markets. Fruit are best eaten fresh or can be used in cooking (cheese cakes and ice creams). The survey suggests that 100% of the crop is grown in far north Queensland (1330 trees). The tree bears early and prolifically.

**Nutrient and phytochemical content**

Rollinia is an excellent source of vitamin C with one hundred grams of the fruit containing 82% of the RDI (Morton 1987).

Lignan content has been studied (Queiroz Paulo, Kaplan et al. 1991) as well as the leaf essential oil profile (Ito, Cordeiro et al.).

**Bioactivity and health properties**

Leaf extracts have shown antimicrobial activity *in vitro* (Ito, Cordeiro et al.) as well as inducing anxiolytic-like actions in rodents with motor coordination impairment seen at high doses (Estrada-Reyes, Lopez-Rubalcava et al.). *In vitro* binding studies in mouse brain has shown significant interactions with the GABA/benzodiazepine receptor complex, which is the probable mechanism for central nervous system depressant effects (Estrada-Reyes, Lopez-Rubalcava et al.).
Sapodilla (Manilkara zapota)

Background and growing situation in Australia

Sapodilla or chico is native to Mexico and central America. The fruits aromatic and sweet “brown sugar” like flesh has led to its cultivation throughout tropical regions of the world. It is particularly popular in India and latex from the trees was extracted as the base for chewing gum prior to the development of synthetic gum base. The survey suggests there are 1076 trees with 79.6% (856 trees) in north Queensland and 220 trees in the NT. The tree is ideal for back yard production. The fruit lends itself to fresh eating and the flesh can be stirred into creams, ice creams and mousse.

Nutrient and phytochemical content

A typical sapodilla (170g) is an excellent source of fibre (30% RDI) and vitamin C (62% RDI) (USDA).

Polyphenols in the ripe fruit (Ma, Luo et al. 2003), proanthocyanidins in the unripe fruit (Hongyu, Tingting et al.) and the leaf content, including fatty acid profile and major phenolic compounds (Fayek, Monem et al.), have all been described.

Bioactivity and health properties

Leaf extracts have shown antimicrobial (Nair and Chanda 2008), antihyperglycemic (Fayek, Monem et al.) and hypocholesterolemic (Fayek, Monem et al.) activity in vitro. Proanthocyanidins from unripe fruit have shown the ability to inhibit alpha-amylase and alpha-glucosidase in vitro (Hongyu, Tingting et al.).

Fruit flesh extracts have shown in vitro inhibition of breast cancer cell proliferation and significant nitric oxide scavenging ability (Jayakumar and Kanthimathi). Intraperitoneal administration of a stem bark extract has lengthened survival time, reduced Ehrlich ascites carcinoma cells and improved haematology in mice (Osman, Rashid et al.).
Soursop (Annona muricata)

Background and growing situation in Australia

Soursop or guanabana is a relative of the better known custard apple and native to central and South America. The fruit flesh is ideal for use in tropical flavoured ice-creams and juices. The bulk of soursop is grown in north Queensland (2440 trees or 97.6% of total plantings). There are reported to be 60 trees in the NT. The estimated production potential of soursop, at a yield of 20 kg/tree is 50 tonnes valued at $0.30M. Opportunities exist for industry expansion if the fruit can be successfully introduced to the specialist food service market.

Nutrient and phytochemical content

Soursop is an excellent source of vitamin C with one hundred grams of the fruit containing 51% of the RDI (USDA).

Acetogenins in the pulp (Melot, Fall et al. 2009), seeds (Badrie, Schauss et al.) and leaves (Badrie, Schauss et al.) have been described. Alkaloids from leaves have also been isolated (Matsushige, Kotake et al.).

Bioactivity and health properties

Acetogenins from seeds and leaves have shown cytotoxicity in vitro to a range of human cancer cell lines including lung carcinoma (Badrie, Schauss et al.), breast carcinoma (Ko, Wu et al.), colon adenocarcinoma (Badrie, Schauss et al.), colon adenocarcinoma (Badrie, Schauss et al.), pancreatic carcinoma (Torres, Rachagani et al.), and prostate carcinoma (Badrie, Schauss et al.). Administration of annonacin (one of the acetogenins) has decreased cell survival, induced cell growth arrest, increased apoptosis and reduced tumour size in mice with xenografts of human breast cancer cells (Ko, Wu et al.).

Leaf extracts have shown significant effects in diabetic rats with lowered blood glucose (Adewole and Ojewole 2009; Adeyemi, Komolafe et al. 2009), restored body weight (Adeyemi, Komolafe et al. 2009), lowered total cholesterol, triglyceride and LDL cholesterol (Adewole and Ojewole 2009), increased insulin levels (Adewole and Ojewole 2009), as well as pancreatic beta-cell regeneration (Adeyemi, Komolafe et al.). In one human study, when leaf extract was administered together with glibenclamide to diabetic patients there was better glycaemic control reported than with glibenclamide alone (Arroyo, Martinez et al. 2009).

Leaf extracts have shown anti-inflammatory (reduced paw edema, exudate volume and leukocyte migration) and pain relieving effects in several animal models (de Sousa, Vieira et al.; Roslida, Tay et al.). A stem bark extract has also shown wound healing ability in rats (Paarakh, Chansouria et al. 2009).
Star Apple (*Chrysophyllum cainito*)

**Background and growing situation in Australia**

Star Apple is an attractive fruit native to South America but well known through Asia with a particular following in the Philippines. Trees are grown throughout northern Australia where they are often planted for their attractive foliage. The survey data suggests there are a total of 1,717 trees with the bulk (68.3%) grown in the NT. There are purple skinned (cv. Grimal and Haitian) and green skinned (cv. Philippine Gold) fruit with green skinned fruit generally receiving a higher market price.

**Nutrient and phytochemical content**

Star Apple is considered to be a good source of vitamin C (20% RDI/100g) (Morton 1987).

Phytochemical content including phenolic acids (Fukuji, Tonin et al.) have been described in several studies (Luo, Basile et al. 2002; Einbond, Reynertson et al. 2004; Li, Xie et al. 2008).
Discussion

In general the nutrient compositional data of tropical exotic fruits still lacks the scope of that of temperate fruits. Vitamin C content is consistently high across the fruits. Some of the fruits also have notable amounts of vitamin A, B-vitamins and fibre.

There is a rich diversity of phytochemicals present in the fruit flesh, seeds, skins, bark and wood of the tropical exotics studied. Specific fruit consumption benefits have been shown for durian, guava, mangosteen and pitaya in animal and/or human feeding trials. Further research is required to more fully investigate the benefits of consumption.

There was no recent nutrient data found for Australian grown fruit, which was reflected by the fact that only three fruits were present in the NUTTAB database. There is scope to develop proposals for discussion with FSANZ to investigate how data can be generated and/or compiled to enable for more fruits to be in the database. This information may be valuable to consumers interested in these fruits.

Despite this there is a developing interest by local research groups in investigating the compositional and bioactivity of tropical exotic fruits in Australia. To date this has focussed on more main stream tropical fruits with work being undertaken by PhD students on the phytochemicals and bioactivity from different varieties of Australian grown mango flesh and peel (Daud, Aung et al.; Wilkinson, Monteith et al. 2008; Monteith, Wilkinson et al. 2009), and more recently papaya. The University of Queensland research group who have undertaken this work on mangos have recently published a review on the compounds and bioactivities in tropical fruits (Pierson, Dietzgen et al.). These positive outputs, following on from the 2008 Tropical fruits in human nutrition and health conference, need to be maintained by keeping the relevant researchers connected to coordinate and stimulate further research. It is anticipated that research will continue through relatively small student projects and approaches for recruiting good students are needed.

As Australian varieties/cultivars are based on imported seed stock, and Australian breeding programs have been very limited, there were no specific advantages identified between the varieties/cultivars grown in Australia and those grown overseas. In fact it appears that there are more nutrient and phytochemical rich cultivars existing in overseas countries due to much larger germplasm resources, analytical work identifying cultivar differences (for example (Ashraf, Maah et al.; Englberger, Alfred et al. 2007)), and in some cases specific breeding programs targeting elevation of nutrient and phytochemical contents (Zheng, Jiang et al. 2008).

In general, due to the large differences in practices employed across the Australian industry and little comparative information on horticultural practices, there is no evidence suggesting that growing practices and/or supply chain handling are markedly different for Australia and fruit grown overseas. There is no evidence suggesting that Australian approaches improve nutrient or phytochemical content.

Opportunities for use of extracts of these fruits for food use is highly limited in Australia due to the relatively small amount of fruit, geographical dispersion of production, lack of processing waste stream, and much higher production costs than countries from which products are (or could be) imported. The use of certain fibres (for example carambola) to carry nutrients/phytochemicals in food systems may be worth evaluating if there are marketable differences from other fibre sources, which can be protected by process or technology IP, and if Australian fruit production is large enough to support production. The most promising opportunity is for the use of achachairu in processed food applications. This fruit is grown in significant amounts in a single location and there is no current threat of imported product. Identification of functional and marketable characteristics of processed products should be undertaken to evaluate potential.
There is evidence that the use of certain fruit/plant extracts can be utilised in a nutraceutical or pharmaceutical fashion to mediate a variety of health benefits. The best opportunities for utilisation of Australian grown fruit are listed below.

- **Achachairu**: As mentioned previously the significant amount of fruit grown in a single location and lack of large commercial plantings overseas are key factors for potential commercial viability of extracts. The recent reports highlighting the potential of seed extracts and/or purified compound guttiferone to mediate pain relieving and cholesterol lowering effects should be investigated using Australian material.

- **Durian**: polysaccharide extracts from husk may have applications in cosmetic formulations. However consideration of local fruit production volumes, geographical dispersion of production and competition with overseas production must be firstly considered to determine if there is any economic validity for such a proposal.

- **Guava**: there is a large evidence base for the use of leaf extracts, particularly in controlling diabetes and metabolic syndrome. There are commercial products available internationally and consideration must firstly be given to whether Australian grown and made product could compete with imported product. Consideration to minimum production volume requirements, possible processing locations and import competition must be made to determine preliminary viability.

- **Jackfruit**: the potential for leaf extracts that help control diabetes and metabolic syndrome could be explored. However consideration of local fruit production volumes, geographical dispersion of production and competition with overseas production must be firstly considered to determine if there is any economic validity for such a proposal.

- **Longan**: the potential for polysaccharide extracts could be explored. There is intense Chinese research into sourcing starting material with elevated levels of the phytochemical(s) of interest, developing optimised extraction procedures and technologies and the health properties of the extracts. There are commercial products available internationally and consideration must firstly be given to whether Australian grown and made product could compete with imported product.

- **Mangosteen**: there is a reasonably large evidence base for the use of pericarp extracts, particularly in animal models of cancer. However there is potential to explore the suitability of pericarp extracts in acne treatments. There are a range of mangosteen products available internationally and consideration must firstly be given to whether Australian grown and made product could compete with imported product.

- **Soursop**: there is some evidence supporting the use of leaves for their anti-cancer properties however much more work is required to validate effectiveness and safety of such products. There are commercial products available internationally and consideration must firstly be given to whether Australian grown and made product could compete with imported product.
Implications

- The information in this report detailing the nutrient and health benefits of tropical exotic fruit consumption could be developed into promotional and/or educational materials.

- Waste fruit (including seeds, peel etc) may be able to be utilised in food and nutraceutical extracts. Achachairu has the most potential due to its relatively high fruit volume, single growing location and lack of international competition.
Recommendations

- Undertake work to put the nutritional and health benefit information for these fruits into suitable formats (web based etc) for promotional and/or educational purposes.

- Develop and present a proposal to FSANZ to develop NUTTAB records for the fruits that do not currently have one.

- Develop a suitable forum to keep a connected and coordinated approach for further research in Australia, and stimulate student interest in research projects, following on from the 2008 Tropical fruits in human nutrition and health conference.

- Develop a plan to investigate opportunities for utilisation of retail-rejected Achachairu fruit as flesh/peel/seed products/extracts for food and nutraceutical uses.
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Collation of Health Literature for Tropical Fruits and Extracts
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This report collates data on the nutrient and phytochemical content of tropical exotic fruits, the evidence for health effects from consumption of these fruit and the use of extracts from edible and non-edible parts of these plants. The knowledge of Australian fruit compared with that grown overseas is presented together with opportunities for future work by Australian researchers. Opportunities for developing commercial extracts for use as food or nutraceutical uses are also presented.

The report is targetted at tropical exotic fruit growers and marketers and researchers involved and/or interested in tropical exotics research.

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