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The Potential for a New Value Adding Industry for Noni Tropical Fruit Producers

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Foreword

Morinda citrifolia (noni) grows widely throughout the Pacific and is native to Australia. It is a source of traditional medicine in coastal Aboriginal communities in Cape York, the Pacific Islands and South East Asia, and in recent years has experienced significant economic growth worldwide through a variety of health and cosmetic claims. The largest markets for noni are North America, Europe, Japan, Mexico, Asia and Australia with the worldwide market for these products estimated at US\$400 million.

The aim of this study was to investigate the potential for a new value adding industry for noni producers. Researchers examined existing literature on the plant *Morinda citrifolia* (noni) and its juice extract and assessed the agronomic best practices, the fermentation process and the supposed therapeutic effects. An independent market research report on the global noni juice market is included indicating market opportunities and potential returns to Australian producers.

In examining existing literature, current agronomic practices, fermentation processes and preliminary market information, the researchers concluded that further research will be required to fully explore the potential of this crop for successful cultivation and profitability.

Some areas of need for future research include:

- Costs of production and returns and gross margins analysis.
- Identification of the microflora and mechanisms of action involved in the reported anaerobic fermentation process.
- Compositional analysis of macro and micro ingredients.
- Significant research to confirm the bioactivity of the various products including animal studies and clinical trials.

This project was funded from RIRDC Core Funds which are provided by the Australian Government.

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We thank AIC for permission to include their market research report on noni juice.

Abbreviations

CTAHR	University of Hawaii at Manoa, College of Tropical Agriculture and Human Resources
EFSA	European Food Safety Authority
FDA	Food and Drug Administration
HACCP	Hazard Analysis Critical Control Point
IP	Intellectual Property
TGA	Therapeutic Goods Administration

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Executive Summary

Who is the report targeted at?

This report is targeted at growers, distributors, processors, juice producers, marketers, fruit and health food industry representatives and government agents including food technologists, scientists and trade, market and investment staff.

Background

Morinda citrifolia (noni) is a small tropical evergreen tree which has been used as a source of traditional medicines for hundreds of years by Australian aboriginal, Pacific Island and South East Asian communities. It is native to South East Asia (primarily Indonesia), Papua New Guinea and northern Australia. It is found through most tropical islands in the Pacific and Indian Oceans as well as Central and South America, the Caribbean and some parts of Africa. In Australia, it grows from Mackay in Queensland along the coast north through to the top of Western Australia.

Noni juice is currently commercially produced either as a pure juice or as a mix with other juices. In 2002, the European Union has accepted noni juice as a novel food. In 2005, the European Food Safety Authority (EFSA) initiated an evaluation of the safety of current noni products due to concern over a possible causal relationship between acute hepatitis and the consumption of noni juice. On September 1st, 2006, the EFSA published its resultant opinion concluding that there was no convincing evidence of any causal relationship. In March 2001, the Complementary Medicines Evaluation Committee of Australia's Therapeutic Goods Administration (TGA) recommended that noni juice is suitable for use as an active ingredient in listable therapeutic goods. However, the Committee also noted that there does not appear to be any evidence to support indications relating noni to immune support. The TGA has since released draft guidelines for composition of noni juice and noni powder. The U.S. Food and Drug Authority has not evaluated noni juice or related substances but has issued some warning letters regarding health claims.

The Australian Noni Industry

The Australian Noni Growers Association is a group of North Queensland growers who formed a network to share knowledge, collaborate and liaise with all interested parties in fostering research into this emerging crop and with the aim of creating a viable industry for noni.

In March 2006, Cyclone Larry devastated most of the noni crop in North Queensland and growers have had to move to faster growing, incoming producing crops such as bananas. Prior to the cyclone, the Association met regularly to discuss production issues and future plans and to disseminate existing research on noni's agronomy, processing, health benefits and market information. Members worked towards analysing existing research and were endeavouring to incorporate and prioritise research findings in formulating a strategic plan.

Currently, most growers have put plans of commercial production of noni on hold while they recover financially from the impact of the cyclone. However, one producer, trading as "Pink Noni", expects to produce 2000 litres of noni juice in its first production run in mid 2007. This variety may be more commercially viable than previous ones due to larger fruit size, better taste, faster growth and may lend itself to more efficient production methods.

The current members of the Association are acutely aware that further research is needed into some agronomic and processing aspects of fruit including identifying best varieties particularly regarding yield and taste factors, fermented juice versus fresh pressed juice, product bioactivity studies and detailed market analysis. The Association has identified the need to, where possible, provide in-kind and financial support to relevant research projects relevant to their research priorities.

Aim

The aim of this study was to investigate the potential for a new value adding industry for Australian noni producers. By searching, compiling and reviewing the extensive existing literature search on the plant *Morinda citrifolia* (noni) and its juice extract, the researchers were able to assess agronomic best practices, the fermentation process and the broad range of supposed therapeutic effects. Market research information was also included to assist in future analysis of market opportunities and potential returns to Australian producers.

Results

Noni has an extremely wide range of environmental tolerances so production should be possible in a wide range of tropical environments in Australia but yields will be greatest on highly fertile soils with abundant available water. Considerable variation exists in noni plant and fruit characteristics but there is no recognized germplasm collection in existence.

This work has demonstrated that the basic mechanisms and associated microflora of the reported noni juice fermentation process is not well understood and that there is very little scientific literature available on the fermentation process of noni juice. The more recent research literature that is available on noni is driven by the commercial potential of noni among the rapidly growing number of “natural medicines” and “health foods”. It is difficult to determine from the little available literature and conflicting reports, if the ‘traditional aging’ method of processing noni juice, reported as an anaerobic fermentation process is actually a lactic acid fermentation or a putrefaction process.

Various compounds have been identified in noni fruit in relation to possible health benefits. *In vitro* research and limited animal experiments have shown that noni has antimicrobial, anti-cancer, antioxidant, anti-inflammatory, analgesic and cardiovascular activity.

Further research needs to be done to fully characterise the composition of noni fruit, noni juice and noni powder. In addition, the limited research available on bioactivity studies needs to be confirmed and further developed.

Implications

A wide range of potential production systems for noni should be investigated including those with low inputs located away from north Queensland’s wet tropical coast as they may require less capital investment and thus represent lower risk. There is a good opportunity for exploration in Australia and overseas to locate plants with desired characteristics including fruit size, plant habit, disease resistance and concentration of medicinally active components.

As noni products are largely for medicinal purposes, it can be argued that plants should be grown organically or at the very least without the application of conventional pesticides. Noni products from aboriginal communities and other Australian sources could become an important part of the bush tucker trade.

In a commercial situation, it would be advantageous if a processor could add a starter culture to the Noni fruit or pulp at the beginning of the process when the fruit are first placed into the fermentation vessels. As with modern fermentation techniques, optimum processing parameters combined with a quality starter culture (with known characteristics and under controlled conditions) would allow the processor to potentially produce a reliable consistent safe product every time. Standardisation of the processing steps will not only help produce a safe product, it will also provide consistency to the biologically active ingredients in the juice. Subsequently, a product with consistent quality has more potential to retain repeat business in a competitive market providing more opportunity for success of the business.

The Australian TGA released a Draft Compositional guideline for noni juice in August 2002 and has recently released a Draft Compositional guideline for *Morinda citrifolia* dried fruit pericarp powder. It is likely that similar compositional guidelines will be developed for other products and in other

countries. Product composition needs to be better understood, particularly as the cultivars and growing areas become more diverse. In addition, significant research needs to be undertaken to confirm the bioactivity of the various products (animal studies, clinical trials, etc).

Recommendations

- Commercial growing of noni in Australia is in its infancy. There is no information available in Australia on actual costs of production and returns for product and these will be influenced by many management factors as well as pest and disease incidence. A gross margins analysis of plantings in Australia would provide much needed economic information on which to base assessment of industry potential.
- The diversity of noni needs to be examined and better understood to assist a developing industry with product assurance and marketing of improved products to ensure competitive advantage.
- Product image is very important to the customer looking for health benefits. A developing noni industry should pursue organic certification and support R&D which investigates more profitable organic production systems.
- Noni as a component of the bush tucker trade is still largely undeveloped. Presumably Australian origin is mandatory for products sold under such a banner. State and federal governments should therefore continue to foster the development of native Australian plants such as noni as they will have a strong marketing edge over imported product.
- Scientific investigations are required to identify the microflora involved in the reported anaerobic fermentation process and their mechanisms of action in order to determine the biological processes involved
- Research is required for the development of improved process parameters and the potential development of a starter culture which could be used as a processing aid in the manufacturing of noni juice to ensure a reliable consistent, high quality, safe product every time.
- Alternatively, juice could be pressed fresh from noni fruit without fermentation. This product would involve considerably less processing, lower production costs and improved flavour and smell due to reduced butyric acid. However, a comparison of bioactivity and composition of both unfermented and fermented noni juice would be required.
- As noni cultivars are developed and the germplasm is further screened, compositional analysis needs to determine the levels of macro-ingredients (e.g. protein, lipid, sugars, etc) as well as micro-ingredients (e.g. vitamins, minerals, phenolic compounds, etc).
- Appropriate bioactivity assessments of noni (e.g. juice, powder etc) need to be performed in a number of areas (e.g. anti-microbial, anti-cancer, anti-oxidant, analgesia and cardio vascular) to support the market for this new industry.
- It is important that this fledgling industry in Queensland defines a market supply chain with a functional application area. Noni is unlikely to be a general tonic or 'cure all', and so a specific market needs to be defined, probably on the basis of quality or tested activity (e.g. gut health or skin care in older people).
- The current market for noni juice has conferred upon the fruit a unique and authentic appeal. Market interest in this fruit suggests a bright future, although more studies are needed to identify the nutritional and functional compounds it contains and explain their mechanisms of action in order to determine the real potential of this fruit and the technological processes that preserve these properties.

Methodology

Helen Macpherson 2006

An extensive literature search was conducted across 23 databases and internet search engines (Appendix 1) resulting in 383 bibliographic references ranging from 1873 – 2006.

The terms “noni” or “*Morinda citrifolia*” were used for searching all sources. Although there are many further variations in nomenclature, it was considered that these search terms are the most common in both scientific and mainstream literature on this topic.

Sources consulted for the selection of relevant references for this literature review included a wide range of scholarly databases, internet search engines, academic, government and company websites, patent organisations, bibliographies and key scientific journal articles.

Researchers selected references based on the quality of the literature and on the relevance to the project’s objectives. References which were considered to be predominantly advertising material were generally excluded. Some non-scientific publications were included to provide researchers with an understanding of how the product is being marketed and what claims are being made as to specific product’s health benefits. Where available, regular alerting services were set up so that newly published material could be monitored for inclusion.

References including abstracts were compiled into an Endnote database where duplicates were removed and details were checked for accuracy. A sample bibliography of references from 2005 and 2006 was created for inclusion in this document (Appendix 2).

Review of agronomic best practices

Jeff Daniells 2006

Introduction

Noni (*Morinda citrifolia*) is a small tropical evergreen tree which has been a significant source of traditional medicines for hundreds of years among Pacific Island societies as well as SE Asian peoples and Australian aboriginals. Noni is known by a number of other common names including cheese fruit, great morinda, and canary wood (Australia), Indian mulberry (India), kura (Fiji), nono (Cook Is., Tahiti), nonu (Samoa, Tonga) and mengkudu (Malaysia). This current review is largely based on the excellent review by Nelson (2005).

Despite the long history of use, commercial cultivation of noni as a crop is largely a recent event, presumably coinciding with the growing perception of noni as a panacea within western society since about 1990. Except for the excellent information available on the College of Tropical Agriculture and Human Resources' (CTAHR) 'The Noni Website' (www.ctahr.hawaii.edu/noni/about.asp) there is very little written information which deals with the cultivation of noni as a crop and a lot of what is written is based on the observations and opinions of the various authors rather than published scientific papers to date. This review deals with the growing of noni for fruit production for medicinal purposes.

Botany

Noni belongs to the family Rubiaceae which is the fourth largest family of flowering plants after the Asteraceae, Orchidaceae and Fabaceae and comprises about 650 genera and 13,000 species. The bulk of the family is tropical and predominantly woody trees and shrubs. The Rubiaceae's best known member is *Coffea* (coffee). Other economically important crops include *Cinchona* which yields quinine and *Psychotria ipecacuanha* which yields ipecac which is an emetic (causes vomiting). Many more species are used by various indigenous people as medicinal plants. There are also many well known ornamentals including *Gardenia*, *Ixora* and the *Pentas*.

The genus *Morinda* embraces about 80 species, mostly of Old World origin. Apart from *Morinda citrifolia* (noni) none are of any particular commercial importance. Interestingly Mapoon bush (*Morinda reticulata*) which is native to Cape York, Australia has been known since 1923 to be a selenium accumulator, even when the level of selenium in the soil is very low, and has caused grave selenosis in local horses that graze on the young shoots. Morton (1992) has made the comment that before adopting any species of *Morinda* as a food, fodder or medicinal plant one should ascertain if it tends to accumulate selenium. Noni happens to have selenium amongst its "healthful ingredients" (Anon 2005). According to Cribb and Cribb (1981) both Mapoon bush (leaves) and noni (fruit) have been regarded as being contraceptive.

The botanical name for the genus was derived from the 2 Latin words morus, (mulberry) and indicus (India) in referring to the similarity of the fruit of noni to that of true mulberry (*Morus alba*, family Moraceae). The species name for noni indicates the resemblance of the foliage to that of some citrus species.

Origin and Distribution

Noni is native to SE Asia (primarily Indonesia), Papua New Guinea and northern Australia (Nelson 2005). Its current distribution is pantropical at latitudes of 19° N or S. It is found through most of the tropical islands of the Pacific and Indian Oceans and SE Asia as well as Central and South America and the Caribbean and some parts of Africa. In Australia it has been recorded from about Mackay (~21° S) in Queensland along the coast north through to the top of Western Australia. Since it is native to Australia and has been used by aboriginal peoples it has attracted some interest from various parties including the Queensland Department of State Development & Innovation for inclusion in the bush tucker trade. As yet this is still largely undeveloped.

Noni can be found in disturbed forests, dry to mesic (moderate supply of moisture) forests, alien grassland, open areas near the shoreline, pastures and coconut plantations, in littoral (region near the shoreline) forest understory, fallow areas, waste places and around villages (Nelson 2005). Noni is a tough plant and springs up just about anywhere. The ripe fruits are distributed by various animals including bats. The seeds, which have an air chamber, also travel on ocean currents and this has contributed significantly to its spread and current location within the landscape and globally.

Ecology

Noni is noted for its extremely wide range of environmental tolerances. It can grow in infertile, acidic, and alkaline soils and is at home in very dry to very wet areas. Noni's extensive range of environmental tolerances also includes exposure to wind, fire, flooding and saline conditions. Despite this noni is not considered invasive to the degree that it threatens ecosystems. However, it is treated as a weed in some settings, is very persistent and difficult to kill, and is one of the first plants to colonize harsh waste areas or lava flows (Nelson 2005). All this might make it a very suitable species for reclaiming land damaged by mining activities. Whether it could then be harvested and used safely for medicinal purposes would require investigation.

Noni is found at altitudes from sea level up to 800 m depending on latitude and environment and where mean annual rainfall ranges from 250 – 4000 mm. The range of temperatures noted in noni growing environments is 5-18° C (Min.) to 32-38° C (Max.). Interestingly some noni plants established at Exotic Groves, Woopen Ck. (17° S) about 15 or so years ago died back severely during the cooler months of the year. This has not been noted as yet for noni from other sources but will need to be taken into consideration when making any selections, particularly if production is sought for any cooler climates than the wet tropical coast.

Mature, cultivated noni can easily withstand drought for 6 months or more but not surprisingly production will be curtailed. Noni can tolerate many soil conditions including seasonal waterlogging but does prefer free, well drained soils. Nevertheless low input production systems away from the wet tropical coast might be possible and perhaps less risky in terms of the investment. Noni has several of the features needed in a crop suitable for consideration for aboriginal and islander communities in Cape York.

Noni withstands and even thrives in brackish tidal pools and can tolerate flooded conditions for long periods of time. It is tolerant of extreme salinity in general and is thought to possibly gain nutritional benefit from the minerals contained in seawater (Nelson 2005). Thus there may be particular land use planning applications for noni including flood prone areas and of course areas affected by salt including land inundated by tsunamis or other storm surges. Whether or not noni withstands acid sulphate soils requires investigation.

Noni can grow in a wide range of light intensity from full sun to >80% shade. Thus it is a plant that should be well suited for cropping in a range of intercropping and polyculture situations. It can tolerate windswept locations but yields and overall growth are diminished. Interestingly the woody branches are brittle and are relatively easily broken during high winds. This feature should actually be an advantage for the crop as it should assist in rapid regeneration following cyclones and windstorms rather than permanent loss.

Current members of the Australian Noni Producers Association come mostly from the wet tropical coast of north Queensland. However, noni's wide adaptability suggests that it can be expected to grow and crop quite well in drier tropical climates provided adequate water is applied. Under such conditions less problems are also likely with pests and diseases. Fruit quality might also differ between wetter and drier locations, for instance, are the important active ingredients affected by climate/environment?

General Characteristics

Tree

The noni tree reaches a height of 3-10 m at maturity. Noni leaves are large, elliptical, glossy and bright green. There is much variation in overall plant form, fruit size, leaf size and morphology, palatability, colour of ripe fruit and number of seeds per fruit. The rooting habit is similar to that of citrus and coffee with an extensive lateral root system and a deep taproot.

Plants are quite precocious – flowering within 9 months of field planting. Growth occurs throughout the year provided the growing conditions are favourable.



Figure 1. *Morinda citrifolia* L..

Flowers

Flowers occur on new growth. Thus conditions which promote vigorous growth will tend to be associated with higher productivity. The flowers are described as perfect (hermaphrodite) with 75-90 of them making up the composite fruit which results. The flower/fruit stalks are 10-30 mm long.

Pollination and Fruit Set

Noni flowers and fruits the year round provided the growing conditions are favourable – particularly sufficient soil moisture to allow new shoot growth. Noni flowers are attractive to honey bees and have been observed collecting nectar in Samoa (Roger Goebel pers. comm. 2006). No studies of the pollination biology of noni or the *Morinda* genus have been reported, but it seems likely that the plants are able to self-pollinate as part of their adaptation for colonizing new terrain (McClatchey 2003).

Fruit

The fruit is a syncarp (compound fruit) and is usually cream or greenish white and 4-10 cm long and 3-4 cm in diameter. The seeds are similar in size and shape to apple seeds but the seed coat is much tougher. The fruit when ripe is soft and has a pronounced rancid cheese odour. This latter feature pervades most noni juice preparations but is unlikely to be a deterrent for the medicine market.



Figure 2. Fruits of *Morinda citrifolia* L.

Genetics

There is a relatively high degree of variability in fruit and leaf morphology within the species. However, little selection has so far occurred nor has there been any deliberate attempt at breeding. Despite this McClatchey (2003) has concluded that commercial plantings in Hawaii are probably based on very closely related trees. Nelson (2005) lists 3 varieties:-

- *M. c.* var. *citrifolia* – this is described as a population which contains members bearing a broad range of characteristics.
- *M. c.* var. *bracteata* – small fruited with conspicuous bracts ex. Indonesia and surrounding region.
- *M. c.* cv. ‘Potteri’ – ornamental variegated type (green and white leaf) which occurs throughout the Pacific.

There are no recognized germplasm collections in existence. There would seem to be very good opportunity for exploration to locate plants with desired characteristics including fruit size, plant habit, disease resistance, level of medicinal components etc. McClatchey (2003) recommends that this be done in conjunction with ethnobotanical study of the usefulness of particular types so that ethnopharmacological studies could follow pursuing original cultural hypotheses rather than modern assumptions.

One grower in north Queensland has recently obtained plant variety rights for a selection he has made. The selection has fruit which are pink in colour, are large (>300 g) and have fruit which are firmer in texture. The juice extracted is less cheesy and the fresh ripe fruit is sweeter to eat (higher fructose levels). However, before anyone can go too far with selections like this and others the relationship between characteristics such as fruit size/taste and the level of medicinal components needs to be properly understood.

McClatchey (2003) notes 3 commonly described ‘kinds’ from the Western Pacific:-

- (i) Trees with smaller elliptic leaves, having small fruit arranged at nodes along the branches, and thin stems/branches whose bark and roots are used for dyes.

- (ii) Trees with long, strap-like leaves, having larger, lightly scented to non-scented fruit, thicker stems and shorter branches that are used for many indications treated by professional healers.
- (iii) Shorter bushy trees with large elliptic to round leaves and large, strong smelling fruit that may be used medicinally, particularly for topical home remedies.

Interestingly McClatchey (2003) noted that the roots of one kind of *M. citrifolia* were reportedly selected for their usage as a toxin for killing fish.

Walter and Sam (2002) note there are 2 forms of *Morinda citrifolia* in Vanuatu and the Solomons – one wild, the other cultivated for its edible fruits but it is rare. The edible form is noted to be sweeter.

It is clear we know very little about the diversity of *Morinda citrifolia* (McClatchey 2003). The diversity needs to be examined and better understood to assist with noni product assurance (quality control) and marketing of improved products.

Cultural Practices

Propagation & Nursery Management

Noni is relatively easy to propagate from seeds (albeit sometimes with seed dormancy problems), stem or root cuttings and air layering (marcotting). According to the UNITECH Biotechnology Centre in Lae, Papua New Guinea there are also protocols available for tissue culturing of noni. In Hawaii the preferred methods of propagation are by seed and cuttings from orthotropic growth (vertical rather than lateral).

For seed production, ripe fruit from plants with the desired characteristics should be selected. Nelson (2003) notes there is heritable variability for fruit size, fruit shape and number of seeds. Once the fruits have fully softened the seeds can be extracted by pressing the flesh against a sieve that will retain the seeds. It is not known for how long the seeds remain viable but will be a function of the storage conditions. Seed scarification is believed (Nelson 2005) to hasten seed germination but in my experience high maximum temperatures (>30° C) combined with the use of fresh clean seed is sufficient to obtain high germination within about a month in most cases.

A wide range of media, both natural and artificial will work but best growth will be obtained with a mix that is well drained and supplies abundant nutrients. It is critical also to ensure that the media is not contaminated with nematodes, particularly rootknot nematodes (*Meloidogyne* spp.) which will infest the field site and greatly debilitate the plants leading to much reduced yields.

Most nurseries in Hawaii prefer natural potting mix for noni and germinate the seeds in trays. Germination is more uniform in light partial shade (20-30%). When plants reach the 4-leaf stage they are carefully transplanted to individual containers (6 cm square and 12 cm deep). Seedlings continue to be grown in light partial shade until nearing field establishment when they are then sun-hardened. Seedlings 20-25 cm high (5-6 months old) establish well in the field (Nelson 2005).

It may be possible to establish field plantings with younger plants but management (soil moisture, pest control etc.) would need to be precise as the plants will be less robust and weed control strategies will be more critical. Direct seeding strategies as practised for tea (*Camelia sinensis*) are likely to be problematic if seed germination problems occur but such an approach could greatly reduce the costs of establishment – currently a major production cost in what is still a risky undertaking. E.g. if establishment costs could be reduced by this approach it may be possible to plant significantly more area initially to bolster early production of the industry and better support the initial viability of a processing and bottling factory. Whether or not discrete trees or a continuous hedge are required needs to be investigated. High density plantings would also probably assist in achieving higher yields in the first few years.

Stem cuttings have the advantage of reducing the time required to obtain plants ready for transplanting. Their other advantage would be that they are genetically uniform to the extent that one tree can be multiplied from. Cuttings about 20-40 cm long from vertical growth are preferred. They take about 3 weeks to root and are ready for transplanting in 2 months (Nelson 2005).

Field Preparation & Planting

While noni will tolerate a wide range of environmental conditions, best results (yields) can be expected on well drained soils where temperatures are optimal the year round. On the wet tropical coast, plants are likely to benefit from drainage works including mounding particularly on the heavier alluvial soils.

Sites infested with root-knot nematodes, to which noni is very susceptible, should be avoided. Presumably root-knot nematode damage would be more severe on sandy soils.

Dedicated field plantings of noni seem to have been mostly established as monocultures. However, some serious problems such as black flag (*Phytophthora botryosa*) in Hawaii and root-knot nematode in the Cook Islands and Samoa are typical of the crop being moved into cultivation. The majority of the world's noni products still come from wild harvest and small scale mixed cropping situations where it seems less disease problems are experienced than field planted monocultures.

The percentage of current noni products produced organically (certified or equivalent in terms of inputs) is not known but a guesstimate of at least 50% is probably close. As noni products are largely for medicinal purposes it can be argued that plants should be produced as close to natural (however that might be defined) as possible. The emphasis would be on only natural inputs as far as fertilizers and pesticides are concerned. This is likely to be a critical part of noni product marketing. A 'squeaky clean' product and production system will be the preferred and premium output. On this note existing and potential growers must consider whether a monoculture is the appropriate production system from both a pest/disease control standpoint and also the product image. Noni produced in mixed plantings with perhaps longer term tree crops may be a sustainable production system while at the same time identifying noni as a crop to grow in association with, for example, mangosteen (*Garcinia mangostana*) or langsat (*Lansium domesticum*) to achieve earlier cash flows to enhance the viability of tree crops with long juvenile stages. However, the associated tree crop(s) would also need to be managed 'organically'.

In Hawaii recommended plant spacing is 3-4.6 m between plants which gives densities of 473-1111 plants/ha. Higher density is thought to enhance pest and disease problems.

Canopy Management

Noni plants can grow to 10 m in height so strategies which can be employed to keep the height down to facilitate harvest will be very important. In Hawaii it is recommended to prune the vertical branches of plants less than 3 years old (after/during their first significant fruit production) to promote bushiness (Nelson 2001). The pruning is said to serve a dual purpose of reducing vegetativeness and thus decreasing the severity of disease outbreaks.

Hand pruning on a regular basis is likely to be a significant cost in production so other approaches that might be more cost effective should be investigated. These would include:-

- (i) Identifying selections with naturally short bushy habit.
- (ii) Mechanized pruning provided it does not cause severe damage to the plants.
- (iii) Lateral stem cuttings (plagiotropic growth or side shoots) have been used in Hawaii and tend to grow in a prostrate habit but may be more susceptible to branch splitting when the fruit load is heavy – perhaps they might be suited to some sort of V-trellis system to both support and display fruit for harvest.
- (iv) Since noni belongs to the coffee family it probably coppices (pruning back to a stump) well so a severe pruning of this nature every few years once the plant gets too high might be a useful strategy.
- (v) Perhaps there is a place for root pruning.

- (vi) Less fertile soils in areas where irrigation can be used to control growth may reduce plant height but probably at the expense of fruit production.

The prunings should be suitable for mulching the crop particularly if passed through a mulching machine. There may also be application for the prunings as a stock feed.

Irrigation

Noni, once established, is able to survive extended drought but even on the wet tropical coast of Queensland irrigation will be cost effective in most years because of the relatively high value of the noni product. Irrigation requirements will be largely governed by climatic conditions.

Crop Nutrition

Research is still needed to determine the optimum fertilizer requirements for noni. There does not appear to be data on the full range of plant nutrients in the fruit or plant parts (crop removal figures) on which fertilizer recommendations could be based. In the short term plant analysis surveys of existing plantings will help point to likely optimum/critical ranges to aim for in indicator leaves which can then be used to guide nutrient inputs. Types of fertilizer to apply will then depend upon required inputs, and the marketing approach to be taken – organic or conventional. In Hawaii nitrogen-rich balanced fertilizers are considered to be important in quickly establishing the crop canopy then reducing nitrogen inputs for more mature fruiting plants whilst boosting phosphorus (Nelson 2003). The latter comments about phosphorus are likely incorrect and rather should be referring to boosting potassium instead. If the industry decides to focus on organic production then compost, and production of it, will be an important input for maximizing productivity.

Pest Management

Noni is susceptible to attack by a wide range of pests and disease causing pathogens. Just what will be present and a problem largely remains to be seen. Nelson (2005) makes the comment that when noni is grown in diverse forested ecosystems it usually suffers from few significant pest and disease problems or damage but when grown in monocultures it is much more susceptible to attack by many more pests and diseases and with greater intensity than in natural ecosystems. Nelson lists a range of pests including aphids, scales, weevils, leaf miners, whiteflies, caterpillars, thrips and mites. Noni plants are also quite palatable to grazing animals including cattle and wallabies. Nelson also lists a range of diseases including leaf spots and stem/leaf/fruit blights as well as root knot nematodes.

Weeds

Weeds of various kinds will require particular attention during the establishment phase of the crop. If organic production is sought then mulches of various kinds should be investigated. Interestingly Nelson warns against the dangers of whipper snippers for weed control causing ring barking of trees if incorrectly used. In 2003 I witnessed serious damage to many noni trees in a Fiji plantation which was the result of careless use of a whipper snipper.

Harvesting

Although it depends upon the type and size of the plant at planting, one can normally expect the plants to begin to bear fruit about 9 months after field planting. However, production is light in the first 2 years and Nelson (2001) comments that some Hawaiian growers choose to forgo harvest during the first and second years in favour of pruning back the branches instead.

If the environment is favourable noni fruits may be harvested all year round. However, fruit production will diminish during cooler weather and during dry conditions if there is inadequate water.

Expected yields in Hawaii are 114-227 kg/plant/year depending on nutrition and plant spacing but yields can exceed 227 kg with good crop management. Fruit is usually picked just as they begin to ripen, while they are still hard. According to Ken Newton (CCK, Samoa) this picking stage is very important for achieving the desirable acid content (Roger Goebel pers. comm.. 2006). When harvesting the fruit are readily snapped off the tree by hand.

No one seems to have recorded how long it takes from flowering to harvest. Fruit should be harvested before it is ripe to avoid problems with fruit fly infestation. Fruit left to ripen on the plant is also more likely to be attacked by birds, bats and other animals.

In Closing

The future for a noni industry in Australia will hinge on the following:-

1. Actual costs of production and returns for product and these will be influenced by many management factors as well as pest & disease incidence.
2. A solid foundation of proof of efficacy is needed.
3. The industry will need to identify a premium market niche e.g. organic production system and certification will be required.
4. Selection of a variety with high potency which could provide IP. Therefore collecting, selection and perhaps breeding linked with nutrition profiles, bioavailability and clinical trials will be required.
5. A quality assured product is required. A system such as HACCP should be put in place.
6. Supply chain through to consumers should be built on solid relationships.
7. Value adding to the product to create/accentuate unique features e.g. colour of juice, taste etc.

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Review of the fermentation process for quality control

Brett Wedding 2006

Introduction

Herbal and natural products have been used for centuries in every culture throughout the world. Among the many medicinal plants used in traditional folk medicine, *Morinda citrifolia* L. of the Rubiaceae (coffee) family (noni, Indian mulberry, cheese fruit, dogfruit, nonu) is one of the most widely used medicinal plants in Polynesia prior to European contact (Nelson, 2005; Fahs, 2003). The use of noni continues its popularity among modern populations. The traditional uses of noni plants vary from one country to the other in the South Pacific region including northern Australia. The juice extracted from the fruit is consumed as a drink and has been reported to have a broad range of medicinal and nutritional properties. Dixon et al. (1999) report that until the early 1990's, noni medicinal products fell within the domain of home production. Starting in 1990-1991 the demand for noni escalated dramatically resulting in the establishment of commercial operations producing many different types of noni products ranging from beverages to powders, tablets and capsules.

Noni juice is currently commercially produced either as a pure juice or as a mix with other juices, it may be bottled with or without pasteurisation. In conjunction with its increase in popularity, noni juice has recently been accepted in the European Union (EU) as a novel food (European Commission, Scientific Committee for Food, 2002). At present, there is a limited amount of published scientific literature on noni, particularly the fermentation process. Despite the fact that noni has been used as a medicinal plant for centuries and scientific investigations into its medicinal properties began over fifty years ago (Dixon et al., 1999), the small number of published research is disproportionate with the huge popularity of this plant and its perceived health benefits. As a result, optimisation of agricultural and post harvest handling practices, and processing technologies have largely been neglected. This paper attempts to report on the state of progress on noni juice production, with specific reference to the fermentation process for juice extraction.

Noni Juice

In general, raw fruit juice is usually a strong acidic solution with a high sugar concentration (10 to 25 percent soluble sugars) which makes it an unfavourable medium for the growth of bacteria but highly suitable for yeasts and moulds (Battcock, 1998). Raw fruit juice also naturally contains many yeasts, moulds, and bacteria, derived from the surface of the fruit. Unfortunately, the complete physico-chemical composition of the noni fruit has not yet been reported and only partial information is available on noni juice (Table 1). Noni fruit contains 90 percent water and the main components of the dry matter appear to be soluble solids, dietary fibres and proteins (Chan-Blanco et al., ND). Depending on the type of fruit and its maturity, noni fruit generally contain moderate amounts of protein (e.g. 11.3% of the juice dry matter (Chan-Blanco et al., ND)), and contain substantial quantities of carbohydrates, including varying proportions of sucrose, fructose and dextrose (Jensen et al., 2005). Approximately 51 volatile compounds have been identified in the ripe fruit, including alcohols (3-methyl-3-buten-1-ol), organic acids (mainly octanoic and hexanoic acids), esters (methyl octanoate, methyl decanoate), lactones [(E)-6-dodeceno- γ -lactone], and ketones (2-heptanone) (Chan-Blanco et al., ND).

According to Chan-Blanco et al. (ND), minerals account for 8.4% of the dry matter, and are mainly potassium, sulphur, calcium and phosphorus; traces of selenium have also been reported in the juice. Some vitamins have also been reported in the fruit, mainly ascorbic acid (24-158 mg/100g dry matter), and provitamin A (Chan-Blanco et al., ND). About 160 phytochemical compounds have been already identified in the noni plant, and the major micronutrients are phenolic compounds, organic acids and alkaloids (Wang and Su, 2001). Of the phenolic compounds, the most important reported are anthraquinones (damnacanthal, morindone, morindin, etc.), and also aucubin, asperuloside, and scopoletin (Chan-Blanco et al., ND).

Table 1. Physico-chemical composition of noni juice (Adapted from Chan-Blanco et al., ND)

Characteristics	Chunhieng (2003) ^a	Shovic and Whistler (2001) ^a	European commission (2002) ^b	Cook Island Noni Management Ltd (2003) ^c
pH-value	3.72	-	3.4-3.6	3.87
Dry matter	9.8±0.4%	-	10-11%	-
Total soluble solids (°Brix)	8	-	-	5.7
Protein content	2.5%	0.4g/100g	0.2-0.5%	0.6g/100ml
Lipid	0.15%	0.30g/100g	0.1-0.2%	<0.1g/100ml
Glucose	11.9±0.2g/l	-	3.0-4.0g/100g	1.1g/100ml
Fructose	8.2±0.2g/l	-	3.0-4.0g/100g	1.1g/100ml
Potassium	3,900mg/l	188mg/100g	30-150mg/100g	225mg/100ml
Sodium	214mg/l	21mg/100g	15-40mg/100g	35mg/100ml
Magnesium	14mg/l	14.5mg/100g	3-12mg/100g	18mg/100ml
Calcium	28mg/l	41.7mg/100g	20-25mg/100g	9/mg/100ml
Vitamin C	-	155mg/100g	3-25mg/100g	-

^aNoni fruit.
^bTahitian Noni™ Juice (Commercial Noni juice that contains 89% Noni juice and 11% common grape and blueberry juice concentrates).
^cCook Islands Noni Marketing Ltd (Commercial Noni juice).

Noni fruit juices are processed in a variety of methods. For example, noni juice may be fermented versus unfermented, fresh-pressed or drip-extracted (Newton, 2003). There is a lot of controversy over which is better, fresh juice or aged juice. Ram (2003) reports that fresh fruit tends to be sweeter and a bit easier to drink. While aging involves a fermentation process which is not well understood at this time (Ram, 2003). Reportedly, noni juice is not a pleasant thing to drink; its flavour has been called “terrible” and “objectionable”, and it was once likened to “rancid cheese” (Schoenhals, 2004). It is often mixed with other juices to improve the taste of the product (e.g. with grape, raspberry, blackberry or strawberry flavours) (Chan-Blanco et al., ND). Some processors dilute the noni juice with water and use sugar to sweeten the product to make it more palatable (Nelson, 2003).

Processing Methods

There are a variety of methods employed to produce noni juice, some of the main methods used commercially are briefly discussed:

Traditional Aging (Fermentation) Method

The traditional aging method requires the fruit to be harvested when it is beginning to ripen, determined by the colour change from green to pale yellow and partially translucent at which stage the characteristic pungent smell starts to develop. Once the fruit is collected, it ripens very quickly usually within 12 to 36 hours (Russell, 2000). Any fruit that is damaged or diseased should be rejected. The green immature fruit are generally rejected, as by using them, it seems to result in a more harsh and bitter flavour in the juice (Newton, 2003). The fruit are washed and dried then placed into large food containers or fermentation vessels (e.g. glass, stainless steel or food grade plastic) for a minimum period of 8 weeks up to approximately 6 months (Newton, 2003; Russell, 2000). Some commercial operations pulp the fruit before placement into the fermentation vessels. The containers are then sealed to maintain an anaerobic environment (no oxygen present), and contact between the fresh air and juice is minimised throughout the process.

Over time the juice starts to seep out of the fully ripe and soft fruit contained in the fermentation vessel. Through fermentation (reportedly acidification (Ram, 2003)), the sugars in the noni juice are transformed to organic acids causing the pH to be reduced to approximately pH 3.5 or less (Ram, 2003; Russell, 2000). According to Nelson (2003) due to the low pH of the fermented noni juice, pasteurisation may not always be necessary. Through this process the noni juice becomes less sweet and more acidic and sour.

The fermentation process leads to the production and accumulation of gases within the fermentation vessel. These gases may build up to a potentially explosive pressure if not released. For this reason, commercial operations incorporate some form of fermentation lock into the fermentation vessel to allow gas to escape from the sealed vessel. A fermentation lock is a device that allows the release of fermentation gases from the vessel while preventing the entry of unwanted fresh air and potential airborne contaminants.

At the end of the fermentation period a large percentage of the fruit disappears into the juice. The remaining fruit is pressed to separate off the remaining pulp, and the juice is often left for settling before decanting. Otherwise, depending on the market requirements, the juice may be filtered to remove any remaining sediment. The final shelf stable pure noni juice is often referred to as 'fermented juice'. The longer the fruit is aged the darker the juice becomes (e.g. dark brown to black), and the flavour becomes smoother and more moderate, a process that Newton (2003), compares to the ageing of a fine wine.

A slight variation to the above method involves adding water to the food vessel (often jars, drums or barrels), before sealing and leaving in the sun for some days (McClatchey 2002). Subsequently, the liquid is drained off and the remaining fruit pulp and water are pressed. According to Ram (2003) this fermentation process is more of a putrefaction (decomposition) process and noni juice is commonly commercially produced in this manner. However, this liquid is not a pure noni juice since water has been added. The juice colour varies from white to light amber.

Environmental Considerations

High temperatures during juice collection and fermentation, plus high levels of light exposure may cause undesirable chemical reactions to occur to noni juice (Newton, 2003). Thus, the most consistent commercial juice products are obtained under controlled conditions where both the temperature and light exposure are regulated during the fermentation and storage periods (Cook Islands Noni Marketing Ltd, ND).

Whole fruit versus pulped fruit

Newton (2003) reports that more juice could be extracted from pulped fruit than from whole fruit. For fresh-pulped fruit, the average recovery of juice was 65%, in comparison to 48% juice recovery for whole fruit. Newton (2003) also reports that the recovery of juice increases with age of raw material prior to extraction. Hard green fruit release less juice than soft ripened fruit, and produce a less sweet, bitter flavour.

Non-Aged Drip Extraction Method

This method follows the same procedure as the 'traditional aging' method, except that the noni juice is not allowed to undergo fermentation and the juice retains a relatively fruity, sweet taste (Nelson, 2003). The juice that seeps from the noni fruit is collected every couple of days, preventing fermentation. This product requires refrigeration (or freezing) and/or the addition of preserving agents or stabilisers to maintain product stability (Russell, 2000).

Fresh-pressed Method

The more recently developed non-aged processing method involves pressing ripe noni fruit and the resulting pure liquid becomes the finished product. Commercially this is achieved with the use of a hydraulic fruit press. This noni juice has a sweeter (less acidic), fruitier flavour than fermented noni juice (Nelson, 2003). Refrigeration, freezing, pasteurisation and/or preservatives may be used to prevent fermentation. Some processors allow the fresh-pressed juice to ferment naturally in the bottles or containers for a period of weeks or months prior to consumption (Newton, 2003).

Reconstitution Method

The reconstitution processing method involves reconstituting the juice from dried fruit powder (either sun dried, dried in a mechanical drier or freeze-dried) resulting in a product similar to non-aged juice. If a quality dried noni fruit powder is used in correct proportion of water or other fruit juices, a product similar to non-aged noni juice may be formed.

Compositional Guidelines

The Therapeutic Goods Administration (TGA) of Australia released a draft compositional guideline (<http://www.tga.gov.au/docs/pdf/compguid/drmoricj.pdf>) in August 2002 for *Morinda citrifolia* juice. The draft guidelines state that:

- Concentrated *Morinda citrifolia* juice is *Morinda citrifolia* juice that has been concentrated by the removal of water by mechanical means.
- Reconstituted *Morinda citrifolia* juice is *Morinda citrifolia* juice that has been concentrated and later reconstituted with water suitable for the purpose of restoring the composition of the *Morinda citrifolia* juice from which it was made.
- Reconstituted *Morinda citrifolia* juice may contain: added flavouring, *Morinda citrifolia* juice, and added sugars.
- Concentrated *Morinda citrifolia* juice may contain added sugars in such proportions to ensure that when reconstituted according to the directions the directions stated on the label, the reconstituted *Morinda citrifolia* juice complies with the compositional guideline (Table 2).
- Sweetened concentrated *Morinda citrifolia* juice and sweetened reconstituted *Morinda citrifolia* juice are respectively concentrated *Morinda citrifolia* and reconstituted *Morinda citrifolia* juice to which sugars have been added in accordance with the compositional guideline (Table 2).
- Reconstituted *Morinda citrifolia* juice shall also comply with the criteria based in Table 2.

In the compositional guideline, sugar-related criteria refer to products containing no added sugars. Where a product contains added sugar, compliance with those criteria shall be determined after allowance for the proportion of sugar permitted to be added (TGA, 2002).

Table 2. Draft Compositional Guidelines for *Morinda citrifolia* juice (From TGA, 2002)

Characteristics	Minimum	Maximum (not more than)	Target value	Comment
pH	3.7	4.0	3.8	
Brix ⁰ *	7.0	9.0	7.8	
Moisture (%)	90.00	92.5	91.4	
Titratable acidity (w/w NaOH)	0.10	0.15	0.125	
Total aerobic microbial count		10 ⁴ per mL or per g	0	This should include those shown below for yeast, mould, enterobacteria, <i>E. coli</i> , and <i>Salmonella</i> . As per AGRD2**. Method as per BP 2000***
Yeast		10 ² per mL or per g	0	
Mould		10 ² per mL or per g	0	
Enterobacteria		10 ² per mL or per g	0	
<i>E. coli</i>		nil in 1mL or 1g	0	
Salmonellae		nil in 1mL or 1g	0	
Pesticide residues	Levels and methods as specified in BP 2000			
Flavour	Characteristics of good, clean <i>Morinda citrifolia</i> fruit with no off flavours or colours			
Colour	Consistent light brown to brown colour with the pulpy appearance of fruit puree			
* The Brix scale is a hydrometer scale for sugar solutions, graduated so that readings in degrees Brix at a standard temperature represent percentages by weight of sugar in the solution.				
** AGRD2 = Australian Guidelines for the Registration of Drugs, Volume 2.				
*** BP 2000 = British Pharmacopoeia (2000).				

Pasteurisation

Thermal treatments applied to the preservation of food are intended to reduce or destroy the microbiological activity (pathogens and spoilage microorganisms), reduce or destroy the enzymic activity of the food. Pasteurisation is a relatively mild treatment, in which food is heated to below 100°C. In low acid foods (pH>4.5) it is used to minimise possible health hazards from pathogenic microorganisms and to extend the shelf life of foods for several days or weeks. While in acidic foods (pH<4.5) it is used to extend the shelf life for several months by destruction of spoilage microorganisms (yeast and moulds) and/or enzyme inactivation. In both types of foods, minimal changes are caused to the sensory characteristics or nutritive value. The use of high temperature short time (HTST) conditions (e.g. 88°C for 1sec, 94°C for 0.1 sec or 100°C for 0.01 sec, also termed flash pasteurisation) allow for best retention of nutritional and sensory quality (Fellows, 2000). Processing at lower-temperatures and longer-times (i.e. 63°C for 30 min) causes greater changes in flavour and greater loss of vitamins than HTST.

Typically, the pasteurisation of acid fruits and juices, consists of heating to about 70-100°C for about 30 to 60 seconds, and hot filled into containers at no lower than 70-77°C (more often 90-95°C), and held at this temperature for 1-3 minutes including inverting the container before cooling (Fellows, 2000; Splittstoesser, 1996). Alternatively the pasteurised product can be packaged into aseptic containers. Pasteurisation can also be achieved after filling into containers.

Noni juice has been reported to be pasteurised commercially at 87.5°C for at least 3 seconds or equivalent (Mi GmbH, 2005); the Cook Islands Noni Marketing Ltd (ND) pasteurise at 95°C for 15 seconds. There is a lot of controversy over pasteurised versus non-pasteurised noni juice in relation to whether the thermal treatment has any damaging affects in the inherent health-giving properties of the juice. This needs to be verified by further scientific investigations. Despite this, Nelson (2003) reports that pasteurisation does appear to alter the flavour of noni juice.

Bottling

As oxygen and light may reduce the noni juice shelf life, the choice of bottling container may be a major consideration. The majority of noni juice producers bottle noni juice products in either clear

glass or coloured glass (i.e. green), or clear food grade plastic bottles. Clear containers offer protection to the consumer by allowing the consumer to visually inspect the product for spoilage or physical contamination. Nelson (2003) reports that glass is preferred to plastic for longer shelf life and quality control, as plastic may allow some oxygen to enter the container, although financial and logistical considerations may preclude its use. While glass bottles are impermeable to oxygen, they are extremely heavy, and the dangers associated with breakage is always a concern. In contrast, a rigid plastic bottle is light in weight, robust, and offers a considerable saving in container cost per unit volume. However, consumers generally associate glass with a reliable, premium product. This is particularly seen in our elderly population, which have grown up using glass jars and bottles and continue to do so.

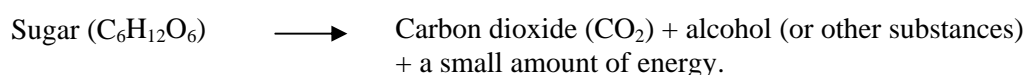
Quality Control

Quality control is needed to produce a consistent high quality product. All raw materials used should be of suitable grade (i.e. “rubbish product in – rubbish product out”). All critical steps in the manufacturing process should be critically monitored. Processing must be performed under hygienic conditions to prevent contamination with unwanted microorganisms resulting in spoilage or potential food poisoning. This risk may be ameliorated through the application of Good Hygienic Practices (GHP) with Good Manufacturing Practices (GMP), whilst a pasteurised product should be regarded as microbiologically safe. Standardisation of the processing steps will not only help prevent microbiological and chemical contamination of the product, it will also provide consistency to the biologically active ingredients in the juice.

Fermentation Processes

Preservation of foods by fermentation depends on the principle of oxidation of carbohydrates and related derivatives to generate end-products which are generally acids, alcohol and carbon dioxide (Caplice and Fitzgerald, 1999). These end-products control the growth of food spoilage microorganisms. The microflora of fresh fruit and vegetables is typically dominated by Gram-negative aerobic bacteria and yeasts, while lactic acid bacteria make up a minor proportion (Harris, 1998). However, most of the plant juices will undergo a spontaneous lactic acid fermentation when conditions are anaerobic and the temperature is appropriately adjusted (Harris, 1998).

Anaerobic respiration or fermentation does not use oxygen and can be summarised by the following formula:



Briefly, glucose is broken down by a series of enzyme controlled steps to yield pyruvic acid which is broken down, yielding the end products carbon dioxide, alcohol and lactic acid or other organic acid together with a small amount of energy (Parry and Pawsey, 1992). As indicated lactic acid fermentation bacteria produce lactic acid from sugar, and it is this acid that gives protection against other microbes that do not tolerate an acid environment. A major prerequisite for this acid to become effective in practice is the simultaneous formation of a certain quantity of acetic acid, ethanol and, antibiotics (Kyzlink, 1990).

The lactic acid bacteria are a diverse group of organisms with a diverse metabolic capability. Lactic acid bacteria may be homofermentative and only produce lactic acid; or heterofermentative and produce lactic acid plus other volatile compounds and small amounts of alcohol (Battcock and Azam-Ali, 1998). All lactic acid producers are microaerophilic and therefore require small amounts of oxygen to function. The optimum pH range for lactic acid fermentation bacteria is pH 3.5 to 5.5 (Kyzlink, 1990). In comparison, alcoholic fermentation by yeasts involves the conversion of sugar to ethanol and carbon dioxide providing the preservation effect. The optimum pH for fermenting fruit juices is just below 3.5 (pH range 2.5 to 4.3) (Kyzlink, 1990), which protects the juice against most detrimental bacteria and is beneficial to the growth of yeasts (i.e. wine production). Most yeasts require an abundance of oxygen for growth, however, some can ferment sugars to alcohol and carbon dioxide in the absence of air but require oxygen for growth (Battcock and Azam-Ali, 1998).

Ram (2003) reports that the noni juice fermentation is a bacterial fermentation with no apparent yeast organism involved. Ram (2003) suggests that through fermentation, the sugars in the noni juice are transformed to organic acids causing the pH to be reduced to approximately pH 3.5 or less. Ram (2003) also indicates that there is not a significant amount of alcohol produced by the fermentation. Dixon et al. (1999), on the other hand reports that the fermented noni juice contains methyl and ethyl alcohols, while according to Chan-Blanco et al. (ND), large amounts of sugars in the noni fruit are not fermented when fruits are stored in closed containers, suggesting that the fermentation process could possibly be a putrefaction process.

Putrefaction is a complex microbial decomposition, usually anaerobic of non-acid or low acid foods generally rich in proteins (Kyzlink, 1990). The material that is affected by putrefaction has a repulsive odour, undergoes brown discolouration and other colour changes, and finally deteriorates. The material is alkalised and gases such as ammonia, carbon dioxide and hydrogen sulphide are produced. All naturally acid foods, such as the majority of fruits with a pH lower than about 4, are protected against putrefaction (Kyzlink, 1990). Non-acid foods can be protected from putrefaction by artificial, preventative acidification with organic acids; such acidification is used on pickled vegetables. Putrefaction can also be prevented by acidifying fermentation.

Butyric acid fermentation is also an anaerobic process. The microorganisms responsible utilise sugar, pectins, starch, proteins and lactic acid at low concentrations and produce large quantities of gases (Kyzlink, 1990). The organisms can tolerate rather high acidity, pH range 4.2 to 4.7, and convert lactic acid into butyric acid, which is much less effective in inhibiting spoilage-causing microorganisms, especially moulds (Kyzlink, 1990). In normal fermentation, butyric fermentation is hampered by the rapid rise of acidity, but may appear anytime that the pH of the product (especially vegetables) rises above 4.2, for instance due to the activity of various de-acidifying surface microbes.

Summary

There is very little scientific literature available on the fermentation process of noni juice. The more recent research literature that is available on noni is driven by the commercial potential of noni among the rapidly growing number of “natural medicines” and “health foods”. It is difficult to determine from the little available literature and conflicting reports, if the ‘traditional aging’ method of processing noni juice, reported as an anaerobic fermentation process is actually a lactic acid fermentation or a putrefaction process.

Further scientific investigations are required to identify the microflora involved in the reported anaerobic fermentation process and their mechanisms of action in order to determine the biological processes involved. This may enable the development of significantly improved and refined processing parameters including the development of a potential starter culture which could be used as a processing aid in the manufacturing of noni juice. Ideally, for a commercial situation it would be advantageous if a processor could add a starter culture to the noni fruit or pulp at the beginning of the process when the fruit are first placed into the fermentation vessels. As with modern fermentation techniques, a starter culture with known characteristics under controlled conditions would allow the processor to potentially produce a reliable consistent safe product every time. Subsequently, a product with consistent quality has more potential to retain repeat business in a competitive market providing more opportunity for success of the business. Alternatively, juice could be pressed fresh from noni fruit without fermentation. This product would involve considerably less processing, lower production costs and improved flavour and smell due to reduced butyric acid. However, a comparison of bioactivity and composition of both unfermented and fermented noni juice would be required.

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Review of therapeutic properties

Craig Davis 2006

Introduction

The fruit and the juice of *Morinda citrifolia* L. are the primary source of traditional medicines, however, all parts of the plant (seed, leaf, bark and root) are recognised for various medicinal properties. The traditional uses of Noni are extremely diverse, but primarily it is used as a general tonic and a remedy for imbalances of the digestive, intestinal, respiratory and immune systems.

Ancient healing manuscripts handed down from generation to generation, cite the Noni fruit as the primary ingredient in their natural health preparations. Traditional healers would pick the fruit before it was fully ripe and place it in direct sunlight. When fully ripe, the fruit was mashed into a puree and the juice extracted through a cloth. The juice was now ready for use. As a general tonic, the juice was taken during times of rest. In addition to the fruit, every other part of the Noni plant was valued and used.

Traditional Uses

Traditional uses of Noni include the treatment of the digestive system (*e.g.* diarrhoea, intestinal parasites, indigestion and stomach ulcers), internal disorders (*e.g.* diabetes, high blood pressure, headache, kidney and bladder, tumours and fevers), eyes, mouth and throat (*e.g.* eye infections, inflamed and sore gums, sore throat with cough, gingivitis and toothache), bones and joints (*e.g.* arthritis, sprains and broken bones), chest (*e.g.* cough, tuberculosis, asthma and respiratory afflictions), gender-specific ailments (*e.g.* childbirth and pregnancy, menstrual cramps, regulation of menstruation and prostate complaints), skin (*e.g.* abscesses, boils, blemishes, wounds and infections), and as a tonic to slow aging.

The Polynesians have been using the noni plant for food and medicinal purposes for more than 2000 years. In traditional pharmacopoeia, the fruit is claimed to prevent and cure several diseases. The likely mode of action is stimulation of the immune system to fight bacterial, viral, parasitic and fungal infections and prevent the formation and proliferation of tumours (Dixon *et al.*, 1999). Noni is generally consumed as juice, although leaves, flowers, bark and roots can also be used (Dixon *et al.*, 1999; McClatchey, 2002). Amongst the traditional cultures, the bark produces a red dye and the roots a yellow dye (White, 1994).

The bland tasting fruit is edible (although it has an unpleasant taste when ripe), and among traditional cultures may be eaten raw or cooked. In Australia, indigenous people usually eat the fruit raw with salt. In Asian cultures, it is often cooked in curries. Amongst many cultures, it was considered a famine food and was regularly eaten in times of food shortage (Tan, 2001).

Current Uses

The main use of *Morinda citrifolia* L today is as a liquid tonic extracted from the fruit. An industry has developed around this fruit juice which is marketed as "Noni". It is used as a remedy for imbalances of the digestive, intestinal, respiratory and immune systems. It is becoming very popular internationally and locally, and is in demand. All of the tonic sold in Australia today is imported (mostly from Hawaii, Fiji and Tahiti) and it produced from plantation and native trees. In Australia, Noni has not been commercialised and the utilisation of this species is limited to occasional harvest of products from natural-grown trees, primarily by indigenous communities. Noni is the established and widely accepted name in the marketplace.

Noni juice is believed to promote an alkaline body chemistry, the optimal state for good health. Tissues degrade and disease thrives in an acidic environment. It is said to be the "premiere" adaptogen (a substance that has a global balancing effect on all body systems). Noni juice is a rich source of anti-oxidants which are important in neutralizing "free radicals" or particles that cause DNA damage that

can lead to cancer. It has a low glycemic index (a 3:1 ratio of carbohydrates to fibre) which helps to balance blood sugar levels.

Two recent clinical studies reported a relief of arthritis and diabetes associated with noni consumption (Elkins, 1998; Solomon, 1999). Consumption of noni juice is currently high, not only in the producing countries, but also in the United States, Japan and Europe. Some countries (*e.g.* Costa Rica and Cambodia), have increased the fields being cultivated in noni. The fruit is often marketed fresh or as juice in both formal and informal markets. It is also produced as pasteurized juice, either pure or mixed with other juices.

Noni juice has recently been accepted in the European Union as a novel food ingredient to be used in pasteurised fruit drinks (European Commission, Scientific Committee for Food, 2003). The Australian Therapeutic Goods Administration (TGA) has developed Draft Compositional Guidelines for *Morianda citrifolia L.* (Noni) dried fruit pericarp powder and *Morinda citrifolia L.*(noni) juice. In addition, The European Commission has recently deemed noni juice safe (non-toxic) at or above recommended consumption levels (Anon 2006). However, there has been little scientific research to review the actual nutritional and functional properties of noni products and its phytochemical composition. Consequently, optimization of agricultural/post-harvest practices or processing technologies still requires significant work.

Chemical composition of noni

About 160 phytochemical compounds have been identified in the noni plant. The major micronutrients are phenolic compounds, organic acids and alkaloids (Wang and Su, 2001). Of the phenolic compounds, the most important reported are anthraquinones (*e.g.* damnacanthal, morindone, morindin), and also aucubin, asperuloside, and scopoletin (Wang and Su, 2001). The main organic acids are caproic and caprylic acids (Dittmar, 1993), while the principal reported alkaloid is xeronine (Heinicke, 1985).

The chemical composition of various parts of the plant is thoroughly documented in Chan Blanco *et al.* (2006). The complete physicochemical composition of the fruit has not yet been reported and only partial information is available on noni juice (**Table 3**). The fruit contains 90% of water and the main components of the dry matter appear to be soluble solids, dietary fibres and proteins (Chunhieng *et al.*, 2003). The protein content is surprisingly high, representing 11.3% of the fruit juice dry matter. The main amino acids are aspartic acid, glutamic acid and isoleucine (Chunhieng *et al.*, 2003).

Table 3. The physico-chemical composition of noni juice

Characteristics	Chunhieng (2003) ^a	Shovic & Whistler (2001) ^a	European Commission (2002) ^b
pH-value	3.72	-	3.4–3.6
Dry matter	9.870.4%	-	10–11%
Total soluble solids	8 °Brix	-	-
Protein content	2.5%	0.4 g/100 g	0.2–0.5%
Lipid	0.15%	0.30 g/100 g	0.1–0.2%
Glucose	11.970.2 g/l	-	3.0–4.0 g/100 g
Fructose	8.270.2 g/l	-	3.0–4.0 g/100 g
Potassium	3900 mg/l	188 mg/100 g	30–150 mg/100 g
Sodium	214 mg/l	21 mg/100 g	15–40 mg/100 g
Magnesium	14 mg/l	14.5 mg/100 g	3–12 mg/100 g
Calcium	28 mg/l	41.7 mg/100 g	20–25 mg/100 g
Vitamin C	-	155 mg/100 g	3–25 mg/100 g

^aNoni fruit.

^bTahitian Noni™ Juice (Commercial noni juice - 89% noni juice and 11% grape and blueberry juice).

Minerals (mainly potassium, sulphur, calcium and phosphorus) account for 8.4% of the dry matter. Traces of selenium have been reported in the juice (Chunhieng *et al.*, 2003). Vitamins have been reported in the fruit, mainly ascorbic acid (24–158 mg/100 g dry matter) (Morton, 1992; Shovic and Whistler, 2001), provitamin A (Dixon *et al.*, 1999), and Vitamin C (Peerzada *et al.*, 1990).

Phenolic compounds have been found to be the major group of functional micronutrients in noni juice. Damnacanthal, scopoletin, morindone, alizarin, aucubin, nordamnacanthal, rubiadin, rubiadin-1-methyl ether and other anthraquinone glycosides have been identified in noni (Morton, 1992; Dittmar, 1993; Dixon *et al.*, 1999; Wang and Su, 2001). Damnacanthal is an anthraquinone that has been characterized recently and has some important functional properties (mainly anti-carcinogenic) (Solomon, 1999). Scopoletin is a coumarin that was isolated in 1993 at the University of Hawaii and has been found to have analgesic properties as well as a significant ability to control serotonin levels in the body (Levand and Larson, 1979). Other researchers have shown that scopoletin may also have anti-microbial (Duncan *et al.*, 1998) and anti-hypertensive effects (Solomon, 1999).

Different Hawaiian teams (Heinicke, 1985; Solomon, 1999) reported the presence of a novel component, proxeronine, in the noni. It would be the precursor of xeronine, an alkaloid that is claimed to combine with human proteins, improving their functionality. These authors attribute most of the beneficial effects of noni to xeronine. However, the chemical characterization of this alkaloid and the method used to assess its content have not been published.

Over 50 volatile compounds have been identified in the ripe fruit (Sang *et al.*, 2001), including organic acids (mainly octanoic and hexanoic acids), alcohols (3-methyl- 3-buten-1-ol), esters (methyl octanoate, methyl decanoate), ketones (2-heptanone), and lactones [(E)-6-dodeceno-glactone] (Farine *et al.*, 1996).

Biological activity of *Morinda citrifolia*

Antimicrobial effects

The antimicrobial effect of noni may have been the first observed property. The fruit contains relatively large amounts of sugars that are not fermented when fruits are stored in closed containers at ambient temperature. This property is used to transport the fruit by boat from the scattered Pacific islands to processing plants without specific treatment.

It has been reported that noni inhibits the growth of certain bacteria, such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Proteus morgaii*, *Bacillus subtilis*, *Escherichia coli*, *Helicobacter pylori*, *Salmonella* and *Shigella* (Atkinson, 1956). The same author claims that the antimicrobial effect observed may be due to the presence of phenolic compounds such as aucubin, L-asperuloside, alizarin, scopoletin and other anthraquinones. Another study showed that an acetonitrile extract of the dried fruit inhibited the growth of *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Escherichia coli* and *Streptococcus pyrogene* (Locher *et al.*, 1995). It has also been found that ethanol and hexane extracts of noni have an anti-tubercular effect since they inhibit by 89–95% the growth of *Mycobacterium tuberculosis* (Saludes *et al.*, 2002). The major components identified in the hexane extract were E-phytol, cycloartenol, stigmasterol, β -sitosterol, campesta-5,7,22-trien-3-b-ol, and the ketosteroids, stigmasta-4-en-3-one and stigmasta-4-22-dien-3-one. Other studies have reported a significant antimicrobial effect on different strains of *Salmonella*, *Shigella*, and *E. coli* (Bushnell *et al.*, 1950; Dittmar, 1993). Many of these studies have shown that the antimicrobial effect is highly dependent on the stage of ripeness and on processing, being greater when the fruit is ripe, without drying.

Anti-cancer activity

The immunomodulatory properties (capacity to enhance the host immune system) of noni juice has been proposed as an anti-cancer action. The ethanol precipitable fraction of noni juice has been found to have immunomodulatory and anti-tumour effects against Lewis lung carcinoma. On cell models, this polysaccharide-rich substance (composed of glucuronic acid, galactose, arabinose, and rhamnose), stimulates the production of T-cells, thymocytes and macrophages that produce cytokines, which are

important mediators of tumour cytostasis and cytotoxicity (Hirazumi *et al.*, 1996; Hirazumi and Furusawa, 1999). This extract also stimulates the release of several mediators from murine effector cells such as cytokines, which slow down the cell cycle in tumors, increase the response of cells to other immunized cells that fight tumor growth, and have a potent macrophage activator activity, suspected of playing a role in the death of tumours (Hirazumi *et al.*, 1996; Hirazumi and Furusawa, 1999). When mice were inoculated with Lewis lung carcinoma, those ingesting a daily dose of 15 mg of noni juice had a significant increase (119%) in life span. Nine out of 22 mice with terminal cancer survived for more than 50 days. In addition, the ingestion of noni extract, combined with conventional chemotherapy in the treatment of mice with cancer, proved to increase life spans (Hirazumi *et al.*, 1994).

Another Japanese team studied the effect of damnacanthal (an anthraquinone extracted from a chloroform extract of noni roots). The researchers found that damnacanthal induced the normal morphology of a particular type of cells found in human neoplastic (K-ras-NKR) cells that multiply uncontrollably and are highly malignant (Hiramatsu *et al.*, 1993). Commercial noni juice has been shown to be able to prevent the formation of chemical carcinogen-DNA-adduct formation. (Wang and Su, 2001). Rats with artificially-induced cancer in specific organs were fed for one week with 10% noni juice in their drinking water. They showed reduced DNA-adduct formation, depending on sex and considered organ (Wang and Su, 2001).

A 2005 study (Issell, 2005), defines a Phase 1 clinical trial which assesses the efficacy of noni. Although no tumour regressions were noted, pain was significantly reduced, and dose response relationships were observed for health status, physical functioning and fatigue.

Anti-oxidant properties

The anti-oxidant properties of ethanol and ethyl acetate extracts of noni fruit have been assessed using the ferric thiocyanate method (FTC) and thiobarbituric acid (TBA) test. The authors found that the ethyl acetate extract exhibited strong inhibition of lipid oxidation comparable to the same weight of pure α -tocopherol and butylated hydroxytoluene (BHT) (Mohd *et al.*, 2001).

Radical scavenging activity was also measured *in vitro* by the tetrazolium nitroblue (TNB) assay on a commercial juice, by assessing the potential capacity of the juice to protect cells or lipids from oxidative alteration promoted by superoxide anion radicals (SAR). The SAR scavenging activity of noni juice was shown to be 2.8 times higher than that of vitamin C 1.4 times that of pycnogenol and almost of the same order as that of grape seed powder (Wang and Su, 2001).

Anti-inflammatory activity

The anti-inflammatory activity of an aqueous extract from noni juice was observed by inducing a locally acute inflammatory response, with the help of a pro-inflammatory agent (bradykinin). It was shown that the oral administration of a noni juice extract (200 mg) rapidly inhibited the formation of rat paw edema. This effect may have resulted from interference with the B2 receptor-mediated mechanism by which bradykinin induces rat paw edema (McKoy *et al.*, 2002).

Another study showed that commercial noni juice has a selective inhibition effect on some cyclooxygenase enzymes (COX-1 and COX-2) involved in breast, colon and lung cancer, and also in anti-inflammatory activity (Su *et al.*, 2001). The inhibition of the activity of these enzymes by noni juice was compared with that of commercial non-steroidal inflammatory drugs such as aspirin, Indomethacin and Celebrex. Noni juice showed selective inhibition of COX enzyme activity *in vitro* and a strong anti-inflammatory effect comparable to that of Celebrex and without side effects.

Analgesic activity

Recent research examined the analgesic properties of a commercial juice in rats. The results showed that rats fed with 10% and 20% noni juice had greater pain tolerance (162% and 212%, respectively) compared with the placebo group (Wang *et al.*, 2002). A French research team has also studied the analgesic and sedative effects of noni on mice through the writhing and hotplate tests. Noni root extract (1600 mg/kg) showed significant analgesic activity in the animals, similar to the effect of morphine (75% and 81% protection using noni extract and morphine, respectively), and it also proved to be non-toxic (Younos *et al.*, 1990).

Cardiovascular activity

Recent research has demonstrated the effects of noni fruit on preventing arteriosclerosis, a disease related to the oxidation of low density lipoproteins (LDL). Methanol and ethyl acetate extracts showed 88 and 96% inhibition, respectively, of copper-induced LDL oxidation (using the thiobarbituric acid reactive substance method). This beneficial effect could be due to the presence of lignans and phenylpropanoid dimers (Kamiya *et al.*, 2004).

Conclusion

The *Morinda citrifolia* plant, and especially its fruit, has been used for centuries in folk medicine. Different studies, some of them with controversial methodologies, showed that this fruit contains several nutritional and functional compounds, but most of them have not been quantified. The most important compounds identified in noni fruit are phenolics, such as damnacanthal and scopoletin, organic acids (caproic and caprylic acid), vitamins (ascorbic acid and provitamin A), amino acids such as aspartic acid, and minerals. Another compound named xeronine, supposedly an alkaloid, has been reported but its structure has never been published. The main proven functional properties of noni fruit are related to the control of several diseases. *In vitro* research and limited animal experiments have shown that noni has antimicrobial, anti-cancer, antioxidant, anti-inflammatory, analgesic and cardiovascular activity.

The current market for noni juice has conferred upon the fruit a unique and authentic appeal. Market interest in this fruit suggests a bright future, although more studies are needed to identify the nutritional and functional compounds it contains and explain their mechanisms of action in order to determine the real potential of this fruit and the technological processes that preserve these properties.

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Recommendations

- Commercial growing of noni in Australia is in its infancy. There is no information available in Australia on actual costs of production and returns for product and these will be influenced by many management factors as well as pest and disease incidence. A gross margins analysis of plantings in Australia would provide much needed economic information on which to base assessment of industry potential.
- The diversity of noni needs to be examined and better understood to assist a developing industry with product assurance and marketing of improved products to ensure competitive advantage.
- Product image is very important to the customer looking for health benefits. A developing noni industry should pursue organic certification and support R&D which investigates more profitable organic production systems.
- Noni as a component of the bush tucker trade is still largely undeveloped. Presumably Australian origin is mandatory for products sold under such a banner. State and federal governments should therefore continue to foster the development of native Australian plants such as noni as they will have a strong marketing edge over imported product.
- Scientific investigations are required to identify the microflora involved in the reported anaerobic fermentation process and their mechanisms of action in order to determine the biological processes involved.
- Research is required for the development of improved process parameters and the potential development of a starter culture which could be used as a processing aid in the manufacturing of noni juice.
- Alternatively, juice could be pressed fresh from noni fruit without fermentation. This product would involve considerably less processing, lower production costs and improved flavour and smell due to reduced butyric acid. However, a comparison of bioactivity and composition of both unfermented and fermented noni juice would be required.
- As noni cultivars are developed and the germplasm is further screened, compositional analysis needs to determine the levels of macro-ingredients (e.g. protein, lipid, sugars, etc) as well as micro-ingredients (e.g. vitamins, minerals, phenolic compounds, etc).
- Appropriate bioactivity assessments of noni (e.g. juice, powder etc) need to be performed in a number of areas (e.g. anti-microbial, anti-cancer, anti-oxidant, analgesia and cardio vascular) to support the market for this new industry.
- It is important that this fledgling industry in Queensland defines a market supply chain with a functional application area. Noni is unlikely to be a general tonic or 'cure all', and so a specific market needs to be defined, probably on the basis of quality or tested activity (e.g. gut health or skin care in older people).
- The current market for noni juice has conferred upon the fruit a unique and authentic appeal. Market interest in this fruit suggests a bright future, although more studies are needed to identify the nutritional and functional compounds it contains and explain their mechanisms of action in order to determine the real potential of this fruit and the technological processes that preserve these properties.

Appendix 1

Search Sources

Database/Search Engine	Description	Coverage
AANRO	Australian Agriculture & Natural Resources Online :Bibliographic & research information about Australian agriculture and natural resource management	Not known
Academic Search Elite	Multi-disciplinary database offers full text for nearly 1,850 scholarly journals, including nearly 1,300 peer-reviewed titles	1985+
Agricola	Agricultural index and some abstracts. USDA National Agricultural Library and NTIS Agricultural and biological literature	1970+
Agris	Worldwide literature on all aspects of agriculture relating to developing countries, economics, development, marketing, rural sociology, aquatic sciences and fisheries, food science and human nutrition	1975+
Biosis Previews	Indexes abstracts and indexes information from more than 5,500 international life sciences sources	1969+
Business Source Premier	Full text business database with more than 3,000 scholarly business journals, covering virtually all subject areas related to business.	1922+
CAB Direct	Covers worldwide issues in agriculture, forestry, and allied disciplines. Sources include journals, books, conferences, reports, and other kinds of literature published internationally.	1900+
Cochrane Library	The Cochrane Library contains high-quality, independent evidence and includes reliable evidence from Cochrane and other systematic reviews, clinical trials, and more. Cochrane reviews bring you the combined results of the world's best medical research studies.	1989+
Current Contents Connect	Current Contents Connect® is a multidisciplinary current awareness Web resource providing access to complete bibliographic information from over 8,000 of the world's leading scholarly journals and more than 2,000 books.	1998+
Forest Science Database	Contains information on all aspects of forestry, ecology and management, agroforestry systems, forest products and the biology and genetics of woody plants. The database holds records from journals, monographs, conferences, books, and annual reports from more than 130 countries.	1939+
Food Science & Technology Abstracts	An extensive collection of abstracts prepared from the world's food science, food technology and food-related human nutrition literature	1969+
Global Health	Definitive international public health database and the only specialist bibliographic, abstracting and indexing database dedicated to public health research and practice. It contains over a million scientific records from 1973 to the present, with over 70,000 records added each year.	1973+
Google Scholar	Google Scholar is a subset of Google and attempts to link to scholarly research materials (e.g., articles, papers, etc.) on the web and covers a portion of the scholarly literature.	Not known
ISI Web of science	Indexes over 8,500 high impact research journals from a wide range of disciplines, and as such provides an interdisciplinary view of international research literature .	1992+
JStage	Japanese Science and Technology Information Aggregator Electronic	1999+
OAIster	OAIster is a project of the University of Michigan Digital Library Production Service. Its goal is to create a collection of freely available, previously difficult-to-access, academically-oriented digital resources that are easily searchable by anyone. 7,498,800 records from 639 institutions	Not known
Pascal	The world renowned PASCAL database is a unique multidisciplinary and multilingual bibliographic database. It covers all the major international journals, reports, conference proceedings, periodical articles and doctoral dissertations in all aspects of the Sciences and Medical Sciences	1987+

Database/Search Engine	Description	Coverage
PubMed	Over 14 million citations for biomedical articles back to 1953 and provides citations and abstracts to biomedical literature. Includes animal health citations. From the National Library of Medicine.	1965+
Science.gov	Science.gov is an interagency initiative of 16 U.S. government science organizations within 12 Federal agencies providing public access and a unified search of the government's vast stores of scientific and technical information.	Not known
Scirus	Scirus is the most comprehensive science-specific search engine on the Internet. Driven by the latest search engine technology, Scirus searches over 250 million science-specific Web pages	Not known
Scopus	Scientific, technical, medical and social science literature from 14000 titles from 4000 publishers and websites	1966+
US Patents	Issued patents	1976+
US Patents	Published applications	2001+

Appendix 2

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Appendix 3

Market Research Report – NONI JUICE
AIC Australian Institute for Commercialisation



Australian Institute
for Commercialisation

Market Research Report – NONI JUICE

May/June 2005

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Partner

Philippe and Naomi Petiniaud

This AIC Market Research report profiles the global noni juice market

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1) Introduction and Market Overview

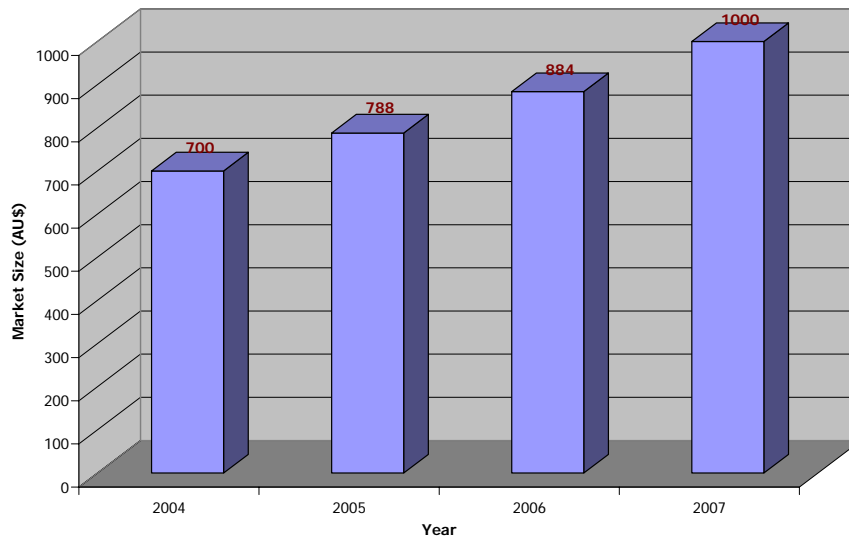
Noni juice, derived from the native Oceania fruit Noni, has experienced significant market penetration since its introduction into the global functional foods/nutraceuticals market in the mid 1990s. The major markets include the United States and Japan, with Europe a lucrative and emerging market. Almost all noni juice is derived from fruit grown in the Oceanic regions of Tahiti, Samoa and Cook Islands, with Hawaii and Indonesia also producing a significant amount.

2) Market Size

2.1 Global Market

In 2004, the global Noni Juice market was estimated to be valued between AU\$700 to \$750 million. The market is expected to experience strong growth at least for the next few years to reach AU\$1 billion by 2007.

Chart 1 – Size of global Noni Juice market (2004-2007)



Year	Market Size (AU\$)
2004	700
2005	788
2006	884
2007	1000

Estimated Compound Annual Growth Rate (CAGR): 12.62%

Source: Developed for this research¹

In regards to volume, around 7,000 to 8,000 tonnes of noni fruit are expected to be harvested for juice production in 2005. This figure is predicted to rise in parallel with increased market value to 2007.

2.2 Australian market

¹ Based primarily on revenue information from Tahitian Noni International, trade information from Oceania regions and sales information from Japan

The Australian market for Noni juice is well represented on the world stage and accounts for an estimated 5 to 7 per cent of the global market. This equates to between AU\$35 to 52.5 million (Established for this research²).

The primary reasons behind Australia's significant market share include:

- The establishment of the market since the mid to late 1990s – noni juice has been imported into Australia for nearly 10 years, whereas some major overseas markets (such as in Europe) have only recently been established or are yet to be established. As these markets mature and prosper, Australia may lose some of its market share in comparison.
- The considerable distribution network of noni juice in Australia
- The diet- and health-conscious nature of many Australians

3) Market Dynamics

3.1 Global Markets

The United States of America and Japan currently represent the two largest markets for Noni juice. Other significant markets include Canada, Thailand, Philippines and Oceania countries such as Australia, Tahiti and Samoa. Since gaining regulatory approval as a novel food in 2003, the European Union (EU) presents a lucrative emerging market for Noni juice.

3.2 Market Drivers

The following are the key drivers for growth of the noni juice market:

- *High demand for healthy and/or functional foods* – many people especially in the U.S., Australia and Japan, are adopting diets to incorporate functional foods and/or nutraceuticals. This change has been labelled by some as the Complementary and Alternative Medicine (CAM) Movement.
- *Widespread regulatory approval* – as noni juice is sold as a dietary supplement and not as a pharmaceutical product, it is not required to undergo strict approval processes (e.g. from the FDA in the US) for its marketing and sale. This has allowed for the widespread adoption of noni juice.

3.3 Market Restraints

The key restraint of the noni juice market is:

- *Lack of medical and scientific evidence on the health benefits of noni juice* – although there is plenty of research being conducted on noni, there remains a lack of reputable and widely-published evidence on the health benefits that noni juice offers. This has led to some consumers being sceptical about purchasing noni juice.

² Based primarily on information derived from data related to the global noni juice market, the Australian health and functional foods market and comparison of noni with other functional foods

4) Recent Market Activities

There is a high amount of activity in the increasingly competitive noni juice market. Below is a non-exhaustive list of major recent activities -

4.1 Tahitian Noni International opens new plant

April, 2005 – the developer and exclusive provider of Tahitian Noni® Juice, Tahitian Noni International, recently opened a new manufacturing and processing plant on the west coast of Tahiti in the community of Mataiea. At more than 85,000 square feet (8,000m²) and at a cost of more than US\$21 million (16.7 million euros) the plant is the largest single-roofed facility in Tahiti and can process more than twice the amount of noni fruit than the previous plant (Business Wire).

4.2 Niue's first Nonu juice hits the market

December, 2004 – Niue delivered its first organic Nonu shipment into the international marketplace. The 9,000-litre-shipment, in 1000 litre containers, is the first of the natural medicinal liquid to leave the island in bulk. It's heading for Auckland where it will be bottled and marketed initially in Foodtown and Woolworth supermarkets and health stores.

The processed fruit from the nonu tree (*morinda citrifolia*) was harvested from Niue's bush areas where it grows wild. Future shipments will include nonu being grown on the 150 hectare Vaiea farm; the former international alpaca quarantine station, as a joint venture Niue Government/Reef Group project develops. The farm has already been planted with 7,000 young trees with 30,000 currently in a nursery (PACNEWS).

4.3 PINA group gains novel foods approval

December, 2004 – the members of the Pacific Island Noni Association (PINA) have received European marketing approval for noni juice from UK Authorities, after demonstrating that their products are substantially equivalent to that sold by Tahitian Noni International (NutraIngredients).

4.4 Samoans place hope in smelly cash crop

November, 2004 - Tia and George Tinielu have established a home, office and processing factory dedicated to Nonu. Their company, Nonu Samoa, won the Samoan exporter-of-the-year award in 2002 and 2003, after exporting around 70 tonnes of Nonu a month to Japan and the U.S.

The company has received tremendous support from the Samoan non-governmental organisation, O Le Sisiomaga Society Inc, and is continuing to target the rapidly growing markets of Asia and North America (Kyodo News)

4.5 Nature's Products seeks noni juice market in UK

October, 2004 – New Zealand based company Nature's Products has applied to Britain's Food Standards Agency for approval in this market, based on the equivalence of the product already being sold in other parts of Europe (e.g. Germany).

4.6 Niue's elixir of life

September, 2004 - Auckland company Reef Shipping and the Niuean Government have opened a nonu juice factory in Niue, which, at full production, will process 200 tonnes of nonu, a month. The factory and a 1215-hectare (300-acre) nonu farm will eventually provide work for 100 people, and will produce about half the fruit needed. About 100 tonnes a month will have to be bought elsewhere.

Reef Shipping Chief Executive Mr Harris-Daw says that fruit will be sourced from villages around the island, where nonu grows freely in the wild, and, depending on quality, will be bought for 25c to 50c a kilogram. That may not sound like much, but in a country with a population of just 1500 and an average wage of about \$3 an hour, the \$25,000 to \$50,000 that could be generated each month takes on a whole new significance (Dominion Post).

4.7 Tahitian Noni launches novel fibre blend

July, 2004 – Tahitian Noni International has announced the release of a versatile fibre called Tahitian Noni Fiber Blend. The company claims that it is a perfect balance of soluble and insoluble fibre containing the benefits of noni fruit (Nutraceuticals International).

4.8 Japan eager to add domestic noni to marketplace

2004 – Due to the Complementary and Alternative Medicine (CAM) Movement currently being experienced in Japan and in many other parts of the world, farmers in Okinawa (Japan) are working hard to add domestic noni to the marketplace (The Japan Times).

5) Legal Status and Issues

As Noni is marketed as a dietary supplement and not as a pharmaceutical product, it is not subject to the regulations of sanctioning bodies such as the U.S. Federal Drug Administration (FDA) and the Australian Therapeutic Goods Administration (TGA). Thus, Noni has been approved for use as a nutraceutical or functional food in practically almost all global markets. However, in some regions such as the United Kingdom, it requires approval from agencies which control the marketing and approval of food and beverage. In Britain's case, it is awaiting approval from the Food Standards Agency's Advisory Committee on Novel Foods and Processes.

In Europe, noni juice was authorised for the European Union market for use in pasteurized fruit drinks in 2003 (Commission Decision 2003/426/EC). In its assessment in 2002, the EU Scientific Committee on Food (SCF) considered noni juice, at the observed levels of intake, as acceptable and therefore safe for human consumption. However, the SCF also stated that the data supplied and the information available provided no evidence that noni juice offered any special health benefits beyond those of other fruit juices.

For this reason, there continues to be significant legal issues concerning noni. There is still no scientific evidence available to justify claims that noni juice confers special health benefits or that it cures or prevents diseases and medical conditions. The concern expressed by authorities is that consumers may be misled by these scientifically-unsubstantiated health claims in contravention of the EU labelling Directive. However, more importantly, they fear that consumers suffering from any of the wide range of medical conditions listed in some promotional material may choose to forego conventional medical treatments in favour of noni juice. While the sale of noni juice is legal in the EU as a food, medical claims about the product are illegal. Any product that carries specific medicinal claims requires pre-market approval as a medicine.

Nevertheless, a number of independent distributors continue to claim that noni confers wide-ranging health claims. Some claims that have been found include 'Noni relieves diabetes and fibromyalgia' and 'Crohn's disease meets its match - Noni'. One distributor prepared an A4-sized sheet which listed a total of 28 conditions for which thousands of people claim to have been helped by noni juice (Nutraceuticals International).

6) Pricing Analysis

The price of noni juice varies greatly depending on the region and supplier. In the Pacific Islands, the juice is estimated to be sold by just AU\$9 per litre, whereas the juice has retailed for nearly AU\$500 per litre in Europe. The median price seems to be around AU\$60 per litre. Below is a table outlining the retail price³ of Noni juice in various countries:

Table 1 – Pricing Analysis of Noni Juice products

Region	Standard price per bottle (AU\$)	Price per litre (AU\$)	Supplier
Worldwide	\$100 per litre bottle	\$100 ⁴	Tahitian Noni International
	\$43 per 750ml bottle	\$57	Nature's Products
	\$20 per litre bottle	\$20	Noni Maui
Pacific Islands	\$13 per 1.5 litres	\$8.67	N/A
Europe	\$100 to \$500 per litre	\$100 to \$500	N/A
Thailand	\$49 to \$65 per litre	\$49 to \$65	N/A
Korea	\$100 per litre	\$100	N/A
Australia	\$50 per litre bottle	\$50	Tree of Health
	\$49.60 per 946ml bottle	\$52	Tahitian Gold
	\$35 per 375ml bottle	\$93	Tropical Fruit World

Source: Developed for this research

³ The price of Noni Juice was accurate at the time of conducting the research.

⁴ Discount is given for bulk purchases

7) Competitor Analysis

The noni juice market is dominated by American-based company Tahitian Noni International which has extensive production and distribution capabilities across the world. In total, there are an estimated 250 companies globally that produce noni products, with nearly all sourcing their noni fruit from Asia Pacific regions such as French Polynesia, Hawaii or Cook Islands or Indonesia (Associated Press Newswires). Below is a profile of the major organisations involved in noni production, marketing and research –

7.1 Tahitian Noni International (formerly Morinda Inc.)

The leading market player recorded sales of over US\$500 million in 2004. Tahitian Noni sources all its Noni fruit from French Polynesia, where the company has recently opened a new Noni manufacturing and processing plant. In addition, the company has manufacturing sites in the U.S., Japan and China.

Tahitian Noni International has experienced continual growth since its establishment in the mid 1990s and currently has 1.3 million distributors in over 70 countries. Recently, the company has opened a line of “noni cafes” in Asia to showcase its product lines.

Key Personnel

Chairman and CEO, Kerry O. Asay
Vice President, Kim S. Asay
Global Sales and Service, Ethan Barborka
Research and Development, Jarakae Jensen
Human Resources, Craig Smith

Location

333 W. River Park Dr.
Provo, UT 84604-5787
Provo, United States of America

7.2 Pacific Island Noni Association (PINA)

PINA is a non profit organization that combines and supports the interests of noni fruit processors in the Pacific Region. It was formed after the realisation that Pacific Noni Processors needed to co-operate to be able to compete on the world stage. Thus, the association represents the members and their products to third parties, other organizations and buyers of noni products.

As a sign of its success, the members of PINA recently received European marketing approval from UK authorities after demonstrating that their products were equivalent to those sold by Tahitian Noni International. See Appendix 1 for a list of PINA’s members (NutraIngredients and PINA).

7.3 Kamauoha Foundation

To accelerate the development of the Hawaiian noni industry, the Kamauoha Foundation, a non-profit organisation aiming to foster and encourage agricultural, resource economics and community-based development, has established a noni farm and fruit processing facility. The farm covers 87 acres and the plant is capable of producing 2,000 litres of juice per day. As a result from its progress the Foundation has recently developed its own brand of noni juice labelled “North Shore Noni” (Associated Press Newswires and Kamauoha Foundation).

Other Hawaiian noni brands include Tru Noni and Hawaiian Noni Blessings.

7.4 Sari Noni

Indonesian (Sari) Noni is different in comparison than Tahitian and Hawaiian Noni as it undergoes an “Ancient Java Fermentation” process. In addition, it is slightly cheaper. In Indonesia, it is sold under the “Sari Noni” and “JavaNony” brands.

7.5 Places performing research into Noni

University of Hawaii	Dr. Scot C Nelson Associate Specialist (Plant Physiology) Phone no: (808) 981-5207 Email: snelson@hawaii.edu
University of Illinois	Dr. M Y Wang College of Medicine Department of Pathology
Keio University	Dr. T Hiramatsu Department of Applied Chemistry Faculty of Science and Technology
John Hopkins University	Dr. Paul Taladay John Hopkins Medical Institute
Southern Cross University (Lismore NSW)	Dr. Lesley Stevenson Manager, Natural Products Centre for Phytochemistry Phone no: (02) 6622 3211 Email: lstevens@scu.edu.au

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Dominion Post – www.dominionpost.com

European Report

Food Week – www.foodweek.com.au

Hoovers Inc – www.hoovers.com

Food Industry Week (NZ)

The Japan Times – www.japantimes.co.jp

Kamauoha Foundation – kamauoha.bravejournal.com

Kyodo News – www.kyodonews.com

M2 Presswire – www.m2.com

The Nation (Thailand) - www.nationmultimedia.com

New Zealand Press Association - www.nzpa-online.co.nz

The Northern Times – www.questnews.com.au

Nutraceuticals International

NutraIngredients – www.nutraingredients.com

Pacific Island Noni Association (PINA) – www.pina.ws

PACNEWS – Pacific News Agency Service – www.pacnews.org

PR Newswire - www.prnewswire.com

Samoa Observer – www.samoaoberver.ws

Sari Noni - www.sarinoni.com

Sunday Times (Perth) - www.sundaytimes.news.com.au

Sunday Mail - www.thesundaymail.news.com.au