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Assessing the Potential for a Gac (*Cochinchin* gourd) Industry in Australia



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Assessing the Potential for a Gac (*Cochinchin* gourd) Industry in Australia

by Sophie Parks, Minh Nguyen, David Gale and Carly Murray

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Researcher Contact Details

Name: Dr Sophie Parks
NSW Department of Primary Industries

Email: sophie.parks@dpi.nsw.gov.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600

PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au.
Web: <http://www.rirdc.gov.au>

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Foreword

Gac (*Momordica cochinchinensis* Spreng.) is a nutritious tropical fruit with high concentrations of carotenoids (antioxidants) compared with other well known fruits and vegetables. It is mildly flavoured and has applications as a fresh product and the potential for processing into nutrient supplements and/or orange-yellow natural colourants. Gac may be suitable as a field crop in tropical and subtropical Australia, or as a greenhouse and summer crop in more temperate areas. However, little information is available on its cultivation and production requirements or on its potential marketability in Australia. This project aimed to provide growers with preliminary information on crop cultivation and potential markets for gac fruits.

As part of this project, several fruit producing crops were demonstrated in the field and in the greenhouse, and experiments showed that seedlings and cuttings were cultivated relatively easily in greenhouse conditions. Its high antioxidant value has given gac a 'super fruit' reputation and there is already consumer demand for gac with packaged products imported from Vietnam. These products range from frozen or powdered gac, to health drinks containing gac. In addition to its use as a fresh fruit, other potential markets include the cosmetics industry (skin care products) and food manufacturers wanting to fortify foods with antioxidants or utilise the natural colouring found in gac.

This study indicates the opportunity for a niche gac industry in Australia which has the ability to focus on quality products. Its close relative bitter melon, an Asian vegetable, could provide a similar industry model for production of fresh gac fruits. To proceed in establishing an industry it will be important to better understand the factors that influence yield and the quality of fruits, conduct on-farm and processor trials, and to provide a forum for potential stakeholders where linkages can be promoted and to map a path for industry development.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our New and Developing Plant Industries R & D program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

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Craig Burns
Managing Director
Rural Industries Research and Development Corporation

Team members

Project leaders: Dr Sophie Parks
Research Horticulturist, NSW Department of Primary Industries

Conjoint Associate Professor Minh Nguyen
University of Newcastle

Other key personnel:

Mrs Carly Murray
Technical Officer, NSW Department of Primary Industries

Mr Basem Al-Khawaldeh
Technical Officer, NSW Department of Primary Industries

Mrs Michelle Smith
Education Officer, NSW Department of Primary Industries

Dr Wei Liang
Senior Technical Officer, NSW Department of Primary Industries

Mr David Gale
Graduate Officer, NSW Department of Primary Industries

Mrs Lorraine Spohr
Biometrician, NSW Department of Primary Industries

Mr Joshua Jarvis
Technical Officer, NSW Department of Primary Industries

Mrs Tran Thi Xuan
PhD Candidate, University of Newcastle

About the Authors

Dr Sophie Parks is a Research Horticulturist at the New South Wales Department of Primary Industries and has more than 17 years experience in the study of the cultivation of new and traditional crops. She is a Conjoint Senior Lecturer at the University of Newcastle.

Associate Professor Minh Nguyen is a Life Fellow of the Australian Institute of Food Science and Technology with over 40 years experience in food manufacturing, teaching and research. He is a Conjoint Associate Professor at the University of Newcastle and an Adjunct Associate Professor at the University of Western Sydney.

Mrs Carly Murray is a Technical Officer at the New South Wales Department of Primary Industries and has more than 10 years experience in horticultural production.

Mr David Gale completed a graduate officer appointment with New South Wales Department of Primary Industries in January 2013.

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Executive Summary

What the report is about

Gac (*Momordica cochinchinensis* Spreng.) could be a horticultural crop in Australia. It has high concentrations of carotenoids (antioxidants) compared with other well known fruits and vegetables, and has applications as a fresh product and the potential for being processed into nutrient supplements and/or orange-yellow natural colourants (Figure 1). Its mild flavour gives it great potential for incorporation into a wide range of food products. This report outlines the preliminary research conducted on growing and producing the crop which could be used as an introductory guide for growers wanting to set up their own trial, once planting material becomes more available. The current and potential markets for the fruits and processed fruit products highlight how a gac industry could develop in Australia based on the sale of fresh fruits and freeze-dried powders made from the fruits.

Who is the report targeted at?

This report is relevant to those who will be part of the developing gac industry. This includes farmers interested in growing the new crop and companies interested in processing the fruits and utilising the processed products.

Where are the relevant industries located in Australia?

Currently, in Australia, there are no commercial growers of gac. Location of this industry would be similar to that of bitter melon growing in tropical and subtropical areas as a winter crop (Northern Territory, Northern Western Australia, Northern NSW and Queensland) and as a summer and greenhouse crop in more temperate areas. During the project, a small field crop was produced in Darwin and two greenhouse crops were produced in Gosford, on the Central Coast of NSW.

Background

The gac species is endemic to parts of south-east Asia, Malesia, India and even the Cape York Peninsula of Australia and the fruit is traditionally used in a sticky rice dish from Vietnam called xoi gac. It is normally cooked but it could also be eaten fresh. Compared with other fruits and vegetables, the gac fruit is extremely rich in carotenoids (antioxidants), namely lycopene (at five times the concentration of that found in tomatoes), beta-carotene (at eight times the concentration of that found in carrots) and lutein. Carotenoids are used world-wide by the health and food industries and are currently sourced from tomatoes (lycopene and beta-carotene) and marigolds (lutein). In Australia, gac could be grown as a new Asian vegetable and as an alternative source of carotenoids. Australian research has already indicated that the aril of this fruit can be processed by freeze-drying it into a high quality powder that retains its colour and nutritional qualities for over one year. The mild taste of gac allows it to be widely incorporated into processed products.

Male and female plants are required for production since the species is dioecious. Plant gender cannot be identified from seed and can only be established on flowering. Female flowers need to be hand pollinated to ensure fruits of maximum size. Although the commercial production of gac occurs in Vietnam and Thailand on a small scale, little information is available on its yield potential or on the production factors that influence yield and fruit quality.

Aims/objectives

This study aimed to:

1. Determine the suitability of gac as a field and greenhouse horticultural crop.
2. Estimate the costs of fruit production under several production scenarios (greenhouse and field), and source some potential costs associated with freeze-drying the fruit aril.
3. Describe current and potential markets for fresh gac fruits and for processed products made from the fruits.

Methods used

The evaluation of gac as a horticultural crop was examined using greenhouse experiments. Several growers in different locations were also supplied with seeds or plants to trial as a field crop.

Estimates of the costs of fruit production under several production scenarios were modelled on the cost estimates previously determined for cucumber crops. Some costs associated with fruit processing were based on freeze-drying gac aril into a powder.

Current and potential markets for fresh gac fruits and for processed products made from the fruits were described based on information about existing gac products available overseas and from interviews and correspondence with potential users of gac (health consultants, Vietnamese restaurants, food manufacturers, cosmetics industry). We also reviewed the current research being conducted in Australia to provide an indication of the potential for other gac products and industry development.

Results/key findings

This project has demonstrated the feasibility of gac production in Australia as a greenhouse and field crop. The successful propagation of plants from cuttings also shows that nursery production has the potential to supply the industry with identified male and female plants. Current Australian research into the genetics of gac will be helpful in developing new varieties with desirable agronomic characteristics.

Estimating potential gross margins suggests that gac production could be profitable in field and greenhouse systems in Australia based on costs of about \$5-6 per kg and a fresh fruit sale price of \$8 per kg. This estimate of production cost is higher than those reported for other vine crops and it is not competitive with overseas prices for the frozen aril market. Despite this, it is expected that improvements in yield are likely through research that focuses on factors that determine fruit number and weight, and aril development. It is hoped that a system for pollination can also be developed to reduce the time it takes to hand-pollinate flowers. These developments would reduce costs and increase profitability of the production system.

The gac industry in Australia could be based on fresh fruits and on processed products. The development of an industry for fresh fruits could capitalise on the current demand for Asian vegetables and demand for highly nutritious fruits or 'super fruits'. There are many opportunities for supplying high quality products made from gac including freeze-dried powders, in particular to meet the high demand for carotenoids which are antioxidants. Most parts of the gac fruit can be made into powders, and oil can also be extracted from the aril and from the seeds. The entire fruit is not being fully exploited in processing at present. Better utilisation of the fruit (skin, pulp and seeds) would increase profitability.

Implications for relevant stakeholders

Gac is a new horticultural crop with potential as fresh and processing industries. Farmers have the opportunity to supply gac as a fresh fruit for Asian cuisine or healthy eating or for processing to meet the increasing world-wide demand for carotenoids. An Australian processing industry could be based on freeze-dried components of gac providing the market with gac products of the highest quality.

Recommendations

Further research in Australia would facilitate the establishment of commercial gac production and a cutting edge processing industry. Recommended future projects could include the following:

1. conducting a forum to promote linkages among future stakeholders in the industry
2. developing science-based information on fruit production and processing of gac
3. establishing some production trials in cooperation with growers
4. establishing some trials using gac products in the food manufacturing industry
5. stimulating consumer interest in gac to develop demand.

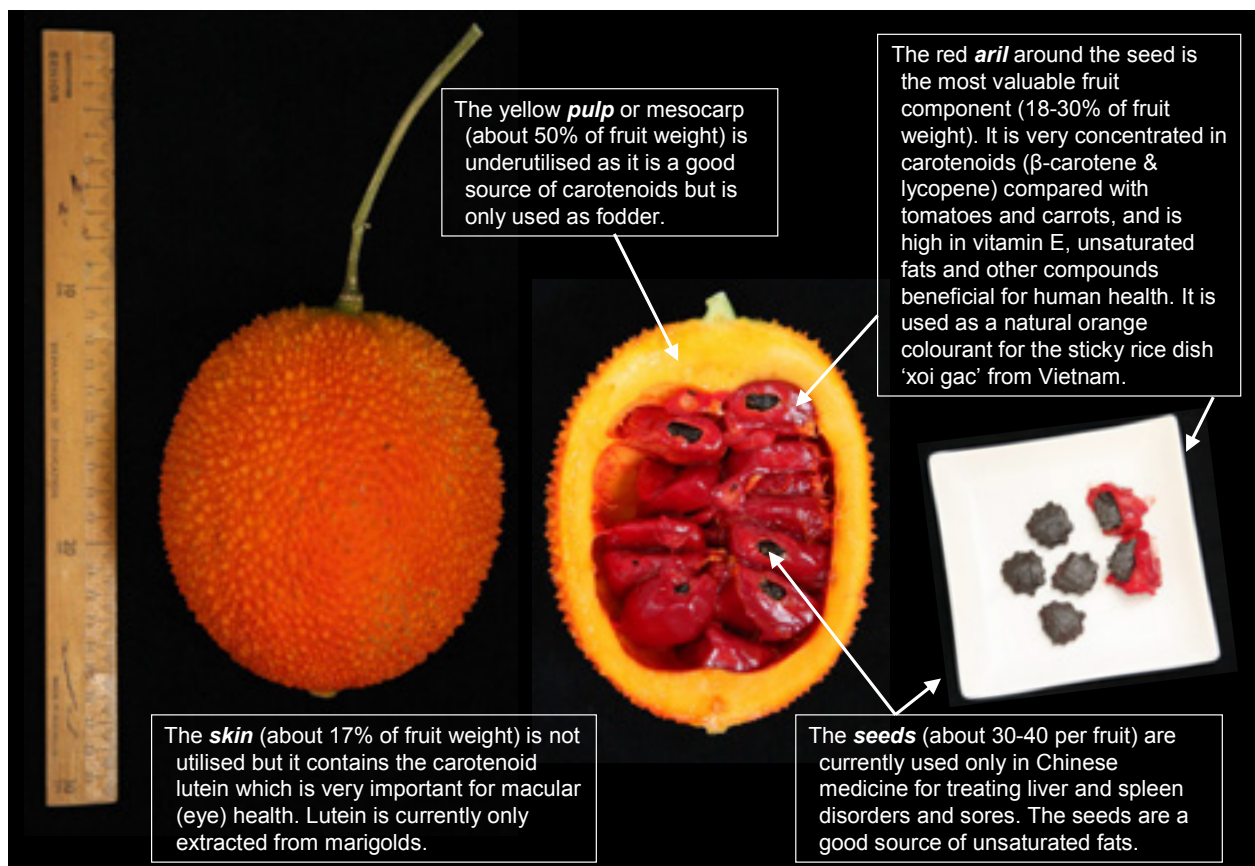


Figure 1. The components of a gac fruit and their properties.

Introduction

Gac or cochinchin gourd (*Momordica cochinchinensis* Spreng.) is a tropical perennial vine belonging to the Cucurbitaceae family. It is endemic to Vietnam and areas of South East Asia, and has even been discovered at the tip of Cape York Peninsula in northern Queensland. The aril, or flesh surrounding the seeds, is very concentrated in carotenoids, including lycopene and beta-carotene which are natural antioxidants with the potential to treat and prevent cancer and vitamin A deficiency. Another carotenoid, lutein, important for eye health, is present in the fruit skin. Gac fruit also contains a high concentration of vitamin E protecting the natural polyunsaturated oils in the fruit from becoming oxidised.

In Vietnam, this fruit is grown as a household vegetable and is used as a natural colorant in glutinous rice for breakfast and as a traditional meal for special occasions such as weddings and for the lunar new year. It has a very mild flavour which makes it ideal to be incorporated into a range of foods. Research by the project collaborator Assoc. Prof. Minh Nguyen has shown that this fruit can be processed into a freeze-dried powder that retains its orange colour and nutritional qualities for over one year, highlighting the potential for its use in the food industry as a natural colourant and for nutrition supplementation.

Currently, gac is only grown as a commercial crop on a limited scale in Vietnam and Thailand. The species is dioecious, having male and female plants, and hand pollination is required to increase fruit set, so often production is low. Being a tropical plant, this heat-tolerant crop can be grown in the field in tropical regions but it could also be developed as a summer and greenhouse crop for temperate regions of Australia. Little information is currently available on the cultivation requirements of gac or on how to fully utilise the components of the fruit. Research is needed to address these issues since there is great potential for a range of gac products to be developed for the food, health and cosmetic industries.

Objectives

This project aimed to identify the potential for a gac industry in Australia. The objectives were:

1. To conduct research trials with gac plants to develop information on its cultivation requirements and to identify areas for future research relating to the agronomy of the crop
2. To describe existing and potential markets for fresh gac fruits and gac fruit products
3. To provide estimates of the costs of crop production in the greenhouse and in the field, and costs of processing of gac into refined products.

Commercial possibilities

SWOT analysis for the gac industry

The potential for the development of a gac industry is summarised in Table 1.

Table 1. SWOT analysis for the development of an Australian gac fruit industry.

<p>Strengths</p> <ul style="list-style-type: none"> • The fruit is attractive in appearance and has a high nutritional value (antioxidants) • The variant in Australia is 'red gac', the most nutritious and highly valued type • There is an established range of uses and markets overseas for fresh fruits and processed aril (flesh around seed) as frozen, oil and powdered products • Gac has a mild flavour and is a natural colourant (yellow-orange), suitable for using in a range of foods and processed products • Currently, there is a strong research effort in Australia into genetics, crop production and processing of gac • There is an established value chain for a crop with a number of similarities (bitter melon) to use as a model • The crop is perennial with establishment costs only required approximately every 5-7 years • On-farm field trials and greenhouse research trials demonstrate the viability of gac production in Australia 	<p>Weaknesses</p> <ul style="list-style-type: none"> • Poor utilisation of all the fruit components. Currently, only a small proportion of the fruit being the aril (flesh around the seed), is of high value, the rest is used as animal fodder. • More research is required as little information is available to estimate market potential, production potential and postharvest requirements of gac • Limited awareness of gac among farmers, consumers and other potential users • Gac is a new and unfamiliar crop in Australia • Potential for unrealistic expectations from first-time growers • No industry partners have been identified
<p>Opportunities</p> <ul style="list-style-type: none"> • Interest already registered in gac (farmers, Asian restaurants, health consultants, small scale cosmetics manufacturing, food manufacturing), reflects a wide range of potential value-added applications for the fruit in Australia • Increasing international reputation for gac as a 'super fruit' • Organic production • Development of new processed products from fruit parts normally used for animal feed (eg extraction of lutein for eye health supplements) • Development of new varieties (eg sweet gac) • Development of higher quality products than currently available • Development of a new Asian vegetable/fruit product in Australia • Potential to rapidly establish a niche market in fresh fruit for migrant Australians who are familiar with gac (Vietnam, Thailand, India origin) • Alternative to other horticultural crops • Ability for production in tropical (as a field crop) and temperate areas (as a greenhouse and summer field crop) provides counter-season markets and climate change resistance • Potential as an indigenous food product since the plant is endemic to Cape York Peninsula 	<p>Threats</p> <ul style="list-style-type: none"> • Potential for poor uptake by growers and consumers • Lower cost imports competing with Australian products (despite potential for high quality Australian products) • Potential for waning popularity of 'super fruits' amongst consumers • No funding for continuing R & D • Competition with other Asian fruit and vegetables • Development of the industry in other regions (Vietnam, India, Thailand) • Perception by growers that gac is a tropical fruit may limit industry expansion

Potential growing locations

The gac plant is closely related to the bitter melon plant (*Momordica charantia*) and field production would occur in similar locations. They are both vine crops and require a trellis for growth. In contrast to bitter melon, gac is a perennial vine and requires hand pollination of the flowers for fruit production. Gac is found growing naturally in tropical and subtropical climates and in Australia would be a winter field crop in NT, Qld and northern WA, and a summer field crop in NSW and Victoria. Greenhouse production would extend the season in temperate areas. Already as part of this project, a gac crop has been produced outdoors in Darwin, the major bitter melon production area in Australia, and as an experimental greenhouse crop on the Central Coast of NSW. The authors are also aware of it being grown in Sydney and Melbourne but were unable to obtain any more information about these crops.

Overseas, commercial gac crops are located in Vietnam and Thailand but estimates are not available on the size of the industry.

Potential market position

Gac fits into the Asian vegetable category of the horticulture industry in Australia. A situation statement for the industry conducted by the National Horticultural Research Network (McDougall *et al.*, 2012) shows that this sector has grown faster compared with the traditional leafy vegetable categories with Asian gourds (including bitter melon) being the fastest growing in terms of value (88% between 2004 and 2009). Potentially, gac could have a fresh market comparable to bitter melon. In 2008-2009, the bitter melon sector had a gross value of \$1,325,000.

Gac has the potential to be a market competitor of bitter melon as it has a similar health food status and would be available at the same time and in similar locations. Gac fruits may also compete with, or even complement, the super fruits market in Australia. *Super fruits* is a marketing term to describe fruits that consumers perceive as offering more than just basic nutrition and include pomegranate and mangosteen amongst others.

Current and potential markets for gac fruit

Gac fruits are rich in nutrients such as carotenoids especially beta-carotene, lycopene and lutein, fatty acids, vitamin E, polyphenol compounds and flavonoids (Kha *et al.*, 2013). The levels of some components of freeze-dried powder made from gac aril are listed in Table 2. Freeze-dried gac aril was generally recognised as safe (GRAS) for the purposes of being used as a food additive in the USA in 2010 (Heldebrant, 2010). The freeze-dried gac powder is generally recognised as safe when 20 mg of gac powder is used per kg of beverages, dietary supplements and functional foods or when 10 mg of gac powder is used per kg of nutrition bars. There are many applications for gac with a number yet to be realised commercially.

Table 2. The levels of some components in freeze-dried powder made from gac aril.

Component	Content
Total fats	5-7 %
Total carbohydrates	84-89 %
Protein	<1 %
Moisture content	3-6 %
Vitamin A as retinol	<10 mg/100g
Vitamin C	80-100 mg/100g
β -carotene	0.9-1.8 g/100g
Lycopene	3-5 g/100g

Fresh fruits

As a fresh product, the uses for gac are predominantly in Asian cuisine, particularly Vietnamese. It is used in the specialty rice dish, xoi gac (Figure 2). The recipe is described in Appendix 1. Although gac is usually cooked, it does not require cooking for consumption. To have wider appeal, gac could be promoted as a highly nutritious fruit. For example, tomatoes are promoted as having high levels of phytonutrients, including lycopene which may lower the risk of some cancers. The gac aril has natural levels of lycopene about five times the concentration of that found in tomatoes. Its natural orange colouring and mild flavour also lends itself to be used as a natural colouring in cooking, much like the way saffron and turmeric is used.

During the project, a gac fruit was sourced from an Asian grocer in Sydney on two occasions. The fruits were approximately 1.5 kg and were sold for \$10 per kg. Although rarity of the fruit probably contributed to the sale price, discussions with a Vietnamese restaurant owner confirmed that this was a reasonable price that she would be prepared to pay for fresh fruits.



Figure 2. The traditional Vietnamese dish xoi gac made with sticky rice and aril.

Market for frozen aril

Frozen aril is exported from Vietnam and Thailand (Figure 3) but the size of the market is unknown. A 200 gram pack containing aril and seeds was purchased at an Asian grocer in Sydney for \$3.50 ie \$17.50 per kg. The larger fresh fruits grown in the experiments supplied about 600 g of aril (plus seeds).



Figure 3. Example of a frozen aril product. Red jackfruit is another name given to gac.

Market for juices

Gac is available as an ingredient with other fruit products in several juices on the market produced overseas but available in Australia online (Figure 4). G3 juice is produced in the USA and currently retails online for about \$80 AUD for a 750 ml bottle. The aril for these juices is sourced from Vietnam and Thailand.



Figure 4. Example of juices on the market containing gac aril.

Processed fruits

Most parts of the gac fruit can be made into powders, and oil can also be extracted from the aril and from seeds. A processing scheme for gac of current and potential processes is shown in Figure 5. Current products containing processed gac include cooking powder, drinks, health supplements and cosmetics. Encapsulation is a process used in food manufacturing which could be used to further protect and stabilise the bioactive components of the gac aril. The bioactive is enveloped within a wall of carbohydrates, cellulose, gum, lipids or protein to protect the bioactive core. The benefit is a refined gac product that retains its quality characteristics for longer. Research on this topic is being conducted at the University of Newcastle. Currently it is mostly the aril that is commercially processed and made or incorporated into other products (juice, powder and oil). The remaining pulp and skin are sometimes powdered and incorporated into the aril powder. Otherwise, the pulp is used as animal fodder.

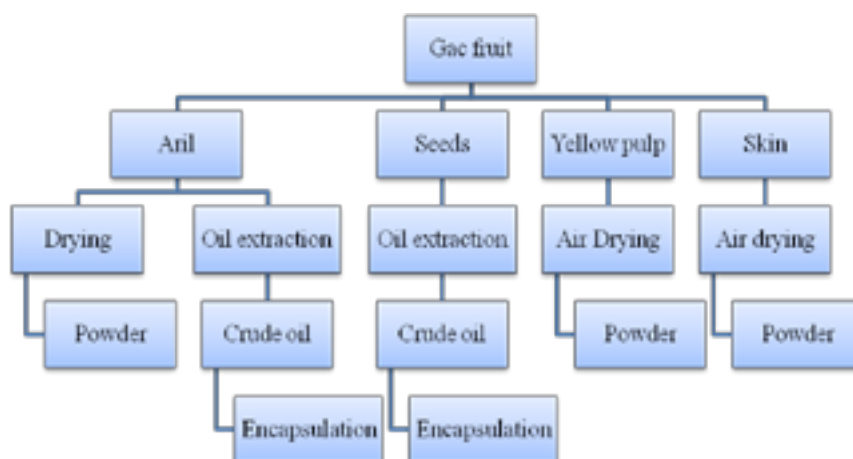


Figure 5. A potential processing scheme for gac fruit proposed by Kha et al., (2013). Currently the seeds are not processed, and the process of encapsulation for aril oil is under investigation.

Market for powder

Gac powders are produced for cooking (Figure 6) and there is also interest in producing powders as health supplements, for example as an ingredient in juices. The quality and price of gac powders varies considerably depending on the amount of aril in the sample and how it has been processed. Cheaper, poorer quality powders contain the pulp and skin of the fruit as well as the aril and have been air dried. Expensive, high quality powders contain only the aril and have been freeze-dried which gives a high quality powder. Recent observations conducted at the University of Newcastle suggests that the freeze-dried powder keeps for at least a year with good packaging under cool, dark and dry conditions (Kha, 2010; Kha *et al.*, 2010).



Figure 6. Example of gac cooking powder.

A look at the current prices for air-dried gac powder includes a product from China (JoryHerb Ltd) with the whole sale price of 1-12 USD per kg, depending on the amount of aril included. Another air-dried product from Vietnam (Oriental Agriculture Corp) has a whole sale price of 12-19 USD per kg.

The freeze-dried powders of super fruits generally command high prices on the marketplace compared with air dried ones. The current online sale price for a one pound container (454 g) of freeze-dried gac aril from Royal Tropics, USA, is 45 USD (99 USD per kg). Freeze-dried powders of other fruit products command higher prices (online). For example, 500 g of freeze-dried strawberry powder (Lio-Maduixa) is currently 107 USD (214 USD per kg) and 500g freeze-dried acai (palm fruit) powder (Riolife) is 117-125 USD (234-250 USD per kg).

Market for oil

Oils are extracted from gac by mechanically pressing the aril. Other extraction methods have been proposed but have not been investigated at this point. The oil is sold in capsules and marketed as a health supplement for the prevention of vitamin A deficiency, for skin health and for eye health (Figure 7). The current market price for whole gac oil is 100 USD per litre in capsule form (Vinaga at www.vitalea.org). When encapsulated, gac oil can be used in a wide variety of food products. This is new area of research being carried out at the University of Newcastle.



Figure 7. Example of gac oil capsules.

Qualities of gac products and their potential uses

Source of the carotenoids lycopene, beta-carotene and lutein

The gac aril has been identified as having a high concentration of both lycopene (about five times that of tomato) and beta-carotene (about eight times that of carrot) which are natural antioxidants with the potential to treat and prevent cancer and vitamin A deficiency. The pulp is also a good source of lycopene and beta-carotene. The beta-carotene present is responsible for the natural orange colouring of gac. The skin of the gac fruit is an excellent source of lutein which is important for eye health and potentially a supplement to alleviate problems associated with cataract and macular degeneration.

Currently, tomatoes are the main source for lycopene used as a health supplement for prostate health and as a natural orange-red colourant for foods. Tomatoes are also the main source for beta-carotene. However, one American-based company (Superfruit Nutrition, LLC) is supplying freeze dried aril powder and puree made from gac and they are marketing it as a high source of lycopene/beta-carotene and natural colourant. Marigold flower is currently the only commercial source of lutein for health supplements. Gac skin has the potential to be used as a lutein source.

The global market for carotenoids was worth almost 1.2 billion USD in 2010 with the potential to increase to 1.4 billion USD by 2018 (BCC Research, 2011). In 2010, the market for beta-carotene was worth 261 million USD, for lutein was worth 233 million USD and for lycopene was worth 66 million USD.

Source of fatty acids

There is potential to develop new products from gac using the fatty acid components of the aril and seeds. In particular, fatty acids from gac could be used as an alternative to saturated fats in the diet since they are rich in monounsaturated and polyunsaturated fats. The presence of these fats in the aril improves the absorption of carotenoids by the body. The seeds are also rich in fatty acids and other potentially useful compounds, and are used in Chinese medicine, but they are usually discarded.

Plant cultural details

Overview

Momordica cochinchinensis (Gac, cochinchin gourd, sweet gourd) belongs to the family Cucurbitaceae which includes cucumbers, squash, luffa and bitter melon. The plants grow on trellises with thick, dark green main stems, and laterals that grow to over 3 m long. The species is dioecious, having male and female plants, which can only be identified once they are flowering. The species is perennial and grows in tropical and temperate climates where in winter the plant dies back and reshoots from the plant base in spring. The production season of the plant could be extended using greenhouse technologies in temperate areas.

A greenhouse *Momordica cochinchinensis* (Gac) crop was grown at the Department of Primary Industries, Gosford Primary Industries Institute, NSW, Australia (151°19'E, 33°23'S) from May 2010 to June 2011, incorporating two experiments and is fully described by Parks *et al.*, (2013). The crop took approximately 44 weeks from seed germination to harvest of fruits.

Propagation

Several methods of gac propagation have been trialled during this project and by others. These methods of propagation include germination from seed, striking cuttings, grafting and multiplication from tubers.

Seed germination

In May 2010, 15 seeds were extracted from a single gac fruit, sown in trays of seed raising mix (2:1:1 pinebark: sand: peat moss), with seeds laid flat and sown approximately 10 cm apart, then covered with mix (Figure 8). These trays were placed in a propagation house with an average temperature of 25 °C and average relative humidity of 80 %. Following germination of all 15 seeds (21 days after sowing), seedlings were transplanted into 150 mm pots with potting mix (1:1 coir: perlite) and placed into a polyethylene covered greenhouse with climate control.

Seed germination was straight forward, was not affected by prolonged dormancy and did not require the deshelling of seeds. Seed dormancy of Gac has been described as a problem elsewhere (Joseph and Bharathi, 2008). Several growers who were provided with seed experienced trouble with germination. This was attributed to unusually cool and wet summer conditions. Recent experiments suggest that temperatures greater than 20 °C and less than 35 °C are most suitable for optimal germination.

One problem with seed-grown plants is that more male than female plants are produced. The exact ratio of male to female plants produced from the seeds of one fruit has not been identified. Taking cuttings from female plants or using the unwanted male plants as rootstock with female scions are two ways to boost the number of female plants. The ratio of 1 male to 10 female plants has been suggested as adequate to supply enough pollen for good fruit set.



Figure 8. Layout of 15 seeds sourced from one fruit used for the first crop.

Cuttings

In August 2011, cuttings were taken from the three female gac plants identified from Experiment 1. Cuttings were between 15 and 20 cm in length with a basal diameter of between 3 and 6 mm. On each cutting one leaf was retained and cut in half. The base of the cutting was cut diagonally with a scalpel to ensure a clean wound. Cuttings were dipped into one of two indole-3-butyric acid (IBA) hormone treatments, powder (3 g/kg) or gel (3 mL/L). The controls were not treated with hormone. Each of these three treatments was replicated 10 times in four types of growing media. The four growing media types were: 1) rock wool blocks moistened with water and placed in seedling trays, 2) distilled water in sterile tubes covered with parafilm, 3) potting mix (2:1:1 pinebark: sand: peat moss) moistened with water and placed in 125 cm³ pots, and 4) potting mix moistened with water and placed in 125 cm³ pots and sealed in plastic bags according to the closed media sachet technique (CMST) (Mythili and Thomas, 1999). The cuttings were placed in a propagation greenhouse and watered with overhead sprinklers. Relative humidity and temperature at the surface of pots were 80-100 % and 15-26 °C, respectively.

After six weeks, 50 healthy cuttings were removed from the media in which they were growing and placed into individual pots. They were placed in the greenhouse, under similar conditions as described for Experiment 1. Long term survival was assessed with flowering commencing 138 days following the start of the propagation experiment.

Cutting survival in the water and rock wool media types was consistently high over the 6 weeks for all three hormone treatments (Table 3). At week 6 there were no significant hormone treatment effects on cutting survival detected for the CMST, rock wool or water media types ($P>0.05$). For the potting mix media at week 6, the difference in survival between hormone powder and gel treatment was not significant ($P>0.05$). The 10 cuttings in the potting mix without a hormone treatment did not survive (Table 2). This trial showed that propagation of cuttings is possible in several types of growing media and that a rooting hormone is not necessarily required to strike roots. Future work will focus on identifying moisture and temperature conditions for maximising strike rates in specific media.

Table 3. Proportion of cuttings surviving each week for each media type and hormone treatment (10 cuttings per treatment x media combination).

Week 6 data were analysed separately for each media type, with back-transformed approximate least significant differences as follows: Closed media sachet technique (CMST) =0.43, Potting Media=0.42, Rock wool=0.39, Water=0.39.

		Growing Media Treatment			
Hormone Treatment	Week	CMST	Potting Mix	Rock wool	Water
Gel	1	1	1	1	1
Gel	2	0.9	0.5	0.9	1
Gel	3	0.6	0.4	0.9	1
Gel	4	0.4	0.4	0.8	0.9
Gel	5	0.4	0.4	0.8	0.9
Gel	6	0.4	0.4	0.8	0.7
None	1	1	1	1	1
None	2	0.8	0.5	1	1
None	3	0.7	0.5	1	1
None	4	0.3	0.1	0.8	1
None	5	0.3	0.1	0.8	1
None	6	0.3	0	0.7	0.8
Powder	1	1	1	1	1
Powder	2	0.9	0.6	1	1
Powder	3	0.4	0.3	1	1
Powder	4	0.3	0.2	1	1
Powder	5	0.3	0.2	1	1
Powder	6	0.3	0.2	0.9	0.9

Grafting

Grafting is a challenging but useful technique that would enable the utilisation of unwanted male gac plants. One study reports on the use of grafting in gac production (Joseph *et al.*, 2011). The woody main stems of the unwanted male gac plants were cut at 1.5 m above ground level and these became the rootstock material. Tender scion sticks, 10-20 cm long with 3-5 nodes, and matching the girth of the rootstock, were taken from the growing tips of female plants and grafted onto the beheaded male plants. Leaf sprouts were observed after two weeks.

To achieve this, a vertical split of 2.5-3.5 cm is made at the top of the rootstock stem. An angled cut of 2.5-3.5 cm is then made on both the sides of the base of the scion so that it can be inserted into the split made on the rootstock. The tapered base of the scion is inserted into the split of the rootstock to ensure that the cambium meets. The join is fixed together by taping it with a polythene grafting strip.

The scion, including graft juncture, is then covered with a plastic bag to prevent wilting through transpiration. A few drops of water are sprinkled inside the bag before tying to maintain high humidity and to provide shade to avoid scorching. The graft union generally takes place within a week, with the polythene strap removed after two weeks, or when the graft juncture starts thickening. Given sufficient moisture, flowering can occur within 6 weeks (Joseph *et al.*, 2011). The study produced a mean of 25 fruit (350-700 g/ fruit) per grafted plant within 3 months of grafting compared with a

mean of 16 fruit from seedling-plants and 8 from rooted-cuttings. Since there has been limited research into the grafting of gac, this will be an area for further study by the project team.

Tubers

Gac can be grown from divided root tubers first planted into pots then transplanted. Propagation by this method was attempted as part of this project. However, plants available for this task were limited and no new plants were obtained from this method. This subject requires further research.

Soil or growing medium

Gac is typically grown in soil but this project also demonstrated its suitability for production in soilless media. Favoured soil types have not been described for gac. However, bitter melon, also a cucurbit, prefers a well drained soil with a pH between 6 and 6.5 (Traynor, 2005). For soilless growing, gac plants responded well to being grown in bags of coir (coconut fibre) and successfully reached maturity. Performance was not as good in another soilless potting mix based on composted pine bark which had a greater water holding capacity and reduced aeration compared with coir. This suggests that like bitter melon, gac prefers a well drained soil or growing medium.

Fertiliser and water

For Hydroponics

Gac was trialled with the approach used for a hydroponic cucumber crop. The hydroponic stock solution was made up into two 60L containers labelled A and B and filled with water (Table 4). In the greenhouse, the irrigation dosing system automatically takes up equivalent amounts of each stock solution to reach the desired electrical conductivity (EC) and pH in a 200 L barrel. For the seedling to flowering stage EC 1.2 dSm⁻¹ and pH 6-6.5 were used. From the flowering stage onwards an EC 2.4 dSm⁻¹ and pH 6-6.5 was used. Solution formulae for other crops may work as well. For a good introduction to commercial hydroponics see Mason (2005).

Table 4. Stock solutions made for the hydroponic gac crop, based on a formula used for cucumbers.

Part A To 60 litres of water add:	
Calcium Nitrate	4500g
Iron EDTA (Fe EDTA)	180g
Part B To 60 litres of water add:	
Potassium Nitrate	6000g
Mono-potassium Phosphate (MPK)	1200g
Magnesium Sulphate	3600g
Manganese Chelate	48g
Zinc Chelate	15g
Boric Acid	15g
Copper Chelate	33g
Ammonium Molybdate	7.2g

Nutrient recommendations for field grown gac

The following recommendations from Traynor (2005) and Palada and Chang (2003) are based on field grown bitter melon *Momordica charantia*. Before planting out a crop, a standard soil test should be undertaken to determine the soil type and its nutrient status and pH. Once known, fertiliser programs can be adjusted accordingly.

Fertilisation can be tailored to the two specific growth stages: from planting (or seedling) to flowering, and from fruit initiation onwards. For the first growth stage, the required rate of NPK per hectare per week is as follows: 25 kg N, 5 kg P, 18 kg K. From fruiting, the rate is 12 kg N, 5 kg P, 18 kg K, and 5 kg Ca (Traynor, 2005).

Alternatively, supply an initial basal (organic) application per hectare of 28 kg N, 28 kg P₂O₅, 28 kg K₂O and a basal (inorganic) application of 36 kg N, 54 kg P₂O₅ and 36 kg K₂O. Once the plants have 6 true leaves the four side dressings of 30 kg N, 7.5 kg P₂O₅ and 15 kg K₂O are applied once at fortnightly intervals (Palada and Chang, 2003).

Compost and manure may be applied before planting. Both compost and manure applications are a good organic source of the major elements N, P and K reducing the quantities of chemical fertilisers required for the crop. They help to increase biological activity in the soil and can increase water holding capacity, reduced weed growth, reduced erosion and improve overall soil structure (Eghball and Barbarick, 2005).

Temperature

For the purposes of increasing gac production on a commercial scale, this study has demonstrated the value of greenhouse technology, particularly in temperate areas. Gac can be grown outdoors in temperate areas; however, it dies back during winter before reshooting in spring. Greenhouse technology which provides year-round control of the climate can be used to extend the season of this tropical crop in temperate zones. A further advantage of growing gac in a greenhouse environment is that the exclusion of soil and insects from the system reduces the need for some pesticides and the closed structure permits the use of biological controls. In this study, the greenhouse and hydroponic system, and practices used previously by the authors for bitter melon (*Momordica charantia*) (data not shown), permitted the establishment of a healthy Gac crop during winter in a temperate climate.

Trellising and plant training

Gac is a climbing vine crop so it needs to be trellised and trained to allow it to fully develop and produce fruit. Trellising also prevents fruit from growing on the ground and rotting since it is soft when ripe. When observed growing on farms in Vietnam, gac is usually established on formal and improvised trellises.

During this study plants were transplanted into coir grow bags 40 days after cuttings were taken, once true leaves and tendrils had established. Bags were placed 1 metre apart and plants were grown up a horizontal trellis with wires placed at 1 m, 1.8 m and 2.8 m above the ground. When the main stem reached the top wire, the growing point was removed and two main laterals were trained horizontally.

There are several options for supporting plants which can be used in greenhouses and the field; two options can be seen in the following Figures 9 and 10.



Figure 9. The trellis used for gac in the greenhouse study. Bags were 1 metre apart and horizontal wires were at 1m, 1.8 m and 2.8 m above the ground.



Figure 10. The A frame trellis used for a gac crop growing in Hanoi, Vietnam.

Pollination

Gac is a dioecious species with male and female flowers on separate plants. A picture of a male and female flower is shown in Figure 11. Hand pollination is required to obtain good fruit set in gac as pollination by insects is not as reliable (Maharana and Sahoo, 1995). The process of hand pollination will be a major activity for any gac crop.



Figure 11. Male flowers have larger petals and are light in colour. Female flowers have a darker yellow flower with 5 simple elliptical petals. The female flower has an inferior ovary.

In three successive crops grown by the research team, the male flowers appeared several weeks before the flowering of the female plants. At times, there were not enough male flowers for pollinating the female flowers. This asynchronous flowering presents a challenge in growing the crop. Research is now underway to determine the ideal storage conditions for pollen so that it remains viable for much longer than under natural conditions. Research suggests that under natural conditions pollen is only viable for 36 hours (Maharana and Sahoo, 1995). In the first experiment, fruit set was achieved and full fruits were grown using frozen pollen for pollinating three female flowers. The frozen pollen had been dried at room temperature (20°C) for approximately 2 days prior to freezing in a standard domestic freezer. This indicates that there is good potential for storing pollen. Other research will investigate spraying a suspension of pollen in water onto the stigma as described in the pollination of date palm (*Phoenix dactylifera* L.) (Awad, 2010).

Pollen from male flowers was used to hand-pollinate the female flowers by dabbing the stamen (male) on the stigma (female), by applying fresh pollen to the stigma using a paint brush, or by applying frozen pollen to the stigma using a paint brush. Petals were removed from the pollinated flower and a dated label attached to the nearest stem to avoid pollinating the same flower twice and to assist with data collection. After pollination, fruit development was monitored and a mesh bag was used to support the weight of the fruit on the vine. The process from pollination to harvest is shown pictorially in Figure 12.

The three female plants, obtained from the original 15 seeds, produced approximately 48 flowers. These could not be traced back to the individual female plants since the crop was well intertwined. Unfortunately, 15 of the flowers could not be pollinated as they were past anthesis (flower opening) when identified. Thirty three flowers were hand pollinated 30 with fresh pollen and three with frozen pollen. Nine flowers died while 24 flowers were successfully pollinated and produced a fruit, including the three that were pollinated with frozen pollen.



Day 0- pollination



Day 3- Pollination successful



Day 18



32 days- spike tips turn orange, net supports are used to support heavy developing fruit



Day 37



56 days - ½ orange



66 days- Harvest

Figure 12. Pictorial representation of the development of gac fruit from pollination through to full fruit development over a period of approximately 66 days. This fruit was the heaviest produced weighing 2162 grams.

Pests and diseases

Very little literature exists on the pests and diseases affecting gac. During the greenhouse experiments, pest and disease issues were not a major problem. Some minor pests encountered included: spider mites, thrips, fungus gnats, aphids scale and mealy bug. These were treated with biological control agents. On one occasion in summer, the field trial growing in Lismore, Northern NSW, was attacked by the red shoulder leaf beetle (*Monolepta australis*). This beetle stripped most of the leaves from the gac plants. This particular pest occurs in Northern NSW, Queensland and the Northern Territory. The plants were cut back and reshooted.

As gac production increases, new pest and disease problems will become apparent. Regardless of the pest or disease, the control options used must comply with regulations set by the Australian Pesticides and Veterinary Medicines Authority. Visit their website for more information.

Yield

The first experimental crop in this project, produced from seed, yielded approximately 8 fruits per plant. The 20 undamaged fresh fruit from the first experimental crop weighed between 517-2162 g (mean=1212, standard deviation=443). Three of these fruits were dried in the oven and their dry weight was recorded (data not shown) giving an approximate dry weight percentage of 11 % of the fresh fruit weight. In another study undertaken in India, 25 fruits were produced per grafted plant, although the fruit weight was limited to 350-700 g (Joseph *et al.*, 2011).

A decline in the individual weight of fruits was observed as the harvest progressed. The relationship between the fruit fresh weights and their flower pollination dates is shown in Figure 13. For reasons that cannot be explained, this trend was not apparent in the second crop produced.

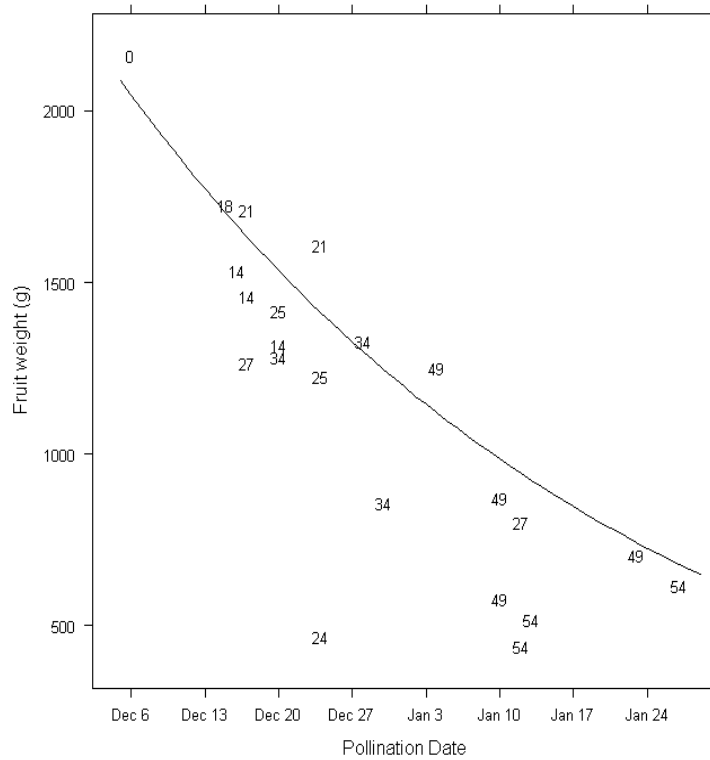


Figure 13. Response of individual fruit weight to flower pollination date showing raw data and fitted line. The value assigned to each datum point represents the time of harvest for that fruit, in days following the harvest of the first fruit. The fitted line is an exponential relation accounting for 71.0% of the variability in fruit weight [$y=380 + 1893*(0.9562^x)$].

Fruit quality increased with an increase in fruit fresh weight. Quality was evaluated in terms of the number of developed seeds and the proportion of the fruit weight that was aril. Smaller fruits (lower weights) had fewer seeds that were fully developed compared to larger fruits (higher weights) (Figure 14). Similarly, smaller fruits had relatively less aril than larger fruits (Figure 15).

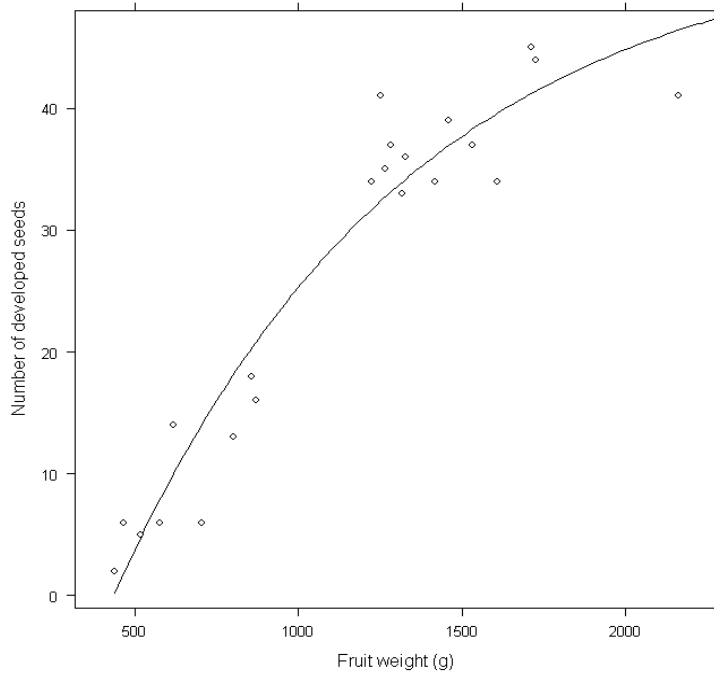


Figure 14. Response of the number of developed seeds to fruit weight showing raw data and fitted exponential relationship. The fitted line accounts for 91.5% of the variability in developed seed number $[y=54.47 - 88.29*(0.99893x)]$.

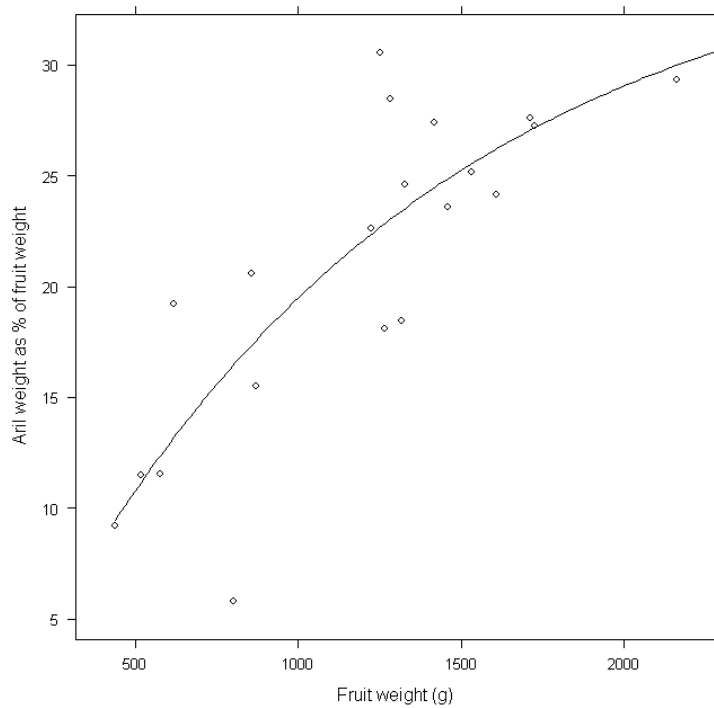


Figure 15. Response of aril weight, as a percentage of fruit weight, to fruit weight showing raw data and fitted exponential relationship. The fitted line accounts for 63.8% of the variability in aril weight as a percentage of fruit weight $[y=36.5 - 38.85*(0.999172x)]$.

Fruit weight appears to be important in determining the proportion of aril obtained from the fruit. The larger, heavier fruits contain proportionally more aril than smaller, lighter fruits. This has great significance since the valuable aril represents only a small part of the fruit and maximising this would be of economic importance. The mesocarp (pulp) of the harvested fruit accounts for between 52 and 75% of the total fruit by weight. The aril accounts for only 6-31% of total fruit weight. The aril component of gac has been reported elsewhere as 10, 18 and 24.6% of fruit weight (Ishida *et al.*, 2004; Nhung *et al.*, 2010; Kha, 2010) and the mesocarp as 49% of fruit weight (Kha, 2010), corroborating our findings. No other published study considers the impact of fruit size on the proportion of aril obtained.

Factors known to affect fruit size in other cucurbits could be investigated as a means to developing systems that promote larger fruit. Plant density is important, with wider plant spacing leading to increased fruit size for vertically-trained watermelon (*Citrullus lanatus*) and cantaloupe (*Cucumis melo*) (Watanabe *et al.*, 2003; Ban *et al.*, 2006). Also, fruit production and the distribution of biomass to developing fruits in cantaloupe and squash (*Cucurbita pepo*) are affected by flower production and fruit removal (El-Keblawy and Lovett-Doust, 1996a; El-Keblawy and Lovett-Doust, 1996b). This has implications for the practical management of plants through pruning and training practices and is an area under investigation for gac.

Variety development

Momordica cochinchinensis is a highly variable plant species (Wilde and Duyfjes, 2002) which provides opportunities to develop productive cultivars with good quality characteristics, including the concentration of bioactive compounds. Currently, at RMIT University in Melbourne, work on gac genetics sourced from south-east Asia is being undertaken by Dr Tien Huynh. This research could lead to better selection for favourable traits, such as high lycopene or fruit weight. It could also lead to the development of a test to determine if germinated seeds are male or female, speeding up the process of selecting material propagated by this method.

Economic analyses

The aim of the following economic analyses was to compare the independent economic viability of three greenhouse based and one field based gac production systems. This information will give growers with existing greenhouses or available land for outdoor production, an indication of the costs associated with gac production. A further aim was to estimate the costs associated with freeze-drying gac aril. Air-dried gac aril is a current product on the market but freeze-dried aril, which best preserves the nutritional qualities of the product, is in limited supply. An Australian industry could focus on the freeze-dried gac market.

Cost benefit analyses of greenhouse and field production

Scenario description

Economic analyses were carried out on greenhouse and outdoor plantings of gac using VegTool 1.1 (Kelly *et al.*, 2011). Information on gac production is limited. Results from the experimental work were used where possible but this cost benefit analysis was largely based on greenhouse cucumber production with the assumption that a greenhouse gac crop will have similar requirements. Therefore, the results from the cost benefit analysis should be interpreted with caution. Other assumptions underlying the analysis are detailed in Table 5.

Definitions

- Low technology = Minimum investment, tunnel style construction. No active heating or cooling, passive cooling in summer achieved via manually opened vents and ends of the tunnel house. Some air circulation fans may be used.
- Medium technology = Moderate investment, single layer polyethylene greenhouse. Use of hydronic heating when required, passive cooling in winter by manually opened vents, and fan cooling in summer.
- High technology = Large investment, double layer polyethylene greenhouse. Use of hydronic heating, and cooling with fans, fogging and evaporative pads when required. Climate control is fully automated.
- Outdoor = wooden/steel posts with steel cable to support the gac vine.

Scenario assumptions

Table 5. Assumptions made for the economic analysis of gac production.

Item	Assumption
Cropping period	One season of approximately 42 weeks
Production area	500 m ² (based on previous experimental area)
Planting density	0.75 plants per m ² (based on previous trial experience)
Yield reduction relative to decrease in production	Estimated yield was reduced by 10% for each step down in level of greenhouse technology used. (i.e. 19% reduction from high → low technology) (Parks, Orr, & Al-Khawaldeh, 2011). A further yield reduction of 10%, from the level of the low technology scenario to the outdoor system was applied.
Seeds & Plants	Includes the cost of striking cuttings using hormone powder and planting in cocopeat bags.
Biological control agents	Have been included in “Chemicals”
Cost of electricity in the low technology system	An estimate of the cost of operating pumps and air-circulation fans for the growing season.
Other Operating Costs	This is a nominal figure which represents the cost of maintenance of pumps, fans and other equipment, as well as trellising and hydroponic channel repairs.
Geographic location	Temperate areas - south of 23.4 °S
Source material	Cuttings were used with hormone powder and planted in cocopeat bags.
Harvesting	Fruit was hand picked using ladders
Nutrition	Plants fertigated using drippers
Price	Up to \$10 per kg (wholesale), with a regular expected price of around \$8 per kg, based on the sale price of fruit in one grocery store and the price which potential customers have said they would be willing to pay.
Yield	A conservative estimate based on the mean of two trials undertaken in this project - 6 fruit per plant at 1.0 kg per fruit.
Processing and marketing	Expected to be the same for each of the 5 scenarios
Outdoor system	Utilising a hydroponic fertigation system, but without the covering structure, making it akin to a low technology system, but with a reduced electricity bill and a reduction in yield due to climactic impacts.
Pollination	All scenarios require pollination by hand to obtain good fruit set (Maharana and Sahoo, 1995).
Structure	These scenarios do not include the cost of building a greenhouse.
Freight and packaging	These costs are not included in these analyses

Relevant calculations

Planting density x Area = Number of plants

$$0.75 \text{ plants} / \text{m}^2 \times 500 \text{m}^2 = 375 \text{ plants}$$

Number of plants x Average fruit per plant = Estimated total fruit number

$$375 \text{ plants} \times 6 \text{ fruit} / \text{plant} = 2250 \text{ fruit}$$

Total fruit number x Average fruit weight = Estimated total fruit weight

$$2250 \text{ fruit} \times 1 \text{kg} / \text{fruit} = 2250 \text{kg}$$

Gross margin results and discussion

A detailed summary of the cost benefit analysis can be referred to in Appendix 2. The cost estimate for producing gac fruits was approximately \$5-6 per kg across all systems and \$2.60 per kg for the low technology system with a double yield. In Table 6, the cost benefit analysis shows that the largest gross margin and highest percent return on investment was achieved in the high technology system (excluding the low technology double yield scenario). A higher yield would be attained in the high technology system relative to the costs of production. However, this does not include the high cost of building a high technology greenhouse. The low technology system, at the current yield, was the second most profitable scenario. This can be attributed to the reduction in operating expenses relative to yield. The cost of operating the medium technology greenhouse with its single skin covering is higher than the high technology with its insulating double skin.

The low technology (double yield) scenario in Table 6 is based on the profit which could be achieved if yield was doubled. This is possible through a better understanding of the agronomic characteristics of the gac crop and its requirements for optimal yield and fruit quality. Varietal development could also contribute to improved yields. Anecdotal evidence of gac production in Vietnam suggests that the number of fruit produced per plant far exceeds six, the number of marketable fruits obtained in the experiments.

Table 6. Comparison of gross margins for producing gac under four production scenarios.
(no formal statistical analysis undertaken).

System	Gross Margin	Return on Variable Input Costs	
		Gross margin Variable costs	% Return on investment
Low technology	\$5 029	<u>5,029.02</u> 9,370.98	53.67
Medium technology	\$3 701	<u>3701.02</u> 12,498.98	29.61
High technology	\$6 677	<u>6,677.02</u> 11,327.98	58.94
Outdoor	\$3 189	<u>3,189.02</u> 9,970.98	31.98
Low technology (double yield)	\$19 429	<u>19,429.02</u> 9,370.98	207.33

Protected cropping offers the advantage of extending the growing season for gac grown in temperate zones, and easier management of pests and diseases. Although this economic analysis of low greenhouse technology appears favourable compared with production outdoors, it does come at a cost, not often measured in economic terms. For example, typically a low technology greenhouse experiences high internal temperatures (> 35 °C) at mild external temperatures of about 20 °C (Parks *et al.*, 2011). At these temperatures worker comfort and productivity is low and above 36 °C it is recommended that work should cease (Public Service Association of NSW, 2003). Additionally, high temperatures reduce the efficacy of biological control measures which means a grower is more likely

to rely on chemical pesticides. High technology greenhouse production is a larger investment but reduces the risk of lower worker productivity, and the risk of crop failure due to extreme temperatures or severe pest and disease outbreaks.

Capital outlay for freeze-dryers

Freeze-drying is the preferred method of preservation of gac aril as it maintains the integrity of the product better than other drying methods. Table 7 provides information on a range of Cuddon (New Zealand) freeze-dryers suitable for this purpose. The prices supplied by the manufacturer were current at the time of writing.

Table 7. An example of some commercial freeze-dryers produced by Cuddon.

The prices include delivery, installation and commissioning, operating and maintenance manuals and training, 2 sets of product trays, and 12 months warranty.

Item	Capacity	Design Specification	Max kW Power requirement	Price USD Each
CUDDON FD18	18 kg moisture removal	-40°C Ice condenser temp & -20°/+70°C Shelf temp	4	138,184
CUDDON FD80	80 kg moisture removal	-40°C Ice condenser temp & -20°/+70°C Shelf temp	12	197,644
CUDDON FD1000	1000 kg moisture removal	-40°C Ice condenser temp & -20°/+70°C Shelf temp	137	1,129,632

Per unit costs of freeze-drying aril will depend on the capacity of the freeze-dryer purchased, the cost of aril, and all other costs associated with powder production. Research will be needed to determine the optimal loading of fresh aril, in kg per m², on the drying trays. These are likely to be similar to the capacity of the dryer. For example, the FD18 would take approximately 18 kg of fresh aril in one load. It is expected that a load would take between 22-24 hours to dry the aril, in all dryer models. To obtain 1 tonne of freeze-dried aril will require 5 tonnes of fresh aril at a moisture level of 80%. To dry this amount of aril would take 278 loads in the FD18 but only 5 loads in the FD1000.

The establishment of a small industry in Australia, based on freeze-drying processing, is a promising development for Australian horticulture because it provides an opportunity for value-adding to fruit and vegetable products. In northern Tasmania, Ranicar Pacific is a food processing company currently producing freeze-dried vegetables for the food supplement market in Asia and the USA, through a Victorian company called Super Sprout (Grant, 2012). They estimate that they will process between 100 and 150 tonnes of fresh vegetables in one year using a recently purchased \$200,000 freeze dryer made in China, running it 24 hours per day, 7 days per week. They will process 50 tonnes of fresh beetroot alone, producing 5 tonnes of freeze-dried beetroot powder and predict that they will be in a position to purchase another freeze dryer in 12 months time. The company representative John Ranicar considers this fruit and vegetable freeze-drying industry as a growth industry in Australia. Given this trend, it is possible that gac growers will be in a position to access this developing industry for the immediate production of freeze-dried gac products.

Implications

This work highlights the opportunities for a gac industry in Australia and demonstrates the feasibility of production in field and greenhouse systems in a range of Australian locations. Growers would be able to supply fruits for the Asian vegetable sector and could also market gac as a super fruit. Further, growers could supply fruits for processing to meet the increasing world demand for carotenoids. An Australian processing industry could be based on freeze-dried components of gac providing the market with gac products of the highest quality.

The establishment and development of the industry will need support. A proposal for the development of the industry is shown in Figure 16. A website is also proposed that could provide current information about gac and the industry as it emerges, as described in Appendix 3.

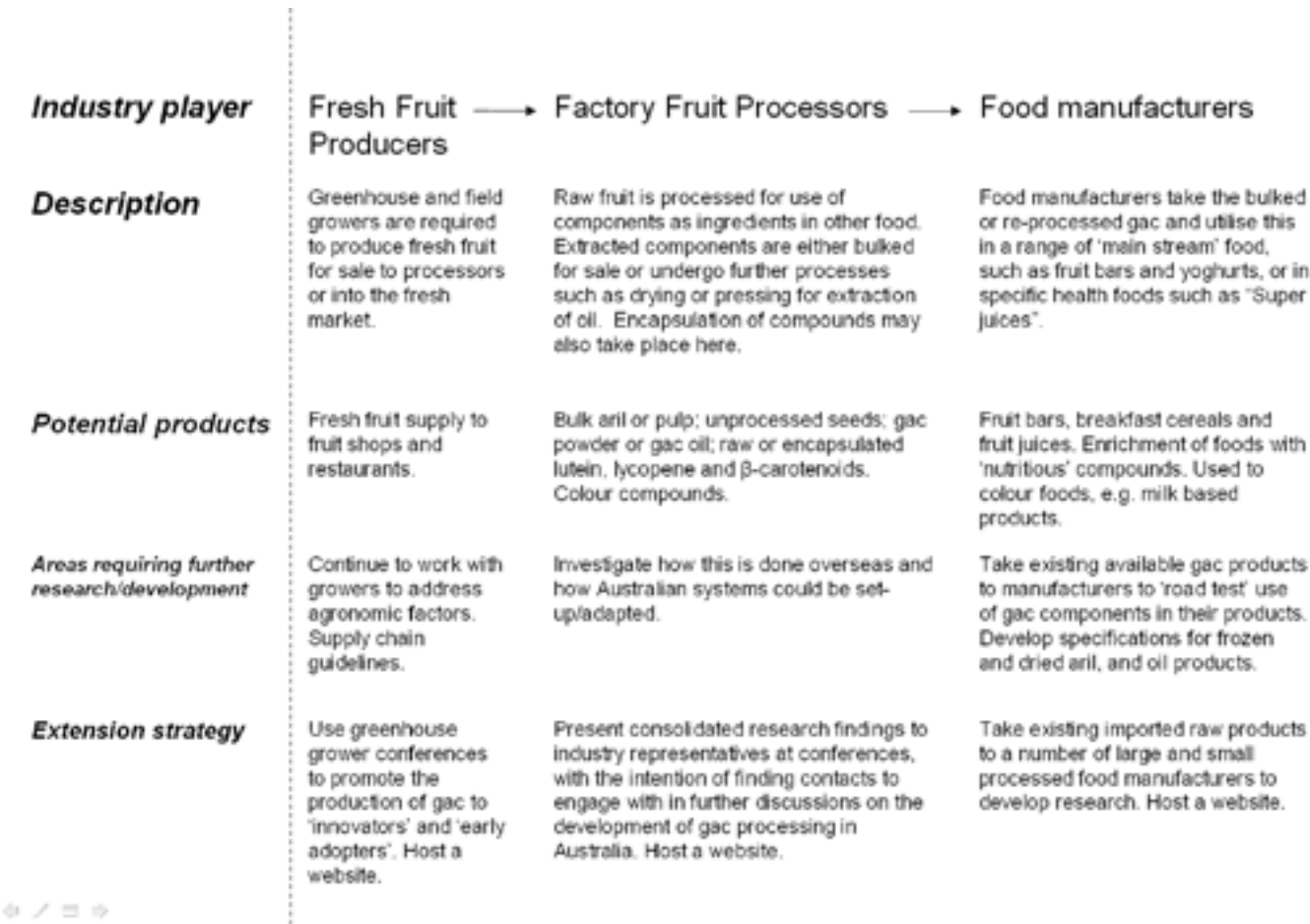


Figure 16. Extension strategy for the Australian gac industry.

Recommendations

Development of a gac industry in Australia would provide growers and consumers with a new Asian vegetable fruit which also has marketability as a ‘super fruit’. Further, a gac industry would be in a position to supply high quality carotenoids to an increasing carotenoid market projected to be worth 1.4 billion USD by 2018.

To achieve the establishment and development of a gac industry will require support. Further scientific research would need to:

1. develop science-based information on fruit production and processing of gac
2. establish some production trials in cooperation with growers
3. establish some trials using gac products in the food manufacturing industry

Establishing and developing the industry also requires an advisory component that could:

1. conduct forums to promote linkages among future stakeholders in the industry
2. generate consumer interest in gac to develop demand

Appendices

Appendix 1. Recipe for xoi gac

This recipe was kindly supplied by Lucy Tran

Serves 4 as a snack or remove the sugar and serve it as a side dish for any meat or BBQ dishes.

Ingredients

2 cups of sticky rice, washed

About 3 cups of water (may not use the lot)

1 cup of gac fruits arils (seeds intact)

2 tablespoons of coconut milk (optional)

1/2 teaspoon of salt

2 heaped tablespoons of sugar

Method

Put the washed rice into a rice cooker. Add gac fruit arils, coconut milk, salt and sugar, then mix well. Add enough water until it is about 1 cm above the rice. Leave the rice to absorb all the flavours for 15 minutes before turning on the cooker. Cook until the liquid has been absorbed.

Hints: The conventional method of cooking sticky rice on the stove top can be a challenge but care must be taken not to burn the pot. The best way is to bring the pot to the boil and simmer the rice until all the water is absorbed, then put the lid on and leave the pot on the stove at a minimum heat for 10 minutes.

Variation: Normal rice can be substituted. Just increase the water level above the rice to 2 cm.

Appendix 2. Cost benefit analysis summary

Name of Scenario	Gac2-Low Tech	Gac2-Low Tech (Double yield)	Gac2-Med Tech	Gac2-High Tech	Gac2-Outdoor
Crop	Gac	Gac	Gac	Gac	Gac
Season	Summer	Summer	Summer	Summer	Summer
Water Requirement	2 ML per Ha	2 ML per Ha	2 ML per Ha	2 ML per Ha	2 ML per Ha
Your Area Unit	1 Other 0.05 Hectares	1 Other 0.05 Hectares	1 Other 0.05 Hectares	1 Other 0.05 Hectares	1 Other 0.05 Hectares
Your Harvest Unit	Kilogram	Kilogram	Kilogram	Kilogram	Kilogram
Yield	1,800.00 Kilograms 36,000.00 Kilograms/Hectare 36.00 Tonnes/Hectare	3,600.00 Kilograms 72,000.00 Kilograms/Hectare 72.00 Tonnes/Hectare	2,025.00 Kilograms 40,500.00 Kilograms/Hectare 40.50 Tonnes/Hectare	2,250.00 Kilograms 45,000.00 Kilograms/Hectare 45.00 Tonnes/Hectare	1,620.00 Kilograms 32,400.00 Kilograms/Hectare 32.40 Tonnes/Hectare
Average Price	\$8,000.00 per Tonne \$8.00 per Kilogram	\$8,000.00 per Tonne \$8.00 per Kilogram	\$8,000.00 per Tonne \$8.00 per Kilogram	\$8,000.00 per Tonne \$8.00 per Kilogram	\$8,000.00 per Tonne \$8.00 per Kilogram
Gross Income	\$/Area Unit 14,400.00 \$/Hectare 288,000.00	\$/Area Unit 28,800.00 \$/Hectare 576,000.00	\$/Area Unit 16,200.00 \$/Hectare 324,000.00	\$/Area Unit 18,000.00 \$/Hectare 360,000.00	\$/Area Unit 12,960.00 \$/Hectare 259,200.00
Operating Costs					
Seed & Plants	1,568.00	1,568.00	1,568.00	1,568.00	1,568.00
Fertiliser	29.86	29.86	29.86	29.86	29.86
Fuel	0.00	0.00	0.00	0.00	0.00
Chemicals	1,963.52	1,963.52	1,963.52	1,963.52	1,963.52
Water	20.00	20.00	20.00	20.00	20.00
Labour	3,389.60	3,389.60	3,389.60	3,389.60	3,389.60
Electricity/Gas	400.00	400.00	3,528.00	2,352.00	300.00
Packaging	0.00	0.00	0.00	0.00	0.00
Freight/Transport	0.00	0.00	0.00	0.00	0.00
Other Operating Costs	2,000.00	2,000.00	2,000.00	2,000.00	2,500.00
Total Costs	\$/Area Unit 9,370.98 \$/Hectare 187,419.62	\$/Area Unit 9,370.98 \$/Hectare 187,419.62	\$/Area Unit 12,498.98 \$/Hectare 249,979.62	\$/Area Unit 11,322.98 \$/Hectare 226,459.62	\$/Area Unit 9,770.98 \$/Hectare 195,419.62
Gross Margin	\$/Area Unit 5,029.02 \$/Hectare 100,580.38	\$/Area Unit 19,429.02 \$/Hectare 388,580.38	\$/Area Unit 3,701.02 \$/Hectare 74,020.38	\$/Area Unit 6,677.02 \$/Hectare 133,540.38	\$/Area Unit 3,189.02 \$/Hectare 63,780.38
Gross Margin per ML Water	50,290.19	194,290.19	37,010.19	66,770.19	31,890.19
Weeks from Planting to Final Harvest	42.00	42.00	42.00	42.00	42.00

Appendix 3. Gac website proposal

Purpose

To consolidate publically available resources associated with the gac project on a simple, easy to use, webpage.


Existing content for inclusion

- Fact sheets that can be updated on:
 - Propagation,
 - Soil or growing medium,
 - Fertiliser and water,
 - Climate,
 - Trellising and plant training,
 - Pollination,
 - Pests and diseases,
 - Yield,
 - Variety development – future outlook for the industry.
- Research updates.

Additional content required

- Register of interest in growing, processing, or manufacturing with gac,
- New fact sheets,
- Upcoming events.

Example of the Gac homepage

		
<p>Register your interest here:</p> <p>Name:</p> <p>Email:</p> <p>I want to:</p>	<p>Fact sheets:</p> <ul style="list-style-type: none">• Propagation,• Soil or growing medium,• Fertiliser and water,• Climate,• Trellising and plant training,• Pollination,• Pests and diseases,• Yield,• Variety development – future outlook for the industry.	<p>External links</p> <p>Project information</p>

Glossary

anthesis	The time of flower or flower bud opening.
aril	The flesh surrounding a seed, often brightly coloured.
cambium	The zone of actively dividing cells in a stem that causes its increasing girth.
carotenoids	A group of lipid-soluble yellow, orange and red pigments responsible for the colour of many fruits and roots. These include amongst others beta-carotene, the principal source of vitamin A required in the diet, lycopene and lutein.
dioecious	Male and female (unisex) flowers are borne on separate plants.
electrical conductivity (EC)	This is a measure of the total concentration of all the chemical elements contained within a solution.
graft	A stem from one plant (the scion) is fused with a rooted portion of another (the rootstock) to form a single plant.
hydronic heating	A heating method using hot water rather than warm air. In a greenhouse the hot water is delivered through pipes, often laid on the floor of the greenhouse. The pipes are configured to also be used as rails for trolleys.
monoecious	A plant bearing separate male and female (unisex) flowers.
perennial	A plant that lives for more than two years and once flowering, produces flowers annually.
stock solution	The concentrated solution of mixed nutrients which is added to (diluted with) water to make the nutrient or hydroponic solution.
super fruit	A marketing term to describe fruits that consumers perceive as offering more than just basic nutrition.
tuber	A swollen stem or root that functions as an underground storage organ.

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Assessing the Potential for a Gac (Cochin gourd) Industry in Australia

By Sophie Parks, Minh Nguyen, David Gale and Carly Murray

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Gac is a nutritious tropical fruit with very high concentrations of antioxidants compared with other well known fruits and vegetables. It is mildly flavoured and has applications as a fresh product and the potential for processing into nutrient supplements and/or orange-yellow natural colourants.

Gac may be suitable as a field crop in tropical and subtropical Australia, or as a greenhouse and summer crop in more temperate areas. However, little information is available on its cultivation and production requirements or on its potential marketability in Australia. This project aimed to provide growers with preliminary information on crop cultivation and potential markets for gac fruits.

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