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**Rural Industries Research and
Development Corporation**

The effect of post harvest handling on selected native food plants

**A report for the Rural Industries Research
and Development Corporation**

by J K McDonald, N A Caffin, S Sommano and
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Foreword

Nutrition science research is continuing to demonstrate links between diet and disease, particularly heart disease, some cancers, osteoporosis, obesity and gut health and the preventative role antioxidants may play in these conditions. There is a growing consumer concern with health, diet and lifestyle, particularly as the population in developed countries ages, driving the development of “functional” foods. The functional food market worldwide is growing rapidly and is currently worth approximately US\$6 billion annually. Consumers are also concerned with issues of food safety and the degree of processing of their food supply.

There is also growing interest in value adding native food plants for local and export markets. The initial idea for this project came from suppliers of wild harvested bush tomatoes concerned about shelf life and quality issues. It became clear that manufacturers like Robins Foods Pty Ltd, actively involved in producing and marketing food products for local and overseas markets incorporating native plant food ingredients, especially bush tomato, were also interested in quality issues and the possibility of identifying a role for native plant foods in the functional food market.

The research project therefore focused on commercial issues facing native food producers and food processors: that of delivering consistent quality products to commercial end users based on a food technology and nutrition platform.

The project investigated current wild harvest and post harvest activities in the native food value adding chain using bio active components (the antioxidants lycopene and ascorbic acid) in the selected native food plants as indicators of quality changes through post harvest handling, storage, transportation and processing under current conditions and practices.

It was the intent of the project team that the recommendations outlined in this report may be used as a model for the whole industry regardless of the native food plant involved.

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

This report, an addition to RIRDC’s diverse range of over 1500 research publications, forms part of our New Plant Products: Native Foods R&D program, which aims to identify and evaluate processes or products with prospects of commercial viability and to assist in the development of integrated production, harvesting, processing and marketing systems.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O’Brien
Managing Director
Rural Industries Research and Development Corporation

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Abbreviations

<i>CAPAG</i>	Central Australian Producers Action Group
<i>DPI&F</i>	Department of Primary Industries and Fisheries
<i>UQ</i>	University of Queensland
<i>CSIRO</i>	Commonwealth Scientific and Industry Research Organisation
<i>CRC</i>	Cooperative Research Council
<i>FSANZ</i>	Food Standards Australia and New Zealand

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Executive Summary

A commercial issue currently facing native plant food producers and food processors, and identified by the industry itself, is that of delivering quality products consistently and at reasonable cost to end users based on a sound food technology and nutrition platform.

A literature survey carried out in July 2001 by the DPI&F's Centre for Food Technology, Brisbane in collaboration with the University of Queensland to collect the latest information at that time on the functional food market as it pertained to native food plants, indicated that little or no work had been published on this topic.

This project addresses two key RIRDC sub program strategies: to identify and evaluate processes or products with prospects of commercial viability and to assist in the development of integrated production, harvesting, processing and marketing systems. This project proposal also reflects a key RIRDC R&D issue for 2002-2003; that of linking with prospective members of the value chain.

The purpose of this project was to obtain chemical data on the post harvest stability of functional nutritional components (bio actives) in commercially available, hand harvested bush tomato and Kakadu plum.

The project concentrated on evaluating bioactive stability as a measure of ingredient quality.

The main strategies were to:

1. Measure antioxidants and protein in freshly harvested fruits and seeds over at least one season to determine the concentrations of components such as vitamin C and lycopene.
2. Measure these functional ingredients after:
 - a. post harvest handling (milling in the case of bush tomatoes and freezing for Kakadu plums),
 - b. during storage of the raw material (at the harvest site, by the supplier and at the manufacturing site),
 - c. after further processing into retail products and
 - d. over the shelf life of the retail product as an indicator of stability under various conditions typical of current practices.
3. Make recommendations to the producers and processors where applicable to enhance ingredient quality and stability.
4. Provide the Australian native food industry in general with information on the positive nutritional benefits of these native fruits and seeds to assist in ongoing promotional activities.

The screening of some bioactive compounds in selected Australian native plants has been studied before and the published data was used as a guide. Lycopene, ascorbic acid and anthocyanins were analysed in bush tomato; ascorbic acid was detected in Kakadu plum, wild lime, finger lime and Davidson plum; and anthocyanins in the Davidson plum.

A questionnaire for post harvest and handling was designed and distributed to bush tomato suppliers. A field trip was also made to Alice Springs to conduct interviews with key suppliers. Only two suppliers out of the three was available but the information they provided on how the bush tomatoes were collected and handled, pre processed and stored for distribution to southern manufacturers, is documented in this report. Originally it was intended to see first hand the harvesting and pre processing stages for the bush tomatoes, but the unavailability of bush tomatoes due to late rains and unexpected issues of commercial confidentiality meant this part of the task was not able to be achieved.

However, samples of hand harvested material and dried and milled bush tomato were provided by the suppliers for further analysis. Variation in antioxidant levels depending on drying treatments and colour were observed: 3.5 to 5.0 mg/100g ascorbic acid and 2.5-8.5 and mg/100 g anthocyanin, as well as changes in colour.

The variation in ascorbic acid content in frozen wild lime was 2.5 to 8.0 mg/100g, and 3.6 to 5.1mg/100g anthocyanins. Ascorbic acid content in the wild lime averaged 87.7mg/100g and Kakadu plum 2759mg/100g. Anthocyanin content of Davidson plum averaged 695 mg/100g although initial screening suggested a much higher value.

Results from the trials evaluating the effect of preparation and processing of final product where levels of ascorbic acid were measured in the frozen whole fruit, the pre prepared fruit pulp and then the final Kakadu plum sauce, demonstrated large losses of ascorbic acid.

Bush tomato sauce was produced on a small scale in the laboratory using similar conditions to commercial processing. Results indicated that the effect of heating was to increase the level of lycopene. This has previously been reported for lycopene in other products and may be due to release of lycopene from the food matrix.

A shelf life study over 9 months at different storage temperatures was conducted on two retail products made from bush tomato. Although there was some initial increase in lycopene content, overall the results showed that no significant differences occurred during the trial.

Implications

1. It is recognised that as only small percentages of native food ingredients are used in current manufactured products, making conclusions about the integrity of bioactive components through the manufacturing cycle are difficult to draw with any certainty. Until larger quantities of ingredients are incorporated into end products it will be difficult to identify the potential of native food ingredients to build a functional food marketing platform for retail products.
2. Seasonality has a significant impact on the availability of quality and volume required by commercial manufacturers. In 2002 when initial contact with the industry partner was made to develop the concept for this project, the bush tomato harvest in central Australia exceeded all expectations. By 2003, the lack of rainfall meant that fewer bush tomato plants were fruiting and stock from 2002 was used to supplement the lower volume. By 2004 the volume of bush tomato had fallen away and stored product from the previous two seasons was being drawn upon to meet manufacturers' orders for retail and export markets. This had a significant impact on being able to identify and follow batches of material through distribution and identify the effects of post harvest activities on the bioactive components from hand harvest to final product. This will always be an issue with hand harvesting.

Recommendations

1. Develop and implement a Quality Assurance program for the following:
 - a. Correct botanical identification of raw material (in consultation with indigenous harvesters)
 - b. Identification of optimum storage conditions and packaging to ensure product integrity throughout the distribution chain (from collection points in the indigenous communities)
 - c. Batch numbering system and analysis from point of harvest that is maintained throughout the supply chain
 - d. Identification of optimum conditions for pre processing activities such as milling and drying
 - e. Specification development for the raw material (native food ingredient) to raise confidence in the market place regarding quality and safety.
 - f. Improved receival processes to ensure manufacturers handle and store the ingredients correctly to prevent contamination and deterioration of ingredients prior to processing.
2. Investigate the impact of raw material variation on bioactive content to develop criteria for selection of native fruits for optimum levels of antioxidants.

3. Investigate the potential use of these bioactive compounds as natural antioxidants to use in the maintenance or extension of shelf life in processed food products, particularly minimally processed foods.
4. Investigate other potential native plant sources of antioxidants that may be more easily sourced/grown and harvested.

Introduction

In 2001, an industry forum run by Central Australian Producers Action Group (CAPAG) for bush tomato suppliers centred around Alice Springs. The forum identified that the improvement of post harvesting activities should be a priority for further action to further enhance the marketability of hand harvested bush tomatoes and to improve returns to suppliers and to the indigenous wild harvesters, mainly the older women in local and remote communities.

Discussions with two bush tomato suppliers currently providing dried milled bush tomato for retail food products, indicated that from a processing perspective the main issue facing manufacturers is the importance of providing consistency of quality of supply and improving post harvest handling methods.

A report commissioned by RIRDC on prospects for the Australian native bush food industry (Graham and Hart, 1997) indicated the importance of native food producers meeting mainstream food industry needs by providing native fruits and seeds in a form that could be readily used by food manufacturers and would therefore compete with conventional food ingredients in terms of ease of use and price.

In July 2001 the then DPI Centre for Food Technology (CFT) and the University of Queensland conducted a collaborative literature survey to collate the latest information on the functional food market as it pertained to native food plants. This review indicated that little or no work had been published on this topic.

There was support from the industry for an investigation focussed on a better understanding of the effects of post harvest handling and processing on the inherent functional properties of native food plants; and to identify quality assurance aspects of post harvest activities. To provide this data, raw material and finished product samples were accessed from suppliers and the industry partner and used to evaluate the retention of functional ingredients during post harvest storage and after processing. This would assist producers and processors enhance ingredient quality and stability.

The purpose of the research project was to focus on selected native plant foods from a food technology and nutrition perspective in order to provide new information on the effect of value adding activities on the level of the nutritional components (bioactives). The retention of two antioxidants (lycopene and vitamin C) was analysed as one measure to identify the effect of current post harvest practices in the supply chain on the stability of these nutritional components.

Objectives

To obtain chemical data on the post harvest stability of functional nutritional components in commercially available bush tomato, Kakadu plum, wild lime and Davidson Plum. The main strategies to achieve this outcome were:

- To measure antioxidants and protein in freshly harvested fruits and seeds over at least one season to determine the concentrations of components such as vitamin C and lycopene.
- To measure these functional ingredients after (a) post harvest handling (milling in the case of bush tomato and freezing for Kakadu plum) (b) during storage (c) after further processing into retail products and (d) over the shelf life of the retail product as an indicator of stability after various condition typical of current practices.
- To make recommendation to the producers and processors to enhance ingredient quality and stability.
- To provide the Australian native food industry in general with information on the positive nutritional benefits of these native fruits and seeds to assist in ongoing promotional activities.
- To determine the effect of post harvest handling and storage under current conditions and practices, on levels of functional ingredients.

Methodology

1. The effect of current post harvest practices on quality parameters including retention of antioxidant and in three commercially significant native plants (bush tomato, wild lime and Kakadu plum) were analysed.
2. The effect of food preservation methods such as drying, freezing and acid heat treatments on the retention of functional ingredients in food systems was investigated.
3. Shelf life evaluations were conducted over a 9 month period to assess the effect of storage conditions on the retention of functional ingredients after processing.
4. Recommendations to producers and processors have been made for improving these practices and where applicable, to enhance ingredient quality and stability.

Relevance and potential benefits

Recommendations from this research, if adopted, will assist all participants in the native food value adding supply chain to enhance the quality and therefore the acceptance and value of the native food plants already in use as ingredients in the food industry, benefiting all stakeholders in the native food industry.

Communication Strategy

- Attendance at the Bush Tucker Industry Summit, Cairns, November 2003.
- Presentation to the Australian Institute of Food Science and Technology (AIFST) 37th Annual Convention, Brisbane, 25-28 July, 2004.
- Presentation to the 2nd Australian New Crops Conference, University of Queensland, Gatton Campus, 20-24 September 2004.
- Discussions of recent changes in collection methods and semi processing of bush tomatoes with suppliers located in Alice Springs from the supply perspective (July 2005).
- Paper describing the project and results and recommendations to be submitted to *Food Australia* with RIRDC's permission.

Chapter 1 Commercially Important Native Food Plants

1.0 Bush Tomatoes (also known as Kampurarpa) (*Solanum centrale*)

Appearance

The fresh fruit is about 13-15 mm round, red or brown in colour with a taste similar to dried raisin.

Distribution

Widespread in arid regions, extending from north-eastern Western Australia through the Northern Territory and South Australia to western Queensland and north-western New South Wales.

General information

Issacs (1987) indicated that many native species of *Solanum* are toxic with some containing the toxic alkaloid solanine. The fruit of these species are very similar to small green tomatoes however only two *Solanum spp* are safely eaten by native aboriginal people: Kampurarpa, Desert Raisin (*S. centrale* or *S. ellipticum*) and Ngaru, Desert tomato (*S. petrophilum*) (Isaacs, 1987). The ripening period of these species is different – Kampurarpa ripens from the end to the beginning of the year and the Ngaru at the middle of the year.

Traditional uses

Kampurarpa (Desert Raisins) are ground with water on a flat stone using a grinding stone. The brown paste is then formed into a ball shape which is dried by exposing to the sun. The Ngaru are eaten raw or are sometimes dried by keeping next to the fire. When needed to be stored, they are strung on sticks and may be kept for long period before using.

Bioactive compound

The dried ground fruits are used as flavouring or spice in savoury dishes. They contain β -carotene and lycopene. Miller *et al.* (1993) investigated the composition of Bush Tomato and found that the dried fruit contains about 1.5% dietary fibre and 0.017% Vitamin C.



Figure 1. Bush tomato

1.2 Kakadu Plum, (*Terminalia spp.*) (also known as Arangal, Madoorr, Gubinge, Kabinyn, Gabiny)

Appearance

Pale green olive-sized fruit with a stone that clings to the fruit flesh.

Distribution

Found in the Northern Territory and Western Australia (Ahmed *et al.*, 2000).

General information

There are about 30 species of *Terminalia* in Australia (Hegarty *et al.*, 2001). Although most of them are safe to eat, a toxic and unpleasant compound may be found in some parts of the plant such as the leaves and bark.

Traditional uses

Not only is the Kakadu plum eaten fresh, but a Kakadu plum drink is a traditional food for aboriginal people as well. To prepare, the fresh or dried fruit are soaked in water for a couple of days.

Moreover, gums formed by some species of *Terminalia* including Kakadu plum are directly eaten, cooked in sand or ground to a powder after soaking has formed the edible jelly (M Bunenyerra, NT, *pers. comm.* 2000, cited in Hegarty *et al.*, 2001).



Figure 2. Kakadu plum

Bioactive compound

Kakadu plum have a high Vitamin C content which ranges from 0.2–5.9% and as such the fruit has been recommended for further marketing studies and the optimisation of Vitamin C production (Ahmed *et al.*, 2000).

1.3 Wattleseed (*Acacia* sp)

Appearance

Acacia species are shrubs or trees. The seeds of several Acacia species are used by Aborigines as food (Ahmed *et al.*, 2000).

Distribution

Coastal, from the north Queensland to Victoria.

General information

Nearly 1000 species of *Acacia spp* can be found in Australia. The useful compound it contains which made it famous during the colonial times is tannin. The aboriginal method for removing the seed coat is to parch, grind, and winnow (Hegarty *et al.*, 2001).

Traditional uses

The Australian Acacia species are used both for cuisine and medicine. For food, seeds, gums, roots and associated insects are used as an ingredient.

Bioactive compounds

Although Acacia species are used for flavouring or coffee substitutes (Ahmed *et al.*, 2000), no record of its bioactive components has been found. Only dietary fibre has been examined and found to be about 44% of the edible portion (Miller *et al.*, 1993).



Figure 3. Wattles

1.4 Davidson plum (*Davidsonia prurie*)

Appearance

Brilliant burgundy colour. Fruits vary in size from grape to large plum sized.

Distribution

Rainforests of north-eastern Queensland and north-eastern New South Wales.

General information

The ripening fruits have purple in colour or rather flesh red. It gives a very sour and tangy taste. Producing plum like fruit, 3-6 diameter (19-20 g), the small trees naturally grows in sub tropical rainforest in northern NSW and north-east Queensland.(Hegarty *et al.*, 2001).

Traditional uses

Only one species (*Davidsonia pruriens*) was recorded to be eaten by native people (Hardwick, 1994). Low (1991) gave an example of the use of this kind of plant in that it was stewed in the sugar to be properly appreciated.

Bioactive compound

In 1976 Wilkins *et al.*, identified four flavonols: epicatechin gallate, epigallocatechin gallate, gallic acid and anthocyanin.



Figure 4. Davidson plum

1.5 Wild limes (*Microcitrus* spp.)

Microcitrus is a member of sub-family Aurantioidea of the family Rutaceae. The genus *Microcitrus* is newly named due to their very small juvenile leaves and the minute size of their flowers (Birmingham, 1998). There are five species of *Microcitrus* found in Australia.

1.5.1 Finger lime (*Microcitrus australasica*)

Appearance

The shape of the fruit is cylindrical-fusiform or finger shaped. The skin colour of finger limes range from crimson, blood red, purple, black, yellow to green.

Distribution

The natural distribution of finger lime is from the Richmond River, in northern NSW to Mt Tambourine in Queensland. It is found growing in sub-tropical rainforest as an under storey tree with an average height of 6 m, on a range of soil type.



Figure 5. Finger lime

1.5.2 Round lime (*Microcitrus australis*)

Appearance

The bush bears rounded fruit which are 2.5-8 cm in diameter. The rough greenish-yellow skin of the fruit is very thick (up to 7 mm).

Distribution

It is endemic to south-eastern Queensland from Beenleigh to Gympie, in low land sub-tropical rainforest.

1.6 Desert lime (*Eremocitrus glauca*)

Appearance

The fruit is round to oblate in shape and approximately 2 cm in diameter, weighing from 1-3 g. The skin is light yellow-green on maturity and contains large oil gland.

Distribution

The natural distribution of this species is the semi-arid regions of eastern Australia, from Rockhampton to Longreach in Queensland, south to Dubbo in central New South Wales and west to Quorn, in the Flinders ranges of South Australia.

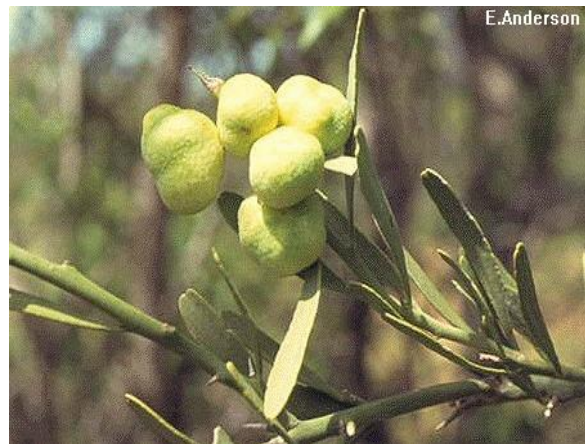


Figure 6. Desert lime

Traditional use

Low, 1991 stated that only a few records about how aboriginals use for these native species. However, the new colonists exploited them as a drink and marmalades. Fresh fruits of finger lime as well as desert lime can be used as a garnishing and a food processing ingredients such as salad dressings, sauces, marmalades, desserts, jellies or pastries. The round lime skin can be extracted for essential oil extraction (Birmingham, 1998).

Bioactive compounds

Only finger lime was detected for vitamin C content (Miller *et al.*, 1993). It was found that finger lime contains about 1% of vitamin C content.

1.7 Lemon myrtle (*Backhousias citriodora* F. Muell)

Appearance

The green long leaves contain the essential oil.

Distribution

Rainforests of coastal Queensland, from around Brisbane to Mackay.

General information

Essential oil from the leaves provides the aroma and flavour for which the plant is used in foods and beverages.

Traditional uses

Only limited records are available, although the pleasant aroma of the leaves would have been known to aboriginals.

Bioactive compounds

The leaves and the flowers give a strong lemon flavour. The leaves contain 95% citral. However, little research has been worked on bioactive compounds (Ahmed, 2000).



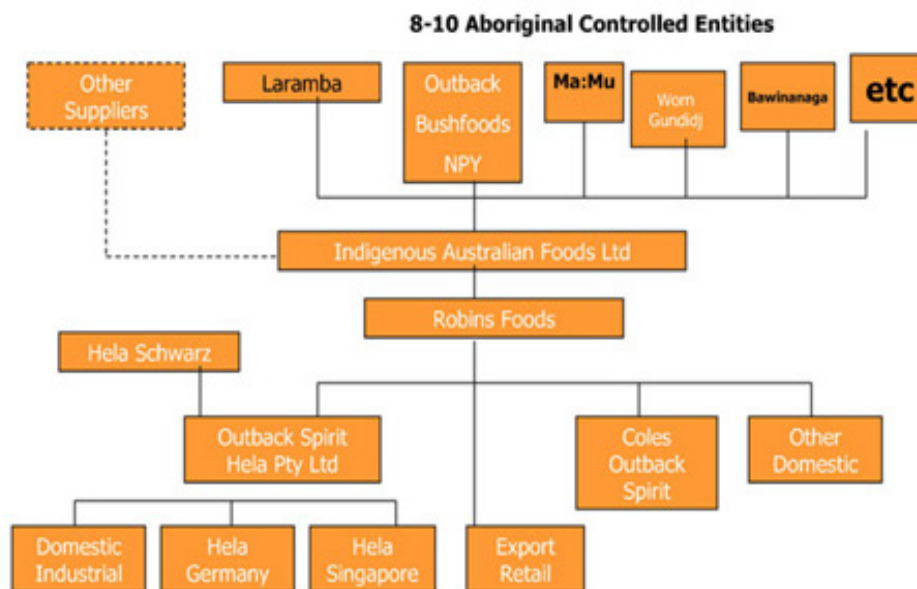
Figure 7. Lemon myrtle

1.8 Current COMMERCIAL Activities

At the Indigenous Bush Tucker Industry Summit, a presentation by Mr Wayne Street described *The Indigenous Australian Foods Supply Chain (IAF)*, a national supply chain study involving a commercial partnership arrangement between a number of indigenous enterprises and communities, Robins Foods and Coles (see Flow chart below).

http://www.diversityaustralia.gov.au/inc/doc_pdf/coles.pdf

AUSTRALIAN INDIGENOUS FOODS SUPPLY CHAIN



Mr Street highlighted some challenges for the industry, specifically the limited funding available for supply chain development given the relatively small production and marketing volumes. His estimate of the total worth of the Australian Bush Food Industry was approximately \$10 million per annum.

The Summit concluded that although mainstream and niche market opportunities exist these need to be clearly defined and developed accordingly.

((http://www.credc.com.au/archive/Conferences/Proceedings_Bush_Food_Summit_Nov_2004.pdf)

Chapter 2 Commercial Practices and Food Safety

2.0 Introduction

The two main food safety issues for the industry are 1) the identification of anti nutritive compounds in native food plants and 2) the potential for food poisoning outbreaks because of unsafe food handling practices during packaging, storage and processing.

Some of the anti nutritive compounds found in bush tomatoes, Kakadu plums and wattle seed are listed in Table 1.

Table 1. Examples of native food plants and their anti-nutritive compounds

Name	Nutritional Study	Anti Nutritive Compounds	Recommendations
Bush tomato (<i>Solanum spp.</i>)	High in water soluble vitamins and minerals, dietary fiber, low in fat and calories, good source of Vitamin A, C and lycopene (In general) ² .	Unspecified alkaloids have been found in fruits and leaves ¹ . Alkaloid solasodine gives bitter taste.	Because the concentration of poisonous alkaloid was somewhat less in ripe than green fruit, the fruit needs to be harvested when ripe or when red ¹ . Freeze drying prior to storage may preserve the vitamin content.
Kakadu plum (<i>Terminalia spp.</i>)	High in Vitamin C content and dietary fibre ² .	No evidence of toxins found in flesh and kernels. However, the leaves are known to be quite toxic ¹ .	Freeze drying prior to storage may preserve the vitamin content.
Wattles, Wattle seed (<i>Acacia Species</i>)	High in fatty acid composition, has low glycaemic index and anti-tumour activity ¹ .	Contains protease inhibitor which interferes with the trypsin and chymotrysin, promoting hay fever and rhinitis and causing some allergic symptoms during harvesting ¹ .	Considerable heating is required. Wearing filter masks is recommended to prevent allergic reactions during gathering ¹ .

¹ M.P. Hegarty, *et al.*, 2001

² Fauconier, M, *et al.*, 2001

2.1 Current Food Safety Regulations

Under the Australia and New Zealand Food Standards Code (FSC) Food Standards Australia New Zealand (FSANZ), 2005, the bush food industry must comply with food safety practices to ensure that food does not become unsafe or unsuitable for consumption.

Food Safety Standard 3.2.2 - Food Practices and General Requirements sets out the specific food handling controls related to the receipt, storage, processing, display, packaging, transportation, disposal and recall of food products.

Other requirements relate to the skills and knowledge of food handlers and their supervisors, the health and hygiene of food handlers, and the cleaning, sanitising and maintenance of the food premises and equipment within the premises.

Specifically, Primary Food Production (Standard 3.1.1) Food Safety Standard (FSANZ, 2005) refers to the growing, cultivation, picking, harvesting, collection or catching of food, and includes the following:

- a) the transportation or delivery of food on, from or between the premises on which it was grown, cultivated, picked, harvested, collected or caught
- b) the packing , treating (for example, washing) or storing of food on the premises on which it was grown, cultivated, picked, harvested, collected or caught, and
- c) any other food production activity that is regulated by or under the Act prescribed by the regulations for the purposes of this definition.

Also, Handling (Standard 3.1.1) Food Safety Standard (FSANZ, 2005) includes the making, manufacturing, producing, collecting, extracting, processing, storing, transporting, delivering, preparing, treating, preserving, packing, cooking, thawing, serving, or displaying of food.

2.2 Objectives

The aim of this study was to document value adding activities along the supply chain. This information was provided by bush tomato suppliers and the manufacturers at the retail end of the supply chain.

2.3 Methodology

A questionnaire was designed and given to suppliers to fill in relating to their experiences with hand harvesting and pre processing activities. (see Appendix 2). An individual interview and an on -site investigation was undertaken when bush plants were in season. The information was collected and eventually documented as flow charts for each native food product. Observations and recommendations were made for each process step where relevant to ensure compliance to the requirements food safety as set out in the Code.

2.4 Results and Discussion

2.4.1 Post harvest and handling method of Kakadu plum

No data is available on the percentage rate of change in moisture contents as an indicator of quality changes because of the difficulty in tracing samples along this supply chain. Varying moisture content has implications for product deterioration and mould growth as well as infestation problems. Currently the infrastructure for sorting or grading is limited.



Figure 8. Mature fruits, pale green olive-sized (Photo S Sommano)



↓
Manufactures

↓
Washing

Chilled fruits are roughly cleaned by water to remove excess material

↓
Freezing

Cleaned fruits are stored in commercial freezer at -18°C

The fruit is wild harvested in northern regions of Northern territory and Western Australia. It is then packed in plastic bags and frozen for distribution. As with hand harvested fruit there is a very large variation in the fruit in size, colour and ripeness



Figure 9. Whole frozen Kakadu plums (*Photo S Sommano*)

2.4.2 Bush tomato value adding chain



Figure 10. Bush tomato fruit on the bush, Desert Knowledge Park, Alice Springs
(*Photo S Sommano*)

↓
Hand harvesting

Primary food production by indigenous women from various indigenous communities in central Australia

Only fruits that turn from green to yellow when ripe are picked to minimise the presence of poisonous alkaloids. Ripe fruit that becomes dry and dark in colour (resembling a raisin) is also collected (shaken off the bush or from the ground). The fruit (both yellow and dry) is collected in hessian bags provided by the buyers.(Yates and Horner, NT, pers. comm. June 2005)

↓



Figure 11. Collecting bush tomatoes



Sorting and sun drying by the community

Back in the community camp the stalks are rubbed off and the fruits are sorted by the women and dried in the sun on mats/rugs.



Transport to producers

The fruit is then packed into plastic bags and transported to the buyers' premises at ambient temperatures



Supplier



Storage – at ambient temperatures



Washing

Either a chlorine wash is used to minimize the contamination of E-coli due handling practices during sorting and packing

Or a hot water is used to remove sand, stalk and leaves and remove any surface contamination



Sun drying

Sun drying for 2-10 days



Oven drying at 80°C for 2 hr

To kill any moth eggs



Grinding and packaging for distribution



(Photo S Sommano)



(Photo S Sommano)

Figure 12. Whole samples



(Photo S Sommano)



(Photo S Sommano)

Figure 13. Ground samples

2.5 Conclusions

1. The pre processing (drying and milling) of the bush tomatoes in particular is a new initiative. Putting in place recommended processes to comply with the Australia New Zealand Food Standards Code and providing documentation to support the compliance will take more time and work by the industry. Success will depend on the suppliers and manufacturers working more closely together to ensure a consistency of supply that meets food safety protocols.
2. It was not possible to document changes in the % moisture contents of samples through the supply chain as it was difficult to identify batches. Development of an accurate batch numbering system and simple QA testing regime for moisture content, colour, size and extraneous matter would ensure consistency of supply and is essential, particularly as packing together fruits of varying moisture content may have implications for product deterioration (mould growth and infestation).
3. Development of specifications for raw material and finished product will have the benefit of raising the confidence of purchases of native food ingredients and final product and help increase Australian ingredients in local and export markets.

Wild harvesting provides economic and social benefits for the indigenous communities who participate. There is the opportunity to go back “on country”, providing an opportunity for social interaction between generations and the transfer of desert knowledge, as well as the addition of native foods to the every day diet and additional cash payments to the women. Therefore further quality assurance programs will need to be implemented in a way that takes account of all these lifestyle factors.

2.6 Recommendations

1. The industry must comply with the regulations covering safe food production.
2. The industry must address the issues relating to the presence of anti-nutritive compounds in raw material as per Table 1.
3. Quality assurance training and implementation needs to take into account lifestyle issues for indigenous communities involved in hand harvesting.

Chapter 3 Effect of Hand Harvesting and Post Harvest Practices on Bioactive Components

3.0 Introduction

Australian native fruits as they are used in indigenous communities are mostly collected and treated in simple ways. However physical treatments including drying, cooling, freezing etc. may affect the availability of bioactive compounds contained in the native fruits.

After harvesting, bush tomatoes are normally dried before being transported to pre processing sites in Alice Springs. Aboriginal collectors dry the fruit using the sun. Further drying may take place after the bush tomato is delivered to the pre processor who packages it whole or after milling (P Yates, NT pers. comm., June 2005). Heating can affect the stability of bioactive compounds found in bush tomatoes.

Wild limes are delivered to the manufacturer as frozen wild limes. The whole fruits are frozen at -18°C and stored in a freezer. Not only can freezing result in physical injury, it can also cause alteration of the pigments, which are sources of bioactive compounds, due to the release of acids as a result of cellular damage (Fellows, 2000).

Kakadu plums are rarely available fresh. Kakadu plum can be purchased frozen or pureed. Kakadu plum is known to have the highest ascorbic acid content of fruits, approximately 3000 mg per 100 g of the fruit (Brand-Miller *et al.*, 1993). The ascorbic acid content can be reduced during the process of freezing or when the fruit is being heated to make a puree.

3.1 Objectives

To identify the effect of post harvest practices and of pre processing storage conditions on bioactive components: lycopene in bush tomato, ascorbic acid content in Kakadu plum, wild lime and bush tomato and anthocyanin content in Davidson plum and bush tomato.

3.2 Material and Methods

3.2.1 Documentation of post harvest and handling methods of native bush plants

As described in Chapter 2, information on hand harvesting and pre-processing of native foods was collected from suppliers.

3.2.2 Initial screening of bioactive compounds in Australian native plants

Dried bush tomato, frozen wild lime and frozen Kakadu plum were sourced from the industry partner (Robins Foods, Braeside Vic). Samples of dried and ground bush tomato were randomly taken from boxes stored at ambient temperature in Robins Foods warehouses. The bush tomato had been stored for around 6 months in the warehouse and was probably from the 2002 harvest - the last major harvest in the Northern Territory. The collected samples were placed in plastic zip top freezer bags and stored below -18°C until further analysis.

Frozen whole fruits of Kakadu plum and wild lime were also obtained from Robins Foods. About 10 g of fruit was sampled from the top, middle and bottom layers of the plastic bags stored in the company freezer. Samples were collected in plastic zip top freezer bags and stored at below -18°C until further analysis.

Davidson plums were received frozen from Australian Rainforest Products (Blue Knob, NSW). After the stones were removed from the fruits, the fresh were then blended in to a puree and stored below 5°C until further analysis.

Frozen wild lime and Kakadu plum were freeze dried before the screening of bioactive compounds. Wild lime was cut in half and Kakadu plum was sliced after removing the stone. The samples were then placed on to a tray, covered with parafilm and frozen for 3-4 hours before freeze drying. Dried pieces of the samples were ground and kept below 5°C until further analysis.

3.2.2.1 Lycopene content in bush tomato

The analysis of lycopene was adapted from Eitenmiller and Landen (1999).

Sample extraction

Ten grams of dried bush tomato was weighed into a 50 ml, round bottom, plastic centrifuge tube. To this was added 10 ml of hexane-acetone-ethanol (50:25:25) and 5 ml of water which was then agitated for 30 minutes. This was followed by centrifugation at 5000 rpm for 10 minutes. The hexane layer containing the lycopene was collected. The extraction was done twice and the extracts combined. The combined extract was evaporated under N₂ to dryness and stored below 5°C until further analysis. The procedure was carried out in triplicate.

HPLC analysis

After redissolving with 2ml of hexane and filtering through 0.45µm nylon filter, the extract was injected onto a HPLC Hypersil column using methanol/tetrahydrofuran/water, 67:27:6, v/v/v as the mobile phase.

3.2.2.2 Ascorbic acid content in wild lime Kakadu plum and Davidson plum

Sample extraction

To each sample of dried fruit (approximately 0.5g Kakadu plum and 1.0 g wild lime, finger lime and Davidson plum respectively) 15 ml of 0.05N phosphoric acid (H₃PO₄) was added. .

The mixture was then agitated for 30 minutes and centrifuged at 5000 rpm for 15 min. The supernatant was transferred to 100 ml volumetric flask. The extraction was repeated and the supernatants combined. Sodium metabisulphite (500 µg/ml)was added and the supernatant purified by passing through a C₁₈ cartridge, preconditioned by flushing with methanol followed by deionised water, and a 0.45µm Millipore filter. The experiment was carried out in triplicate.

HPLC analysis

The filtered supernatant was injected onto a HPLC Prevail column using 97:3 25mMKH₃PO₄: acetonitrile as a mobile phase.

3.2.2.3 Anthocyanin content of Davidson plum and bush tomato

One gram of dried bush tomato or 10g of the Davidson plum puree were accurately weighed into a blender and 10 ml of acidified methanol (0.1% HCl) was added. The sample was homogenised until smooth and agitated for 15 minute at room temperature. The sample was also centrifuged at 3000 rpm for 15 min. The supernatant was transferred to a 50ml volumetric flask and made to volume with acidified methanol. To obtain an absorbance between 0.200 and 1.000 at 530 nm the sample was also diluted 100 times with acidified methanol. The filtration through 0.45 µm filter cartridge was needed before analysing with a spectrometer. The result was expressed as mg cyanidine 3-glucoside equivalents/100g fresh fruit.

A red pigment was extracted when extraction was carried prior to the determination of ascorbic acid (aqueous extraction). Bush tomato was therefore analysed for anthocyanin.

3.2.3 Effect of post harvest and handling on bioactive content

Bush tomato samples were collected from different producers with different post harvest and handling methods as documented. One kilogram of whole fruit as well as a kilo gram of ground bush tomato, were packed into plastic bags was collected at the production site of the first supplier (Rod Horner, Alice Springs, NT). Equivalent amounts of the fruits (whole and ground) were bought from another supplier, Peter Yates (Diliji, Outback Bushfoods Pty Ltd, Alice Springs, NT).

One kilogram of Kakadu plum consisting of fruit of different sizes was sent frozen from the supplier. (Ray Hall, Winnellie, NT). A kilogram of frozen wild lime was collected from a distributor (Robins Foods, Braeside Melbourne, Vic). The whole fruits were packed into plastic bags which were stored in a box with dry ice. Frozen Davidson plum and finger lime (1 kilogram each) were sent from the producer Australian Rainforest Products (Blue Knob, NSW).

Stones were removed from the Kakadu plum and Davidson plum samples and all the pieces except the dried bush tomato, were cut into thin pieces. All these pieces were placed on to trays and kept frozen prior to freeze drying. Samples were kept below -18⁰C until further analysis.

3.2.3.1 Lycopene in bush tomato

The extraction and HPLC analysis were as the same as described in 3.2.2.1.

3.2.3.2 Ascorbic acid in wild lime, finger lime, Kakadu plum and Davidson plum

The extraction and HPLC analysis were as the same as described in 3.2.2.2.

3.2.3.3 Anthocyanin content in bush tomato and Davidson plum

The extraction and HPLC analysis were as the same as described in 3.2.2.3. One gram of dried Davidson plum was used instead of 10g of Davidson plum puree.

3.4 Results and Discussion

The results for the screening of bioactive compounds in Australian native plants are shown in Table 2.

Table 2. Initial screening of bioactive compounds in samples of bush tomato, wild lime, Kakadu plum and Davidson plum

Name	Bioactive compound	Analysis	Reference*
		mg/100g	mg/100g edible portion
Kakadu plum	Ascorbic acid	323 fresh weight (1183 dry basis)	406 - 5320
Wild lime	Ascorbic acid	6.09 fresh weight (27.1 dry basis)	0 – 82
Dried bush tomato	Beta carotene	0.003	n/a
Dried bush tomato	Lycopene	0.003	n/a
Dried bush tomato	Ascorbic acid	2.39	1 – 59
Dried bush tomato	Anthocyanins	10.2	n/a
Davidson plum	Anthocyanins	474. fresh weight	5-240**

*Brand Miller, J., James, K. W. and Maggiore, P. M. A, Tables of Composition of Australian Aboriginal Foods, 1993, Aborginal Studies Press, Canberra.

**Figures supplied by T.Treloar Department of Primary Industries and Fisheries, Qld for eating plums (*Prunus salicina*) grown in Australia

The results in Table 2 showed that Kakadu plum contained ascorbic acid at about 300 mg/100g. However, previous analyses reported nearly 3000 mg ascorbic acid per 100 g of the edible portion of Kakadu plum (Brand- Miller *et al.*, 1993.). This represented an average figure and the amount of ascorbic acid ranged from 406 to 5320 mg/100 g in the samples tested. In this study the Kakadu plum was frozen and kept for some period of time. Therefore some losses are likely especially during thawing. There are also likely to be differences in both content and losses due to the large size variation of the fruits (Nursal and Yucecan, 2000).

Wild lime contained only a small amount of ascorbic acid. There are many varieties of bush limes. The values given by Brand Miller *et al.* (1993) did not indicate which variety was analysed. This may in part explain the wide variation in values together with losses during the storage of the fruit.

The results showed that the lycopene content might not be a good representative of bioactive compounds in dried bush tomatoes. It was impossible to obtain samples of fresh bush tomato for comparison. As a result ascorbic acid and anthocyanin content were also analysed in the bush tomato.

Analysis for anthocyanin showed that bush tomato contained 10.2 mg/100 g of dried sample. By comparison the anthocyanin content of Davidson plum was very high at around 475 mg/100 g fresh weight. This is much higher than eating plums grown in Australia. The value for the bush tomato is still a relatively significant amount.

Table 3. Effect of post harvest and handling methods on the content of bioactive compounds

Sample	Condition when supplied	Moisture %	Bioactive Compounds		
			Lycopene mg /100 g	Ascorbic acid mg/100 g	Anthocyanin mg/100 g
Bush tomato Producer 1	Whole	4.62 ± 0.17	Bld	2.62 ± 0.02	3.73± 0.12
	Ground	3.05 ± 0.10	Bld	2.55 ± 0.11	3.6 ± 0.20
Bush tomato Producer 2	Whole	4.46 ± 0.25	Bld	5.23 ± 0.01	5.09± 0.22
	Ground	2.99 ± 0.29	Bld	8.43 ± 0.11	4.40 ± 0.48
Wild lime	Frozen	77.5 ± 4.12	-	111.5 ± 7.0 (dry basis) 25.09 ± 1.58 (fresh weight)	-
Finger lime	Frozen	78.90 ± 2.4	-	415.66 ± 26.24 (dry basis) 87.7 ± 5.54 (fresh weight)	
Kakadu plum	Frozen	72.68 ± 1.59	-	10097 ± 453 (dry basis) 2758± 124 (fresh weight)	-
Davidson plum	Frozen	88.910 ± 3.529	-	32.45 ± 4.29 (dry basis) 3.60 ± 0.47 (fresh weight)	6270.0 ± 90 (dry basis) 695.6± 9.9 (fresh weight)

Bld = below level of detection

The results in Table 3 showed that there was variation in the bush tomatoes from different producers with respect to moisture, ascorbic acid and anthocyanin content. The ascorbic acid values are comparable to the ones in Table 2 but the anthocyanin values are a bit lower.

There are two methods of post harvest and handling bush tomato. Sun drying is basically used to remove the moisture from bush tomato. However, a hot air oven is also employed for preserving bush tomato. As a comparison, sun drying gives a light- golden brown bush tomato whereas oven drying produces a dark brown fruit. The bush tomato preserved using sun drying contained less of the bioactive compounds than the bush tomato samples that were oven dried. It was observed that a higher rate of nutrients loss was found in the sun dried bush tomato with the higher moisture content. Thus, the stability and retention of bioactive compounds are not only dependent on drying conditions but also on the moisture content of the sample. Since ascorbic acid is labile it is useful as an index against which to compare the behaviour of other nutritive compounds in food (Erenturk *et al.*, 2005).

The post harvest and handling methods for bush tomato could be improved by optimising drying conditions to maintain a desired level of bioactive compounds and also to maintain an attractive appearance. The first step is to remove moisture of the bush tomato by hot air oven avoiding case hardening. The use of sodium metabisulphite could also be introduced as a post harvest treatment to control browning in fruits (Jiang. *et al.*, 2002). This needs further study in bush tomatoes, from both a technical and marketing perspective, as any labels on dried fruits treated this way would have to carry an allergen warning.

The results showed that Kakadu plum contained ascorbic acid at about 2800 µg/100 g. This is comparable to published values and is much higher than the content found in the initial screening analyses. The values reported in Table 3 were from relatively fresh fruit whereas the history of the samples in Table 2 were largely unknown. These results illustrate that large losses of bioactive components can occur during handling and storage.

Wild lime contained a significant amount of ascorbic acid. There is difference in values between the initial values and the values in Table 3. The ascorbic acid level in finger limes was done for comparison and found to be higher than the wild lime.

A very high content of anthocyanins was found in Davidson plum despite the difference between the values shown in Tables 2 and 3. Nonetheless, there could have been an alteration of anthocyanin content during frozen storage. Chaovanalikit *et al.* (2004) found that there was an effect of frozen storage on hydroxycinnamates in berry fruits but flavonol glycosides also a class of polyphenolics were quite stable. Further work needs to be done to determine the effect on individual anthocyanin compounds and the effect of freezing.

3.5 CONCLUSION

Lycopene, ascorbic acid and anthocyanins were found in bush tomato. A comparison of the results of the sun drying and hot air oven drying (at approximately 70°C) suggested that sun drying resulted in a greater loss of bioactive components but produced a better appearance.

Ascorbic acid was detected in Kakadu plum, wild lime, finger lime and Davidson plum which showed variation when compared with the reference values. Some of the differences were too large to explain by a variety of sizes and species of the fruits and were probably due to losses occurring during storage.

A very high content of anthocyanins was found in Davidson plum and additional work is being carried out to investigate this further.

These results should be treated as indicative. More samples would be needed to confirm these results.

3.6 Recommendations

1. The drying process for bush tomatoes needs to be monitored and controlled to optimise moisture content to prevent the loss of bioactives and the development of moulds and yeasts while maintaining the eating quality of the fruit during storage.
2. Shelf life studies need to be set up to evaluate time/temperature effects on different packaging to optimise quality for end users.
3. Specifications for the final dried bush tomato product need to be developed by the suppliers to build the integrity of the product in terms of quality of supply. This includes batch identification for traceability purposes.
4. Collection of more analytical data through the supply chain from point of collection to the final dried and packed bush tomatoes to assist in the development of the specifications.

In summary there needs to be protocols put in place to optimise collection, drying, grinding; packaging and storage activities. Also, specifications need to be developed for the whole and milled product.

Chapter 4 Evaluation of Bioactive Compounds during Processing

4.0 Introduction

Pasteurization temperatures are necessary to prolong shelf life by destruction of spoilage micro-organisms and/or the inactivation of enzymes. There have been numerous research studies on the effects that food processing practices, particularly heat processing, have on the stability vitamins. Heating for example, leads to the degradation of ascorbic acid. For example, Nursal and Yucesan (2000) found that boiling frozen spinach resulted in approximately a 50% reduction in ascorbic acid.

However, the impact of real time manufacturing processes on antioxidants of native food products has not yet established.

It was hypothesised that significant alteration in bioactive contents of bush food products would occur as the result of processing.

4.1 Objectives

To investigate the effect of processing on the bioactive compounds under:

- a) “real time” processing in a commercial manufacturing environment and
- b) controlled lab scale processing.

4.2 Evaluation of the stability of bioactive compounds in commercial manufacturing conditions

4.2.1 Materials and Methods

4.2.1.1 Sample selection

Arrangements were made with the industry partner (Robins Foods, Braeside, Melbourne, Vic) to liaise with the manufacturer of the three retail products of most interest to this study: Bush tomato chutney, Bush tomato ketchup and Kakadu plum chilli sauce.

Two cartons of each product (12 bottles) were sampled from the production line at the beginning, middle and end of the run for analysis (total of 6 cartons per product). The samples were transported to Brisbane under ambient conditions and then stored in a cold room at less than 5⁰C before analysis.

4.2.1.2 Analysis of lycopene and β -carotene in finished product (retail): Bush Tomato Ketchup and Bush Tomato Chutney

The analysis of lycopene was adapted from Eitenmiller and Landen (1999) as already described in Chapter 3.

Sample preparation

Two bottles of each product from the different production run times were randomly selected from the cartons and duplicate extracts from them prepared for analysis. The extraction was done twice and the extracting solution was prepared fresh on the day of analysis. The extract was then evaporated under N₂ to dryness and stored at less than 5⁰C before analysis.

HPLC analysis

The samples were dissolved in hexane and filtered. The hexane layer was injected in to a HPLC using methanol/tetrahydrofuran/water, 67:27:6, v/v/v as mobile phase.

4.2.1.3 Analysis of ascorbic acid in Kakadu plum chilli sauce

Sample preparation

The same procedure as for the bush tomato products was used.

HPLC analysis

The filtered supernatant was injected in to HPLC column using 0.0085 N H₂SO₄ as a mobile phase.

4.2.2 Results

Table 4. Lycopene, Beta carotene and Ascorbic Acid content in commercially processed Bush Tomato Ketchup, Bush Tomato Chutney and Kakadu Plum Chilli Sauce

Product	Production run sampling regime	Bioactive Compounds	Quantity mg/100 g	SD
Bush Tomato Ketchup	Start	Lycopene	0.255	± 0.042
	Middle		0.250	± 0.028
	End		0.206	± 0.039
Bush Tomato Ketchup	Start	Beta carotene	0.0052	± 0.0008
	Middle		0.0063	± 0.0003
	End		0.0054	± 0.0008
Bush Tomato Chutney	Start	Lycopene	0.103	± 0.006
	Middle		0.1121	± 0.008
	End		0.125	± 0.013
Bush Tomato Chutney	Start	Beta carotene	0.0012	± 0.0001
	Middle		0.0014	± 0.0002
	End		0.001574	± 0.0003
Kakadu Plum Ginger Chilli Sauce	Start	Ascorbic acid	9.59	±1.06
	Mid		10.38	±6.50
	End		12.02	±2.74

4.2.3 Discussion

The lycopene and beta carotene contents in bush tomato products were relatively stable through the processing. However, the Kakadu plum sauce showed a variation in ascorbic acid content.

The finished samples were collected at the processing line in three interval times, beginning, middle and the end of the run. It was found that in the bush tomato sauce and ketchup the lycopene and beta carotene content were stable throughout the processing run. However, a variation in ascorbic acid content occurred during the processing of Kakadu plum chilli sauce which might be explained by variations in temperature through out the process.

Gahler *et al.* (2003) studied the alteration of vitamin C, total phenolic and antioxidant capacity during the processing of tomatoes. They found a reduction of ascorbic acid content during the thermal processing of tomatoes. Nonetheless, the total phenolics concentration and water soluble antioxidant capacity increased which could be possibly explained by the liberation of phenolics from the matrix.

4.3 Evaluation of the stability of bioactive compounds under controlled laboratory conditions

4.3.1 Materials and Methods

Formulated bush tomato sauce

Because of the confidential nature of the commercial formulations the laboratory scale samples were formulated using the ingredient lists, analysis and product specifications of each product as a guide. The percentage of ground bush tomato was doubled to ensure that there would be enough lycopene detected after processing. Flavouring ingredients were not incorporated into the formulations as the processing and formulation parameters of interest related to pH and holding and filling temperatures. The major ingredients were water, thickener, food acids and the ground bush tomato. The formulation was balanced to a pH range of 3.5-4.0. The product was brought to 80°C, hot filled into six jars and inverted to sterilise the inside of the lid. The jars were then left to cool at ambient temperature and then the bioactive content analysed.

The lycopene and beta-carotene contents were measured as previously described.



Figure 14. Bush Tomato Sauce

4.3.2 Results

Table 5. Analysis of laboratory scale product

Bioactive compounds	Dried Bush Tomato	Lab scale Sauce containing 16% dried bush tomato w/w	% change during the process
Lycopene (mg/100 g)	0.0033±0.0005	0.0011±0.0002	(+) 47.83%
beta-carotene content (mg/100 g)	0.0031±0.0003	0.0037 ±3.9 x10 ⁻⁵	(+) 13.40%

The lycopene and beta carotene content in the dried, ground bush tomato was compared with the laboratory produced sample containing 16% of dried bush tomato. It was found that the bioactive content increased by 48% and 13% in lycopene and beta carotene respectively.

4.3.3 Discussion

Shi and Le Maguer (2000) demonstrated that lycopene is able to undergo at least two changes during tomato processing: isomerization and oxidation. Thus, the increase in lycopene content may be explained by isomerization. The *trans*-isomer of lycopene is mostly found in dietary sources such as fresh tomato.

Thomas *et al.*, (2002) suggested that *cis*-isomers of lycopene are more easily absorbed by the human gastro intestinal system than the *trans* conformation, because of its short length and a good solubility.

The isomerisation of *all-trans* lycopene to *cis* isomers is a result of heat in food processing and cooking methods. The formation of lycopene *cis* isomers is successfully induced by excessive thermal exposure for example, high temperature heating of pureed tomato at 200°C for a couple seconds to remove moisture rapidly, increased the level of *cis* isomers from 4.2% to 19.1% (Nguyen and Schwartz, 1989). Thus, it is possible that the same chemical alteration may be happening in the bush tomato and that the increase in lycopene content is due to isomerisation.

However, Thomas *et al.* (2002) suggested that thermal treatment and processing result in only a small increase in *cis*- isomers. Therefore, it is likely that other factors are also responsible for an increase in lycopene content.

Shi and Le Maguer (2000) indicated that composition and structure may affect the release of lycopene from the tomato tissue matrix. Chopping, homogenisation and cooking could increase the bioavailability of lycopene by mechanically disrupting or softening plant cell walls and weakening the links between lycopene and the tissue. This has been suggested as the reason why there is greater bioavailability of lycopene in cooked tomato products over fresh tomato (Shi and Le Maguer, 2000).

4.3 Conclusion

The processing of acidic food such as ketchup, tomato and plum sauce involves a mild heat process. This study demonstrated that during the processing, lycopene and beta carotene contents were stable. However, the ascorbic acid content of Kakadu plum sauce varied.

The bioactive content of bush tomato before and after heating process has been compared using laboratory scale processed sauce. An increase in the amount of both lycopene and beta carotene was found. This may be explained by isomerization and/or release of lycopene from the food matrix.

4.5 Recommendations

For acidic foods like tomato sauce and ketchup, pasteurisation by a water spray unit is strongly recommended because it provides a high quality product and much better control (Ennen, 2001). The use of HTST processing might also be a more suitable alternative to maximise the retention of bioactives, as it reduces the time product spends at high temperatures for sterilisation. It is however, more costly in terms of processing and packaging required.

Chapter 5 Evaluation of Bioactive Compounds during Storage

5.0 Introduction

Shelf life, the time it takes for a product to become unacceptable to consumers, is a critical issue often overlooked or treated lightly in even mainstream retail products. After native plant products are manufactured, the finished goods are stored and distributed to retail stores. Before consumers purchase the products from supermarket shelves, the environment in which the products are stored affect the survival of bioactive compounds. The environmental conditions of interest are: temperature, light and time.

5.1 Objectives

To set up a storage trial to evaluate the effect of different storage conditions (temperature and light) on the stability of bioactive components in two commercial products: bush tomato ketchup (8% dried bush tomato) and bush tomato chutney (8% dried bush tomato).

5.2 Materials and Methods

5.2.1 Sample collection

The processed samples, bush tomato ketchup and bush tomato chutney were collected from Robins Foods (Braeside, Melbourne). For each of the two products, 60 jars were randomly collected, packed and sent to the laboratory for the trial.

a) Bush tomato ketchup (BTK)



Packing volume: 250 ml/ 8.5 fl oz

Ingredients: tomatoes, apples, cane sugar, bush tomatoes (8%), onion, vinegar, chilli, salt, garlic, mountain pepper, spices, vegetable gum

b) Bush tomato chutney (BTC)



Packing volume: 285 gm/9.98 oz

Ingredients: tomatoes, apple, cane, sugar, onion, bush tomatoes (8%), onion, vinegar, chilli, salt, spices.

5.2.2 Storage temperature regimes

Control (4°C)

Six cartons of each product, each containing 6 jars, were kept in the cold room at <math><4^{\circ}\text{C}</math>. Two jars were randomly selected from any of the cartons to analyse the bioactive content at 0.5, 1, 2 and 3 months and then at 3 monthly periods thereafter for 18 months, as shown in Table 6.

Low ambient (20°C)

For the dark conditions, 6 cartons of each product, each containing 6 jars, were kept in an incubator with the temperature set at 20°C. Two jars were randomly selected from any of the cartons to analyse the bioactive content at 0.5, 1, 2 and 3 months and then at 3 monthly intervals thereafter for 18 months, as shown in Table 6. For the light conditions, a fluorescent light illuminated the samples in the 20°C room for the entire experiment. The samples to be subjected to dark conditions were kept sealed within the cartons, whereas the samples to be subjected to light conditions were stored outside of the cartons (see Figures 17 and 18).

High ambient 27°C

Two cartons of each product were kept in an incubator with the temperature set at 30°C. Two jars were randomly selected from any carton to analyse the bioactive content after they have been stored for 3, 6 and 9 months.

Accelerated (37°C)

Two cartons of each product were kept in an incubator with the temperature set at 37°C. Two jars were randomly selected from any carton to analyse the bioactive content at 1, 2 and 3 months and then at 3 monthly intervals thereafter, as shown in Table 6.

Table 6. Storage trial sampling schedule over 9 months

Month(s)	Control	Ambient temperature 20°C		27°C	37°C
		Light	Dark	Dark	
0	*	*	*		*
0.5	*	*	*		
1	*	*	*		*
2	*	*	*		*
3	*	*	*	*	*
4					
5					
6	*	*	*	*	*
7					
8					
9	*	*	*	*	*



Figure 15. The 20°C dark storage conditions



Figure 16. The 20°C light storage conditions

5.2.3 Analysis of bioactive components

Since the products had tomato as the base ingredient together with bush tomatoes, lycopene was measured as described in Chapter 4.

5.2.4 Other analyses

Total soluble solids

The total soluble solids was measured at the start of the storage trial using a digital refractometer.

pH and titratable acidity

The titratable acidity of each product was determined by titration with NaOH (0.1M) as the presence of the major acid in the product, that is, the percentage citric acid in the wild lime products and the percentage acetic acid in the bush tomato products. These measurements were made at the start of the storage trial only.

Microbiological measurements

Total plate count

Total microbial counts were carried out aerobically on total plate count agar. The dilutions of each sample in peptone water, 10^0 , 10^{-1} and 10^{-2} , were plated out and overlaid with agar. Bacterial colonies were counted after 72 hours of incubation at 30°C.

Yeasts and moulds

One ml of each sample was spread onto MYC agar which contains nutrients supplemented with antibiotics, a cold-soluble gelling agent and a dye to enhance the visualization of growth on the plate. The colonies were counted after incubation at 30°C for 48 hours. The microbial analyses were carried out at the start of the storage trial to ensure that viable product was being used in the trial.

Sensory

Sensory testing

Observational sensory testing was carried out at the same frequency as the chemical analyses listed in Table 6. Three panellists were given three samples, one labelled as the reference (control temperature) sample, and asked “which of the two samples is the same as the reference”. In this manner, a sample from each storage temperature was compared to the control to determine whether the control sample could be differentiated from the other storage temperatures. Differences in flavour and colour were noted.

Appearance

The appearance of the three products was evaluated prior to storage.

Colour

The change in colour at the start and end of the storage trial was determined from tri-stimulus L^* , a^* , b^* measurements taken using a Hunter colorimeter. The sample was poured into a glass petri dish and overlaid with a glass lid, making sure that no bubbles were present on the sample surface. Colour measurements were made at 3 different positions, including centre and outer areas, on the surface of the sample and the measurements averaged.

5.3 Results and Discussion

5.3.1 Storage trial

a) Measurement of bioactive components

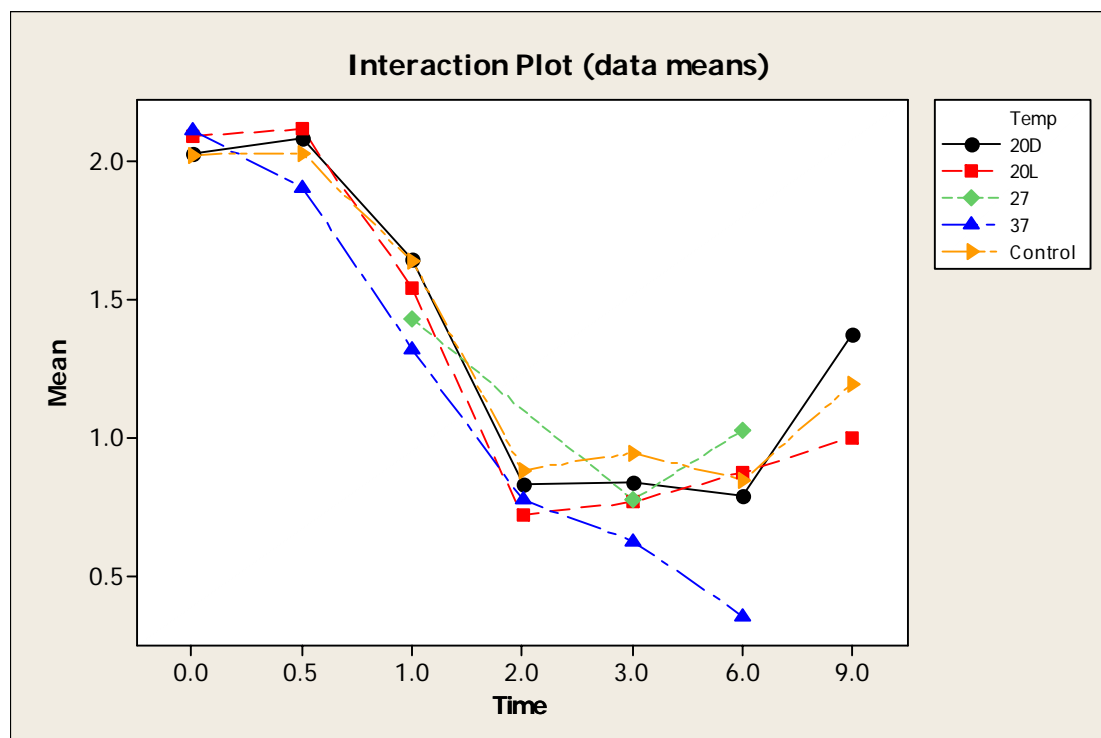


Figure 17. Amount of lycopene (mean for average mg/100 g) in bush tomato chutney during 9 months storage

Table 7. Amount of Lycopene (mean for average mg/100 g) in bush tomato chutney

Conditions	Control	20 (Light) °C	20 (Dark) °C	27 °C	37 °C
0	2.019	2.089	2.0240	-	2.108
0.5	2.026	2.113 ^s	2.0777	-	1.900 ^s
1	1.633	1.538	1.6412	1.429	1.318 ^s
2	0.881	0.719 ^s	0.8334 ^s	-	0.775 ^s
3	0.942	0.766	0.8370 ^s	0.774 ^s	0.625 ^s
6	0.844	0.874	0.7883	1.023	0.352 ^s
9	1.192	0.998	1.3693	-	-

* Values are mean (n=2) for average (n=2)

** Values with a superscript "s" are significantly different to the control (p<0.05)

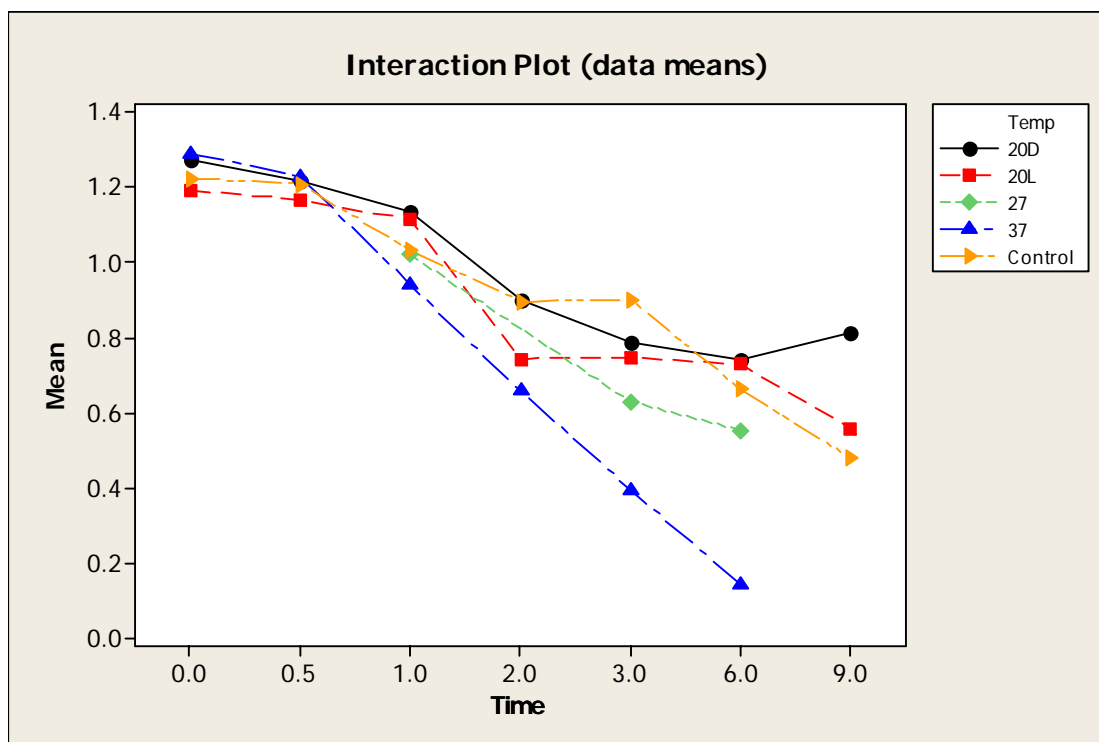


Figure 18. Amount of lycopene (mean for average mg/100 g) in bush tomato ketchup during 9 months storage

Table 8. Amount of lycopene (mean for average mg/100 g) in bush tomato ketchup

Conditions Time	Temp				
	Control	20 (Light) °C	20 (Dark) °C	27 °C	37 °C
0	1.224	1.191	1.273		1.292
0.5	1.210	1.168	1.219		1.229
1	1.033	1.115	1.136	1.021s	0.941s
2	0.896	0.743s	0.900		0.657s
3	0.901	0.748	0.789	0.628s	0.394s
6	0.663	0.729	0.739	0.554	0.142s
9	0.479	0.557	0.813s		

* Values are mean (n=2) for average (n=2)

** Values with a superscript "s" are significantly different to the control (p<0.05)

The initial lycopene values in the products were quite low. The actual percentage of tomato in the two products was not known only the percentage of bush tomato. Lycopene values for fresh tomatoes have been reported as 3.10-7.74 mg/100 g and for tomato ketchup as 16.60 mg/100 g (USDA, 1998). This is for a US style product.

Figures 17 and 18 showed a decreasing amount of lycopene in bush tomato ketchup and chutney during a period of 9 months. In both products about half of the lycopene was lost in the first 2 months of storage. In the bush tomato chutney the level of loss of lycopene had plateaued by 2 months storage except for the 37°C storage temperature which was still declining. At 6 months storage the level of lycopene had declined by about 84%. In the bush tomato ketchup the level of lycopene continued to decline steadily. In the sample stored at 37°C the level of lycopene had declined by 90% at 6 months storage.

There was a significant effect ($p < 0.05$) of temperature on the retention of lycopene in both products. The samples stored at 37°C were significantly different ($p < 0.05$) to the control after 1 month storage. Lycopene content is fairly sensitive to high temperature (Sharma and Le Maguer, 1996a,b; Fish and Davis, 2003 and Shi *et al.*, 2003). Lycopene can undergo two changes during heat treatment; decrease in total lycopene and an increase in *cis*-isomer level. However in those studies, the *cis*-isomer level increased only during an initial heating and dramatically decreased thereafter.

The results also showed that light does not have much influence on lycopene degradation (only 0.5 and 2 month BTC and 2 month BTK were significantly different ($p < 0.05$) to the controls). However, the study of Shi *et al.* (2003) showed that when tomato puree was subjected to different radiation, the loss in total lycopene increased significantly as the intensity and time of light irradiation increased. In the current study, the light conditions in which the samples were stored did not show a consequential effect on the lycopene content. However there could be an effect at higher light intensities.

5.3.2 Physical measurements and sensory assessment

Sensory testing showed that the test panel could tell the difference in the samples after they were kept for 3 months. This was an assessment only because of the small number of panellists and consequently not statistically significant.

There was a correlation between sensory evaluation and colour measurement of the products. Figure 19 shows the over all colour difference (ΔE) of the products. As the size of the measured colour difference became bigger the test panel was able to detect the difference when the value approached 1 at time three months. Heating may bring a major change in colour. Firstly, it leads to the development of browning colour and the formation of volatiles in high sugar contained products. Secondly, *cis* isomers of lycopene which are induced by thermal processing show a less red colour than natural all *trans*-lycopene (Belitz and Grosh, 1999, Shi Le Maguer, 2000 and Sukan and Russell, 2002). Therefore, increased temperature during the storage trial was more likely to induce a colour change in the samples.

Another factor is the degradation of lycopene and β -carotene which are the major source of the red colour in tomato and tomato product. These compounds are sensitive to heat, light and the presence of oxygen. Sharma *et al.* (1996a) found that when concentrating tomato pulp during heating some loss of lycopene content occurred. The same work also indicated that when fibre-rich fraction sample of tomato pulp were stored under three different conditions (vacuum and dark and dark and air, and air and light) at -20, 5 and 25°C for 60 days, the lycopene loss was maximum in the presence of air and light at 25°C. Thus, in the current study, samples stored at 37°C or at 20°C in the presence of light showed more differences to the control than the samples stored at 20°C in the dark.

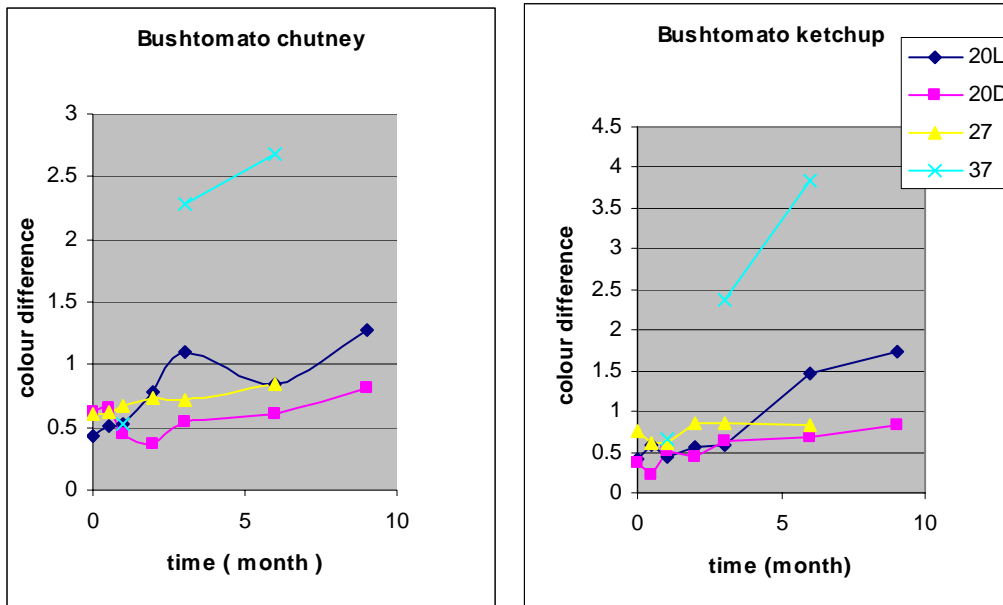


Figure 19. The colour different value (ΔE) of the products over 9 months

The results for the microbiological test, total solids, pH and total titratable acidity are shown in Table 9.

The microbiological results showed that the heating used in processing the products had been adequate in destroying bacteria in the products. In term of using commercial sterilization, any surviving spores or microorganisms are no longer capable of growth (Hayes, 1992). Heat treatment necessary for retail products is determined to a considerable extent by pH of the food. High acid food or the food $\text{pH} < 4.5$ can be heated with mild heat treatment since the microorganisms that grow in relatively low pH are heat sensitive. In low acid tomato products like canned tomatoes, and tomato juice, heating at correct retort temperatures is normal practice since thermophiles such as *B. coagulans*, *A. hermophilic* and *Clostridia* a gas producing organisms are heat labile.

Tomato ketchup can undergo fermentation due to the contamination of lactic acid bacteria such as *Lactobacillus brevis*.

There are only two type of yeasts and moulds that could possibly cause spoilage: *Byssoschlamys fulva* and *B. nivea*. However, heating at 85°C for more than 30 minutes can destroy them (Hayes, 1992). The bush tomato products are considered high acid food $\text{pH} < 4.0$. No bacterial colonies were detected in the products indicating that there was an adequate heating treatment throughout the process. However, yeast and moulds were found in bush tomato ketchup. As mentioned, *B. fulva* and *B. nivea* are two species which cause serious spoilage. However the bush tomato products were heated at 95°C for 30-40 minutes which destroys these organisms. As a result, the amount of yeasts and moulds found in the bush tomato products were not likely to be a serious problem.

Table 9. Microbiological test, total solids, pH and total titratable acidity of the products at time zero

Sample	Time (months)	Storage temp	Storage conditions	Rep	Total Plate Count (per gram)	Yeast and moulds (per gram)	TSS (°Brix)	pH	Titratable acidity (% acetic acid)
Bush tomato chutney Date of Manufacture: March 2004	0	Control	Dark	A	0	< 10	> 41.0	3.63	0.76
	0	Control	Dark	B	0	< 10	> 41.0	3.62	0.71
	0	20°C	Light	A	0	< 10	> 41.0	3.64	0.71
	0	20°C	Light	B	1	< 10	> 41.0	3.61	0.74
	0	20°C	Dark	A	0	< 10	> 41.0	3.60	0.73
	0	20°C	Dark	B	0	< 10	> 41.0	3.60	0.74
	0	37°C	Dark	A	0	75 EST	> 41.0	3.61	0.73
	0	37°C	Dark	B	0	< 10	> 41.0	3.61	0.74
Bush tomato ketchup Date of Manufacture: April 2004	0	Control	Dark	A	0	40 EST	22.4	3.60	1.04
	0	Control	Dark	B	0	10 EST	22.6	3.62	0.95
	0	20°C	Light	A	0	10 EST	21.4	3.60	0.97
	0	20°C	Light	B	0	25 EST	24	3.60	1.01
	0	20°C	Dark	A	0	< 10	20.7	3.60	0.96
	0	20°C	Dark	B	0	< 10	24	3.60	0.99
	0	37°C	Dark	A	0	25 EST	23.1	3.61	0.99
	0	37°C	Dark	B	0	25 EST	23	3.61	0.98

5.3 Conclusion

Initially the purpose of this part of the project was to tag the bioactive compounds in the raw material through the supply chain from harvest to final manufactured product to identify where in the supply chain, special care might need to be taken, to minimise shelf life limiting factors. This was to provide more information to assist suppliers and end users work together to optimise supply chain conditions for better retention of the bioactive compounds investigated.

However, as explained in previous chapters the lack of consistency in supply due to external factors beyond the control of this project in terms of raw material availability, consistency of supply and finished product sample collection due to contract manufacturing commercial contingencies made this a objective difficult to meet.

The trial however was able to run a shelf life trial to compare real time manufactured product with formulations made up under controlled conditions in the laboratory to provide an initial guide to changes in the bioactive compounds over time. It is concluded that the results from this trial would need to be repeated using raw material tagged from harvest to incorporation in final product to substantiate these preliminary results.

Implications for hand harvested native food products

It is recognised that as only small percentages of native food ingredients are used in current manufactured products, making conclusions about the integrity of bioactive components through the supply chain difficult to draw with any certainty. Until larger quantities of ingredients are incorporated into end products it will be difficult to identify the potential of native food ingredients to build a functional food marketing platform for retail products.

The issue of raw material traceability needs to be addressed urgently. It is well understood the impact that seasonality has on the availability of quality and volume required by commercial manufacturers. However, the need to store product from one season to another to ensure continuous supply needs to be managed carefully as product recalls are expensive for everyone concerned when ingredient quality and safety is called into question

In 2002 when the concept for this project was discussed with the industry partner, the bush tomato harvest in central Australia had exceeded all expectations. By 2003, however, the reduced rainfall before the critical flowering period meant that fewer bush tomato plants were fruiting and stock from 2002 was used to subsidise this lower volume. By 2004 the volume of bush tomato had fallen away and stored product from the previous two seasons was being drawn upon to meet manufacture's orders for retail and export markets. This had a significant impact on this project as it was impossible to identify with certainty batches of bush tomato from harvest to manufacture in one season. This also made it difficult to repeat trials to measure the effects of post harvest activities on the bioactive components from hand harvest to final product in the one season. This information is critical for developing specifications for the post harvest material in the future.

It would be fair to say that the major players we interviewed and worked with during the project, are more than aware that improvements to processes and practice need to be addressed urgently, and they seem to be working towards this end. It also became apparent that it is difficult for the ingredient suppliers to manage the technical aspects of developing their specifications in isolation from manufacturers and retailers, with limited resources and understanding of technical requirements down stream. An improved integrated approach needs to be developed, so that outcomes are met for everyone in the supply chain.

Recommendations

Activities or other steps that may be taken to further develop, disseminate or to exploit commercially the results of the Project include:

1. Implement a Quality Assurance program to leverage export of opportunities to include:
 - a) Correct botanical identification of raw material (in consultation with indigenous harvesters)
 - b) Identification of optimum storage conditions and packaging to ensure product integrity throughout the distribution chain (from collection points in the indigenous communities)
 - c) Batch numbering system and analysis from point of harvest that is maintained throughout the supply chain
 - d) Identification of optimum conditions for pre processing activities such as milling and drying
 - e) Ingredient material specifications for quality and safety to raise confidence in the market place
 - f) Receiving processes to ensure manufacturers handle and store the ingredients correctly to prevent contamination and deterioration of ingredients prior to processing.
2. Investigate the impact of raw material variation on the bioactive components and start to select native fruits for optimum levels of antioxidants.
3. Investigate the potential use of these bioactive compounds as natural sources of antioxidants to use in the maintenance or extension of shelf life in processed food products, particularly minimally processed foods where shelf life is critical in consumer acceptance of products.
4. Investigate other potential native plant sources of antioxidants that may be more easily sourced/grown, harvested and marketed.

Appendix 1. Food Safety Standards

In accordance with the food safety standard, Standard 3.1.1 of the Australia New Zealand Food Standards Code, the meaning of safe and suitable food is as follows:

1. For the purpose of the food safety standards, food is not safe if it would be likely to cause physical harm to a person who might later consume it, assuming it was:
 - (a) after that time and before being consumed by the person, properly subjected to all processes (if any) that are relevant to its reasonable intended use; and
 - (b) consumed by the person according to its reasonable intended use.
2. However, food is not unsafe merely because its inherent nutritional or chemical properties cause, or its inherent nature causes, adverse reactions only in persons with allergies or sensitivities that are not common to the majority of persons.
3. In subsection (1), processes include processes involving storage and preparation.
4. For the purposes of the food standards, food is not suitable if it:
 - (a) is damaged, deteriorated or perished to an extent that affects its reasonable intended use, or
 - (b) contains any damaged, deteriorated or perished substance that affects its reasonable intended use, or
 - (c) is the product of a diseased animal or an animal that has died otherwise than slaughter and not been declared by or under another Act to be safe for human consumption, or
 - (d) contains a biological or chemical reagent, or other matter or substance, that is foreign to the nature of the food.
5. However, food is not suitable for the purposes of the food safety standards merely because:
 - (a) It contains an agricultural or veterinary chemical in an amount that does not contravene the Food Standards Code, or
 - (b) It contains a metal or non-metal contaminant (within the meaning of the Food Standard Code) in an amount that does not contravene the permitted level for the contaminant as specified in the Food Standards Code, or
 - (c) It contains any matter or substance that is permitted by Food Standards Code.

As a result of the definition of a potentially hazardous food, given by Australia New Zealand Standards Code, which potentially concerns food safety, food has to be kept at certain temperatures to minimise the growth of any pathogenic micro-organisms that may be present in the food or to prevent the formation of toxins in the food.

Food safety of food handling (commercial bush food products)

Handling is defined in the Food safety standard, Standard 3.2.1 of the Australia New Zealand Food Standards Code as the making, manufacturing, producing, collecting, extracting, processing, storing, transporting, delivering, preparing, treating, preserving, packing, cooking, thawing, serving or displaying of food.

To ensure that food does not become unsafe or unsuitable, Standard 3.2.2, Food safety practices and General requirements, in the Australia New Zealand Food Standards Code, has been established. The standard sets out process control requirements to be satisfied at every step of the food handling process. Some requirements refer to the receipt, storage, processing, display, packaging, distribution, disposal and recall of food. Other requirements relate to the skills and knowledge of food handlers and their supervisors, the health and hygiene of food handlers, and cleaning, sanitising and maintenance of premises and equipment. The key provisions of the standard can be summarized as follows:

Notification

Contact details and information on the nature of the business must be given to the local enforcement agency, unless this information is provided already under an existing food business registration system. If there are any changes, the food business must notify to enforcement agency of the proposal before the change occurs.

Skills and knowledge

Food businesses must make sure that people who carry out or supervise the handling of food have appropriate skills and knowledge in food safety and food hygiene matters. Formal training is not necessarily required. Food handlers can also acquire skills and knowledge through, for example, 'in-house' training, reading information provided by their employer, following specified operating procedures, or attending courses run by industry associations or a local council.

Maintaining potentially hazardous food at correct temperatures

To limit the growth of food poisoning bacteria in food, businesses must minimise the amount of time that potentially hazardous food is at temperatures between 5°C and 60° C. Temperature controls also apply to the receipt, storage, processing, display and transport of potentially hazardous food.

Cooking or another processing step to make food safe

Where food must be cooked or otherwise processed to make it safe, food businesses must carry out this step correctly. For example, minced meat and chickens must be cooked through to kill food poisoning bacteria.

Protecting food from contamination

Food must be protected from contamination. There are also specific requirements for the protection of ready-to-eat food that is on display. These include supervision of the display area, separate serving utensils for each food, and protective barriers.

Food disposal

Food that has been recalled or returned or that may not be safe or suitable must be labelled and kept separate from other food until a decision is made about what to do with the food, in accordance with food disposal requirements.

Food recall

Wholesale suppliers, manufacturers and importers of food must have a written recall system for the recall of unsafe food and must use this system when recalling unsafe food.

Health and hygiene requirements

Food businesses must:

- tell food handlers about their health and hygiene responsibilities;
- make sure that people who have or are carrying a disease that might be passed on through food do not contaminate food. Hepatitis A and illnesses caused by giardia, *Salmonella* and *Campylobacter* are examples of diseases that can be passed on through food;
- make sure that a food handler with infected skin lesions or discharges from his/her ears, nose or eyes does not contaminate food;
- provide adequate hand washing facilities and make sure that they are used only for washing hands, arms and faces; and
- make sure that people on the premises do not contaminate food.

Cleaning, sanitising and maintenance

- Food contact surfaces must be cleaned and sanitised to keep micro-organisms at safe levels. This applies to food serving equipment such as plates and cutlery, and to any equipment or surfaces that may come into contact with food.
- Food premises, fittings and equipment within the premises must be clean and in a good state of repair and working order.

- Chipped, cracked or broken utensils must not be used.

Thermometers

Food business handling potentially hazardous food must have a probe thermometer accurate to $\pm 1^{\circ}\text{C}$ so they can measure the temperature of food.

Animals and pests

Premises must be kept free of animals and pests.

Source: www.foodstandards.gov.au

One of the increasing prominences of the food safety of plant foods is the need to have a full understanding of the toxins that are or could be associated with plant bush foods. This will allow more informed selection of plants and assist in marketing to export market which has already been successful in terms of traditional plant-based products (Hegarty *et al.*, 2001).

The toxicological examination of Australian bush plants and chemical analyses were carried out to determine the presence/absence and/or concentration of some compounds with known toxic properties. Hegarty *et al.* (2001) described the possible causes of adverse effects from plant-derived foods:

- Chewing, eating or misuse of some part of the plant
- Allergic reactions and adverse effects from skin or eye contact, or inhalation of irritant substances
- Biological contamination (e.g. bacteria such as *E. coli*, or fungal pathogens such as aflatoxin in stored seeds and flour)
- Mistakes in identification, including the use of mixtures of species, some of which may have toxic properties (e.g. some *Solanum* species which closely resemble edible species)
- Chemical pollutants (e.g. pesticides, herbicides and heavy metals)

Plants are composed of two main forms of compounds. The primary compounds such as protein, carbohydrates and fat are the plant's essential structures which are involved in its translocation, storage and respiratory system. The secondary compounds have many other functions, some of which have yet to be determined. One of the functions is the protection of the plants themselves from herbivores which are known as anti-nutritional compounds. Tannin, for example, is bitter-tasting and also binds to and hinders absorption of nutritive compounds. Some of the secondary compounds are detailed below.

Cyanogenic glucoside (cyanogens, cyanogenic glycoside)

Cyanogenic glucosides are found in wild plants which are attractive to animals and insect herbivores such as wheat, maize, oats, peanut and cassava (Hegarty *et al.*, 2001). The toxin, hydrogen cyanide, is released when the plant tissue is damaged, for example damage of the cell wall by chewing, grinding, cooking and freezing. Also, the decomposition of the compound be glucoside can release toxic gas. Humans can consume small amount of cyanic acid (30-35 mg per day), but twice this amount is lethal for a 70 kg human. The way to minimise the amount of cyanide is to damage the cell wall of the plants and release the free cyanide harmlessly to the air.

Compound of essential oils

Although essential oils are important for use as flavourants and aromatics in food and beverages, perfumes, and cosmetics, only very few components are permitted as additives for use in foods in small quantities. In such cases the restriction is usually because of the suspected association with carcinogenesis as a result of metabolic processes after absorption. Only small amounts are permitted in common food and spices (Hegarty *et al.*, 2001).

Lectins

Lectins are found in the active form in the mature seeds, tubers and sap of many common food plants, particularly the legume family. Lectins can damage the walls of red blood cells, and induce clumping.

They are not very readily absorbed in the digestive tract, but can in some cases damage its cell walls and interfere with nutrient uptake and growth. However, lectins are deteriorated by cooking (Hegarty *et al.*, 2001).

Oxalate

Oxalates are present in the form of soluble salts (potassium or sodium oxalate or the insoluble form, calcium oxalate). They can be found within the cells or between the cells of rhubarb, spinach and unripe tomatoes, which contain a high level of oxalates. Calcium oxalates are excreted in the urine in the form of small, insoluble calcium oxalate crystals. However, high consumption can lead to the accumulation of calcium within the urinary tract and a reduction in the availability of dietary calcium.

Trypsin inhibitors

Trypsin inhibitors are proteins which inhibit the action of the digestive enzyme trypsin, which is unable to break down and release amino acids to the body. Trypsin inhibitors can be found in legume seeds and can be inactivated by heating.

Chemical and/or mechanical and allergenic irritants

The sensitive tissues of the human body (e.g. eyes, lips, mouth and throat) may irritate when in contact with the parts of some plants. Inhalation of essential oils should be avoided by covering the nose with a mask. Also, skin and internal tissues can be affected when contact is made directly with the skin.

Allergens in foods are proteins or glycoproteins, with similar molecular weights (4-10-40 kDa). Allergies decrease with age however peanut allergies are seldom outgrown.

Appendix 2. Post harvest and handling questionnaire

1. **Name:** *of relevant native plant*

1.1 Describe the attribute of fruits at the state of maturity. What does the fruits look like? How mature it is?

.....
.....
.....
.....
.....

1.2 Harvesting season (eg. January – March)

.....
.....

1.3 Harvesting time

() Morning () Afternoon () Evening

1.4 Method of harvesting

() Hand harvesting () Machine harvesting () Others (describe)

.....
.....
.....
.....

1.5 Treatment eg (any treatments used prior to transportation?)

1.5.1 Cleaning with Chemicals

() Pesticides () Fungicide () Others (describe) () None

.....
.....
.....

1.5.2 Mechanical treatments

() Cooling () Drying () Freeze drying () Freezing

What temperature? Which methods? (eg. Cooling – Via cool room or water immersion or spraying with cool water)

.....
.....
.....
.....

1.6 Sorting or Grading according to

() Size () Colour () Shape () Conditions

Describe:

.....
.....
.....
.....

1.7 Packing in to:

() Plastic bag () Box

Describe weight per package?:

.....
.....
.....
.....

1.8 Transportations: Type of vehicles?

() refrigerated () cooled () None

.....
.....
.....
.....

1.9 Storage

() Refrigerated () Frozen

.....
.....
.....
.....

Appendix 3. Process flow chart for production of acid pasteurised products

Processing

Weighing of ingredients (excess bush tomato stored in cool room)



Mixing of all ingredients in tank



Transfer to holding tank and hold at 95°C for 30-40 min



Hot filling into jars or bottles at 95°C



Or Pasteurise filled jars in tunnel using steam, 95°C for 20 min↓



Cooling in tunnel using cold water, 20 min (product cold at end of tunnel)

Packaging

Pack in jars or bottles

Transportation

Transport for local or export market

Product Recall

The use of code system for recalling of unsafe food

Food disposal

Food disposal is kept away from operating unit

Recommendations

Ensure that the time for heating is enough to achieve the microbiological safety of food. Total solids checked to ensure that the sauce is in standard

Monitor product if run is stopped and product held for longer than this time

Comments

Ensure that packing material is fit for its intended use, only use material which is not likely to cause food contamination.

The food needs to be cooled from 60°C to 21°C within 2 hours

The packing area is clean so that food is not contaminated during packing process.

Comments

Ensure that the products are protected from the likelihood of contamination.

The transport vehicles should be inspected before products are loaded. The inspection should cover the sanitary condition and the vehicle's accessories e.g. floor, walls and temperature control (Alli, 2004)

During delivery, the temperature should meet the requirements and should be recorded. Lock and seal containers should be maintained throughout transporting. The system needs to be recorded and explained to the an authorised officer

Comments

Comments

Glossary

Bioactive:

Functional Food:

Anti nutritive compounds: either act as toxins or inhibit the uptake of other nutrients from the gastro intestinal tract

Isomerisation

Sodium Metabisulphite: an approved food additive used to prevent non enzymic browning reactions in dried fruits and regulated by the Food Standards Code.

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