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Food Safety of Australian Plant Bushfoods

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Foreword

Australia has been successful in the marketing of a range of traditional native plant-based foods. However, with increasing emphasis around the world on food safety there is a need to have a greater understanding of the anti-nutritive factors that are, or could be, associated with plant bushfoods to allow more informed selection of plants and assist in marketing to export markets.

The aim of the study was to provide information on the food safety of the emerging bushfood industry with a written report which will assist the industry to promote an image of safety for its products, many of which are new on the market and therefore unfamiliar to potential clients.

This report details a project that critically examined existing botanical, chemical and toxicological information on the current major commercial bushfoods as well as their history of use in traditional Aboriginal cultures. Information is also included on several additional species which have considerable commercial potential. Based on this assessment, chemical analyses were carried out on a range of bushfood samples provided by the industry, to determine the presence/absence and/or concentration of some of classes of compound or individual compounds with some toxic properties.

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

This report, a new addition to RIRDC's diverse range of over 600 research publications, forms part of our New Plant Products and Native Plants R&D programs, which aim to support development of a profitable and environmentally sustainable plant-based Australian bushfood industry that is founded on an international reputation for the reliable supply of consistently safe and high quality food.

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About the Authors

Dr Merv Hegarty AM is a research chemist, specialising in the potentially toxic components of native Australian and other plant species. He has studied the chemistry of pasture species at CSIRO in Brisbane since 1952, and has continued in retirement as an honorary Research Fellow. Dr Elwyn Hegarty is a botanist, specialising in Australian native plants, especially rainforest trees and vines. Their consulting company, Plantchem Pty Ltd, undertakes research into the safe commercial use of native and other crop plants for foods, beverages and pharmaceuticals.

Professor Ron Wills has over 30 years experience in research on a wide range of raw and processed foods and agricultural commodities with efforts directed towards improving the efficiency of postharvest handling and processing systems, determining commodity and product quality and obtaining more efficient utilisation of crops. He has published 250 refereed research papers and 8 monographs including a 4th edition book on postharvest horticulture which is also published in Spanish, Chinese, Malaysian and Persian.

Acknowledgments

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The success of the analytical program was made possible by the technical skills and persistent dedication of Ms Debbie Shohet from the University of Newcastle.

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Incentives for the study

Confidence in safety is a prime consideration when choosing foods, but is often taken for granted when a food is known to have been consumed for many years without evidence of adverse effects. However, most commercial bushfoods are new products, being introduced to a highly competitive market. Potential consumers may have no previous experience of their appearance, taste and potential use, and may possibly not realise that the term "bushfood" in commercial terms does not imply opportunistic wild-harvesting of foods, which had been necessary for survival in traditional cultures. The resulting natural caution, which may limit the market for many unfamiliar bushfood products, might well be reduced by evidence supporting an image of safety, based on an apparent absence to date of reported adverse effects or harmful constituents. However, absence of such reports cannot be taken as a complete guarantee of safety, because many of the hundreds of compounds that may be present in any single plant are as yet unreported, and the degree of potential toxicity of a particular compound may vary with other factors, such as quantity consumed and personal tolerance. Therefore it is always easier to claim that a particular food may not be safe than that is it harmless.

In 1996, during the formative stages of the modern bushfood industry, a conference involving many of the principals of bushfood companies, private growers and representatives of Aboriginal communities was held in Brisbane. Information in the form of Conference Notes was provided, and the outcomes were summarised in RIRDC Research Paper 97/22: "Prospects for the Australian Native Bushfood Industry" by Graham & Hart. The paper recorded concerns which had been expressed during that meeting about inadequate information about the chemical constituents and safe use of bushfoods, and listed a number of species which at the time were seen as presenting the best commercial opportunities. The present report was commissioned in order to overcome the difficulty of obtaining scientific information about bushfoods, which might support their assumed individual safety for use, or as an alternative indicate any needs for caution due to possible adverse effects.

Traditional vs modern uses of bushfoods

In Australian traditional cultures, with food-gathering an important and time-consuming part of everyday life, seeds, fruits and other plant products of high nutritional value were especially valued. Modern clients of the bushfood industry, whose nutritional needs are more readily satisfied, tend to seek novel foods of attractive – even unique – appearance, flavour and aroma, and to use them in dishes which may contain several other ingredients. So bushfoods, as used in modern cuisine, do not always reflect traditional uses. On the other hand, foods such as cycad seeds and yams, which Aboriginal people consumed only after extensive and necessary detoxification processes, and other important foods, such as plant gums and tubers, have rarely been of interest to the commercial industry. In addition, Aboriginal uses of a large number of plant species for medicinal and other personal, but non-food, purposes cannot be taken as an indication that they may be suitable in any way for food use. Rather, medicinal use is likely to be an indication of the presence of bioactive compounds which may be undesirable in foods. The larger bushfood producers tend to base their inventories on a few well-recognised native fruits and seeds which have a history of safe use as Aboriginal foods, or which have attractively aromatic or spicy leaves, while ignoring important Aboriginal foods from other parts of plants, such as tubers, gummy or sugary plant exudates, and associated insects.

Review of existing information

This has required continuing searches of the scientific, industry and popular literature for information on the botanical description, chemical composition, and possible toxicity of the major bushfoods, together with wide solicitation of anecdotal reports about adverse effects attributed to the collection, processing and/or consumption of bushfoods. Databases searched included Biological Abstracts, Medline, Food Science and Technology Abstracts, Agricola, Commonwealth Agricultural Bureaux abstracts, Chemical Abstracts, Current Contents and Science Citation Index. Relevant scientific papers, and articles in books and magazines, were located from these abstracts, and where possible the full text was accessed. Bushfood industry newsletters and magazines were regularly consulted. The information obtained is summarised in Section 2

The searches often extended to close relatives of bushfood species, because where information for a particular species is absent or limited, an indication of the general chemical characteristics may be indicated as a basis for further investigations, if required. In addition, chemical information for bushfoods that were not clearly defined by species in the brief, or were not originally listed in it, has been included (Section 2.3) where such a need was suggested by questions from members of the industry, or information in industry publications. A list of bushfood species mentioned in the text is given in Appendix 3. In addition, some of the many better-known plant species which should not be used as bushfood because of possible toxicity are listed in Table 2.1.

It was evident that the largest bodies of chemical information were for the constituents of essential oils - the main basis of flavour and aroma in many bushfoods – and from screenings for the presence of alkaloids, cyanogens and saponins. However, in the vast majority of cases, only non-edible parts of the plants had been tested, and the results cannot be relied on as an indication of the chemistry of the parts which are actually consumed, such as fruits, seeds and nuts.

Samples and chemical tests

Bushfood samples were obtained from a number of wholesalers and producers (acknowledged in Appendix 2.1). Where possible, details of botanical identity and provenance were established and voucher samples retained, but this was not possible for wholesale samples of mixed origin. Because of the large number of species involved, even at the initial stage, a minimum of two samples of each species, from different providers, was sought for comparative purposes. This would provide a broad indication of where further analyses of any species might be required, should any reports of possible toxicity emerge at a future date. Most samples originated from Queensland, New South Wales and South Australia, where the industry is most diversified, but it proved difficult in practice to obtain samples from areas where the product ranges are smaller.

Chemical constituents of plants are often arbitrarily divided into two classes according to function. Those known as *primary* compounds are involved in structural or transport systems and are common to large numbers of plants. *Secondary* compounds are also numerous, and are often peculiar to a limited numbers of plant species. These compounds include those which have defensive functions, may be involved in metabolic and other natural processes (or by-products of these processes) or have functions which are presently unknown. It is the secondary compounds which are most likely to be those with potential for toxicity to humans or other animal or insect species. It cannot be assumed that because a fruit or other bushfood is eaten avidly by birds or other herbivores that it will be equally innocuous to humans, who have somewhat different metabolic systems for dealing with various potentially bioactive constituents of foods. Relatively few of the many known alkaloids in plants have been reported to have toxic properties, while other potentially harmful compounds, including cyanogens, are present in many common foods in small quantities which do not cause adverse effects. They are only likely to be harmful if such foods are consumed in excess, or a person has a particular intolerance to a chemical component of a food.

Screening analyses for the presence/absence and estimated or more exact concentration of secondary compounds including alkaloids, cyanogens, oxalates and saponins were conducted on fresh and frozen samples of the major bushfood species, the types of test being limited in a few cases by the availability of samples. Species tested included acacias, aspens, bunya nuts, myrtles, native citrus, Davidson's plums, hibiscus, muntries, native mints and basils, Illawarra plums, quandongs, bush tomatoes, riberries, native peppers, Kakadu plums and Warrigal greens. Additional tests were conducted in the second year to determine the more important essential oil constituents of a number of commercial bushfoods used for flavouring.

Outcomes of the study

The results of analyses were generally very reassuring, and where previous studies existed, conformed well with those results. New records, for example for the presence of oxalates and saponins and cyanogens, did not exceed values recorded for widely-consumed non-bushfoods. The presence of alkaloids in the native citrus species was similar to that in commercial oranges and lemons, although still among the higher values for bushfoods as tested.

The main potential causes of adverse effects to bushfoods were found to be:

- overindulgence in unripe or very acid fruits, very strong and spicy flavourings, or bushfoods selected and processed without due care. Adverse effects can be exacerbated by other foods or beverages consumed at the same time
- mistakes in identification of source material, as in the case of some *Solanum* species which contain potentially toxic steroidal alkaloids
- failure to appreciate that almost all commercial bushfoods have only been cultivated for a short period, and that their chemical composition may be more variable than that of long-established crop plants
- expectation that foods prepared from native species are safe to eat if there is a recorded history of traditional use, regardless of whether Aboriginal preparation of the food had involved extensive detoxification processes.

The highly variable individual human tolerance of particular constituents of foods. There is at present no reliable method of listing or investigating the cause of unusual reactions that may be attributed to particular bush foods, and any circumstances which might assist to explain or disprove the reports.

The results above are presented with the reservation that though every effort has been made to find information about the safety aspects of bushfood species, much information is unwritten or difficult to access. The previous chemical data about edible parts of native plants are extremely scattered and often lack necessary detail. In addition, the limited number of samples of each species analysed during this study was not able to represent the full range of variation of particular compounds, or classes of compound within those species. For example, the distribution of at least some potentially bioactive compounds, including the less desirable constituents of essential oils within many of the species, is well-known to be highly variable. Continuing analytical studies are already assisting producers to select the most desirable plants for commercial propagation, cultivation and sale.

The study is intended to advise members of the industry of what is currently known about the chemistry of bushfood species and their history of use in traditional communities, as a resource for use for commercial purposes and requirements such as registration under novel foods regulations, as well as to indicate areas where further research is required.

1. Introduction

1.1 The Brief

The authors were asked to

- Review the literature and anecdotal information relevant to the safe use of Australian native plants in commercial foods and beverages. These species include those listed by Graham & Hart in *Prospects for the Australian Native Bushfood Industry* (RIRDC Research paper 97/22).
- Conduct a range of chemical tests on each species, as indicated by an absence of previous information and/or any records of harmful effects from use in foods.
- Advise on safety aspects of the quality management of bushfoods, based on results of the above studies.

The study deals with the inherent chemical characteristics of these bushfoods, rather than other safety issues relevant to quality control, processing and storage, and shelf life, for which suitable HACCP procedures are being developed. Though lists of nutritional values are available for some species, there is still very little information on the nature, identity or potential bioactivity of the very numerous other natural chemical constituents of bushfoods. Therefore, where evidence has been located that Aboriginal people consumed particular modern bushfood species, either as food or for medicinal purposes, references are included in order to facilitate any requirements for registration as novel foods

The results of the study are presented with the qualifications that

(a) The chemical composition of even the plants that are widely used as foods is extremely complex and variable, and includes many classes of compound. In this study, unless there has already been some indication of inherent toxicity in a particular plant or its close relatives, the analyses have been confined to determining the presence/absence of some of the larger classes of compounds which contain some potentially toxic members. Should reports of adverse effects arise in future, the record of these analyses will assist in locating the class of compound to find the potential cause.

(b) It is beyond the scope of this study to investigate any of the naturally high variations in chemical composition within particular bushfood species, which are only slowly being documented. These variations are likely to be much greater in wild-harvested or newly cultivated species than in introduced crops which have been selected, bred and cultivated for use in foods over many centuries.

(c) Where a particular compound in a food plant is potentially harmful, methods of selection and processing, domestic preparation for consumption, and the quantity, frequency of intake and personal tolerance of such a compound will influence the possibility and degree of any adverse effect on health. Many common foods contain very small and evidently harmless, amounts of naturally-occurring compounds which would be considered undesirable, or even toxic, if they were added to (or already present in) foods at higher concentrations.

(d) Although the authors have searched diligently for written or oral reports of any inherent natural toxicity in the species mentioned in this report, and carried out analyses using reliable and well-accepted methods, they cannot wholly exclude the possibility that some unexpected adverse effects may result from consumption of one or more of these bushfoods in particular circumstances and quantities. In addition, the limited number of samples of each species tested cannot be guaranteed as representative of all possible sources of those plant materials. The authors can therefore take no responsibility for actions taken by any persons or organisation on the basis of this report.

1.2 Background to the study

The practical, but unwritten, knowledge which Aboriginal people had accumulated regarding the selection and safe use of the food plants around them was usually neither highly regarded, nor often sought, by early European colonists, who preferred to cultivate their own traditional foods. However, some records of Aboriginal food preferences were eventually included in regional studies of cultural practices, such as Roth (1901-1903). In the latter half of the twentieth century there was an increasing number of reliable, comprehensive reports of Aboriginal uses of Australian plants for food and medicine, some produced by local groups of Aboriginal people and others by academic and government sources (e.g. Smith 1991, Newton Smith 1983; Northern Territory Botanical Bulletins 1976-current; Sola & Gott 1992; Stuart-Fox 1999). At times, interpretation of these reports has been complicated by the local variations in Aboriginal names for similar plants of different species, such as bush tomatoes. Names for species, or groups of species, had often reflected qualities such as their suitability as sources of medicines, rather than the subtle but distinguishing floristic differences which are now the main criteria in botanical classification.

The analytical records of Australian bushfood species to date have been dominated by studies of nutritional composition (e.g. Brand Miller *et al.* 1993, see Appendix 1) and analyses of essential oils or solvent extracts used in flavouring, aromatherapy and industrial processes. Following various published reports of analyses of particular plants and groups of species over many years, there have been broader-based regional chemical screenings. These have mostly been for alkaloids, saponins, or cyanogenic compounds *(e.g.* Webb 1949, 1952; Simes *et al.*1959) or, more recently, to locate bioactive compounds of possible therapeutic value (*e.g.* Collins *et al.* 1990). There are various State-based records of plants which have been reported as toxic to livestock, such as Bailey (1906) McBarron (1977) and Gardner & Bennetts (1956), sometimes with notes on the chemical basis of the toxicity. However, results from the more recent, wide-ranging, commercially-supported and pharmaceutically-oriented screenings for bioactive compounds are rarely presented for public information.

In most cases where analytical data have been widely available, they are usually for only the most readily and continuously available plant parts, such as the leaves, bark and roots. These usually have variously dissimilar chemical composition from fruits. Interpretation of the widely-scattered, older records is complicated by botanical name changes and reclassifications, as well as the frequent reliance on long-dried Herbarium samples, and the slower and less sensitive older analytical methods. There was an evident need to apply modern tests to fresh or frozen samples of edible plant parts now used for commercial foods (Hegarty & Hegarty 1996).

1.3 Possible causes of adverse effects from plant-derived foods

"Major ill effects from (Australian) plants are produced mostly from chewing, eating, misuse or mistaken use of parts" (Francis & Southcott 1967). While some of these reactions are due to the presence of harmful chemical compounds, other possibilities are:

- allergic reactions and adverse effects from skin or eye contact, or inhalation of irritant substances.
- biological contaminants (e.g. bacteria such as *E. coli*, or fungal pathogens such as aflatoxins 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 adjoining edible species)
- chemical pollutants (e.g. pesticides, herbicides and heavy metals).

To complicate the interpretation of anecdotal evidence of toxicity, an unfamiliar food such as a bushfood is often blamed for illness following its consumption, despite other possibilities such as an infection. A Dutch study found that natural toxins were perceived by both the public and by food experts as posing less of a hazard than microbial spoilage, wrong food choices and contaminants, while GM foods, additives and food irradiation shared the lower orders of concern (Schlotjes 1996, cited by Schilpzand 1999). It is possible that the level of public concern regarding GM foods may have been increased following more recent publicity and debate.

In the chemical sense, plants are composed of :

- primary compounds - those which that form the plant's essential structure, and are involved in its translocation, storage and respiratory systems. Many of these such as proteins, carbohydrates including sugars and structural components, and various types of fats (fixed oils), their precursors and metabolic products, are abundant in plants generally, and
- secondary compounds - only some of which have known functions, for example protecting the plant from herbivory. For the majority, no specific function has yet been determined, and some at least may just be metabolic by-products. A minority of the thousands of known secondary compounds may in some circumstances prove harmful when present in foods, and many are known to be beneficial. Many secondary compounds are present in plants in minor quantities. It is important to reiterate that individual secondary compounds, harmful or otherwise, have usually been obtained from extracts of vegetative parts of a plant rather than the fruits or seeds.. In addition, the concentration of secondary compounds can vary from plant to plant of the same species, as well as with factors such as maturity, season, flowering cycle, variation in climate, soil, and recent attack by grazing animals or insects. Toxicity of a compound to one organism such as a rat, insect, bird, cow or sheep does not necessarily imply toxicity at the same or any other level to humans, and vice versa, because each has a different ability to detoxify potentially harmful compounds. For example, the detoxification processes in animals such as cattle, sheep and goats are strongly influenced by the presence of microorganisms in the rumen. Another such example is given by Levitt (1981) regarding the bitter, toxic fruits of the native strychnine tree *(Strychnos lucida*) which contain strychnine, but are eaten by birds without ill-effects. Therefore, toxicity results for non-human species can only be taken as an indication of the possibilities for humans.

There are a number of possible causes of adverse reactions to foods (Speijers & van Egmond 1999). These include antinutritional compounds, such as tannins, which bind to and hinder the absorption of nutritive compounds, and those which produce effects during and after digestion, such as alkaloids, cyanogens and allergens. The classes of secondary compounds to be mentioned in this report include:

1. Alkaloids.

Large numbers of various classes of alkaloids have been identified and named, and contrary to some popular opinion they are not all bitter-tasting. For the vast majority, there is no evidence of toxicity. Some may have defensive functions within the plant, and some may be metabolic end-products, for which no function can yet be suggested. A positive record of alkaloids within a part of a plant is therefore a very unreliable indication of toxicity. In cases where a toxic alkaloid may be suspected, further chemical testing would be required. For most Australian plants, including bushfoods, few if any individual alkaloids have been identified, even in cases where a definite presence has been established. Extensive screenings of Queensland and Western Australian plants for the presence of alkaloids have shown that while similar percentages of families and genera from each State contained alkaloids, at the species level the proportions of positive records were uneven (WA: 7.5% of 1301 species; Qld 13.3% of 1550 species; Aplin & Cannon 1971, citing Webb 1952). Previous positive records for Australian species are summarised in Bick (1996), but both positive and negative results are given in the original reports (e.g. Webb 1949, 1952 and Collins *et al.*1990). Various methods of extraction and detection, and different samples, have often provided conflicting results, especially in older records.

2. Cyanogenic glucosides (also called cyanogens, cyanogenic glycosides).

Hydrogen cyanide(=hydrocyanic acid, prussic acid or HCN) is a toxic gas which is released from some plants when tissues are damaged (e.g. when cell walls are damaged by chewing, grinding, cooking or freezing) enabling a particular enzyme (a glucosidase) to be placed in contact with a compound which is then capable of releasing cyanide. A disproportionately large number of the most important human food plants is cyanogenic. These include wheat, maize, oats, peanuts and cassava - plants which even in the wild are particularly attractive to animal and insect herbivores. The release of hydrogen cyanide (HCN) is therefore believed to be a plant defence mechanism. The human body can deactivate the small quantities of cyanide present in such foods, though larger quantities can be fatal. For example, humans consuming a diet based on cassava can consume an estimated 30-35 mg of HCN per day, but twice this amount is lethal for a 70 kg human (Jones 1998). Both the bound and free cyanide present in cassava are minimised by a combination of soaking, sun-drying and cooking, causing any free cyanide to be released harmlessly into the air (Bradbury & Holloway 1988).

The fact that in many cases not every plant within a population of known cyanogenic species will actually produce and accumulate the source of cyanide, and contain an enzyme of the necessary type to release it, has important ecological and agricultural implications (Maslin et al. 1990).

3. Components of essential oils.

Essential oils are composed of a mixture of steam volatile compounds, mainly terpenoids and related substances. Those used for culinary purposes are most often extracted from leaves. The mixture of components of oils from different plants of the same species may be extremely variable, and the results are also influenced by the method of extraction. Though essential oils usually constitute a maximum of about 1%- 2% of plant tissues, they are largely responsible for the flavours and aromas of foods, beverages, perfumes and cosmetics. Depending on local legislation, a very few components (e.g. pulegone, thujone) are only allowed as additives for foods in minute quantities, and safrole is completely banned. In such cases, restriction is normally because of suspected association with carcinogenesis as a result of metabolic processes after absorption. The restrictions are usually based on the results of tests with rats, mice or other animals, which may have different tolerances from humans. Nevertheless, the same compounds may often be present and allowable in small quantities in common foods and spices, which have no history of toxicity in foods as consumed in normal quantities. Much Australian research has concentrated on the composition of valuable industrial essential oils from eucalyptus and "pines" (*Callitris* spp.), but the composition of oils from other groups of Australian plants was also often well documented (e.g. Gildemeister & Hoffman 1922; Lassak & Southwell 1977; Southwell 1987). Modern analytical procedures now allow extremely rapid and comprehensive determination of essential oil composition.

4. Lectins

These are proteins and are potential haemagglutinins. This term reflects the diagnostic test used to detect lectins, which 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 circumstances damage its cell walls and interfere with nutrient uptake and growth. Lectins are found in active form in the mature seeds, tubers, and sap of many common food plants, especially those of the legume family, e.g. soybeans and red kidney beans, but they are degraded by cooking. They are found less often in other families.

5. Non-protein amino acids.

Some can be found in all plants, but particularly in the legume family, where neurotoxic lathyrogens and djenkolic acid are often present in seeds. The reassuring results of studies of seeds of many Australian *Acacia* species, which belong to this family, are summarised in section 2.2.1.

6. Oxalates

Oxalates are present in plants as soluble salts (potassium and sodium oxalate), oxalic acid, or insoluble calcium oxalate. They are contained both within cells, and as sharp crystals (raphides) between the cells. Leaves usually contain more oxalates than leaf-stalks (Bradbury & Holloway 1988), and rhubarb, spinach and unripe tomatoes usually contain some of the higher levels. A small amount of oxalic acid is naturally present in the human body. Soluble oxalates are readily absorbed, metabolised and excreted by the body. The insoluble calcium oxalate - not all derived directly from dietary oxalate - can be excreted in the urine in the form of small, insoluble calcium oxalate crystals, but ingestion of excessive amounts of oxalate can lead to the accumulation of larger crystalline "stones" within the urinary tract, as well as reduction of the availability of dietary calcium. Both gallstones and kidney stones contain a lot of calcium oxalate, so it is essentially a cumulative toxin. Oxalate poisoning has caused some deaths of livestock that grazed on abundant fresh growth of *Tetragonia* species with high levels of soluble oxalate (Everist 1981).

7. Saponins
These are glycosides of various chemical structures, which form a non-alkaline soapy foam when shaken with water. They are often bitter-tasting and are not destroyed by processing or cooking. While they are mostly not considered to be toxic, not being very readily absorbed into the body, if ingested in quantity saponins can cause digestive problems. Dietary saponins taken in limited quantities can be beneficial to health. Those present in some legume seeds, e.g. chickpeas, alfalfa and navy beans, can assist in lowering blood cholesterol level (Fenwick & Oakenfull 1983).

8. Trypsin inhibitors. These are proteins found in some legume seeds such as soybeans. They are undesirable because they inhibit the action of digestive enzymes, so that proteins in foods cannot be completely broken down and digested. Many Australian *Acacia* seeds have been found to contain trypsin inhibitors. However, these compounds can be inactivated by baking or boiling (further information in *Acacia section*).

9. Chemical and/or mechanical and allergenic irritants
Occasionally, sensitive tissues such as those of the eyes, lips, mouth and throat may become inflamed after contact with particular parts of some plants during harvesting, processing or consumption. For example, skin and eye contact with the irritant hairs of *Davidsonia pruriens, Brachychiton* species, or *Hibiscus sabdariffa* may need to be avoided, and some of the native grapes contain needle-like irritant crystals (Cribb & Cribb 1974), which "burn" the back of the throat. Contact with or inhalation of undiluted, volatile essential oil extracts should be avoided by use of protective clothing and ventilation. Very strong hot spices such as those derived from chilis and some Australian *Tasmannia* species require a high degree of dilution before use. In such cases, the degree of sensitivity varies between individuals, and may increase on persistent exposure. Undiluted essential oils are also likely to cause adverse effects on contact with the skin or internal tissues. A useful searchable botanical dermatology database is maintained at http://bodd.cf.ac.uk/BoDDHomePage.html.

Allergens in foods are all proteins or glycoproteins, mostly of a similar molecular weight (10-40 kDa). Some allergic responses are related to age at first exposure, and may decrease with age, but others, for example peanut allergy, are seldom outgrown. In European studies, the majority of allergic food reactions in adults are caused by fruits, vegetables and nuts, and are related to pollen allergy. Oral itching is the commonest - often the only - symptom. (Madsen & Wuthrich 1999).

10. Other potentially toxic compounds
Many other compounds and classes of compound are present in a limited number of plant species, and if the intake is high enough may produce a range of adverse effects. However, they have not been indicated in the chemical and botanical literature, or industry anecdotes, as likely to be found and/or cause problems from any bushfoods currently on the market. For this reason they have not been included in the limited range of tests possible during this study. Such compounds include:

- cardiac glycosides (mostly in Apocynaceae, Liliaceae & Scrophulariaceae - e.g. digitalis, oleander)
- glucosinolates (sulphur-containing goitrogens, mostly found in Brassicaceae - the cabbage family)
- polyphenolic compounds (include tannins which, depending on quantity, can inhibit digestive processes)
- sesquiterpenoid compounds (other than those mentioned above under essential oils)

- furanocoumarins (phototoxic compounds), for example as in celery (*Apium graveolens*).
- metallic elements and compounds accumulated in or deposited on plants (e.g. aluminium, selenium, lead, copper, cadmium)

2. Review of Existing Information

2.1 Methods

2.1.1 Species Investigated

The premier commercial bushfoods as identified as by Graham and Hart (1997) were essentially those that had been listed in the papers of a bushfood conference held in Brisbane (ANBIC 1995). In both of these lists, a number of bushfoods were identified in places only by inclusive common names, such as "mints", "wattles" and "bush tomatoes". However, for groups such as these more than one species may be utilised by the industry (or by traditional communities), depending on availability and their individual suitability for particular purposes. These considerations have influenced the selection of individual species included in the study.

In addition, over the last five years the industry has extended its preferences to include alternative species, which were not on the original list, and some of these species were provided and included in the analyses. The original listing also did not include either macadamia nuts, *Macadamia integrifolia* and *Macadamia tetraphylla,* which separately, or as commercial crosses, have provided the most commercially successful of all Australian bushfoods, or bunya nut (*Araucaria bidwillii*) which is abundant and already has a record of safe traditional and modern use. Some information on studies of the chemical constituents of these nuts is provided, as it is not widely available. While essential oil-based flavouring extracts from native species are considered beyond the scope of this study, limited analyses of the essential oils of some species used as flavourings have been included.

2.1.2 Records and Sources of Information Consulted

These have included

- searches of botanical databases and original reports to check the synonymy and recent name changes for bushfood plants. Databases consulted have included Biological Abstracts, Medline, Food Science and Technology Abstracts, Agricola, Commonwealth Agricultural Bureaux abstracts, Chemical Abstracts, Current Contents, Science Citation Index and Sigma-Aldrich.com.
- searches for records of use of plant-derived foods for food and medicine in traditional and modern Australian communities. Periodicals consulted have included *The Australian Bushfoods Magazine, Newsletters* published by ARBIA, ASGAP Bushfoods Study Group, Australian New Crops, Queensland Bushfood Association and Southern Bushfood Association, *Quandong,* and WANATCA Yearbooks.
- searches of databases, books, periodicals and on-line reports for records of analyses of the chemical constituents of bushfood species, and their close and possibly chemically-similar relatives, especially with regard to compounds that have been regarded as potentially harmful.
- discussions with members of the industry and research institutions, including requests for information on publications, current choices and selection of bushfood species, procedures, and the circumstances of any adverse effects attributed to the use of bushfoods. This valuable assistance is acknowledged in Appendix 2.2.
- wider solicitations of anecdotal reports of adverse effects of bushfoods during presentations to groups of growers of bushfoods and other native plants, natural product chemists in Brisbane and Sydney, and in various published material in industry and other periodicals which described the scope and aim of this study.

2.1.3 Comparison of Traditional and Modern (Commercial) Uses of Bushfoods

Aboriginal people had many languages, but there was no opportunity to keep written records. When Aboriginal family groups were fragmented and dispossessed of many of their traditional lands following European settlement, much traditional knowledge of using local food plants was lost. Botanists and persons entrusted with responsibility for Aboriginal affairs (e.g. Maiden 1899; Roth 1901-1908) recorded much information about the traditional uses of native plants but such information was inevitably incomplete, even though long experience had taught the art of selecting and using bushfoods safely (Webb 1973). A very extensive guide to published references concerning the Aboriginal use of many food plants, and sources of regional records, was given by Low (1989). Today, various Aboriginal communities and individual researchers, sometimes assisted by Government agencies, are providing many more details of plant use, and making them available to non-Aboriginal people. Some national and regional resources include lists at www.anbg.gov.au/aborig.s.e.aust/bibliography.html; www.anbg.gov.au/bibliography/bushfood.html; also in Isaacs (1987), Maiden (1889) and regional resources including: (Qld): Iselin & Shipway (no date), Leiper (1984), Roth (1901) NT: Northern Territory Botanical Bulletins including Nos. 16,18,20/21,22,23 and 25; Turner 1994; Mayi *et al.* 1987; Vic: Sola & Gott (1992) SA: Cleland & Johnston (1939) Winfield (1982) and Palmer & Brady (1991) WA: Bindon 1996.

In the early days of European colonisation, settlers occasionally gathered local bushfood opportunistically from the wild but rarely cultivated them. This selection of local plants for foods was more likely to be due to the irregular arrival of domestic stores, or kitchen economies, than a desire for a varied cuisine. Local bushfoods such as pigweed, nettles, Warrigal spinach and native pepper were welcomed as occasional substitutes for the more familiar introduced fresh vegetables and fruits.

Many modern commercial bushfoods have been widely publicised and promoted by restaurants and gourmet food outlets, and their success has relied more on unique flavour and attractive presentation, and less on local abundance and nutritional value. Commercial bushfoods are now not so much dietary staples as minor components of a very much more varied choice of foods than was available to traditional communities. In the case of some Australian commercial bushfoods, such as lemon and aniseed myrtle leaf, mountain pepperleaf, and some of the mints, there is little if any correspondence between traditional and modern usage for food purposes

2.2 Results and Discussion of Records for Leading Commercial Bushfood Species

The following points require introductory comment.

Plant names. Both scientific and one or more of the common names are listed for each species. Many bushfood growers and consumers may not recognise previous or alternative botanical names for some bushfood species when searching for information. The more important or recent changes to scientific names of bushfood species are noted in the text below. Common names applied by the industry to particular species may vary by region, as they have also varied between different Aboriginal language groups.

Choice of plants to be investigated. Some of the commercial bushfood species listed in Graham & Hart (1997), which the brief for this report had specified for study, were identified only by common names, e.g. "mints" and "wattleseed". However, inclusive names such as these may be applied to a range of species, selections, crosses, etc.. Different choices of species may be made depending on region, availability, suitability for horticulture and consumer preference. In such cases, information on additional species has been included.

Nutrititional values are beyond the scope of this report, but some published information for many of the above bushfoods is summarised in Appendix 1 for possible future reference.

2.2.1 *Acacia* Species

(wattles, wattleseed). (Sometimes referred to as *Racospermum* species in recent taxonomic literature).

Family: Mimosaceae (sometimes known as part of the legume family Leguminosae).

Part used in commercial products: Seeds, ground seed products (as a percentage of ingredients) and occasionally flowers.

General information. Approximately 950-960 species of *Acacia* are found in Australia. Most of them are found only in this country, although many other *Acacias* are native to countries outside Australia. In colonial times, some Australian *Acacia* species were highly valued for the tannins present in the bark, which made it useful for tanning hides ("tanbark"). Consumption of seeds was still virtually limited to traditional communities.

For use in modern bushfoods, the commercial choice of Australian *Acacia* species has been based on factors such as seed size, accessibility of sources, natural abundance and longevity of the plants, reliability of cropping and ease of harvesting, drought resistance and resistance to insect damage. The seed coat of *Acacias,* which is often very hard and fibrous, makes up a substantial part of the total weight of unprocessed seeds of some species. The amount of dietary fibre in the seed coat is higher than that of grain seeds, and was often removed in Aboriginal cultures during processing of the seed by parching, grinding and winnowing (publications reviewed by Harwood 1994).

There has been considerable recent research into the nutritional value and chemical composition of edible seeds of a number of tropical Australian *Acacia*s. These include *A. colei* (formerly included within *A. holosericea:* Maslin & Thomson 1992), *A. cowleana* and *A. tumida*. These species have been introduced into parts of Africa where they produce heavy crops of easily harvested and utilized seed crops from otherwise non-arable lands, with none of the potentially toxic characteristics of some African *Acacia* species (see below under "bioactivity"). Despite the successful use of Australian *Acacia*s in Africa, the Australian bushfood industry has favoured a different selection of species for use as commercial foods, including those noted below, and listed in greater variety by Cherikoff (1989).

Traditional use. Various parts of *Acacia* species were used selectively for food and/or medicine in all regions of Australia. Staple foods were prepared from seeds, gums, roots and associated insects, particularly in arid areas where *Acacia*s are abundant and other food sources were limited. Seeds and occasionally pods of some species (e.g. *A. tumida*) were eaten when green, while in other cases the pods were lightly baked to dry out bitter juices so they did not affect the flavour of the edible seeds. Riper seeds were recovered by smashing the pods, recovering seeds with attached arils from the ground or from caches stored by ants. Seeds were then heated, winnowed, pounded or ground, and the flour could be mixed with water and baked to form damper-type small cakes. (Orr & Hiddins 1986; Isaacs 1987; Devitt 1992). In arid areas, the seeds of about 50 *Acacia* species were used for food (Harwood 1994). In Central Australia, the seeds and sometimes gums from about half the 60 or so local *Acacia* species were used in foods (Latz 1995; Lister *et al.*1997). These included *A. aneura, A. notabilis* and *A. victoriae* - the latter two now popular for commercial production. The high nutritional value and wide availability of various wattle seeds (Brand & Cherikoff 1985) especially if the fat-rich aril was retained, made them a valuable resource in arid areas, despite the considerable labour involved in collection, and usually grinding, winnowing and baking.

Compared with the extensive traditional use of wattleseeds from *A. aneura* (mulga) and other species for food in arid areas, Aboriginal peoples in higher-rainfall and coastal areas tended to prefer other foods from the wider range readily available to them (Clarke 1988; Lister *et al.*1997; Pearn 1993). In

Victoria, gum was a more important food source than the seeds (Gott 1985). Only seven of the more than 240 native food plant species commonly used in foods by North Queensland aborigines were *Acacias*, and seeds of only two of the seven were consumed. Only the gums and roasted roots of the other five have been listed as foods. (Pearn 1993; Roth 1901). Elsewhere, species with seeds that were avoided by some or all Aboriginal groups included *A. petrophilum* and *A. quadriloculatum* which are toxic, possibly *A. ligulata,* and *A. validinervia*, the latter being one of the few common *Acacia*s of which the seed was never eaten (Latz 1995). This may also apply to the seeds of *A. georginae* (Georgina gidgee) which can be expected to contain fluoroacetate (the chemical name for "1080", an agricultural poison). This compound is also found in lesser quantity in other parts of the plant, which is well-recognised as poisonous to stock, but the concentration appears to vary quite markedly with locality, season, and even within single stands of the plant (Oelrichs & McEwan 1962).

Scientific studies of Acacia seeds

(a) Nutritional. The results of various nutritional studies of the edible seeds of several species are summarised by Brand Miller *et al.* (1993, see Appendix 1). The fatty acid composition of seeds of twenty Australian *Acacia*s is documented in Brown *et al.* (1987). Most species had more polyunsaturated than saturated fatty acids. In addition, wattle seeds have a low glycaemic index, indicating that the starch is absorbed slowly, resulting in blood glucose levels which can remain elevated for some time even during strenuous exertion. Low glycaemic index foods have also been shown to have higher satiety value and delay the onset of exhaustion in prolonged strenuous exercise (Brand & Maggiore 1992). It was found by Thorburn *et al.* (1987) that following a meal containing wheat bread prepared with the addition of flour from an *Acacia* (*A. coriacea*) to white flour in the proportion of 18% : 82%, lower than usual plasma glucose and insulin levels were recorded, suggesting that *Acacia* flour could be useful in diabetic diets. This activity could help prevent the expression of diabetes in susceptible individuals such as Aboriginals (Brand & Maggiore 1992).

(b) Bioactivity studies. Protease inhibitors (inhibitors of digestive enzymes) were found to be present in seeds of all 18 species tested by Kortt (1985) and the 38 species tested by Weder & Murray (1981). Positive tests were obtained for edible seeds of various species including *A. aneura, A. holosericea, A.murrayana, A. notabilis, A. pycnantha, A. sophorae.* These compounds interfere with the ability of trypsin and chymotrypsin to hydrolyse proteins into peptides for assimilation by the body. They may be sufficiently present in seeds to interfere with the metabolism of proteins from other foods if raw seed flour is used as the main source of protein. Harwood (1994) advises "because of the presence of protease inhibitors, foods incorporating *Acacia* seed should not be eaten raw. Steaming the green seeds, or boiling or baking foods made with seed flour, will eliminate this potential problem."

Anti-tumour activity of parts of many *Acacia* species, other than the seeds, has been documented by Collins *et al.* (1990). Potentially toxic non-protein amino acids such as djenkolic acid have been found in edible seeds of some Australian dry-zone *Acacia* species, but at levels well below those that would cause toxicity problems. (Evans *et al.*1977; Maslin *et al.*1998, Maslin 1999). Lathyrogenic amino acids, which are present in some legume species, and can cause neurological problems and partial paralysis, have been absent from the Australian species so far tested (Evans *et al.* 1977; Murray 1984; House & Harwood 1992; Maslin, 1999).

Acacia species have been widely blamed for promoting hay fever and rhinitis during their spring flowering. There seems to be little local confirmation, though there is occasional scientific evidence from elsewhere (e.g. Ariano *et al.*1991; Hassim 1998; Sam 1998). *Acacia* pollen has been considered too large to enter respiratory capillaries, but it may separate into smaller sections which may then be able to do so (M. Dettmann, University of Qld, pers. comm. 1998) Thompson (2000) reported allergic reactions - an asthma-like symptom and itching skin rash - following handling the seeds and pods of *A. sophorae* during harvesting, but wearing filter masks appears to prevent the condition.

(c) Other chemical and toxicological studies. Locations of positive results (only) for tests of Australian *Acacia*s for alkaloids by various authorities are summarised in Bick (1996). Although listings for various parts of 94 Australian *Acacia* species and subspecies are given, there were only two positive results for seeds ("fruits"), which were not regularly included in testing. Other toxic and anti-nutritional factors such as cyanogens, haemagglutinins and heavy metals have been absent or found at very low levels in seeds of various species tested (Harwood 1994; Maslin *et al.*1998). At least some *Acacia* pods contain bitter-tasting saponins. The leaves of a small proportion of samples of most of the Australian *Acacia* species tested have been shown to be cyanogenic. Seeds were not tested. (Maslin *et al.*1990). Some parts - foliage, bark or green pods, less often seeds - of a few species have been found to be toxic to stock, or were used by Aboriginal people as fish poisons. Not all reports have been substantiated, but the compounds said to be involved have included saponins and occasionally cyanogenic glucosides (Webb 1948; Hurst 1942; Maslin *et al.* 1990).

The commercial Acacia bushfood species include:

- *Acacia victoriae* Benth. - *gundabluey.*

Taxonomy and distribution. *A. victoriae* in the broad sense is found in all mainland States (Maslin 1992). There are two defined subspecies, ssp. *victoriae*, usually found on cracking clay soils, and the more tomentose (hair-covered) ssp. *arida,* usually found on sandy soils and dunes (Pedley 1979; Maslin 1992), but there are intermediate forms. The species is extremely widespread and in many (but not all) years carries substantial crops of seed.

Traditional uses. Seeds of this species were highly favoured by Aboriginal groups over wide areas for food use. There are numerous records of this, including those cited above.

Chemistry. Nutritional aspects of seeds of *A. victoriae* and other *Acacia*s have been extensively reported (e.g. Brand & Cherikoff 1985, Brown *et al.*1987; Appendix 1, this report). The ratio of polyunsaturated to saturated fatty acids in the seeds is approximately 3 : 1 (Brown *et al.* 1987), but as the total fat content is low (c. 3%; Brand Miller *et al* 1993) any overall advantage over other foods on health grounds may be minor. Tests for alkaloids in the leaves and stems of *A victoriae* have proved negative (Collins *et al.* 1990). A wide range of non-protein amino acids (which do not include any that are known to be toxic) has been reported from the seeds of *A. victoriae* (Evans *et al.* 1977). A neurotoxic amino acid (= a neurolathyrogen) which is found in some legume seeds, including African *Acacias*, was not detected in the seeds of *A. victoriae* (Quereshi *et al.*1977). *A. victoriae* was not one of the species tested for protease inhibitors by Weder & Murray (1981) but any small amount of protease inhibitors which it may contain would be inactivated by heating, as with lentils and other legume foods.

Reports of adverse effects. No records of adverse effects have been located. This, together with the long history of traditional use, indicates that *A. victoriae* seeds have no inherent toxicity.

Other Acacias used by the bushfood industry include:

- *Acacia notabilis* F.Muell. (notable or noble wattle)
- *Acacia pycnantha* Benth. (golden wattle) and
- *Acacia retinodes* Schltdl. (wirilda)
- *Acacia sophorae* (Labill.) R.Br., also known as *A. longifolia* var. *sophorae* (elegant wattle, coast wattle)

No chemical information has been found that would indicate possibilities of toxicity for these or others of the preferred commercial *Acacia* bushfood products.

2.2.2 Acronychia Species - "aspens"

There are over twenty Australian species of *Acronychia,* nearly all of which are restricted to Australia. Most tests of *Acronychia* species have been for investigative purposes unrelated to food use, and bark and roots, rather than fruits, have usually been tested, for example for alkaloids, saponins and pharmacological activity (e.g. Collins *et al*. 1990; Gibbs 1974; Simes *et al.* 1959; Webb 1949, 1952). *Acronychia*s are reported to be one of the thirteen Australian genera which are the richest local source of alkaloids, although the documentation of the distribution and identity of the alkaloids in particular parts of the plants is still extremely incomplete. A species formerly known as *Acronychia baueri* or *Bauerella simplicifolia* (now known as *Sarcomelicope simplicifolia*) has been studied as a promising source of bioactive alkaloids. Maiden (1889) did not record any Aboriginal use of the *Acronychia* fruits, and no other historic records have been located.

- Lemon aspen *(Acronychia acidula* F. Muell*)* Family: Rutaceae

Distribution. North Queensland, rainforest areas.

Part used. Whole fruits.

General information. The fruits have a variable but strong tart, lemon-type flavour. They can be eaten fresh, or used in cooked dishes with the addition of a small amount of sugar to stabilise the tart flavour (Robins 1996). The core can be taken out before use.

Traditional uses. As far as is known, Aboriginals of the Atherton region did not use the fruits. However, Stuart-Fox (1999) found that modern Aboriginals in Brisbane rated lemon aspen fruits moderately highly when they were presented as food.

Scientific studies

(a) General. Alkaloids are present in the mature fruits (Webb 1949), but there is little information on other constituents. Saponins, steroids and unsaturated terpenes are absent from the leaves of this species (Simes *et al.*1959), but fruits were not tested.

(b) Toxicological. No indications of toxicity to humans have been located in the literature, including the records of the Qld Poisonous Plants Committee (1938), or from anecdotal reports. As most of the fruits have a strongly acid flavour, it is unlikely and possibly undesirable that more than a few would be consumed at a time. There have been anecdotal reports of possible toxicity of the fruit to pigs in North Queensland, but no evidence of poisonous properties was detected (Qld Poisonous Plants Committee records, 1939; Webb 1948). The only mention of adverse effects of an *Acronychia* species to humans appears to be a 1925 report of a schoolboy who suffered a digestive upset after eating fruits of *A. imperforata* (Webb 1948). The highly acid taste of various unselected, unprocessed, fresh *Acronychia* fruits may have been a contributing factor.

Another Queensland species, *A. aberrans,* has often been confused with the very similar *A. acidula* during wild harvesting. It has a generally more pleasant, less tart, taste than *A. acidula,* and the two species can be distinguished by the fainter aromatic quality of the leaf of *A aberrans* (A.K.Irvine, Atherton, pers. comm. 1998). In this case there seems to be no toxicity problem in mistakenly using a very similar species.

- *Other Acronychia species used for bushfood*

In general, the following species are used for similar purposes to *A. acidula* and some are preferred for taste and marketing purposes. No records have been found of analyses for the fruits of these species, though there is sometimes information available for other parts:

Acronychia bauerlenii T.G.Hartley (Byron Bay acronychia). Byron Bay to McPherson Range Q.
A. imperforata F.Muell. East coast districts of Q, NSW
A. oblongifolia (Hook.)Heynh. (White aspen, common acronychia). Northwards from Eden to SEQ.

A. pubescens (Bailey) C.T.White (Hairy aspen). From Dorrigo north to Wide Bay area.
A. suberosa C.T.White (Corky acronychia/aspen). From Dorrigo to SEQ.
A .wilcoxiana (F. Muell.) T.G.Hartley (Silver aspen). NE NSW to Wide Bay area.

2.2.3 *Araucaria bidwillii* Hook. (bunya nut) *Family:* Araucariaceae.

Natural distribution: South-East Queensland, in some locations between Gympie and the Bunya Mountains, and south-west of Cairns.

Part used. Seeds (or “nuts” or "kernels"). They are normally used after baking or boiling (Parsons 1998) but modern techniques provide glace products and a ground or pelleted product for use as an alternative to wheaten flour, especially by people who are intolerant of gluten.

General information. The tree can attain a height of 40 m and a girth of 1.5 m (Francis 1970). It is rather slow to mature, and the cones containing the seeds can weigh up to 20 kg at the time of falling (Noel 1991).

Traditional uses. Large quantities of the nuts were consumed in South-East Queensland during the feasting season. In years when there were heavy crops, Aboriginal groups would travel far beyond their normal range to participate in the feasts. Bunya nuts are one of the few native Australian plant foods which have been popular in both traditional and European diets, e.g. Iselin & Shipway (c.1998). Aboriginal people placed surplus nuts in waterholes or soaks in times of plenty, or buried them, for later consumption. During germination, an "after-nut", a form of crisp, coconut-flavoured tuber of approximately the same size as the original nut, forms on the main root-stem and was also eaten (Noel 1991).

Chemical information

General. Most research into this species has been directed to maximising the value of timber obtainable from the large trees. The chemical composition of the nuts has received less attention. However, some values for the major classes of nutrients have been documented. These include carbohydrates (39.6%) and protein (11%) (Brand-Miller *et al.*1993, see Appendix 1).

Some further insight into the chemistry of nuts of this genus has been given in reports about the closely related South American species *Araucaria brasiliensis* (syn. *A. angustifolia*) and *A. araucana,* the monkey puzzle tree. Both are used similarly to bunyas for timber and food (Menninger 1977). The edible nuts of *A. brasiliensis,* known as “pinhoes” or “pinhaos”, have been widely used in South American countries in traditional and modern foods, and are also used to prepare a nutritious flour. The starch content of pinhao nuts from South America is 21%, with the granules having some similarities of physical characteristics, solubility, swelling capacity and viscoelastic behaviour to corn starch (Wosiacki & Cereda 1985, 1989) and Cereda & Wosiacki (1985) from abstracts).

The nuts should be collected promptly after the cones fall, dried if necessary and refrigerated or frozen, to delay or inhibit the normal metabolic and structural changes associated with germination, as well as the proliferation of fungal pathogens. Storage time is normally limited to 4-8 weeks without such treatment (Noel 1991), as nuts stored in plastic bags at 20^0C germinate readily (Doley 1990). Occasional ventilation may also be required during cold storage in confined spaces, as metabolic processes increase the moisture content of the seeds (Tompsett 1984; del Zoppo *et al.* 1998).

Toxicological. No reliable records of adverse effects attributed to eating bunya nuts have been located. Cleland (1943) notes a comment from a Gympie doctor, who attributed a case of asthma to a patient having eaten the nuts, but gives no further information. There seem to have been no other similar reports. No reports have been found of adverse effects from the traditional consumption of nuts of the very similar, closely related South American species for various edible products.

Two major lectins have been isolated and characterised from pinhaos (Datta *et al.* 1991; 1993). Lectins are a diverse group, of which a relatively few have some potential for adverse effects in humans. Some of the latter are found in common food plants (e.g. soybean and kidney bean) and require inactivation (by cooking) to avoid harming digestion and growth. As lectins have been reported from other edible *Araucaria* nuts, the present study has included diagnostic tests for lectins in *A. bidwillii,* but not other bushfoods which, on the information available, were unlikely to contain them.

2.2.4 *Backhousias* and *Anetholea* (myrtles). *Family* Myrtaceae.

Those in common use include:

- *Anetholea anisata* (Vickery) Peter G Wilson (formerly *Backhousia anisata*). Aniseed or licorice myrtle. This species has for many years been known as *Backhousia anisata,* but has been renamed *Anetholea anisata* (Wilson 2000). It is included in this section because the change to an unfamiliar name is very recent.

Distribution. Areas adjoining the Qld-NSW border and south to areas near Dorrigo.

Part used. Leaves, fresh or dried. The essential oil of the leaf is extracted, mainly for use in beverages such as liqueurs. Various information relevant to leaf production, and its quality and uses, is given by Hess-Buschmann (1996).

Aboriginal use. No records of Aboriginal use have been located. This may be at least partly due to the very limited area of distribution of the tree.

Chemical information. The attractive flavour and fragrance of aniseed myrtle leaf is due to the fragrant essential oil, which, however, constitutes only 0.5% - 2.0% of the fresh weight of the leaf (Brophy & Boland 1991). There are two chemical varieties of aniseed myrtle (Brophy *et al. 1*995) and a range of intermediate forms (Southwell et al.1996). The distinction is in the proportions rather than the chemical identities of the major components of the essential oil in the leaf. These are anethole (chemically, trans- (or E-) anethole or iso-estragole) and methyl chavicol (also known as estragole). The oil of the commoner, aniseed-type chemical form of the plant (= chemovar, chemotype), which is sought for flavouring purposes, contains 79%-95% of trans-anethole (which gives the plant its strong aniseed taste and fragrance) as well as 4%-10% methyl chavicol, and a range of other compounds (Brophy *et al.* 1995; Southwell *et al.* 1996 ; Blewitt & Southwell 2000). Of the two chemical isomers of anethole, the desirable trans- form is the more abundant, with the cis- or (Z-) form, (which may or may not have some toxic potential) present at about 0.05% (Brophy *et al.*1995). This is similar to the proportionality of trans- and cis-anethole in similar anethole-rich commercial oils from aniseed, fennel and star anise (Southwell *et al.*1997 Blewitt & Southwell 2000; Tisserand & Balacs 1995). Extracts from plants containing essential oils consisting mostly of anethole have been traditionally used in many countries as licorice-type flavouring for foods and beverages, and in modern times even for tobacco, and also in various medicinal preparations used as sedatives, cough mixtures, laxatives, and estrogenic agents. It is considered that the pharmacological activities attributed to anethole are due to metabolic products - polymers of anethole - rather than the compound itself (Albert-Puleo 1980).

Methyl chavicol is associated with anethole in varying proportions in the essential oil of many other widely-used spice plants, such as basil, chervil, tarragon, and fennel. The chemical structure of the two compounds is very similar (Merck 1996). It is used in small quantities in perfumes and cosmetics. While this compound is still, as far as is known, not subject to restriction for use in foods, it has a similar potential to safrole for carcinogenicity if taken in large doses (Tisserand & Balacs 1995). However, in animals, small quantities are readily metabolised to non-toxic products (Zangouras *et al.*1981). Doses of both trans-anethole and methyl chavicol, similar to those likely to be encountered at normal levels of intake, were metabolised by human volunteers and excreted both in the urine and (as carbon dioxide) in expired air, mostly within 12 hours (Sangster *et al.* 1987).

Undiluted, concentrated oils containing both trans-anethole and methyl chavicol are classed as irritants, and the respective LD_{50} values for rats and mice, respectively, are 2090-3050 mg/kg and 1230-1250 mg/kg. Although toxicity to test animals cannot be validly translated to potential results for humans, it suggests that a 70 kg human might need to consume several kilograms of fresh leaf over a short time to suffer the same level of toxicity.

There is little if any further published information available on other constituents of *Anetholea anisata.*

- *Backhousia citriodora F.Muell.* (Lemon myrtle).

Distribution. Areas within Queensland

Part used. The leaf, in whole, dried or ground form. The flowers and fruits are also used at times for flavouring. The citral-rich essential oil from the leaf is a well-established commercial product, known as lemon myrtle oil.

General information. Although, botanically, lemon myrtle is considered a single species, there are acknowledged to be at least two distinct chemical forms (chemovars). The distinguishing feature is the composition of the essential oil in the leaves. This oil provides most of the aroma and flavour for which the plant is used in foods and beverages. In most plants of the species, at least 90% of the oil may consist of citral, a lemon-scented mixture of neral (α-citral) and geranial (β-citral)(Opdyke 1976). In the other main chemovar, citronellal can contribute up to 80%, which makes the leaves unsuitably flavoured for use in foods. The assemblage of compounds in each form of the oil is quite similar, even though the relative abundance of the two most abundant ingredients is variable. (Brophy *et al.*1995; Penfold 1950). Like trans-anethole and estragole in the previous species, citral and citronellal have very similar chemical structures (Merck 1996). Selections for bushfood purposes are usually made from cultivated plants which have been shown by analysis to contain high proportions of citral.

Synthetic citral is also available for food use. It has a minimum citral content of 95%. Natural citral from various plant sources may differ slightly in chemical composition. The level of human perception of citral as a recognisable fragrance is extremely low. As little as 9-43 parts per million can provide a recognisable lemon flavour to various commercial products (Fenaroli 1971). The quantities of citral likely to be ingested when using the whole or ground leaf as a flavorant is small, as the oil normally constitutes about 2% of the total weight of the fresh leaf.

Traditional uses. None have been located, although the pleasant aroma of the leaves would have been known to Aboriginal people. Leaves of other plants with high concentrations of citral in the essential oil, for example lemongrass (c. 75%) and melissa (35%-55%) have been used for flavouring and perfumery in many countries throughout historic times.

Scientific studies.
General. Extensive private analyses of the essential oil have been conducted for producers, and there is a published study comparing the composition of the essential oils of various *Backhousia* species (Brophy *et al.*1995). A more detailed study of the oil from *Backhousia citriodora* was reported by Southwell *et* al. (2000/2001). Apart from citral, each of the other terpenoid compounds in the oil of lemon myrtle may constitute less than 1% of the total. These may include compounds such as β-pinene, β-ocimene, linalool, globulol and viridiflorol. Various tests of leaves for the presence of alkaloids have provided both positive and negative results (Collins *et al.*1990; Webb 1952). A test for the presence of cyanogens in the shoots was negative (Gibbs 1974).

Toxicological. There have been numerous investigations of the possible bioactivity of synthetic citral. It is a natural constituent of many common food sources, especially the rind of lemon and other citrus species, and species mentioned previously. Much information on the metabolism and possible biological activities of concentrated citral has been published in the medical, veterinary, entomological and microbiological literature. It has been shown to have some potential as an antiseptic, antifungal and fumigant, and is already widely used in aromatherapy. Clinical investigations have almost invariably involved the use of the oil on test animals (often by injection rather than feeding) at very much higher concentrations than those found in foods, and the results may not be relevant to any use by humans of citral-flavoured foods. Some concern was expressed by Tisserand and Balacs (1995) that the use of citral in aromatherapy might increase intra-ocular pressure and so promote glaucoma. This comment was based on observations during tests of effects of citral on vascular systems and ocular pressure in monkeys and rabbits (Leach 1956; Leach & Lloyd 1956), but Berggren (1957) could not confirm the observation using further tests during which rabbits were injected with various concentrations of citral. The likelihood of any problem was also discounted by Wells (1960; cited by Everist 1981 p. 544) and there seems to have been no subsequent conformation or discussion of this particular possibility. Other, more recent, studies have examined possible clinical effects of pure citral on developmental processes and various organs in animals including the eye, but it appears that no concerns as to the normal use of citral-flavoured plant material have been expressed.

The main health concern has not been for use at the normal low concentrations in foods, as citral oil has GRAS (generally recognised as safe) status in the USA and other regions, but that concentrated citral, or even the somewhat diluted formulations as used in aromatherapy, may be ingested by mistake, inhaled in confined spaces, or otherwise absorbed or contacted in excessive and potentially harmful quantities. Frequent contact with plant material containing citral-rich essential oils, for example as during processing, can cause skin irritation - especially if detergents such as washing-up liquids have previously removed normal protective secretions from the skin, and limonene or α-pinene are not also present in the essential oil (Opdyke 1976). However, no evidence has been found that the consumption of foods or beverages flavoured with lemon myrtle leaves, which in the fresh state normally contain only about 1% citral, has been associated with health problems.

- *Backhousia myrtifolia Hook. (cinnamon or grey myrtle, ironwood or carrol)*

Part used. Leaves, as infusions.

Natural distribution. Eastern Australia, from Sydney region to Fraser Island.

Aboriginal uses. There appears to be no information about Aboriginal use of this species in foods.

Scientific studies.
General. Like the above species of this group, there is more than one chemotype. Essential oil yields from fresh leaves range from 0.5% to 2.2% (Penfold 1922; Penfold *et al.*1953, Hellyer *et al* 1955; Brophy *et al.*1995). The leaf essential oil of one chemotype contains up to 91% elemicin, two others have approximately 70-86% methyl eugenol and 74% [E]-methyl eugenol respectively, and there is possibly an [E]-isoelimicin chemotype. All these compounds belong to a chemical group of compounds of which several, in various circumstances and concentrations, have been regarded as genotoxic and sometimes carcinogenic to animals. Research on these issues is still proceeding. However, small concentrations of elemicin and/or methyl eugenol are found in a number of common commercial spices such as nutmeg, parsley and tarragon (Tisserand & Balacs 1995). The leaves were found to be free of saponins (Simes 1959), but further chemical information appears to be lacking.

Toxicological. While the use of the fresh or dried leaf for infusions for occasional use may cause no concern, there may be high proportions of undesirable compounds in the extracted oil from some chemotypes. This indicates that up-to-date information on the regulatory status and potential toxicity of the major components of the particular selection (as established by analysis) should be sought when selecting plants to propagate for use in commercial foods.

2.2.5 Citrus - Native limes. ***Family*: Rutaceae**

Notes: The former botanical names of *Microcitrus* and *Eremocitrus* have been discontinued, and all six species are now considered as species of *Citrus* (Mabberley 1998). This is the name under which most had previously been known.

A number of native citrus species have been tested as disease-resistant rootstocks for commercial citrus cultivation, and some crosses between native and related commercial species such as mandarins and calamondins have produced new cultivars with strong commercial potential. Hybridisation of Australian native *Citrus* with commercial *Citrus* species is readily achieved (Jorgenson 1976; Mabberley 1998), and has resulted in registered varieties as "Australian blood lime PBR" and "Australian sunrise lime PBR". It is beyond the scope of this study to consider these developments further. There appears to be less recorded information about Aboriginal uses of native *Citrus* fruits for food than might have been expected.

Most of the published chemical information about the constituents of Australian *Citrus* species refers only to extracts from leaf material, rather than the fruits, for example the mostly positive results for the presence of alkaloids in leaves or bark (Webb 1952; Collins *et al.* 1990. Nutritional information for the fruits of (Micro-)citrus *australis* and (*Micro)-C. australasica* (2 colour forms) is summarised in Brand Miller *et al.* (1993), see Appendix.1.

- *Citrus australasica F. Muell. (*finger lime*)*

Natural distribution. South-eastern Queensland, north-eastern NSW.

Part used. Fruits, fresh or frozen. Groups of small, separate, lemon-flavoured "cells" burst from cut sections of the fruit.

General information. In past years, there were believed to be two distinct varieties of *(Micro)citrus australasica* - a variety *australasica* with green fruit and yellowish-green pulp, and the less common variety *sanguinea* with red fruit, ranging to brown and purple, and usually pink pulp. During the revision of the botanical name to *Citrus australis* (Mabberley 1998), mention of the two varieties was discontinued. However, it is true that Australian *Citrus* species have a high level of genetic variability compared to cultivated citrus (Herrero 1995, from abstract). It now appears that there are very wide natural differences in colour in both the fruit and flesh of finger limes, sometimes even between those growing close together (E. Birmingham, Newrybar; S. Monteith, Brisbane. pers.comms). Though the taste of the flesh is generally regarded as attractively tart, this also appears to vary. The source of these variations - whether genetic or environmental - is still being sought by members of the industry. Samples of variously coloured fruits were provided for the present analyses.

- *Citrus australis* (Mudie) Planchon (round lime, wild lime, dooja).

This fruit resembles other limes in colour, attractive appearance and shape, and is a popular bushfood. Its natural distribution is limited to small areas in south-east Queensland.

- *Citrus garrawayae* F.M.Bailey (Mt White lime) is native to parts of Cape York, and Goodenough Island, PNG. Trials have supported its potential as a successful commercial bushfruit, but there is apparently no chemical information on the fruits.

- *Citrus glauca* (Lindley) Burkill, formerly *Eremocitrus glauca* (Lindl.)Swingle; *Atalantia glauca* Hook.

(desert or wild lime, native cumquat, limebush). This rather spiny species has a patchy natural distribution in arid and semi-arid areas of Queensland, New South Wales and South Australia. The fruits have had longstanding local uses for preparation of citrus-flavoured drinks, and were consumed by Aboriginal peoples (Conrick 1976; Roth 1901). Apart from the edible fruits, the plant has been used for small-scale commercial extraction of its essential oil, which contains α- and β-pinene,and approximately 60 other volatiles (Scora & Ahmed 1995). Results from some chemical analyses of leaves and bark have been located, but there appear to be none for the fruits.

No adverse effects or harmful constituents of the fruits appear to have been recorded or suspected.

There also appears to be no chemical information on the fruits of the remaining two species:

- *Citrus gracilis* Mabb., a newly described Northern Territory species. The fruits are said to have been eaten by Aboriginal people (Mabberley 1998).

- *Citrus inodora* Swingle (Russell River lime), formerly *C. maideniana* Domin., Nth Qld. This was described by Bailey (1899) as "juicy, and of equal flavour with the West Indian lime".

2.2.6 *Davidsonia* Species (Davidson's plums)

Family Davidsoniaceae (formerly included in Cunoniaceae, previously Saxifragaceae).

Names and distribution of species. Three species have now been described (Harden & Williams 2000), and all are being propagated as commercial bushfoods.

(a) The species known in both Queensland and New South Wales as *Davidsonia pruriens* F.Muell. is now considered to be native only to the Cardwell-Cooktown-Atherton region of North Queensland.
(b) Its subspecies *jerseyana* of northern New South Wales is now a separate species, *D. jerseyana* (F.Muell.ex Bailey) G Harden & JB Williams..
(c) *D. johnsonii* JB Williams & G Harden (Smooth Davidsonia) is the formerly un-named, endangered species from small areas near the coast, on both sides of the NSW/Q border, and it is protected by legislation from collection in the wild.

Parts used. Fruits, with seed/s discarded, mostly after sweetening and diluting, as in jams or sauces. The fruiting times of northern (*pruriens*) and southern (*jerseyana*) species are different (Costin 1996).

Traditional uses. Aboriginal children are said to have eaten *D. pruriens* fruits raw, but there appears to be no record of Aboriginal use of the other species (Roth 1901; Hardwick 1996). Modern culinary use of cooked fruits extends back for perhaps a hundred years or more (Bailey 1909).

Scientific studies.
General. Nutritional values for *D. pruriens,* in the broad sense, are summarised in Brand Miller *et al.* (1993), see Appendix 1. These appear to be the only chemical data available for the fruits, although there are some early records of cyanogens in leaves or stems (Petrie 1912; Hurst 1942, Gibbs 1974). The leaf and bark have been tested for alkaloids and anti-tumour activity with negative results (Collins *et al.* 1990).

Toxicological. The irritant hairs which cover the fruit of *D. pruriens* and *D. jerseyana* to a greater or lesser extent should be rubbed off the surface of the fruit, or removed by gently rubbing under running water (Bruneteau 1996). Detached hairs can also be a problem when harvesting the fruit of both species.

There is one report of a patient experiencing vomiting and epigastric pain after eating unripe fruits of a *Davidsonia* species (Flecker 1945, cited by Everist 1981). There seems to be very wide variation in the sourness of the taste of raw fruits from different selections, and, as with other very acid or unripe fruits, individual tolerances may be limited. Petrie (1912) recorded a positive result in a test of the plant (probably not including the fruit) for cyanide.

2.2.7 *Hibiscus* Species (rosellas)

Family. Malvaceae

- *Hibiscus heterophyllus Vent. (native rosella) and related species.*

Natural Distribution. Coastal regions of Queensland and NSW.

Varieties and forms. Native rosella is an extremely variable species, and natural and induced crosses with other species are very common. Confusion with *H. divaricatus* is common (Keena 1997). *H. heterophyllus* is sometimes described as a complex of species, and the overall flower colour and distinctive markings can range from white to a wide range of pink and red tones (Wilson & Craven 1995).

Part used. The flower petals are used to colour and flavour beverages, baked dishes, salads and desserts. The flowers have larger petals than the better-known wild rosella (mentioned below) from which the more conspicuous calyces are selected for use in foods. Nutritional values for the flowers, and those of *H. diversifolius* and *H. tiliaceus*, are given in Brand Miller *et al.*(1993)(see Appendix 1).

Traditional uses. The Aboriginal people of North Queensland ate the roots of young plants, young shoots and leaves of *H. heterophyllus.* The buds and the peeled, thick, starchy but fibrous roots of the related species *H. divaricatus* were also eaten. (Bailey 1899; Weston 1998). A decoction of *Hibiscus* was used to ease the symptoms of coughs and colds (Cribb & Cribb 1974 p.222). The sour leaves of *H. heterophyllus* were known as native sorrel by early European settlers and having been boiled to lose their acidity, used as a substitute for spinach (Low 1989).

Scientific studies.

(a) General. Apart from the analysis of nutritional constituents (Brand Miller *et al.*1993) the chemistry of this species does not appear to have been studied extensively. It might be expected to be similar to that of other tropical *Hibiscus* species for which some records are available. The mucilaginous flowers, used in jam, contain pectins, but require the addition of acid in some form. The jam is always a brilliant rosella colour regardless of the original colour of the corolla (Wrench 1998). All tests for alkaloids in leaves of *H. heterophyllus* and four other native *Hibiscus* species (Collins *et al.* 1990) were negative, as were two tests of the leaves and stem of *H. diversifolius* from Mt Coot-tha, Qld. (Webb 1948). A different test method during this latter study gave a positive result, which might have been due to the reaction of the reagent with starch in the plant (Webb 1952).

(b) Toxicological. Cribb & Cribb (1974) assert that "any hibiscus is almost certainly safe to eat". However, the seed “pod” of some species is covered in sticky hairs that may cause skin irritation. They may be removed from the skin with sticky tape, and the seeds should be extracted from the pod with tweezers (Keena 1997). There do not appear to be any reports of adverse effects from consumption of products from the flowers or buds and calyces in foods. There has been a single anecdotal report that very frequent use of the leaves to make infusions resulted in some form of kidney damage, and it is known that Aboriginal people used the plant sparingly, more as a medicinal plant than a food (Barker 1995). However, numbers of people have used the leaves in infusions over long periods without untoward effects. Some of the potentially bioactive compounds in various *Hibiscus* species (Duke 1992a, b) are not readily water-soluble and so would not be present in infusions unless the crushed leaves themselves were included.

Maiden (1889) and later authors including Watt & Breyer-Brandwijk from Africa (1962) and those cited by Cambie & Ash (1994), have noted that the juice of the leaves of *H. diversifolius* (a very wide-ranging and somewhat variable species) had been used to procure abortions in Fiji. Some, if not all, such mentions appear to be based on a single report by Seeman on a Government mission to Fiji in 1860-1861. With the passage of time, the possibility of such activity appears to have been more or less discounted (Webb 1948; Cambie & Brewis 1997).

- *Hibiscus sabdariffa L. (wild rosella, roselle, Jamaica sorrel).*

General information. Rosellas possibly originated in West Africa, but are now widely naturalised, cultivated and bred in tropical areas. The naturalised population found in northern areas of Australia (coastal NT and Cape York) is believed to have been brought from islands to the north before European settlement, and the plant has been added to the list of native Australian bushfood species. Infusions of the calyces are used as a caffeine-free drink, as well as for preserves and flavourings.

Chemistry. The chemistry of this species has been extensively documented and new constituents are frequently reported. The dried flowers minus the ovary, as normally used in foods and beverages, are sold as "karkade" and contain proteins, carbohydrates, citric and malic acids, gossipetin and hibiscin (anthocyanins), phytosterols and hibiscic acid and a very small amount of ascorbic acid (Duke 1983).

Bioactivity. The fresh or dried red calyces are used in many foods and drinks and in folk medicine for a wide range of conditions. Some people seem to be particularly susceptible to skin irritation when handling the flowers and removing the calyces and fruits, resulting in various forms of skin rashes and mucosal irritation. However, there appear to be few reports of adverse effects of consuming rosella calyces, and even fewer that have been unequivocally supported by testing. There is, however, a multitude of claims in folk-medicine for the medicinal effectiveness of preparations from this species, many of which are listed at:
http://www.hort.purdue.edu/newcrop//duke_energy/Hibiscus_sabdariffa.html. Many such claims have been undergoing stringent testing (e.g. Leung & Foster 1996). Other important and well-researched claims are for antihypertensive action (Jonadet *et al* 1990; Duke 1983, 1992 a, b) antioxidant activity (attributed to protocatechuic acid, Tseng *et al.*1996), and absence of mutagenicity to some organisms (Duh & Yen 1997). Further claims, with or without support following clinical tests, have been made for promoting diuresis, for emollient, antiinflammatory, sedative, laxative and tonic activity, and amelioration of many common ailments and injuries.

2.2.8 *Kunzea pomifera* F.Muell. (Muntries, native cranberry, muntharis)

Family: Myrtaceae

Natural distribution. South-eastern SA and adjacent drier areas of Victoria

Part used. The succulent, small, apple-flavoured fruits, fresh, frozen or dried. They are used for various types of main dishes, and in desserts as a substitute for apple (King 1998). The colour fades to brown if the prepared food is not consumed in a short time (Robins 1996).

Traditional use. Aboriginal use of the fruits as food has been recorded (under a variety of traditional names) for over a hundred years - for example by Dawson (1881), cited by Gott (1982). This fruit is the most-often recorded Aboriginal food species for southern South Australia (Clarke 1998). Dried fruits were also traded between groups in exchange for items of value from other districts (Low 1989).

Scientific studies.
(a). General. Little chemical information is available for the fruits. The leaves contain no alkaloids and have no anti-tumour activity (Collins *et al.* 1990). A related New Zealand species, *Kunzea ericoides* (manuka) is an important source of honeys, which have been found to have substantial anti-

bacterial activity (Allen *et al.* 1991). Phlorglucinols with antiviral activity have been isolated from the same species (Bloor 1992).

(b). *Toxicological:* No reports were found of adverse effects or the presence of deleterious compounds. A personal communication (1998) from Mr Tony Page of Burnley College, who was studying genetic diversity in *Kunzea pomifera*, was that he had eaten the fruits every day for about 10 days and had had no negative experience, nor had he heard of any adverse reaction to the fruit. Muntries were a popular bushfood, both with Aboriginal people and those more accustomed to modern commercial fruits. There was no possibility of misidentification of the plant, and the only problem might be that as the fruit is quite close to the ground, harvesters would need to be mindful that impurities were not included in the harvest. The fruits were said to be easy to clean, durable and able to tolerate a fair degree of handling.

2.2.9. Native mints and basils (various species of *Mentha, Ocimum and Prostanthera).*

Family: Lamiateae (formerly *Labiatae*).

In each species, the leaves and terminal shoots are used as flavourings. Many cosmopolitan kitchen herbs and spices including sage, mint, marjoram, thyme and oregano also belong to the same family. The comments below refer to some of the more popular selections of native mint-type species for use in foods. Some information is included on the composition of their essential oils, which are their main source of flavour. A few components of such oils have been found to be undesirable if consumed in quantity. However, it must be noted that the amount consumed of any of this group of plants, as normally used for flavouring, would not exceed that of similar types of commercial spice plants, which often containing oils of similar composition, and are very widely used without evidence of harm.

2.2.9.1. *Mentha species:*

General information. There are at least six Australian species of *Mentha,* many of which have been used at times in food preparation and for medicinal purposes. The aromatic essential oil is the basis of the aroma and flavour of the mints. In early colonial days, some species were used in infusions as substitutes for European pennyroyal (*Mentha pulegium*), which has a rather similar essential oil composition. The similar bitter taste of the native species was associated with health-giving ("tonic") effects and digestion-improving qualities". (Lassak & McCarthy 1997). Although pulegone, the undesirable component of pennyroyal oil, can affect liver and reproductive functions when ingested in quantity (e.g. 0.5 g/kg body weight in rats), it is still an allowable additive for food flavouring below 0.025 g/kg in various food regulations. (Opdyke 1978; Tisserand & Balacs 1995). Pennyroyal oil is listed in Schedule 2 of the ANZFA Food Code as a restricted substance for addition to, or presence in, foods under Clause 4 of Standard 1.4.1 of the ANZFA Food Code.

Jones and Berry-Smith (1925) noted that the yield of oil of (commercial) *Mentha* species is known to be much influenced by soil, season and time of harvesting. Some information on the chemical composition and bioactivity of *Mentha* species of the Pacific region is cited by Cambie and Brewis (1997).

- *Mentha australis* R.Br. (river mint, creeping mint, Australian mint, native peppermint).

Natural distribution: All Australian States.

Traditional and colonial uses. M. australis has a peppermint aroma when crushed, and a decoction or inhalation of the crushed leaves was reported to have been used to treat respiratory complaints, menstrual disorders and headaches (Roth 1903; Lassak & McCarthy (1997). In colonial days it was used to prepare a "wholesome" tonic (Bailey 1909; Low 1990). However, the plant has been suspected of toxicity to grazing sheep and cattle (Webb 1948). Preparations from larger quantities of the plant may have been used as an abortifacient (Lassak & McCarthy) as, like pennyroyal, its essential contains an irritant factor (pers. comm.from Everist noted by Webb (1948). However, in normal use as a flavouring or spice, extremely small quantities of the oil are consumed.

Scientific studies. A review by Gibbs (1974) reported absence of cyanogenic compounds. No published analysis of the essential oil has been located..

- *Mentha diemenica* Spreng. (= *M. gracilis* R.Br.) (slender mint, native pennyroyal).

Natural distribution: All States except WA. The plant is somewhat variable when specimens from different regions are compared, and is closely similar to *M. satureioides,* with some intermediate forms.

Traditional and colonial uses: Infusions of the peppermint-flavoured leaves were used in early colonial days for intestinal pains and menstrual disorders, as well as to repel insects such as fleas in habitations (Maiden 1889).

Scientific studies and toxicology. Pulegone (24%-44%), and menthone (32%), are the major constituents of the essential oil of this species (Brophy *et al.* 1996). It has been said that that the oil from *M. diemenica* may contain much higher levels of pulegone at some times of the year, but the amount likely to be ingested from use of plant material would be small (for pulegone, see above under introduction to *Mentha* species).

- *Mentha satureoides* R.Br. (native or Brisbane pennyroyal, creeping mint).

Natural distribution. All mainland States.

Traditional uses. Similar to other native mints.

Scientific studies. Gibbs (1974) and Webb (1949) reported that cyanogens were absent from the plant, but positive tests for alkaloids were recorded by Webb (1949). An early analysis of the essential oil of a Queensland sample showed it contained c. 40% pulegone, 20-30% l-menthone, 12% of l-menthol and 8% menthyl acetate (Jones & Berry-Smith 1925). Like *M. pulegium,* (see above under *Mentha* species) decoctions of the plant have been used to procure abortions (Low 1990). The plant has occasionally been suspected of causing mortality of cattle through abortion, and photosensitisation and death of sheep (Webb 1948).

- Other *Mentha* species.

Mentha grandiflora Benth has been considered unsuitable for food use. It also contains pulegone (19%), but other constituents (piperitone oxides) are more abundant. It has a very strong smell of pennyroyal (Brophy *et al.* 1997)

2.2.9.2. *Ocimum species (native thyme)*

- *Ocimum tenuiflorum L.*

This species includes the varieties *anisodorum* and f. *villicaulis*, both formerly considered to be separate species. The species formerly known in Australia as *O. sanctum* (and mentioned as such in early records of plant use), is now included in *O. tenuiflorum,* along with its subspecies *angustifolium* and species sometimes known as *O. anisodorum* and *O. caryophyllinum* (Lassak & McCarthy 1997). There are at least three or four *Ocimum* species, and some subspecies, in the wild in Australia, including those locally naturalised for uncertain periods, and their taxonomy has been variously revised over time.

Natural distribution. Mostly inland, in Queensland, NT, New Guinea, islands to the north and east of Australia, and Asia.

Parts used. Shoot tips and leaves.

General information. Native thyme is becoming of increasing interest to the bushfood industry (Phelps 1997) and is used as an alternative to thyme (*Thymus vulgaris*), sweet basil (*O. basilicum*) and other common herbs.

Traditional and colonial uses. Aboriginal people of the Northern Territory prepared hot, clove-scented infusions from the plant (known as "bush tea leaf"). Infusions of the plant were used as a cure for dysentery, fever and sickness. Europeans regarded the infusions as a tonic and a cure for 'Barcoo Rot" (Brophy *et al.*1993). Grieve (1973) says "it is regarded as an aromatic stimulant in Java."

Scientific studies.
(a) General. Tested under the name of *O. sanctum,* the plant was found to contain alkaloids (Webb 1949). The essential oils of this species have been investigated by Brophy *et al.* (1993). The main constituents were methyl chavicol (estragole; 87%), β-caryophyllene 5% camphor 4%, and less than 1% each of thirteen other compounds. The high yield and composition of the oil was considered similar to that of sweet basil, although previous tests had indicated that the constituents and composition of the native mint oil were variable, and one variety of sweet basil contains less than 5% of this compound (Tisserand and Balacs 1995). Comments in the literature suggest that the aroma of the essential oil of *O. tenuiflorum,* which also has a wide distribution outside Australia, may be variable depending on location (Maiden 1889). Alternatively, further botanical revision may be required (Brophy *et al*. 1993).

(b) Toxicological. The sample of native mint tested by Brophy *et al*. (1993) had a similar concentration of methyl chavicol in the oil to that of the Comoro type sweet basil, as listed in Tisserand & Balacs (1995). These authors cautioned against the use of the high-methyl chavicol oils in aromatherapy, but refer to research showing that that both humans and other animals have some ability to detoxify small quantities of this compound through natural metabolic processes in the liver. It could be expected that the small quantities of native mint used in flavourings, during which they are often subjected to heating processes, should give no cause for concern in normal frequency and quantity, if used similarly to sweet basil.

- Other *Ocimum* species.

The Queensland Herbarium (Henderson 1997) recognises *O. americanum, O. basilicum* (sweet basil) and *O. tenuiflorum* as introduced, but as they appear in very early records, the date of first introduction is uncertain. All are used commercially.

2.2.9.3. Prostanthera species.

Prostanthera. is a wholly Australian genus of over eighty species. Selection of material for production of bushfoods is sometimes complicated by a high degree of taxonomic and chemical variation within species, as well as by natural crosses. The distribution and taxonomic features of some *Prostantheras* from various regions have been described by authors including Conn (1998)

Traditional uses. Aboriginal uses of *Prostanthera* species appear to have been few, and were primarily medicinal (as in Goddard & Kalotis 1985). While Aboriginal people used some *Prostanthera* leaves in medicinal ointments and washes, they also used the crushed leaves of one species (*P. striatiflora*) to poison waterholes and thereby the emus that drank there. (Isaacs 1987; Latz 1995). No alkaloids were found in the plant (Collins *et al.* 1990), and the chemical basis of bioactivity appears to be unknown.

Chemistry and toxicology. As with *Backhousias* and the other native mints, the composition of the small quantities of volatile essential oil is the basis of the sought-after aromas and flavours of selected *Prostanthera* species. Various useful information on the characteristics and essential oil composition of groups of *Prostanthera* species can be found in Althofer (1978), Lassak (1980) and Fulton (2000). The main component of the oil is usually 1,8-cineole (also known as eucalyptol) which constituted over 40% of the steam-distilled essential oils from 23 of 39 species and varieties tested by Lassak (1980). The range for all species tested was 1% -91%. Some variation in results from various provenances are due to different analytical methods as well as to chemical differences within a species.

Studies of three species (*P. rotundifolia, P. incisa* and *P. lasianthos*) showed that the fragrance of the leaves was destroyed by baking, but persisted better when used as an ingredient in microwaved dishes (Fulton 2000). In the same report, sensory tests pointed to a loss of fragrance with storage, the loss being only partial in the case of *P. incisa* and *P. rotundifolia* but quite complete in the case of *P. lasianthos*. The varying degree of loss was supported by GCMS data, which also indicated that the oil of *P. incisa* was more resistant to storage decay than that of *P. rotundifolia.* It was speculated that the bitter tastes of the leaves (decreasing somewhat on storage) might be due to other components as well as to the terpenoids that are present in the oil. The study concluded that "from an extensive literature search centred on the chemicals defined by GCMS the conclusion was drawn that while ingestion of moderate quantities of the leaf was unlikely to produce untoward effects, conservatively a safe adult dose consists of about four and a half teaspoons of the ground dried leaf, or about 0.2 ml of the pure oil, assuming a safety limit that is parallel to that of Eucalypt oil." Medicinal oils from *Eucalyptus* species also contain a high proportion of 1.8-cineole (Boland *et al*. 1991).

Some aspects of the chemistry and ecology of *Prostanthera* species were reviewed by Conn & Whiffen (1984). The results indicated that environmental factors had little or no effect on the composition of the essential oils in the species tested, but might influence the amount present. The composition of the oils was found to be most stable in autumn and winter. Fulton (2000) suggests further investigation is required. It is not known whether routine grafting on to rootstocks of related species, for example of *Westringia,* to extend productive life, could influence the essential oil concentration or composition.

Members of this family usually do not contain saponins, but often accumulate nitrate (Cronquist 1981). Tests for the presence of alkaloids in vegetative parts of five *Prostanthera* species provided a range of results from negative to very strong, depending on species (Webb 1949), but most of the fourteen species tested by Collins *et al.* (1990) provided negative results. A species of *Prostanthera* was suspected of causing dermatitis (Hurst 1942).

The following species are among those currently popular for culinary use:

- *Prostanthera incisa* R.Br.

Natural distribution. parts of Victoria, New South Wales and southern Queensland.

General information. Four varieties of *P. incisa* (*communis, pubescens, sieberi* and *tenulor*) were listed by Chapman (1991). There has been considerable confusion as to taxonomic distinctions between *P incisa* and *P sieberi,* which overlap in distribution, and form a complex of species, varieties and intergrades (Conn 1998). Taxonomic distinctions and chemical variations are not easily recognised during wild-harvesting of material, and in practice commercial material is usually obtained from horticultural selections. An ornamental horticultural selection known as *P. incisa* var. (or cv.) *rosea* may possibly be the closely similar *P. rotundifolia* (Macquarie 1986).

There have been some anecdotal reports of temporary adverse effects from working with or in close proximity to *P. incisa* and inhaling the concentrated fragrance. Dizziness and chest pains have been reported, but no cause has been established. The essential oil varies in composition, but may contain 58%-69% of 1,8-cineole, 6%-15% of globulol, and lesser proportions of other compounds (Lassak 1980; Fulton 2000). The essential oils, which are the basis of use in foods, were almost identical in samples of *P. incisa* and *P. sieberi,* considered as separate species (cineole : globulol ratio 54% : 6% and 49% : 6%, respectively. (Lassak 1980). However, at least in the case of *P. incisa,* there is said to be strong variation between the fragrance, and presumably the essential oils, of adjoining plants. Extracts from the leaves have weak preservative activity, and show some activity against the Gram-positive bacteria, *Bacillis subtilis* and *Staphylococcus aureus,* but none towards Gram-negative organisms (Fulton 2000). No evidence of cyanogens was reported by Gibbs (1974) for either *P. incisa* (shoot) or *P. sieberi* (plant).

- *Prostanthera ovalifolia* R.Br. and related species

Natural distribution. South-Eastern States.
In southern areas, the industry has used selected crosses of species, including *P. rotundifolia* x *ovalifolia*. *P. ovalifolia* and three species regarded as having affinity to it all had quite dissimilar essential oil composition (Lassak 1980). The concentration of 1,8-cineole in the samples was 1%, 9%, 52% and 60%. These differences support the probability of difference at the species level. Tops of *P. ovalifolia* had no anti-tumour activity (Collins *et al.* 1990).

- *Prostanthera rotundifolia* R.Br. (round-leaf mint-bush).

Natural distribution: South-Eastern States
Scientific studies. The essential oils of three forms of the species contained 1,8-cineole as the main constituent (34%-49%). However, there were both quantitative and qualitative variations in the oil composition (Lassak & McCarthy 1997). Fulton (2000) reported 38%-40% 1,8-cineole in oil extracts of fresh leaf, but there was also a substantial quantity (30%-33%) of an unidentified compound. The shoots contain no cyanogenic glucoside (Gibbs 1974) and the leaves had no alkaloids (Collins *et al.*1990).

The leaves of both *P. rotundifolia* from New South Wales, and a related species from Victoria contain antimicrobial sesquiterpenes (Dellar *et al.*1994). *P. rotundifolia* leaf has weak antimicrobial and preservative activity (Fulton 2000). It is believed that lipophilic components of the leaf are responsible for these properties. The volatile oil is carminative (antiflatulent) (Bosisto, cited by Maiden 1889; Lassak & McCarthy 1997).

- *Prostanthera lasianthos* Labill. (Victorian Christmas bush)

Natural distribution. All States.
Scientific studies have been limited. 1,8-cineole (eucalyptol) is the main component of the essential oil, with all components varying with the sample and method of analysis (Lassak 1980; Fulton 2000). The leaves and stems of the plant did not contain alkaloids (Collins *et al.*1990). Extracts from the leaves had no antibacterial activity (Fulton 2000).

2.2.10 *Podocarpus elatus* R Br. (Illawarra plum, brown pine)

Family: Podocarpaceae

Natural distribution. Northern Territory, and from Cape York Peninsula southwards in disjunct areas to southern NSW. The trees are dioecious, hence only female trees produce fruit. It is difficult to establish the sex of a tree before its first, long-delayed flowering. There are several other Australian *Podocarpus* and related species which may also prove to be useful sources of bushfruits.

Part used. The "fruit" is more correctly the fruit stalk, which is greatly expanded, and deep purple in colour when ripe. It is usually much bigger and softer than the hard-coated seed, which is attached to the outer end and is discarded after harvesting. Nutrititional value for both the fruit and the seed (and the edible "nut" of *Podocarpus amarus* (see below, as *Sundacarpus amarus*) are given by Brand-Miller *et al.* (1993).

General information. The taste of the edible portion is highly variable, sometimes strongly resinous and/or astringent with a lingering aftertaste. For cooking, the particularly resinous core is first removed with an olive corer, and stainless steel or ceramic cookware is used rather than aluminium (Robins 1996). Illawarra plums are used for plum and chili sauces, glace fruit, jam, chutney, and cheesecakes. The colour changes from dark purple to reddish when acid is added, for example in jam-making (Wrench 1998).

Traditional uses. The "fruits" were esteemed as food by Aboriginal people of southern New South Wales, and were also eaten in north Queensland (Roth 1901). However, they were possibly less sought-after in northern areas, where the range of alternative types of edible fruit is wider. A north Queensland relative, *Sundacarpus amarus,* formerly *Podocarpus amarus* has larger red seeds and no fruit stalk. The seeds of this species were eaten after roasting, rubbing between stones, and mixing with a little water (Cribb & Cribb 1974).

Scientific studies
(a) General. Little information is available for the edible portion. Resins and colloids (but not acid) are said to be present in the plant (Gibbs 1974). The leaf, bark and wood had no anti-tumor activity (Collins *et al.* 1990).

(b) Toxicological. No reports of toxicity have been found, and it is thought that all *Podocarpus* fruits are edible (Bindon 1993). The gluey or resinous tastes which have often been reported from the fruit-stalk do not appear to lead to any ill-effects. However, working with the wood of a *Podocarpus* species native to eastern Africa has been reported to cause allergic reactions (dermatitis, rhinitis, conjunctivitis; (a reference cited by Watt & Breyer-Brandwijk 1962). The pollen from a Singapore *Podocarpus* species has also been reported to be associated with asthma and rhinitis (Chew *et al.* 2000). No similar mention has been found for any of the Australian species.

2.2.11 *Santalum* Species (quandongs, sandalwoods)
Family: Santalaceae

Six species of *Santalum* are native to Australia, and there are about 20 other species elsewhere in the world. Nutritional values for the flesh and kernels of *S. acuminatum, S. lanceolatum*, and the kernels only of *S. album, S. murrayana* and *S. spicatum* are summarised in Brand Miller *et al* (1993), see also Appendix 1. *Santalum album,* the main source of commercial sandalwood, is found in a few coastal areas of the Northern Territory as well as outside Australia, and is also cultivated in India and elsewhere (George 1986). *S. spicatum* and *S. lanceolatum* are other native species which have been a limited source of commercial sandalwoods. Flesh and/or seeds of some quandongs were important items of Aboriginal diets.

- *Santalum acuminatum (R.Br.) A. DC*. (desert quandong, native or wild peach)

Natural distribution. Q, NSW, Vic, SA, WA, NT.

Part used. Flesh. The kernels are not considered desirable for commercial food use, but have been valued for external use in traditional medicine (see below). The fleshy outer layer is sold fresh, frozen or in halved and dried form. After drying, it can have a long shelf life, before being reconstituted to 2-2.5 times the dried size for use (AQIA/Robins 1997). .

General information. Various selections of early- and high-yielding stock for cultivation have resulted from research by the quandong industry and associated research organisations in SA and WA. (Conroy 1996 and other *Rural Research* and WANATCA articles). Quandongs are partial root parasites, drawing nourishment from various associated plants. Much of the research has involved optimising host-parasite relationships. The species has been introduced into several tropical countries, including Malaysia and Singapore.

Traditional uses. The yellow skin and red flesh of the ripe fruit was eaten raw, or mashed in water to make a drink, or dried and the flesh subsequently reconstituted for use by soaking (Aboriginal Communities of NT 1988). The strongly-flavoured oily kernels were sometimes consumed, in season, possibly more by children than adults ,or were roasted or "just left for a while" before consumption (Latz 1995). The strong unpleasant flavour is mostly due methyl benzoate (see under *S. acuminatum* toxicology), which can be estimated to some extent based on taste (Loveys *et al*. 1984). Quandongs were favoured for use in poultices and liniments for aches and pains (Goddard & Kalotas 1995; Winfield 1982). Aboriginal users were able to select the most desirable kernels for each use from particular trees.

Scientific studies.
(a) General. The flesh of *S. acuminatum* is not particularly sweet, with sugars (principally fructose and glucose) at 7%-12%, and a somewhat higher level of Vitamin C than the average for oranges (CSIRO 1998*).* The kernels contain a high level of oil (56%-67%) and protein (13%-19%) (Rivett *et al*. 1983, 1985). Apart from methyl benzoate, they also contain methyl salicylate, and fatty acids including santalbic acid. There were negative results in tests for saponin and essential oils, but positive (+green) for triterpenes or steroidal compounds. - but less so than the fruit skins (+++green) (Aboriginal Communities of the NT, 1988).

(b) Toxicological.

<u>Santalbic acid</u>. Occasional concerns have been expressed about possible toxicity of the kernels due to the presence of santalbic acid (trans-11-octadecen-9-ynoic acid). This fatty acid was a major component (32%-46%) of the fatty acids in the kernels of five native *Santalum* species studied by *et al.* (1985). It is not known to occur in any other food. Its structure and metabolism in test animals has been found to be unlike that of normal dietary fatty acids, such as those contained in canola oil, with which the oil composition of *S. acuminatum* was compared (Jones *et al.* 1994). It was suggested that further studies were required to investigate whether consuming quandong kernels was hazardous. Rats fed a diet to which quandong kernels contributed 50% of the dietary energy absorbed 90% of the santalbic acid, and the biochemical and metabolic functions of the liver were affected. Santalbic acid appears to be metabolised differently from the usual dietary fatty acids (Jones *et al.* 1999, from abstract). Santalbic acid extracted from the kernels has also been shown to have antimicrobial activity (Jones *et al.* 1995).

<u>Methyl benzoate</u>. This compound has a strong, rather unattractive aroma, and is responsible for the unpleasant aftertaste of the kernels. The methyl benzoate content varies by tree and by year, with variations between 32-1294 ug/g fresh weight having been reported. Roasting did not remove the problem, but heating under 100 Pascals pressure reduced the methyl benzoate content by 34% (Loveys *et al.* 1984).

Quandong kernels have been previously analysed for hydrogen cyanide, but none was detected (Sedgley 1982).

Note: As with other dried fruits which can be stored for a long time, the dried flesh of the fruits may need to be inspected periodically for fungal growth or insect attack.

- *Santalum lanceolatum R.Br.* **(**Northern sandalwood or plum bush*).*

This species has a generally more northerly distribution than *S. acuminatum* and also has edible, rather sweet flesh, which is an Aboriginal food (Roth 1901; Winfield 1982; George 1986; S. Ross, pers. comm.). Kernels were also eaten (Latz 1995). As with the four other Australian S*antalum* species tested, the kernels contain santalbic acid (Rivett *et al.*1985).

- *Santalum murrayanum* C.A.Gardner.

The bitter-tasting outer layer does not appear to support the use of this species as a bushfood.

- *Santalum spicatum (R.Br.) A.DC.* (West Australian sandalwood)

This species is native to Western and South Australia and has edible kernels which are rich in fat and protein (Fox 1997). It has been suggested as an alternative to *S. acuminatum* for bushfood production. The kernels of both species have rather similar composition, except that those of *S. spicatum* are free of methyl benzoate. They do, however, also contain santalbic acid ((Rivett *et al.*1985). The metabolism of the fatty acids of this species has been examined by Liu & Longmore (1997). Extracts from the edible, but reportedly rather dry and bland fruit have been used medicinally by Aboriginal peoples (George 1986). Tops of the plant gave strong positive results in a test for alkaloids (Aplin and Cannon 1971).

2.2.12. *Solanum* species (bush tomatoes)
Family: Solanaceae

NOTES: SOME OF THE MANY NATIVE SPECIES OF *SOLANUM* ARE TOXIC!

General information on Solanum species.

There are about 2000 *Solanum* species worldwide, with most of the 70-80 native species being endemic to Australia. There are at least another 8-12 naturalised species. Although many native *Solanums* have fruits which are, at least when green, very similar in appearance, the species that are known to have been safely used for foods are few in number and tend to be those of semi-arid and arid areas where the choice of food sources was limited. A number of native and introduced *Solanum* species, including the naturalised *S. elaeagnifolium,* which may be found in the same localities as edible species and resemble them in size and appearance, have been recorded as stock poisons (Gardner & Bennetts 1956; Hurst 1942; McBarron (1977). Nutritional values for the fruits of six native species, including *S. centrale,* are summarised in Brand Miller *et al.* (1993).

Traditional uses of native Solanum *species.* The fruits only (preferably fully ripe) of edible species are used for food, often after removal of the seeds, seed pulp and juice. In some bush tomato species, the seeds are bitter and inedible, even potentially toxic when eaten in quantity, while some others suited for use in foods require the removal of the seeds and the surrounding pulp, and any juice, and sometimes cooking, as in the case of *S. coactiliferum* (Latz 1995). The ripe, dried or fresh fruits of a number of species of *Solanum* are staples of traditional Aboriginal diets. Cherikoff (1989) lists twenty bush tomato species eaten by Aboriginal groups, making up over 50% of their diet when in season. Fruits of species known to be edible are usually collected for food use only when completely ripe. Species with fruits which gradually harden to a bone-like consistency when ripe were not used (Latz 1995). An extensive review of Aboriginal management and use of *Solanum* species, including *S. centrale*, is contained in Peterson (1979).

Whole fruits of species including *S. centrale, S. cleistoganum* and *S. ellipticum* were eaten raw. In the case of *S. ellipticum,* the fruits were eaten when the colour changed from flushed purple to pale yellowish-green (Winfield 1982). Seeds of *S. chippendalei, S. esuriale*, *S. coactiliferum* and *S.*

diversifolium were removed after splitting the fruit, and the flesh (or "rind") eaten raw or toasted depending on species (Peterson 1979, Goddard & Kalotis 1988; O'Connell *et al.* 1983; Latz 1995; Robins 1996). *S. esuriale* is known to be toxic to sheep (Lazarides & Hince 1993). Bush tomatoes are still eaten with regularity in Central Australia (O'Connell *et al.* 1983). If the seeds of edible *Solanum* species are eaten with the fruit, the seed coat protects them from digestion, as with seeds of cultivated tomatoes (*Lycopersicon esculentum*) also of the family Solanaceae. As a result, the ground fruit provides more dietary protein than whole fruit. Avoidance by Aboriginal people of many *Solanum* species, based on experience, can now be at least partly explained in those cases where the presence of the bitter and potentially toxic alkaloid solasodine, or other alkaloids of the same class, has been established (see toxicology section below).

Ripe fruits of kangaroo apples, two closely related species - *S. aviculare* (with smooth fruit) and *S. laciniatum* (which has fruit which dry to a warty appearance) - were eaten by Aboriginals, although even ripe fruits of both are known to contain some solasodine. (Bradley *et al.* 1978; Cribb 1974; McBarron 1977; Purdie *et al.* 1982). However, both *S. aviculare* and *S. lactinatum* (apparently a misprint for *S. laciniatum*) are listed in the recently gazetted Schedule 1 of ANZFA Standard 1.4.4 as prohibited plants (see: anzfa.gov.au/draftfoodstandardscode/Standard1.4.4plantsInq.htm) which, when "listed in Schedule 1, or any substance derived therefrom, …. must not be intentionally added to food or offered for sale as food." It appears that, as with related species, the ripe fruit are safer to eat than when unripe, but until the position is clarified, bushfood producers and consumers should take note of the prohibition for commercial use. *S. aviculare* has been grown overseas for use as a commercial source of steroidal compounds used in the synthesis of contraceptives and corticosteroids

Scientific studies:
(a) General. Plants of the Solanaceae commonly contain various kinds of alkaloids, but are seldom cyanogenic (Cronquist 1981). Many positive records of the presence of alkaloids in native plants, such as those of Aplin & Cannon (1971) for Western Australia, refer to leafy material only. The nutritive value of bush tomatoes has been extensively analysed. In general, ripening and drying concentrates the nutrients contained in the fruit, as water comprises 5%-28% of the dried fruit and 45%-78% of fresh fruit (Brand Miller *et al.*1993), see also Appendix 1. The occurrence of Vitamin C is also very variable, diminishing gradually on storage (Cherikoff 1989). The reported nutritive composition of several edible bush tomato species have been compared with those of tomatoes by Peterson (1979), the values for bush tomatoes mostly being somewhat higher.

(b) Toxicological. The toxins of *Solanum* plants, as a group, if present, are more concentrated in the fruits, but are also found in leaves and stems (Dowling & McKenzie 1993). Most toxicity data relate to the poisoning of stock which have consumed foliage as well as fruits. (Hurst 1942, and for more detail, Everist 1981). In most cases, the source of the toxicity is suggested as one of the solanine alkaloid group. There are many confirmed (or in some cases conflicting) Australian reports of toxicity to humans and/or stock from an extensive range of *Solanum* species, suggesting that for some species such problems may vary with location, season, natural variability and maturity of the plants and fruits, and the type of animal which consumes them.

The fruits of a large number of Australian *Solanum* species - both edible and inedible - were tested by Bradley *et al.*(1978) and some were found to contain the bitter and poisonous steroidal alkaloid solasodine. The concentration in most (but not all) of these cases was somewhat less in ripe than green fruits. Ripe fruits of many *Solanum* species appear to be fairly safe (Everist 1981), but there are hundreds of species. Some solasodine may also be found in the edible parts of widely cultivated members of the family Solanaceae - cayenne pepper, tabasco and green-tinged, light-affected potato tubers. It has been found that potatoes with levels of solanine alkaloids greater than 20 mg/100g fresh weight are unsuitable for human consumption (Finlay *et al.* 1998).

Several of the Australian species of *Solanum*, e.g. *S. ellipticum, S. esuriale, S laciniatum* and *S.simile,* appear to have sufficient quantities of either solasodine or other compounds in the ripening fruits to cause Aboriginal people to delay their use, usually until they are ready to fall to the ground (Bradley *et* *al.* 1978). This group found solasodine in fruits and/or other parts of many of 84 species tested, but not *S. centrale.* Fruits of *S. petrophilum* and *S. quadriloculatum* are among those said to be quite poisonous (Everist 1981, Latz 1995), but the Bradley group did not find solasodine in the only sample of *S. quadriloculatum* they analysed. However, others of a variety of related and potentially toxic compounds of the extensive solanine alkaloid group may be present.

- *Solanum centrale*

Solanum centrale J.M.Black (bush tomato, akudjura, desert or bush raisin) is the preferred bush tomato for commercial use. The whole fruit of this species - fresh, dried or powdered -is used fresh or in cooked products. Dried fruits tend to be tastier (less bitter and sweeter) than freshly ripe fruit. *S. centrale* is common through much of the arid region of central Australia, usually in association with spinifex (*Triodia* spp.). There may be some uncertainty regarding the homogeneous nature of this *Solanum* species because of its very wide area of distribution.

Traditional use. The fruits were "probably the most important of all the Central Australian plant foods" (Latz 1995). The unripe fruit of S*olanum centrale* is purplish-green, and it was eaten raw when it became greenish-white to yellow-brown (Winfield 1982). Late-ripening and unripe fruits may persist on the plant during winter. The fruits dry out naturally in hot dry conditions, gradually hardening to a sultana-like (but not bone-hard) consistency and can be shaken to the ground and gathered. The whole dried fruit was rubbed into the sand to "clean" the surface, then pounded or ground into a paste with water, and formed into balls or cakes with a dry crust, which were sometimes protected with ochre (Peterson 1979). Dried fruits which have not been rubbed in the sand to "clean them" (presumably of debris and surface hairs) give stomach pains, although "cleaned" fruits relieve headaches (Winfield 1982). The Warlpiri Aboriginal people are said to recognise two forms of this species, one sweet and one bitter (Latz 1995). The same author also reported that headaches resulted if too many *S. centrale* fruits were consumed.

While consumption by animals cannot be taken as a reliable guide to lack of toxicity to humans, it has been noted that the diet of the common brushtail possum in Central Australia included *S. centrale* (Evans 1992).

Scientific studies. As mentioned previously, Bradley *et al.* (1978) found no solasodine in leaf, stem or fruit of *S. centrale* collected from the Alice Springs district. However, the leaves of samples of *S. centrale* have returned positive results for the presence of unspecified alkaloids (Aplin & Cannon 1971; Collins *et al.*1990). No reports have so far been located of potentially toxic compounds in *S. centrale,* and despite the long and widespread history of use in for foods there are only very few anecdotal reports of even minor ill-effects - which seem to be related to overindulgence.

2.2.13. *Syzygium* species - riberries and lillypillies
Family: Myrtaceae

- *Syzygium luehmannii* (F.Muell.) L. Johnson (riberry). The species was formerly known as *Eugenia luehmannii* F. Muell., and is also known as cherry alder and small-leaved lillypilly.

Natural distribution. Cooktown in Qld to Kempsey, NSW.

Part used. Fruits, fresh in season, or frozen. Seedless selections are preferred, or seeds can be removed during preparation. The leaves may also be used occasionally. Ground seeds are also used as a spice. The nutritional value of the fruits is summarised in Brand Miller *et al.* **(**1993), and Appendix 1.

General information. Numerous forms have been developed through horticultural selection for particular purposes, for example ornamental leaf colouring, compact habit or seedless fruits. The better, most reliably seedless, forms are highly sought after by the bushfood industry, although in some selections the annual percentage of fruits without fully or partly developed seeds can vary. High proportions of seedless fruits have also been attributed to various factors including isolation from other fertile plants.

Traditional uses. It can probably be assumed that Aboriginal people consumed the fruits. It is usually accepted that most of the approximately 60 Australian species of *Syzygium* are edible, although not all are palatable (e.g. Wilson 1989). Fruits of *Acmena (Eugenia) smithii, S. tierneyanum* and *S. suborbiculare* are among those of related species which are known to have been consumed (Maiden 1889; Wilson 1989). Syzygium species being trialled as potential commercial bushfoods also include *S. corynanthum* and *S. oleosum* (formerly *S. coolminianum*). Fruits of Australian *Syzygium* species are generally regarded as safe to eat (Floyd 1993, Wilson 1989).

Scientific studies.
(a) General. There seems to be little published information on the constituents of the fruit of *S. luehmannii*, although the essential oil of the leaf is said to contain limonene, myrcene and pinene. There seem to have been only negative results in tests of the plant for cyanogens, and little likelihood of the presence of saponins (Gibbs 1974). The leaves only of many *Syzygium* species have been tested for alkaloids over many years, with almost completely negative results (e.g. Webb 1949, 1952; Collins *et al.* 1990). No published analyses of the essential oils of either the fruit or seed have been located.

(b) Toxicological. While responses to requests for anecdotal or other evidence of possible adverse effects have been for the most part negative, it does appear that over-indulgence in the fruit - particularly whole fruits containing full-sized seeds - may in some persons induce irritation and hyperactivity of the intestinal tract. Anecdotal reports of apparently unpublished information associating the fresh fruit with severe stomach pains, even appendicitis, and the occasional use of large quantities of the fruits as an abortfacient, have each been mentioned in conversations with people who are considered reliable sources of information. On the other hand, chewing fresh riberries has been credited with curing mouth ulcers (S. Ringer, Maleny, pers. comm. 2000). Without accepting any of these reports without corroborative evidence, it seems advisable that intake of at least the raw fruits, perhaps especially those containing seeds, should not be excessive. There are many fleshy commercial fruits, for example passionfruit and unripe mangoes, for which similar advice applies.

2.2.14. *Tasmannia* species (native peppers)
Family: Winteraceae

- *Tasmannia lanceolata* (Poir.) AC Smith**,** previously known as *Drimys lanceolata* and *Drimys aromatica* (mountain pepper).

Natural distribution. Tasmania, mountainous areas of Victoria, ACT, and NSW as far north as the Hastings River. There are variations in the size and appearance of the plants in different areas (Dragar *et al.* 1998).

Part used. Leaf, or fruit ("pepperberry") products, usually dried and ground, are used as a hot pepper-type spice in European and and Asian-type dishes. The seeds are said to have a hotter taste than the flesh.

General information. In Thai and Japanese cuisine, leaves of the herb *Polygonum hydropiper,* which contains the same uncommon, very hot flavour constituent, polygodial, are also used as a spice for various meat dishes and curries. Polygodial was first isolated and described in Australia from the leaves of this cosmopolitan plant (Barnes & Loder 1962), and was then identified in extracts from *T.* (= *Drimys*) *lanceolata* (Loder 1962), some related plants, and marine organisms.

Traditional uses. It still seems uncertain if the plant was used for any culinary or medicinal purpose by Aboriginal people (Anon, 1997), although there is some evidence that, like the similarly strong-flavoured spice *Polygonum hydropiper,* it may also have been collected and placed in streams to assist in fishing (Fletcher 1991). Mountain pepper was used by European settlers in Australia "as a substitute for pepper, or rather allspice" (Maiden 1889). Under the former generic name of *Drimys,* the bark of *T. lanceolata* was sometimes used during the same period as substitute for herbal remedies prepared from the bark of a South American tree, winter's bark (*Drimys winteri*), which also contains polygodial.

Scientific studies.
(a) General. Only the chemical composition of the essential oil has been investigated thoroughly (Southwell & Brophy 1992; Dragar *et al.* 1998; Menary *et al.* 1999). Loder (1962) found no alkaloids in fresh gathered leaves. In general, polygodial and closely related compounds have been found to constitute between 20% and 40% of the leaf oil. The numerous other constituents include guaiol, linalool and α-pinene. Polygodial is also present in extracts from the fruits. The quantity and proportion of polygodial in essential oil extracts is strongly determined by the method used. It is not as effectively extracted by steam distillation as by organic solvents, and the overall composition of the extracts is strongly affected. Dragar *et al.* (1998) identified plants of two distinct chemical varieties.in solvent-extracted oil from the leaves of Tasmanian samples. It was found that in plants in which the concentration of polygodial was low, it tended to remain so over time, but in those with high concentrations of polygodial, the value was more variable. The level of polygodial peaked in October (Menary *et al.* 1999).

(b) Toxicological. Because the leaves and fruits are particularly hot-tasting, only very small quantities are used as spices or flavourings. This is because even light contact with the concentrated active constituent, polygodial, has been reported to produce very strong and persistent irritation of human tissues, for example in the mouth; tests by Menary *et al.* (1999) indicated that only very small amounts of the high-polygodial extract from *T. lanceolata* could be tolerated on the tongue. In comparative tests of leaves of the South American *Drimys winteri* and *D. aromatica* (now *T. lanceolata*),Greshoff 1906) reported that " leaves of both species have an exceedingly acrid taste, and cause a strong burning sensation on the tongue. The extract (especially of *D. aromatica*) froths strongly and contains much tannin." Although published analytical data are lacking, it appears very likely that polygodial is also responsible for the hot taste of several other Australian *Tasmannia* species.

It has been found that the steam distilled oil of *T. lanceolata* has antimicrobial and antifungal properties, and it has been suggested as "a promising additive for those who seek natural antimicrobial systems for food preservation" (Costello 1998). There have been a number of studies of the antimicrobial, insecticidal and insect-repellent properties of polygodial and plants which contain it, as well as of some pharmacological effects on larger animals (e.g. Anke & Sterner 1991; Gerard *et al.* 1993: Lee *et al.* 1999; Himejima & Kubo 1993; McCallion *et al.* 1982, Mendes *et al.* 1998, Powell *et al.* 1996, and studies conducted at Victoria University of Technology, Melbourne (Anon 1999).

From the information available about the volatile compounds extracted from the oil at different times and places, by various methods, it appears that the only other compound which has caused any concern regarding safety is safrole. This is a compound which, when ingested in more than very small quantities by test animals, can be metabolised to a potentially hepatotoxic and carcinogenic compound. For this reason it has been completely banned since 1961 by the US FDA for use as a food additive, although it is already naturally present in many foods in common use – for example in the oils extracted from nutmeg (0.1-3.3%) and mace (0.2-1.9%) (Tisserand & Balacs 1995). Safrole has had a long history of use as the main flavour component of oil of sassafras and natural root beer before any concern was expressed. Menary *et al.* (1999) reviewed results from numerous samples of *T. lanceolata* leaf from various provenances, which showed highly variable percentages of safrole depending on the plant and the time of year. Oil from the dried fruits contained an average of 23 ppm. A safrole concentration of 14% has been reported in hydrodistilled oil from *T. glaucifolia*, a related New South Wales species (Southwell & Brophy 1992), but this species is not used in foods. Current Tasmanian research is designed to ensure that future selections of *T. lanceolata* for large-scale cultivation will be chosen from stock with little or no detectable safrole (Menary *et al.* 1999).

Leaves and/or bark of two other species of *Tasmannia* tested by Webb (1949, 1952) returned somewhat conflicting results for the presence of alkaloids. The possible presence of cyanogenic glucosides in the leaf does not appear to have been investigated in recent times. The first record was by Greshoff- (1906) using leaf material obtained at Kew under the former name of *Drimys aromatica.* He compared the intensity of reaction of leaves of the better-known medicinal plant *D. winteri* (Winter's bark) with that of the Australian plant, and concluded that *D. aromatica* leaf had considerably more HCN, but the methods may not have been as specific as in modern times. While the possibility of induced generation of HCN by enzymatic activity exists in many plants, including a relatively high proportion of common food plants, drying the leaf and subsequent processing by cooking would inactivate the enzyme if it were present. In addition, human metabolic processes can themselves inactivate modest quantities of HCN such as might be produced from a spice product such as this species. A weakly positive test for alkaloids in the fruit is listed by Bick (1996).

- *Tasmannia stipitata* (Vickery) A.C Sm. (Dorrigo pepper).

Distribution: Parts of NSW, Qld.

Dorrigo pepper has rather similar appearance, hot taste and culinary use to *T. lanceolata.* From the very limited analytical evidence so far published, safrole does not appear to have been recorded as a constituent of the essential oil of this species (Southwell & Brophy 1992).

- *Tasmannia insipida* DC. (formerly *Drimys dipetala).*

Distribution: Parts of NSW, Qld, PNG.

This native pepper is occasionally used as a spice, but is considered to have a less hot taste than the previous species. There is an old record (as *D. dipetala*) of HCN in the leaf (Petrie 1912). Two chemovars have been distinguished on the basis of essential oil composition, one rich in viridilorol and one with none (Southwell & Brophy 1992).

2.2.15. *Terminalia* species
Family: Combretaceae

- *Terminalia ferdinandiana* Exell. (Kakadu plum)

Kakadu plum is botanically also known as *T. latipes* subspecies *psilocarpa* Pedley (in Northern Territory) or *T. prostrata* Pedley in North Queensland and in the Flora of Australia records (Pedley 1990; Dunlop *et al.*1995).

Natural distribution. Northern sections of NT, WA and Qld.

Part used. In modern cuisine, the flesh of the fruit is used for sauces, jams, and flavourings. The fibrous fruit adheres somewhat to the seed ("stone") as in the flesh of a clingstone peach, and the fleshy parts are usually reduced to small particles in a blender during processing. Nutritive values for the edible fruits of six *Terminalia* species and for the edible kernels of two species are summarised by Brand Miller *et al.* (1993) and in Appendix 1.

General information. There are about 250 species of *Terminalia* in tropical countries, and approximately 30 species in Australia, almost all of which have not been found elsewhere. While many *Terminalia* species have edible fruits, and a long history of use in traditional foods, in at least some species other parts of the plant such as the leaves or bark may contain compounds which are undesirable in foods, or even potentially toxic.

Traditional uses. The fresh fruits, seeds, and a drink prepared from the fruit of Kakadu plum are traditional foods of some Australian Aboriginal peoples in north-western Australia. Local names are arangal, madoorr, gubinge (Bardi people) kabinyn (Nyul Nyul) and gabiny (Yawuru). The taste and consistency of the flesh varies with ripeness. Fresh or dried fruits can also be soaked in water for a day or two to make a refreshing drink. Members of the Wurrkikandjarr clan (a djinang speaking clan from the Ramingining region) are not known to have used the seeds as food, though seeds of other Terminalia species were eaten (M. Bunenyerra, NT, pers. comm. 2000).

The gum from some local *Terminalia* species including Kakadu plum was also eaten - cooked in sand, chewed directly or pounded into a powder which after soaking formed an edible jelly. Aboriginal people also use the kernels of at least some of the related species (*T. grandiflora* and the better known *T. catappa* of Pacific coasts and elsewhere) as food, having broken open the thick seed coat with stones. (Kenneally *et al.* 1996; Specht 1958).

Kakadu plum is one of the thirty or so native Australian species which are not known to occur naturally elsewhere. Kernels of some of the related tropical species, especially *T. kaernbachii* and *T. okari* from New Guinea, and *T. catappa*, are much more widely known and used for their edible and occasional medicinal qualities (Menninger 1977). Many of the edible seeds of *Terminalia* species appear to have relatively small kernels in proportion to the thick shell. The information available for edible fruits and seeds of other *Terminalia* species may suggest potential future uses for kakadu plum kernels and shells, subject to satisfactory testing..

Scientific studies.
(a) General. Although the fruits are renowned for containing extremely high levels of Vitamin C, the values are somewhat variable. This may depend on the stage of ripening, storage factors, and/or environmental variables – as values in six samples of fruit have been reported between 0.4% and 5.3%, with a mean of 2.9% (Brand *et al.* 1982; James *et al.* 1986, cited by Brand-Miller *et al.* 1993). Elsewhere Woods (1998) has reported values of 0.2%-5.9% (original data not seen). Certainly the values for Vitamin C content are normally much greater than those found in citrus (Brand et al. 1982), but the value for citrus in general is near the middle of the range for fruit and vegetables.

There is a much larger body of information about several other edible native and exotic *Terminalia* species, which may be useful for comparison. *T. catappa* (sea almond) has seeds that are spread by tropical seas, and have been widely consumed in traditional cultures of northern Australia, many oceanic island and coastal communities, even as far away as the Virgin Islands. Both the soft fruit and kernel are widely considered good to eat. The kernels contain between 51%-64%.of fixed oil (Watt & Breyer-Brandwijk 1962; Gibbs 1964; Cambie and Ash 1994). Negligible amounts of Vitamin C were found in the kernels of either *T. catappa* or the Northern Territory's *T.grandiflora* (James 1983). The oil from the kernel of *T. catappa* is known as Indian almond oil, or in the Philippines, talisay. Talisay oil is said to resemble cottonseed, kapok or peanut oil, is edible and has been used for dietitic and technical purposes (Watts & Breyer-Brandwijk 1962). The Tico Ethnobotanical Dictionary http://www.ars-grin.gov/duke/dictionary/tico/ says that the kernel resembles an almond in flavour, and is eaten raw or roasted along the Orinoco River in Africa, but that "statements that the husk is edible seem doubtful on account of the woody nature of the husk". The nuts are dried in the sun for a few days to facilitate opening. The edible oil from the kernels is extracted by maceration and flotation in boiling water, used in cooking, and is "not as likely to become rancid as true almond oil".

(b) Toxicological. There seems to be no evidence that the flesh or kernels of the native Australian species known have been eaten by humans are toxic, at least in normal use. Some of the Polynesian *Terminalia* species require washing and cooking before being eaten. However, the kernels of at least one exotic species, *T. belerica*, have been described as edible but may induce an "intoxication or narcotic effect" (records cited by Menninger 1977).

No reports of cyanogenic glycosides in fruits of any of the edible *Terminalia* species have been located, but there is an old, sometimes-quoted suggestion (Kirtikar 1893, cited by Tanaka. (1976) that

Kakadu plum seeds might contain cyanogens. This may have been because of a perceived similar appearance to kernels of apricots and plums.

The leaves of some *Terminalia* species are known to be quite toxic. The central Queensland species *T. oblongata* has leaves which are poisonous to cattle and sheep (Collins *et al.* 1990; Oelrichs *et al.* 1994). The leaves of *T. catappa,* which is found in Australia and widely elsewhere in the tropics, are reportedly toxic (Tanaka 1976). There have also been various reports that sawdust, splinters and wood fragments of a number of *Terminalia* species in other tropical countries are responsible for dermatitis or urticaria, as well as respiratory disorders such as asthma and bleeding of nasal and mouth tissues. (e.g. in the Botanical Dermatology database).

2.2.16. *Tetragonia tetragonioides* Kuntze. (Warrigal spinach, warrigal greens, New Zealand spinach).
Family. Aizoaceae

Distribution. Qld, NSW, SA, NZ, Melanesia and Philippines; naturalised and cultivated elsewhere, including Europe and the USA.

Part used. The leaves are used as greens, having been blanched to reduce the presence of mildly toxic soluble oxalates. Recommended procedure: "blanch the leaves in boiling water for about one minute, then plunge them into cold water immediately. This will keep their green colour. Drain. Discard the water." (Ringer 1999).

General information. Tetragonia tetragonioides, also known as *T. expansa,* is native or naturalised in North and South America, China, and islands of the Pacific including Australia (Gray 1997). An alternative view is that it is "…native to New Zealand, naturalised in many parts of the world. Found scattered throughout Australia where it is considered native…." (Prescott 1984). It is occasionally reported as a weed of cultivation. *T. moorei* is a newly described species of arid Australia, formerly included with *T. tetragonioides* (synonym *T. expansa*) (Gray 1997), and has similar uses. Currently, seven native species of *Tetragonia* have been recorded for Australia, as well as four African and cosmopolitan species which are permanently or temporarily naturalised (Prescott 1984; Gray 1997; Heyligers 1999). Nutritional information for the leaves is summarised in Appendix 1.

Traditional uses. Despite the name, information reviewed by Gray (1997) suggests that Warrigal spinach (*T. expansa, T. tetragonioides* or *T. moorei*) was not widely used as a food by Aboriginal people, who lacked cooking utensils. Cleland & Johnston (1939) recorded that in the Northern Flinders Ranges of South Australia, "native spinach" (*T. expansa*) was "not utilised as a food formerly by the natives (sic)…but was at that time used after boiling, or after cooking in a hole."

Scientific studies.
(a) Chemical. Extremely variable values for most of the identified constituents of the plant have been listed by Duke (1992a, b). Selection of low-oxalate forms for cultivation, and the wide distribution along sea-coasts and through naturalisations, contribute to such variations. There is a high sodium accumulation even at low levels of salinity (Wilson *et al.* 2000, from abstract). Various authorities, including those cited by Gray (1997) have found oxalates, alkaloids, saponins and nitrates, and have provided other information as summarised below:

In studies of plants grown in hydroponic solutions with five different nitrate:ammonium nitrogen ratios, lower levels of oxalate were found at 28 days (6.3%) than at 7 days (8.9%). Plants grown in low-nitrate, high ammonium nutrient solutions had the lowest levels of oxalate, but there was no significant effect on most plant growth measurements (Ahmed & Johnson 2000).

(b) Toxicological. Deaths of cattle which have consumed forage including *Tetragonia* have often been reported from inland areas, but updates to taxonomic classification may assist in explaining what appear to be regional differences in toxicity. Hypocalcaemia in grazing stock is believed to be induced by excessive intake of oxalate, leading to symptoms including a staggering gait, listlessness, shortness of breath and scouring. However it has been observed that livestock rarely eat the plants until it they are dry and presumably lower in oxalate (Everist 1981). Excessive nitrate in seedling plants of *Tetragonia* described under various botanical names, has been implicated in deaths of sheep (McBarron 1977;1983). The percentage of soluble oxalate (as sodium oxalate) is less in older than younger leaves and branches, and greatest in seedlings. Carbonic anhydrase activity (counteractive to sulphonamide drugs) is also recorded, as is the presence of cerebrosides which are anti-ulcerogenic compounds (Okayuma & Yamazaki 1983). The plant has been used in traditional medicine in Eastern Asia to treat oesophageal and stomach cancer. There is also a report of an adverse "typical hypertensive reaction" in an American woman being treated with an antidepressive medication (phenelzine, a monoamine oxidase inhibitor) who had consumed a with a more than usually large portion (0.5 kg) of "prickly New Zealand spinach" (*T. tetragonioides*) (Comfort 1981).

Gray (1977) advises that the use of young succulent plants in the raw state “might need to be treated with some degree of caution". It appears that the need to blanch the greens to reduce the oxalate content before use is now widely accepted in the industry (see instructions above) and methods are being developed to minimise the soluble oxalates in selections for future propagation (Ahmed & Johnson 2000).

2.3 Other (Unrelated) Species Included in Analyses

- *Apium insulare* P.S.Short is a giant sea celery, first collected from Bass Strait islands in 1803, but it was not given its botanical name until 1979. It is also found on the nearby Victorian coast and in Lord Howe Island. Early European settlers used the related Botany Bay species *A. prostratum*, but Aboriginal uses are not recorded. The commonly cultivated celery is *A. graveolens,* which is known to produce dermatitis in some people handling it. This is a phototoxic reaction (i.e. activated by sunlight) on unwashed skin which has been in recent contact with the juices of the plant. It is due to the furanocoumarins bergapten and psoralene and related compounds (Duke 1992a) and is most likely to occur when damaged or mouldy leaves are handled. No such reactions to the Australian species appear to have been recorded, but if phototoxic reactions are experienced by processors suitable protective clothing should be worn.

- *Correa alba* Andrews (Cape Barron tea, white Correa, native fuschia). The leaves are used in infusions, and have a history of use by sealers as a substitute for tea (Maiden 1889).

- *Dianella caerulea* Sims (in the taxonomically broad sense) has a number of botanical subspecies and varieties (Henderson 1997; www.anbg.gov.au/cgi-bin/apni). It was included late in the study because of comments received that some *Dianella* fruits "contained naphthalene" and were to be avoided because neurological effects such as dizziness and walking in circles had been reported at various times (e.g.Webb 1948). Several species of *Dianella* have also been *suspected* of poisoning livestock and/or humans, both in Australia and overseas (e.g. Hurst 1942). The naphthalene comments appear to have arisen due to the presence of a naphthalene-1,8-diol, dianellidin, and related compounds in extracts of the dried roots of *D. revoluta* (Colegate *et al.* 1986), followed by a report of toxicity of stypandrone (a toxic naphthalene-1,4-quinone) to which dianellidin is a metabolic precursor (Colegate *et al.* 1987). Stypandrol was shown to induce a different form of toxicity to mice to that caused by ingestion of the whole plant by livestock. Further studies have shown that extracts of the roots of this species have activity against the polio virus, but the activity was not due either to dianellidin or the related dianellin (Semple 1998; Semple *et al.*1998). It is beyond the scope of this report to investigate other research involving *Dianella* species, but until more information is available for the traditional use, chemistry and bioactivity of the fruits of individual species of *Dianella* it seems unwise to consume them in very limited quantities, if at all.

Traditional and modern uses. This species was not used by aborigines on Groote Eylandt (Levitt 1981), and the only record so far located about Aboriginal use of parts of *Dianellas* for food suggests it was limited to leaf bases or roots, following preparation (Elliot & Jones 1980, Low 1989). In the Brisbane region there are indications that a limited small quantity of *Dianella* fruit can be eaten when soft and ripe (Symons 1994). Fruits of four species including *D. caerulea* have been mentioned as edible (Low 1989), but there have been reports that another species, *D. tasmanica,* had irritant berries, and that fruits of the New Zealand native *Dianella intermedia* were blamed for the death of a child (Hurst 1942). Aplin & Cannon (1971) found no alkaloids in the leafy tops of *D. revoluta.* Immature and mature fruits of *D.caerulea* tested by Webb (1949) contained no alkaloids, though one of two subsequent tests of mature fruits was strongly positive (Webb 1952). *Dianella longifolia* (pale flax lily) (also known as *D. laevis*) has been used as a modern bushfood species in southern Australia.

In view of the variability, uncertain toxicological properties, and various anecdotal reports of adverse effects to humans and livestock after ingesting parts of various *Dianella* species, both in Australia and elsewhere (Everist 1981), it is considered that use of the fruits for commercial purposes should be avoided until more detailed information is available.

- *Eucalyptus olida* L.Johnson & K.Hill (formerly *E.* sp. aff. *E. campanulata*; "strawberry gum") is native to a small area of northern NSW. E-methyl cinnamate (up to 98%) is the main component of the essential oil on which the desirable flavour is based (Curtis *et al*. 1990; Boland *et.al.* 1991), and though it is regarded as an irritant (www. Sigma-Aldrich.com, MSDS) it is listed by the US EAFUS in section 21: 172-515 as a (synthetic) flavouring substance which may be safely used in food in "minimum quantities required to produce their intended effect, and otherwise in accordance with all the principles of good manufacturing practice." It was found that the leaf essential oil from a plantation of seedling trees contained 0%->91% of methyl cinnamate, suggesting that material for clonal propagation for food use should be made from known low-cinnamate chemovars.

- *Diploglottis campbellii* Cheel (southern tamarind) is a recently described, endangered species found only in border areas of NSW and Queensland, and was *included* because of interest in its potential as a bushfruit. There are two colour forms of the fruit - yellow and green. The fleshy arils surrounding the seed are used in jam-making, and the contained seeds are occasionally consumed. No previous information is available for its chemistry or toxicology, but it is related to two Australian *Diploglottis* species (native tamarinds), of which the edible arils were also used in jam-making.

- *Leptospermum petersonii* F.M.Bailey (lemon-scented tea tree) is found in northern NSW and south-east Queensland. It has also been known under a variety of scientific names including *L. citratum* (in Australia) and *L. flavescens* var. *citratum,* and is used in infusions. There are two botanical subspecies, as well as at least four broad chemical varieties. The main components of the volatile oil of the "principal (chemical) variety", Variety 1 are varying proportions of citronellal and citral (i.e. neral + geranial) (Martindale 1996). Further information on physiological forms is presented in Penfold *et al.* (1942) and Brophy *et al.* (2000, from abstract). Fertilisation with nitrogen has been shown to influence the composition of the essential oil of this species, increasing the proportion of citronellal and geranial (Diatloff 1990).

- "Forest Berry Herb" is a commercial product supplied to us for testing by the manufacturer. No species name was provided but the ground product is marketed as a bushfood.

2.4 Some Potentially Toxic Species

It is beyond the scope of this study to list all native species which have known undesirable or potentially toxic components, but some of the species most likely to cause problems if consumed are listed in Table 2.1. Extensive information on native plants which have been considered poisonous to stock and/or humans is contained in older publications from various States (e.g. Gardner & Bennetts 1956 (WA), Bailey 1906; Dowling & McKenzie 1993 Webb 1948 (Qld) Francis & Southcott 1967 (SA) Hurst 1942 (NSW), McBarron 1977, 1983 (NSW), as well as Cleland & Lee 1963, Cribb & Cribb 1974/1990), Everist (1981) Covacevich *et al.*(1987) and Seawright (1989) for Australia generally.

Table 2.1. Some native species with a potential for toxicity

Species	Toxic parts	Some toxic constituents and/or information
Abrus precatorius (various common names)	Seeds (when chewed)	Abrin, an extremely toxic protein
Acacia georginae,	Seeds & other parts	Fluoroacetate (Oelrichs&McEwan 1961)
A. quadriloculatum,	Seeds	No information found.
Aleurites rockinghamensis (a candlenut)	Kernels	Phorbol esters?
Castanospermum australe (black bean)	Seeds	A toxic water-soluble alkaloid (castanospermine)
Cycas species (cycads)	Seeds	Azoglycosides (neurotoxic) (Beck 1992)
Dianella (some species)	Fruits	Neurotoxins in fruits?
Elaeocarpus bancroftii (Johnstone R almond)	Fruits	Flesh "not edible" but seeds eaten (Elliot & Jones 1980)
Entada phaseoloides (matchbox bean)	Seeds	Toxic if untreated, and if baked may explode (Dick 1994b)
Hicksbeachia pinnatifolia	Flesh of fruit	outer red flesh is toxic (Thies 1976).
Lepidozamia species (cycads)	Seeds	As for *Cycas*
Macadamia and some closely related species, **<u>except</u>** *M. integrifolia* and *M. tetraphylla* and their commercial crosses.	Seeds ("nuts")	Cyanogens (see Dahler *et al.* 1995)
Macrozamia species (cycads)	Seeds	As for *Cycas*
Pteridium esculentum (bracken fern)	New fronds ("fiddleheads")	Carcinogens; still under investigation.
Rhodomyrtus macrocarpa (finger cherry	Fruits	Can cause blindness; see Flecker 1944, Everist 1981; Low 1991, and www.farrer.csu.edu.au/ ASGAP/APOL7/sep97-4.html.
Ricinus communis (castor oil plant) (possibly naturalised)	Seeds	An extremely toxic lectin, (ricin) and alkaloid (ricinine)
Triunia erythrocarpa, T. robusta, T. youngiana, and possibly related spp.	Seeds	Very strongly cyanogenic
Some native members of the cucumber family (can contain variable levels of bitter, potentially toxic compounds)	Fruits	Seek further information on particular species
Some native grapes	Fruits	Needle-like crystals of some species may irritate the throat of susceptible persons (Cribb & Cribb 1974, 1990).

Parts of some native plant species used by Aboriginal people as staple foods contain potential toxins, as well as valuable nutrients, and so extensive processes of detoxification were developed. Methods included removal of certain parts, baking, grinding, and/or soaking or leaching in running water for extended periods to remove water-soluble toxins (as in black beans, cycads and some yams). Some native plants which should not be used as commercial bushfood are listed in Table 2.1.

Two native "nuts" which are of commercial appeal should be mentioned:

(a) The kernels (i.e.seeds) of the edible *Macadamia* species (*M. integrifolia, M. tetraphylla*), have been used for commercial purposes for over a century, although they may contain a very small and harmless quantity of cyanogenic glucosides (which increases as they germinate). Values may vary in kernels from different trees, especially in the wild. Given a reported lethal dose rate for cyanide in humans of 0.5 - 3.5 mg HCN per kg body weight, a 70 kg human would need to consume approximately 60 kg of the seeds ("nuts") of either species to cause death (Dahler *et al.* 1995). . Cultivated *Macadamia* nuts have been found to affect the nervous and digestive systems of some dogs, although they normally recover completely, and may repeat the experience (McKenzie *et. al.* 2000). Reportedly inedible (and known or assumed to be higher in cyanogen) *Macadamia* species include *M. claudiensis, M. heyana, M. jansenii, M. ternifolia* and *M. whelanii.* (References include Petrie (1912) and Cooper & Cooper (1994). Seeds of some of the closely related genus *Triunia (T. erythrocarpa, T. robusta* (formerly *M. robusta*) and *T. youngiana* are considered to be extremely toxic. Nevertheless, Aboriginal people did in some cases consume some of the potentially toxic *Macadamia* species including *M. robusta*, but only after considerable treatment by soaking and baking (Cribb & Cribb 1990). *Athertonia diversifolia* of the same family is now cultivated and highly valued for its edible seeds, but Aboriginal people removed their bitter outer covering (testa) before eating (AK Irvine, Atherton, pers. comm.1998). Lamont (1985) has reviewed the use of various members of this family for food.

(b) *Semecarpus australiensis* (native cashew) fruits are very attractive in appearance, and resemble the commercial cashew nut in taste. However, they require care in harvesting and handling, followed by heat treatment to detoxify intensely irritant components, collectively known as urushiol, some of which are also found in poison ivy but at an overall lower concentration (Oelrichs *et al* .1997). Contact with the sap of the plant or fruit can cause severe blistering, inflammation and/or swelling of the throat. Inhalation of sawdust can also be highly irritant (Francis & Southcott 1967). Personal reactions vary in intensity from negligible to very severe. Aboriginals roasted the fruits in sand under a fire to inactivate the toxin, but inhalation of the fumes when the nuts are baked in an oven should be avoided (Dick 1994a).

2.5 Obtaining Samples for Analysis

Obtaining representative, reliably identified samples of many fresh bushfoods from the open marketplace proved much more difficult than had been expected for various reasons:

- Bush fruits, particularly, have a very short seasonal availability and most are frozen and forwarded to wholesalers for processing or re-sale. Fresh samples of bushfoods are still difficult to find in most shopping venues, even in weekend markets. Value-added commercial products with multiple ingredients such as herbal teas, jams, preserves and sauces were more readily available but were not suitable for the study.

- Some value-added products, particularly ground-leaf or wattleseed items, are sold under trade or common names, without listing the botanical names of species used (sometimes a mixture) or their provenance. Though such products were welcomed for analysis, the results - while useful – are possibly of lesser value to the industry at large than if exact identification had been possible.

- For comparative purposes, at least two samples were sought for most bushfood species - one from a wholesaler and one in unprocessed, unfrozen form direct from a grower. Samples were sought from expert commercial producers in all States and the Northern Territory, but in many cases there was no response, or promised samples failed to arrive. Obtaining unprocessed fresh samples of fruits in season was particularly time-consuming. The outcome was that the majority of fresh retail bushfood samples were assembled in Brisbane from sources in Queensland and northern New South Wales. These are areas where the industry has most products and growers, and where the objectives of the study were possibly more widely understood through information provided to various relevant publications, and discussions with members of the industry.

3. Analysis of Bushfoods for Anti-Nutritive Constituents

The wide ranging review of existing knowledge of the possible anti-nutritive factors that might be found in the major types of plant bushfoods currently marketed by the industry identified oxalic acid, cyanogens, alkaloids, saponins and certain essential oil constituents as those most likely to be present in the selected Australian plant bushfoods. A total of 41 plant products were supplied by various commercial bushfood wholesalers and individual growers during the 1998/99 season and screened for the above constituents at the laboratories of the Centre for Advancement of Food Technology and Nutrition, University of Newcastle at Ourimbah. The data set was complemented by repeat analyses conducted in the 1999/2000 season on a total of 71 bushfoods but with a limited number of analyses on each sample. The antinutrients and foods selected were based on the previous year's findings.

3. 1 Methods of Analysis

3.1.1 Oxalic Acid

Oxalic acid was analysed using the method described by Libert (1981). This involved extraction of the sample with hydrochloric acid and analysis by HPLC using a reversed-phase column and UV detector. Previously-frozen, fresh or dried plant material (5 g) was added to 1M hydrochloric acid (25 ml) and heated to 90°C in a water bath for 30 min. The mixture was filtered and the filtrate made up to volume (50 ml) with deionised water. An appropriate volume was pushed through a Sep-pak cartridge, discarding the first 2 ml. An aliquot (20 µl) was analysed on a Shimadzu HPLC system consisting of 10AT pump, SIL 10AXL auto-sampler, SPD 10A UV-Vis detector and CTO-10A column oven. The operating conditions were: reversed phase column of Alltima C18, 250 x 4.6mm, (Alltech, Sydney), mobile phase of potassium dihydrogen phosphate (0.5%) and the ion pair reagent, tetrabutyl ammonium phosphate, (0.005M) adjusted to pH 2 with orthophosphoric acid at a flow rate of 1 ml/min, and eluted peak detection at 214 nm. The oxalic acid was quantified from a standard curve prepared with sodium oxalate dissolved in 0.5M hydrochloric acid. The limit of detection of oxalic acid was equivalent to 0.08 g/100 g bushfood.

3.1.2 Cyanogens

The cyanogens were analysed based on a method described by AOAC (1995) and Egan *et al.* (1998). The cyanogens were allowed to hydrolyse in a closed vial, and the liberated hydrogen cyanide was absorbed by filter paper impregnated with picric acid suspended above the sample. The resultant colour change from the reaction between picric acid and hydrogen cyanide was determined spectrophotometrically to give a semi-quantitative determination of the cyanogen content.

Sodium picrate papers were prepared by dipping pieces (10 cm x 1 cm) of filter paper (# 5c, Micro Filtration Systems, Dublin CA) into a 1% picric acid solution and allowed to dry. The papers were then dipped into 10% Na_2CO_3 solution, dried, and stored in a stoppered brown jar.

Freshly homogenized fresh (or in a minority of cases frozen) plant material (0.5 g) was placed in a small vial and a few drops of chloroform added. For dried samples, a few drops of water were added first. A piece of moistened picrate paper was inserted without touching the sample and the vial was tightly stoppered. The vials were held at 30°C for 3 hr then removed to a dark cupboard for a further 36 hr. A control was prepared in the same way but without plant material. The picrate paper was removed and soaked in distilled water (3 ml) for 30min. The absorbance was read at 510 nm on a UV-visible spectrophotometer (Cary 1E, Varian, Walnut Creek CA) using the control as a blank. Semi-quantitative assessment was achieved by comparison of readings with a standard curve prepared from acidification of potassium cyanide solutions with concentrated sulphuric acid and absorption with picrate paper and spectrophotometric analysis as above. The limit of detection of the method was found to be 0.5 ug hydrogen cyanide equivalents which was the same sensitivity reported by Egan *et al.* (1998). The limit of detection based on the weight of plant material used in this study was 0.1 mg hydrogen cyanide/100 g of bushfood. The efficacy of the method was confirmed with a small piece of peach seed kernel which produced a highly positive result to the test.

3.1.3 Saponins

The screening test for saponins was adapted from Harborne (1998) and is based on the foaming of the saponins that occurs on shaking an aqueous alcoholic extract. Dried plant material (1 g) and 20% ethanol solution (10 ml) were added to a vial. The vial was stoppered, shaken for 15 sec then left to stand for 1 hr. Samples with foam still visible after 1 hr were considered positive, and where only a small amount of foam was visible the samples were recorded as slight. A sample of soya bean flour was tested to check the method and this produced a positive result. The sensitivity of the method was assessed using various concentrations of saponin derived from quillaja bark (Sigma, St Louis). A positive test for saponin was achieved with 50 mg/100 g and a slight test with 0.6 mg/100 g.

3.1.4 Alkaloids

3.1.4.1. *General*. Alkaloids are a large group of secondary plant metabolites with a wide range of chemical composition which makes total screening difficult to achieve. The method used was described by Harborne (1998) to detect at least some of any alkaloid present. The basic property of alkaloids is utilised to extract them from the plant matrix with weak acid alcoholic solvent and then precipitated with ammonia. The extract is chromatographed by TLC, any spots are located under UV light and visualised with a range of alkaloid-sensitive spray reagents.

A preliminary study with solasodine was carried out to determine the dilution of a sample extract required to generate a reasonable limit of detection of alkaloids. From a range of dilutions of solasodine in chloroform the limit of detection was found to be with 2 μg of standard. The amount of bushfood use in the analysis was calculated to give a concentration of 40 mg alkaloid/100 g bushfood as the limit of detection.

Dried plant material (0.5 g) was added to a solution of 10% acetic acid in ethanol (20 ml) and the mixture allowed to stand for 4 hr. It was then filtered and the filtrate allowed to stand at room temperature until approximately half of the solvent had evaporated (about 5 hr). Concentrated ammonia was added dropwise until a precipitate formed. The solution was centrifuged for 20 min at 5500 rpm. and the precipitate washed with 1% ammonia and re-centrifuged. The precipitate was dissolved in 2ml of ethanol.

An aliquot (20 μl) was spotted onto a silica gel G TLC plate using a TLC applicator (Camag Linomat IV, Muttenz, Switzerland). The plate was developed in methanol:concentrated ammonia (200:3) and dried before exposing to UV light at 365 and 254 nm. Where some spot was visualised the plate was sprayed with Dragendorff, iodoplatinate and Marquis reagents. The spray reagents were prepared as follows:

- *Dragendorff*: Solutions of (a) bismuth subnitrate (0.6 g) in concentrated hydrochloric acid (2 ml) and water (10 ml) and (b) potassium iodide (6 g) in water (10 ml) were mixed together with concentrated hydrochloric acid (7 ml) and water (15 ml) and the whole solution diluted with water (400 ml).
- *Iodoplatinate*: Solutions of 5% platinum chloride (10 ml), concentrated hydrochloric acid (5 ml) and 2% potassium iodide (240 ml) were mixed together.
- *Marquis*: Formaldehyde (1 ml) was mixed with concentrated sulphuric acid (10 ml).

3.1.4.2. *Solanines*. A more specific method was used to detect solanines in bush tomatoes. Solanines in bush tomato were analysed by a method based on that of Harborne (1998), Hellanäs *et al*. (1995) and Finlay *et al*. (1998). This involved suspending 0.5 g of dried plant material in 10ml of 2% aqueous acetic acid containing 0.5 % (w/v) sodium bisulphate and shaken continuously for 30 min. The filtrate was warmed to 70^{o}C in a water bath and the pH 10 achieved with dropwise addition of concentrated ammonia. The mixture was centrifuged at 5500 rpm. In 1998/99 and the precipitate washed with 1% ammonia and re-centrifuged. Analysis in 1998/99 was by TLC and involved dissolving the precipitate in hot ethanol (2 ml) with 30µL spotted onto a TLC plate as above. Development and visualisation of the TLC plate was by the method of O'Leary (unpublished method, Department of Chemistry, University of Newcastle). The plate was developed in methanol-ethyl acetate (1:1) and visualised under UV light and by spraying with anisaldehyde-concentrated sulphuric acid and heating to 110^{o}C. Standards of solanine, solasodine, β2-chaconine and chaconine were co-chromatographed with the extracts to determine Rf factors and different amounts of solanine were applied to quantify the amount of solanine in the samples. In 1999/2000, a 20µl aliquot of the solution above the centrifugate was taken for analysis by HPLC. The HPLC system was that described above for oxalic acid and eluted peaks were detected at 202 nm. The solanines were qualified and quantified using the standards solanine, solasodine, β2-chaconine and chaconine. The limit of detection based on β2-chaconine was 0.09µg equivalent to 9mg/100g (dry weight) of sample.

3.1.5 Essential Oil Constituents

3.1.5.1. *General.* The essential oil was obtained by steam distillation and assayed by gas chromatography using the methods of Dung *et al*. (1997) and Bos *et al*. (1997).

Fresh plant material (10 g) was steam distilled for 4 hr and the essential oil collected in petroleum ether (bp 60-80°C). The petroleum fraction was dried with sodium sulphate which was removed by filtering through paper. The solvent was evaporated using a rotary evaporator at 60^{o}C and the oil was weighed. The oil was re-dissolved in hexane (GC grade) and made up to volume (10 ml). A 500 µl aliquot was taken and made up to 10 ml with hexane. An aliquot of oil (5 µl) was analysed on a Varian Star 3400cx gas chromatograph equipped with a Varian 8200CX autosampler, and a glass column of AT-5 (30m x 0.25mm) (Alltech, Sydney). In the 1998/99 season, detection was by flame ionisation but in the 1999/2000 season the GC was coupled to a Varian Saturn mass spectrometer. The operating parameters were: column temperature 60°C for 2 min then programmed to 220^{o}C at 4^{o}C/ min., injector and detector temperature at 250^{o}C.,carrier gas was nitrogen at 30 ml/min with a split ratio of 50:1, hydrogen flow at 30 ml/min and air at 300 ml/min. MS conditions: ionisation energy, 70eV, manifold temperature 170°C; scan rate 2 scans/sec; mass range 34-500m/z. Compounds were identified through their mass spectra using a Varian terpene library.

3.1.5.2. *Safrole.* Safrole was further identified through retention time using a standard (Safrole, 97% pure, Acros Organics, New Jersey). The same quantitation factor was applied for the other compounds of interest in the essential oil. The limit of detection of safrole by this system was equivalent to 0.5 mg/100 g bushfood. In order to achieve a higher level of sensitivity of 0.012 mg/100g, analysis was conducted with 20 g of bushfood, without the second dilution by injecting the solution onto the GC-MS with the filament disconnected until the retention time of safrole was approaching.

3.1.6 Lectins

Lectins. A mixed sample of bunya nut kernels from several provenances was also provided to the Australian Red Cross Blood Service, Brisbane, for screening for the presence of lectins, following evidence of their presence in related species. Lectins are glycoproteins which possess a special affinity for particular sugar components in many animal cells, including those of the intestinal wall.

They may damage these cells, leading to reduced nutrient uptake and slower growth (Jaffe 1980). Their presence is most readily indicated by their ability to cause red blood cells to clump.

3.2 Bushfood Samples Analysed

A description of the 41 bushfood products collected in the 1998/99 season, their date of receipt at the laboratory, arrival condition and the inedible parts that were removed before analysis are given in Table 3.1.

The bushfoods mostly arrived in a frozen state and all were stored at -20^{o}C in a sealed polyethylene bag until analysed. When a product was removed from -20°C, it was first suspended in liquid nitrogen for about 15 min when the temperature was lowered to –196°C to ensure the sample remained frozen during homogenisation. The whole of the edible portion of each sample was homogenised to a uniform particle size in a Waring blender for about 2 min. Approximately half of each sample was immediately returned to storage at -20°C and aliquots of all bushfoods removed at different time intervals for analysis of cyanogens, oxalic acid and of 21 bushfoods for safrole. The other half of each sample was dried in a vacuum oven at 45^{o}C for 2 days and the moisture content recorded. The dried samples were re-homogenised in a Waring blender, sealed in a glass jar and stored at room temperature in the absence of light. Aliquots were subsequently removed for analysis for saponins and alkaloids.

A description of the 71 bushfood products received in the 1999/2000 season, their date of receival, arrival condition and the inedible parts removed before analysis are given in Table 3.2.

The bushfoods mostly arrived in a fresh state and an aliquot was removed immediately to conduct cyanogen tests. The remainder of each sample was stored at -20°C in a sealed polyethylene bag for future tests. When a dried aliquot was required the sample was dried in a vacuum oven at 45°C for 2 days. The dried samples were re-homogenised in a Waring blender, sealed in a glass jar and stored at room temperature in the absence of light. Cyanogens were analysed on all samples but the other analyses were conducted on a limited number of bushfoods with the selection base on the need to obtain further data on some bushfoods above that obtained in 1998/99. Oxalic acid was analysed on two species of wattleseed (*A. victoriae* and *A. notabilis*), one sample of lemon myrtled two samples of aniseed myrtle. Saponin tests were conducted on three samples of bunya nuts and on two species of wattleseed (*A. victoriae* and *A. notabilis*). Alkaloid screening was conducted on three species of aspen (*A. wilcoxiana*, *A. oblongifolia* and *A. acidula*) and two species of wattleseed (*A. victoriae* and *A notabilis*). It was also applied to the skin, flesh and seeds of bush lime (*C. australasica* and *C. australis*) and commercial orange and lime obtained from a retail market in Gosford. Solanines were determined on green, fresh and dried bush tomatoes. Essential oil analysis was conducted with three samples of mountain pepper for safrole, native basil (*Ocimum tenuiflorum*) for methyl chavicol (estragole), two mints (*Prostanthera cuneata* and *P. incisa*) for 1,8-cineole (eucalyptol), *Backhousia myrtifolia* for (E)-methyl isoeugenol and aniseed myrtle for eugenol, methyl chavicol and (E)-anethole.

3.3 Results and Discussion

The results of the analytical program conducted in 1998/99 on the 41 bushfood samples for oxalic acid, cyanogens, saponins and safrole are given in Table 3.3.

Table 3.1. Bushfood samples collected in the 1998/99 season.

Sample	Common Name	Botanical Name	Received	Condition	Edible portion
A1	Davidsons plum	*Davidsonia pruriens*	5/02/99	fresh, frozen	fruit flesh
A2	Riberry	*Syzygium luehmannii*	5/02/99	fresh, frozen	whole fruit
A3	Bunya nut	*Araucaria bidwillii*	5/02/99	fresh, frozen	nut kernel
A4	Quandong	*Santalum acuminatum*	5/02/99	fresh, frozen	fruit flesh
A5	Round lime	*Citrus australis*	5/02/99	fresh, frozen,	fruit –seeds
A6	Native rosella	*Hibiscus heterophyllus*	5/02/99	fresh, frozen	flower petal
A7	Lemon aspen	*Acronychia acidula*	5/02/99	fresh, frozen	whole fruit
A8	Aniseed myrtle	*Anetholea anisata*	5/02/99	dry, ground	leaf
A9	Lemon myrtle	*Backhousia citriodora*	5/02/99	dry, ground	leaf
A10	Forest berry herb	(no ID given)	5/02/99	dry, ground	leaf
A11	Native pepper berry	*Tasmannia lanceolata* (frt)	5/02/99	dry, ground	whole fruit
A12	Mountain pepper	*T. lanceolata* (lf)	5/02/99	dry, ground	leaf
A13	Mints	*Prostanthera incisa, Mentha* spp.*,Ocimum* spp.	5/02/99	dry, ground	leaf
A14	Wattle seed	*Acacia* spp.	5/02/99	dry, ground	leaf
A15	Munthries	*Kunzea pomifera*	5/02/99	fresh, frozen	whole fruit
A16	Kakadu plum	*Terminalia ferdinandiana*	5/02/99	fresh, frozen	flesh fruit
A17	Warrigal greens 1	*Tetragonia tetragonioides*	19/04/99	fresh, frozen	leaf
A18	Warrigal greens 2	*Tetragonia tetragonioides*	19/04/99	par-boiled, frozen	leaf
A19	Wild rosella	*Hibiscus sabdariffa*	19/04/99	fresh, frozen	calyx
A20	Illawarra plum	*Podocarpus elatus*	22/07/99	fresh, frozen	cored fruit
A21	Bush tomato	*Solanum centrale*	22/07/99	dry, ground	whole fruit
A22	Bush tomato	*Solanum centrale*	7/04/99	frozen, ripe	whole fruit
A23	"	*Solanum centrale*	7/04/99	whole, dry	whole fruit
A24	"	*Solanum centrale*	7/04/99	frozen, green	whole fruit
A25	Davidsons plum 1	*Davidsonia jerseyana*	19/05/99	fresh, frozen	fruit flesh
A26	Davidsons plum 2	*Davidsonia pruriens*	19/05/99	fresh, frozen	fruit flesh
A27	Davidsons plum 3	*Davidsonia pruriens*	19/05/99	fresh, frozen	fruit flesh
A28	Lemon myrtle	*Backhousia citriodora*	19/05/99	fresh, frozen	leaf
A29	Aniseed myrtle	*Anetholea anisata*	19/05/99	fresh, frozen	leaf
A30	Illawarra plum 1 (wild)	*Podocarpus elatus*	19/05/99	fresh, frozen	whole fruit
A31	Illawarra plum 2 (cult.)	*Podocarpus elatus*	19/05/99	fresh, frozen	semi-ripe fruit
A32	Bunya nut	*Araucaria bidwillii*	19/05/99	fresh, frozen	nut kernel
A33	Finger lime	*Citrus australasica*	19/05/99	fresh, frozen,	whole fruit
A34	Finger lime	*Citrus australasica*	19/05/99	fresh, frozen,	whole fruit
A35	Finger lime	*Citrus australasica*	19/05/99	fresh, frozen,	whole fruit
A36	Finger lime	*Citrus australasica*	19/05/99	fresh, frozen	whole fruit
A37	Round lime	*Citrus australis*	19/05/99	fresh, frozen,	whole fruit
A38	Citrus garrawayae	*Citrus garrawayae*	19/05/99	fresh, frozen	whole fruit
A39	Wild lime	*Citrus glauca*	19/05/99	fresh, frozen	whole fruit
A40	Silver aspen	*Acronychia wilcoxiana*	19/05/99	fresh, frozen	whole fruit
A41	Munthries	*Kunzea pomifera*	11/06/99	fresh, frozen	whole fruit

Table 3.2. Bushfood samples collected in the 1999/2000 season.

Sample	Common Name	Botanical Name	Received	Condition	Inedible Portion
B1	Bunya nut (freshly fallen)	*Araucaria bidwillii*	28/2/00	fresh fruit	husk
B2	Bunya nut (start cone break-up)	*Araucaria bidwillii*	28/2/00	fresh fruit	husk
B3	Bunya nut (cone full break-up)	*Araucaria bidwillii*	28/2/00	fresh fruit	husk
B4	Bunya nut (cone rotting)	*Araucaria bidwillii*	28/2/00	fresh fruit	husk
B5	Bunya nut (sprouting)	*Araucaria bidwillii*	28/2/00	fresh fruit	husk
B6		*Diploglottis campbellii* (yellow aril)	28/2/00	fresh fruit	seeds
B7		*Diploglottis campbellii* (red aril)	28/2/00	fresh fruit	seeds
B8	Mint	*Prostanthera incisa* "Balunyah"	28/2/00	fresh leaf	
B9	Lemon scented tea tree	*Leptospermum petersonii*	28/2/00	fresh leaf	
B10	Lemon myrtle	*Backhousia citriodora* (Limpinwood)	28/2/00	fresh leaf	
B11	Aniseed myrtle	*Anetholea anisata* (*t*-anethole var)	28/2/00	fresh leaf	
B12	Aniseed myrtle	*Anetholea anisata* (methyl chavicol chemovar)	28/2/00	fresh leaf	
B13	Davidsons plum	*Davidsonia jerseyana*	28/2/00	fresh fruit	seeds
B14	Cinnamon myrtle	*Backhousia myrtifolia*	28/2/00	fresh leaf	
B15	Riberry	*Syzygium luehmannii*	28/2/00	fresh fruit	seeds
B16	Riberry	*Syzygium luehmannii*	28/2/00	fresh seed	
B17	Mountain pepper	*Tasmannia lanceolata*	28/2/00	fresh leaf	
B18	Davidsons plum	*Davidsonia jerseyana*	28/2/00	fresh fruit	seeds
B19	Native rosella	*Hibiscus heterophyllus*	28/2/00	fresh leaf	
B20	Riberry	*Syzygium luehmannii*	28/2/00	fresh seed	
B21	Aniseed myrtle	*Anetholea anisata*	28/2/00	fresh leaf	
B22	Brush pepperbush	*Tasmannia insipida*	23/3/00	fresh leaf	
B23	Warrigal greens	*Tetragonia tetragonioides*	23/3/00	fresh leaf	
B24	Aniseed myrtle	*Backhousia anisata*	23/3/00	fresh leaf	
B25	Native basil	*Ocimum tenuiflorum*	23/3/00	fresh leaf	
B26	Round lime	*Citrus australis*	23/3/00	fresh fruit	seeds
B27	Wattle seed	*Acacia victoriae*	23/3/00	fresh seed	
B28	Wattle seed	*Acacia notabilis*	23/3/00	fresh seed	
B29	Fruit salad herb	*Unknown*	23/3/00	dry, ground	
B30	A Dianella	*Dianella caerulea* var. *producta*	23/3/00	fresh fruit	
B31	Cinnamon myrtle	*Backhousia myrtifolia*	23/3/00	fresh leaf	
B32	A mint	*Prostanthera ovalifolia*	23/3/00	fresh leaf	
B33	Illawarra plum	*Podocarpus elatus*	23/3/00	fresh unripe	core
B34	Bush tomato	*Solanum centrale*	17/4/00	fresh, green	
B35	Bush tomato	*Solanum centrale*	17/4/00	fresh, ripe	
B36	Bush tomato	*Solanum centrale*	17/4/00	dried	
B37	Munthries	*Kunzea pomifera*	17/4/00	fresh fruit	
B38	Wild Rosella	*Hibiscus sabdariffa*	26/4/00	fresh calyces	fruit
B39	Illawarra plum	*Podocarpus elatus*	26/4/00	fresh ripe	seeds
B40	Finger lime	*Citrus australasica*	26/4/00	fresh fruit	seeds
B41	Davidsons plum	*Davidsonia pruriens*	26/4/00	fresh fruit	seeds
B42	Native rosella	*Hibiscus heterophyllus*	26/4/00	fresh petals	
B43	Davidsons plum	*Davidsonia pruriens*	25/5/00	fresh fruit	seeds
B44	Illawarra plum	*Podocarpus elatus*	25/5/00	fresh fruit	seeds
B45	Coastal wattle seed	*Acacia sophorae*	25/5/00	fresh seed	
B46	Dorrigo pepperberry	*Tasmannia stipitata*	29/5/00	dried fruit	
B47	Dorrigo pepper	*Tasmannia stipitata*	29/5/00	fresh leaf	

Sample	Common Name	Botanical Name	Received	Condition	Inedible Portion
B48	Mountain pepperberry	*Tasmannia lanceolata*	29/5/00	fresh fruit	
B49	Common acronychia	*Acronychia oblongifolia*	30/5/00	fresh fruit	
B50	Lemon aspen	*Acronychia acidula*	30/5/00	fresh fruit	
B51	Byron Bay acronychia	*Acronychia bauerlenii*	30/5/00	fresh fruit	
B52	Silver aspen	*Acronychia wilcoxiana*	30/5/00	fresh fruit	
B53	Native basil	*Ocimum tenuiflorum*	30/5/00	dried leaf	
B54	Native basil	*Ocimum tenuiflorum*	30/5/00	ground leaf	
B55	Wild lime	*Citrus glauca*	30/5/00	dried fruit	
B56	Riberry	*Syzygium luehmannii*	30/5/00	fresh seed	
B57	Wattle seed	*Acacia victoriae*	30/5/00	dry seeds	
B58	Wattle seed	*Acacia pycnantha*	30/5/00	dry seeds	
B59	Mountain pepper	*Tasmannia lanceolata*	20/6/00	fresh leaf	
B60	Alpine anisebush	*Prostanthera cuneata*	21/6/00	fresh leaf	
B61	Broadleaf peppermint	*Eucalyptus dives*	21/6/00	fresh leaf	
B62	Round leaf peppermint	*Prostanthera. rotundifolia*	21/6/00	fresh leaf	
B63	Strawberry gum	*Eucalyptus olida*	21/6/00	fresh leaf	
B64	Mountain pepper	*Tasmannia lanceolata,* (Toora prov.)	21/6/00	fresh leaf	
B65	Island celery	*Apium insulare*	21/6/00	fresh leaf	
B66	White correa	*Correa alba*	21/6/00	fresh leaf	
B67	Riverwort	*Mentha australis*	21/6/00	fresh leaf	
B68	Lemon scented tea tree	*Leptospermum petersonii*	21/6/00	fresh leaf	
B69	Kibbled bunya flour	*Araucaria bidwillii*	31/8/00	dried fruit	
B70	Quandong	*Santalum acuminatum*	14/9/00	frozen fruit	
B71	Kakadu plums	*Terminalia ferdinandiana*	14/9/00	frozen fruit	
B72	Kakadu plums	*Terminalia ferdinandiana*	.. /8/00	fresh seeds	

3.3.1 Oxalic Acid

Oxalic acid was found in 27 of the bushfood samples at levels greater than the limit of detection of 0.08 g/100 g but 19 of these samples contained <0.25 g/100 g. Of the remaining eight samples, four comprising forest berry herb, mints and warrigal greens (2 samples) contained oxalic acid at 0.62-0.83 g/100 g. The highest levels were present in lemon myrtle (2 samples with 1.52 and 0.68 g/100 g) and aniseed myrtle (2 samples with 1.49 and 0.50 g/100 g).

The findings were confirmed in a limited number of analyses for oxalic acid conducted in 1999/2000. Two samples of aniseed myrtle (B11 and B21) were found to contain 1.10 and 1.02 g/100 g, respectively, and a sample of lemon myrtle (B10) 2.17 g/100 g. No oxalic acid was found in two wattleseed samples, (*A. notabilis*, B28 and *A. victoriae* B57).

Silver beet, spinach and rhubarb were also analysed and found to contain about 0.5 g/100g (0.53, 0.53 and 0.52 g/100g, respectively), values similar to those reported by Wills (1987) in a comprehensive study of commercially available Australian grown fruit and vegetables. On this basis, only the lemon myrtle and one sample of aniseed myrtle contain oxalic acid at levels greater than in mainstream fruit and vegetables. However, all seven foods except warrigal greens, are used primarily to add flavour to cooked dishes and would therefore be consumed in relatively low amounts.

3.3.2 Cyanogens

Hydrogen cyanide evolution was not detected from any of the mostly already-frozen bushfoods collected in 1998/99. All the bushfoods therefore contained cyanogens at <0.1 mg HCN equivalents/100 g, the limit of detection of the method (Table 3.3).

Analysis of the 71 mostly fresh, unfrozen bushfood samples collected in 1999/2000 showed that that cyanogens (as hydrogen cyanide evolution) were detected in six of the samples assayed. The values were generally low with the highest levels being 0.52 mg of HCN equivalents/100 g in lemon scented tea tree, and 0.31 mg/100 g in cinnamon myrtle (Table 3.4). HCN is permitted in Australia at <0.1

mg/100 g in foods. This was the limit of detection in our study. The level of cyanogens in the bushfoods was much lower than the 10 mg/100 g considered to be the threshold level above which cassava needs to be detoxified (Egan *et al*. 1988).

Table 3:3. Analysis of bushfood samples collected in 1998/99 for oxalic acid, cyanogens, saponins and safrole.

Sample	Bushfood	Water (g/100g)	Oxalic Acid (g/100g)	Cyanogens	Saponins	Safrole
A1	Davidsons plum	62.1	-	-	-	
A2	Riberry	60.5	-	-	-	
A3	Bunya nut	45.2	-	-	++	
A4	Quandong	47.7	-	-	-	
A5	Wild lime	56.5	0.17	-	-	
A6	Native rosella	65.8	0.22	-	-	
A7	Lemon aspen	56.5	-	-	-	
A8	Aniseed myrtle	9.8	1.49	-	-	
A9	Lemon myrtle	9.8	1.52	-	-	-
A10	Forest berry herb	14.4	0.68	-	-	-
A11	Native pepper berry	5.8	-	-	-	-
A12	Mountain pepper	11.0	0.15	-	-	-
A13	Mints	8.8	0.83	-	-	-
A14	Wattle seed	1.8	-	-	+	
A15	Munthries	55.6	-	-	-	
A16	Kakadu plum	54.2	0.24	-	-	
A17	Warrigal greens 1	88.6	0.67	-	++	
A18	Warrigal greens 2	91.6	0.62	-	-	
A19	Wild rosella	84.6	0.11	-	-	
A20	Illawarra plum	87.6	0.10	-	-	
A21	Bush tomato	7.9	0.10	-	+	
A22	Bush tomato	63.9	0.09	-	+	
A23	"	8.4	0.11	-	+	
A24	"	72.2	0.09	-	+	
A25	Davidsons plum 1	90.7	-	-	-	
A26	Davidsons plum 2	89.6	-	-	-	
A27	Davidsons plum 3	88.2	-	-	-	
A28	Lemon myrtle	53.9	0.68	-	-	
A29	Aniseed myrtle	50.5	0.50	-	-	
A30	Illawarra plum 1 (wild)	85.6	0.10	-	-	
A31	Illawarra plum 2 (cultivated)	75.6	0.09	-	-	
A32	Bunya nut	46.8	-	-	++	
A33	Finger lime	76.6	0.09	-	+	-
A34	Finger lime	77.9	0.09	-	-	
A35	Finger lime	81.1	0.09	-	-	
A36	Finger lime	78.4	0.16	-	-	
A37	Round lime	75.4	0.09	-	-	
A38	*Citrus garrawayae*	75.8	0.13	-	-	
A39	Wild lime	78.1	-	-	-	
A40	Lemon aspen	78.0	0.09	-	++	
A41	Munthries	53.7	-	-	-	

[-] indicates below the limit of detection of 0.08 g/100g for oxalic acid, 0.1 mg/100g for cyanogens, 0.6 mg/100g for saponins and 0.5 mg/100g for safrole. [+] and [++]for saponins indicate a trace level of about 1 mg/100 g and a positive test of >50 mg/100 g, respectively.

Table 3.4: Analysis of bushfood samples collected in 1999/2000 for cyanogens. (mg HCN/100 g)

Sample	Bushfood	Result	Sample	Bushfoood	Result
B1	Bunya nut (freshly fallen)	<0.1	B37	Munthries	<0.1
B2	Bunya nut (start cone break-up)	<0.1	B38	Wild Rosella	<0.1
B3	Bunya nut (cone full break-up)	<0.1	B39	Illawarra plum	<0.1
B4	Bunya nut (cone rotting)	<0.1	B40	Finger lime	<0.1
B5	Bunya nut (sprouting)	<0.1	B41	Davidsons plum	<0.1
B6	*Diploglottis campbellii* (yellow aril)	<0.1	B42	Native rosella	<0.1
B7	*Diploglottis campbellii* (red aril)	<0.1	B43	Davidsons plum	<0.1
B8	Mint	<0.1	B44	Illawarra plum	<0.1
B9	Lemon scented tea tree	<0.1	B45	Coastal wattle seed	<0.1
B10	Lemon myrtle (Limpinwood)	0.52	B46	Dorrigo pepperberry	<0.1
B11	Aniseed myrtle	<0.1	B47	Dorrigo pepper	<0.1
B12	Aniseed myrtle	<0.1	B48	Mountain pepperberry	<0.1
B13	Davidsons plum	<0.1	B49	*Acronychia oblongifolia*	<0.1
B14	Cinnamon myrtle	0.22	B50	Lemon aspen *(A. acidula)*	<0.1
B15	Riberry	0.17	B51	*Acronychia bauerlenii*	<0.1
B16	Riberry	<0.1	B52	Silver aspen *(A. wilcoxiana)*	<0.1
B17	Mountain pepper	0.11	B53	Native basil	<0.1
B18	Davidsons plum	<0.1	B54	Native basil	<0.1
B19	Native rosella	<0.1	B55	Wild lime	<0.1
B20	Riberry	0.21	B56	Riberry	<0.1
B21	Aniseed myrtle	<0.1	B57	Wattle seed	<0.1
B22	*Tasmannia insipida*	<0.1	B58	Wattle seed	<0.1
B23	Warrigal greens	<0.1	B59	Mountain pepper	<0.1
B24	Aniseed myrtle	0.11	B60	Alpine anisbush	<0.1
B25	Native basil	<0.1	B61	Broadleaf peppermint	<0.1
B26	Round lime	<0.1	B62	Round leaf peppermint	<0.1
B27	Wattle seed	<0.1	B63	Strawberry gum	<0.1
B28	Wattle seed	<0.1	B64	Mountain pepper	<0.1
B29	Fruit salad herb	0.21	B65	Island celery	<0.1
B30	*Dianella caerulea* var. *producta*	<0.1	B66	White correa	<0.1
B31	Cinnamon myrtle	0.31	B67	Riverwort	<0.1
B32	Mint	<0.1	B68	Lemon scented tea tree	<0.1
B33	Illawarra plum (unripe)	0.29	B69	Kibbled bunya flour	<0.1
B34	Bush tomato	<0.1	B70	Quandong	<0.1
B35	Bush tomato	<0.1	B71	Kakadu plum fruit	<0.1
B36	Bush tomato	<0.1	B72	Kakadu plum seed	<0.1

The 41 samples which were tested with negative results in 1998/99 were of processed bushfoods with many samples received in the frozen state. The few positive readings obtained in 1999/2000 were all from fresh samples. It would therefore confirm the expectation that processes such as freezing, baking or grinding, freezing, maceration, soaking, boiling, drying and/or fermentation, which cause damage to plant cells, can variously allow the production and release of cyanide harmlessly to the air, or inactivate compound/s involved in its production. This is consistent with the heavy processing treatment of traditional cyanogen-containing foods such as cassava to render them safe for human consumption.

3.3.3 Saponins

Saponins were detected in 10 of the bushfood samples collected in 1998/99, that is, present at >0.6 mg/100 g. but a definite positive test, that is, >50 mg/100 g occurred with only four bushfoods (Table 3.3). The highest level of saponin was in the fresh sample of warrigal greens but was absent from the parboiled sample, suggesting the use of high temperature inactivates the saponin. A positive test was obtained for lemon aspen and the two samples of bunya nut. The trace amount found in all four samples of bush tomato may be solanine which has been described as both a saponin (Hostettmann & Marston 1995) and an alkaloid (Harborne 1998).

Analysis was also conducted on the three bunya nut samples collected in 1999/2000 and they showed the presence of saponins with the two whole-nut samples (B2 and B3) having >0.6 mg/100 g and the kibbled bunya flour (B69), which contained no additional material but had had previous processing which had already reduced particle size, gave a definite positive test (>50 mg/100 g). Analysis of two wattleseed samples (B28 and B57) gave no response for saponins.

3.3.4 Alkaloid Screening

3.3.4.1. *General*. The results of the screening for alkaloids of bushfoods collected in 1998/99 are given in Table 3.5. This shows that 34 of the bushfood samples gave a response (i.e. contains >40 mg alkaloid/100 g) under UV light with only a single spot appearing in all samples at Rf 0.71-0.86. However, only 15 bushfoods gave a definite positive response. These came from only eight types of bushfood, namely, three samples of lime, the two samples of each lemon myrtle, aniseed myrtle, warrigal greens and munthries, and a single sample of mountain pepper, lemon aspen and riberry. It is noted that the lime and mint samples comprise a range of botanical species.

The response to the colour tests showed 13 bushfood samples gave a positive colour reaction with at least one of the three spray reagents. The two samples of lemon myrtle, aniseed myrtle and warrigal greens and a sample of wild lime gave a positive response to all three tests. Bushfoods that produced a negative colour response also showed consistency as multiple samples of the same plant species generally showed the same lack of response. The exception was the multiple samples of lime (three *Citrus* spp.) which all gave a positive response to UV but differing colour reactions.

The results of the screening of bushfoods collected in 1999/2000 are given in Table 3.6. The main purpose of the re-testing program was to compare the responses of bushfood limes to commercial lime and orange samples. The data show that round lime skin and flesh showed a strong response at Rf 0.78 but the seed gave a negative test. Native limes were assayed whole due to a lack of sample to allow division into plant parts, and this showed a slight positive at Rf 0.78. Commercial lime and orange fruit skin and flesh samples also showed a spot of similar intensity as the citrus bushfoods. Commercial lime and orange also showed another positive response at Rf 0.38 which did not occur in the bushfoods. Re-testing of wattleseed was also conducted due to the 1998/99 sample being an unnamed species with the new data showing a trace level of alkaloids at Rf 0.75. The lemon and silver aspens showed a trace level of alkaloids while the "common aspen" (*Acronychia oblongifolia*) sample tested negative.

While the variation in response by individual bushfoods to the various tests for alkaloids is difficult to interpret in a definitive manner, the findings suggest that the alkaloids being detected in the bushfoods are not of great anti-nutritive concern, due to the similar pattern of occurrence of alkaloids in the commercial orange and lime samples. Since oranges and limes are widely consumed around the world without any nutritional concern, bushfoods, on the present evidence, could also be similarly considered.

3.3.4.2. *Solanines***.** The TLC analysis of the four bush tomato samples collected in 1998/99 indicated that solanine was present in all samples. The intensity of coloured spots in relation to that produced by solanine standards suggested the highest levels in ripe fruit at about 80 mg/100 g dry weight and lowest in green fruit at about 25 mg/100 g. Another spot was found in all the ripe samples at Rf 0.9 but it was not comparable to any of thestandards used in the study.

Table 3.5. Screening of bushfoods collected in 1998/99 for alkaloids (Tests on samples A21-A24 are described in Section 3.3.5).

Code	Bushfood	UV-test				Colour test		
		UV 365	UV 254	Rf	Spot intensity	Dragen	Iodoplat	Marquis
A1	Davidsons plum	-	-	-	-	-	-	-
A2	Riberry	-	black	0.86	+	-	-	-
A3	Bunya nut	-	-	-	-	-	-	-
A4	Quandong	-	-	-	-	-	-	-
A5	Wild lime	blue	purple	0.83	+	purple	purple	purple
A6	Native rosella	red	-	0.74	(+)	-	-	-
A7	Lemon aspen	purple	black	0.73	+	-	-	-
A8	Aniseed myrtle	red	black	0.8	+	green	green	green
A9	Lemon myrtle	pink	black	0.67	+	orange	grey/blue	blue/green
A10	Forest berry herb	red	black	0.72	(+)	-	-	-
A11	Native pepperberry	-	-	-	-	-	-	-
A12	Mountain pepper	brown	black	0.77	+	green	-	orange
A13	Mints (mixed species)	red	-	0.84	(+)	orange	-	-
A14	Wattleseed (no species name)	-	grey	0.84	(+)	-	-	-
A15	Munthries	red	black	0.82	+	-	green	orange
A16	Kakadu plum	-	-	-	-	-	-	-
A17	Warrigal greens 1	red	black	0.81	+	green	green	green
A18	Warrigal greens 2	red	black	0.74	+	green	green	green
A19	Wild rosella	red	-	0.75	(+)	-	-	-
A20	Illawarra plum	-	-	-	-	-	-	-
A25	Davidsons plum	red	-	0.72	(+)	-	-	-
A26	Davidsons plum		-	-	-	-	-	-
A27	Davidsons plum		-		-	-	-	-
A28	Lemon myrtle	red	black	0.84	+	orange	dark blue	black
A29	Aniseed myrtle	red	black	0.72	+	green	green	green
A30	Illawarra plum (wild)	-	-	-	-	-	-	-
A31	Illawarra plum (cult; less ripe)	red	black	0.85	(+)	-	-	-
A32	Bunya nut	-	-	-	-	-	-	-
A33	Finger lime	purple	black	0.81	+	orange	-	orange
A34	Finger lime	blue	-	0.71	(+)	-	-	-
A35	Finger lime " "	blue	black	0.82	(+)	-	-	-
A36	Finger lime " "	red	-	0.71	(+)	orange	-	orange
A37	Round lime	white	black	0.77	+	-	-	-
A38	*Citrus garrawayae*	white	black	0.84	(+)	-	-	-
A39	Wild lime	purple	purple	0.76	+	-	-	-
A40	Silver aspen	-	-	-	-	-	-	-
A41	Munthries	red	black	0.76	+	-	green	-

[-, (+) and +] indicate a negative, slight positive and positive test, respectively. The limit of detection for the UV test is 40mg alkaloid/100 g

Analysis by HPLC was conducted on bush tomato samples collected in 1999/2000 to give better quantification of solanine levels. The chromatograms showed that, of the four standards used, only β2-chaconine was present. On a dry weight basis, the green fruit contained 55 mg/100g of solanine while the ripe fruit contained 11 mg/100 g and the dried fruit 14 mg/100g. However on a fresh weight basis, the levels in green and dried fruit were similar at 11 and 13 mg/100 g, respectively and the ripe fruit was lower at 4 mg/100 g.

In potatoes, a high concentration of solanines is considered to be above 15 mg/100g fresh weight with levels above 20mg/100g considered unsuitable for human consumption (Finlay *et al*., 1998). In addition, potato solanines are reported to be heat stable and not degraded during cooking (Bushway and Ponnampalam, 1981 in Finlay *et al*., 1998).

Table 3 6. Screening of selected bushfoods collected in 1999/2000 and commercial lime and orange for alkaloids

Code	Bushfood	*UV-test*				*Colour test*		
		UV 365	UV 254	Rf	Spot intensity	Dragen	Iodoplat	Marquis
B28	Wattleseed	white	-	0.75	(+)	-	-	-orange
B57	Wattleseed	white	-	0.75	(+)	-	-	-orange
B49	Aspen	-	-	-	-	-	-	-
B50	Lemon aspen	white	-	0.75	(+)	-	-	-orange
B52	Silver aspen	white	-	0.75	(+)	-	-	-orange
B26	Round lime							
"	Skin	red	-	0.78	+	orange	-	Orange/red
"	Flesh	green	-	0.78	+	orange	Orange	Orange
"	Seed	-	-	-	-	-	-	-
B40	Finger lime	green	-	0.78	(+)	-	-	orange
	Commercial orange skin	-	-	0.3	+	-	-	orange
	"	blue	-	0.78	(+)	orange	-	orange
	flesh	-	-	0.3	(+)	-	-	orange
	"	blue	-	0.78	+	orange	-	orange
	Commercial lime, skin	purple	-	0.78-	(+)	orange	-	-
	flesh	-	-	0.3	(+)	-	-	orange
	"	purple	-	0.78	(+)	orange	-	-

[-, (+) and +] indicate a negative, slight positive and positive test, respectively. The limit of detection for the UV test is 40mg alkaloid/100 g

On this basis, the levels of solanines in ripe bush tomatoes can be considered to be not high from a nutritional perspective although green fruit need to be monitored for solanine. The drying process does not appear to diminish the absolute amount of β-2-chaconine in ripe fruit and hence the concentration of nutrients in the dried product gives rise to a higher level of solanines that is similar to that in green fruit and hence will need some commercial monitoring.

3.3.5 Essential Oil

General. Data on analysis of selected bushfoods collected in 1999/2000 for several essential oil constituents of interest, other than safrole (see next section) are presented in Table 3.7. This shows that estragole was present in a combined sample of the three native basils at about 30% of the oil and was the second largest oil constituent. Eucalyptol was the largest oil component in mint and the third largest component in alpine anisebush. (E)-methyl isoeugenol was the second largest oil component in cinnamon myrtle. For aniseed myrtle, eugenol was not detected, methyl chavicol was the second largest component and (E)-anethole was the largest oil component.

The amount of each constituent present was calculated based on an assumption that the response factor relating amount present to peak area on the chromatogram is the same for all terpenes as safrole was the only available standard. The findings are presented in Table 3.7 and indicate that the absolute amount of some compounds is in the order of 1 g/100 g dry weight of bushfood. This level would suggest that some monitoring may be required for at least all the species tested to ensure that a potentially toxic terpene is not at an unacceptable level in commercially marketed material. The amount of each product consumed in a typical food serving would be a critical factor in such assessments. For comparative purposes, concentrations of the same essential oil constituents in common foods are shown in Table 3.8. It should be noted that the amounts of some of these oils which can be added in concentrated form to foods as flavourings are restricted by legislation in many countries, even though foods which naturally contain them in small quantities are widely used.

Table 3.7: Analysis of selected bushfood samples collected in 1999/2000 for selected essential oil constituents

Code	Common name	Compound of Interest	Wt oil (g/ 100g)*	% of oil	Amount (g/ 100 g)*	Comment
B25 + B53 + B54	Native basil (Ocimum tenuiflorum)	Methyl chavicol (estragole)	2.5	30	0.8	2nd largest comp.
B60	Alpine anisebush	1,8-Cineole (eucalyptol)	3.3	10	0.4	3rd largest comp.
B8	Mint	1,8-Cineole	2.6	40	1.1	major component
B14	Cinnamon myrtle	(E)-Methyl isoeugenol	1.1	15	0.2	2nd largest comp.
B21	Aniseed myrtle	Eugenol	1.2	nd	0	
		Methyl chavicol		5	<0.1	2nd largest comp.
		(E)-anethole		90	1.1	major component

* and nd indicate dry weight of bushfood, and not detected, respectively

Table 3. 8. Information for essential oil toxicity and presence in common non-bushfoods

Compound	Presence in essential oils of common foods(1)	Toxicity test values(2) Oral rat LD_{50} mg/kg
[E]-anethole	Fennel: 52%-86%	2090
1,8-cineole (eucalyptol)	Rosemary: 17%-44%	2480
eugenol	Clove bud: 70%-95%	1930
methyl chavicol (estragole)	Chervil 70%-80% French tarragon 70%-87%	1230
[E]-methyl isoeugenol	Not found; methyl isoeugenol has FEMA # 2476 as a food flavouring	2500
pulegone	Pennyroyal: 55%-95%	500
Safrole (BANNED AS FOOD ADDITIVE)	Mace 0.2%-1.9% E. Indian nutmeg 0.6-3.3%	1950

(1) Data from Tisserand and Balacs (1995) and (2). Note that these are percentages of the oil, which is normally of the order of <1%-4% of the total weight of fresh leaves.
(2) Data from www.sigma-aldrich.com MSDS and (1)

Safrole. The data in Table 3.3 show that the six bushfood samples collected in 1998/99 that were analysed for safrole by GC did not give a detectable response. Safrole was therefore present in all samples at <0.5 mg/100 g. Four bushfoods other *Tasmannia lanceolata*, from which variable levels of safrole had been reported, were included in testing, for comparative purposes, but as expected they contained no detectable response in the test for safrole.

Since the literature survey suggested that mountain pepper from some provenances and environments could contain safrole in variable quantities (e.g. Menary *et al.* 1999), additional samples of mountain pepper were collected in 1999/2000 and analysed for safrole by GC-MS where a lower level of detection of could be achieved. In these samples, safrole was found to be present in mountain pepper berry at 0.04 mg/100 g but was below the limit of detection of 0.012 mg/100 g in the two mountain pepper leaf samples. The problem with safrole is that one of its metabolites is known to be carcinogenic in animals, although this does not necessarily reflect the same level of toxicity to humans.

3.3.6 Lectins

Testing in a saline phosphate buffer solution against various types of red cells produced no reaction, although when different types of proteolyic enzyme were added, in two cases (involving papain and ficin) an unknown structure in the cell membrane appeared to be affected. Tests for activity of extracts at various dilutions for granulocyte agglutination (clumping of cells) in a 3 cell typed neutrophil panel were all negative, and it was concluded that no lectin activity against neutrophils was present in the kernels.

3.4. Discussion

The overall findings of the analytical program, when coupled with the literature and industry survey, suggest that current commercial plant bushfoods are generally safe to eat, but a number of types need some care in plant selection or on-going monitoring. Conclusions derived for the specific compounds analysed are:

- Oxalic acid was present in all bushfoods at levels lower than the 0.5 g/100 g found in commercial spinach and rhubarb, except for leaves of lemon myrtle and aniseed myrtle where levels were commonly in the range of 1-2 g/100 g. These leaves are used only as flavourings and they are not consumed in similar quantities to leafy vegetables.

- Only six bushfood samples were found to contain levels of cyanogens above the limit of detection of 0.1 mg hydrogen cyanide/100 g. The highest values were in lemon scented tea tree and cinnamon myrtle at 0.3-0.5 mg/100 g which are much lower than a published safe threshold level of 10 mg/100 g. No cyanogen was detected in any processed bushfood, which supports the expectation that the potential for generation and/or ingestion of cyanide is greatly reduced by treatments such as freezing, baking and/or grinding.

- A positive test for saponins indicating a level >50 mg/100 g occurred with only four bushfoods, fresh warrigal greens (but not in a parboiled sample), bunya nuts and lemon aspen. As indicated in Section 1.3 (7), some types of saponin have cholesterol-lowering properties, but in excess, various saponins can interfere with digestion. Saponins are present in variable quantities in many common foods, such as soya beans, at levels much exceeding those indicated for foods in this study (cf. Fenwick & Oakenfull 1983).

- While a positive test for alkaloids, indicating a level of >0.04 g/100 g, occurred in eight types of bushfood - aniseed myrtle, lemon myrtle, warrigal greens, munthries and *Citrus australasica,* mountain pepper, mints and some of the limes - the variation in response by individual bushfoods to the various tests for alkaloids is difficult to interpret in a definitive manner. However, it is suggested that the alkaloids detected are not of great anti-nutritive concern,due to a similar occurrence of alkaloids in the commercial oranges and limes which are widely consumed around the world without any nutritional concern.

- The solanine, β-2-chaconine was found to be present in bush tomatoes. The levels were much higher in green fruit compared to ripe fruit with the concentration in green fruit at >10 mg/100 g close to the 15 mg/100 g reported as being a high solanine level in potatoes. The solanine level in dried bush tomato was similar to that in green fruit (on a fresh weight basis) indicating that solanine is not degraded during dehydration but becomes more concentrated. The levels are below accepted threshold levels for potato but need some monitoring; the levels of solanine in green and dried bush tomatoes would thus seem to warrant a monitoring system for commercial material.
- Safrole was not detected in all bushfood samples at the level of 0.5 mg/100 g. However, more sensitive analysis of mountain pepper found that the berry contained safrole at 0.04 mg/100 g while the level in the leaf was below the limit of detection of 0.012 mg/100 g. Both values were lower than those reported by Menary *et al.* (1999) for berries, and for almost all leaf samples from a large range of provenances respectively. Work in continuing in Tasmania to identify and select the lowest-safrole sources of material for propagation and use in bushfood products.

  A limited range of testing for-some potentially toxic terpenes showed that they can be substantial components of the essential oil in a number of bushfoods with absolute amounts in the order of 1 g/100 g dry weight of bushfood. This would suggest that some monitoring is required for the species tested to ensure the toxic terpene is not at an unacceptable level in commercially marketed material. The amount of each product consumed in a typical food serving would be a critical factor in such assessments.
- A mixed sample of bunya nuts from several provenances tested negative for lectins.

4. Summary of Conclusions and Recommendations

4.1 Implications of the Study for the Bushfood Industry

The information given in Chapter 2, which was derived from a lengthy list of references, indicate the extensive range of botanical, chemical, and traditional knowledge already available regarding the safe selection and usage of bushfood species. However, it is also evident that much information in the literature would not be readily available to most people in the bushfood industry. While the presentation in this report is a precis of the existing published information for each species, the listing of references will facilitate obtaining further details should a toxicity problem be noted in the future for a particular bushfood.

It will be evident that even with the additional results of new analyses presented in Chapter 3, much is yet to be learned about the chemistry and possible bioactivity of the constituents of Australian native food plants. Although more detailed chemical information such as that provided at the website http://sun.ars-grin.gov/duke/ is available for the constituents of many other commercial food crop plants - such as cereals, fruits, vegetables and nuts - which have been selected, bred and studied over many years, many of the compounds listed there are ubiquitous in plants, and have no known toxicity. For both bushfoods and non-native crop plants, it is only when some form of adverse effect or pharmacological activity of a plant has become known, or is suspected, that analyses - often expensive with modern techniques - are targeted to finding the exact cause.

Because of their short time in the marketplace, most bushfoods are still unfamiliar to most people, and may tend to be readily suspected as the cause of any adverse reaction to a meal in which they have been used. Reassuringly, however, for the great majority of the bushfoods mentioned, there appear to be no reports of adverse effects following normal usage and intake, despite enquiries throughout the period of the study, and no new evidence of unexpected chemical hazards has resulted from the analyses.

The report has not extended to consideration of hazards that do not directly result from inherent chemical and other natural qualities of the bushfoods, which will need to be addressed elsewhere through variously targeted HACCP (Hazard Analysis and Critical Control Points) guidelines. The following summary of the findings of this study as they relate to the bushfoods industry points therefore relevant only to inherent bushfood quality and do not extend to such considerations as handling practices, industrial safety, storage conditions, possible exogenous contaminants or shelf life

Indigestibility tends to be the most commonly observed adverse effect to any kind of food, and factors such as unripeness of fruit, poor preparation, overindulgence and combination with other foods or beverages in a meal may be contributing factors. Though neurological symptoms such as dizziness may be induced by some compounds that are well-known to be present in many of the standard culinary spices, as well as some of their close relatives among the native spices, the amounts normally consumed are negligible and therefore can be considered as relatively harmless.

It is still difficult to locate reliable information on the possibility of allergic reactions to bushfoods, as they may be triggered either by food or non-food factors, especially in people who are particularly susceptible to allergic reactions, and so the incidents are rarely reported.

4.2 Possible Toxicological Hazards Identified from the Literature

- **Misidentification of bushfood sources**.

A major issue is that plant material being utilised is botanically correctly identified. The available information on toxicity only applies to the nominated species and cannot be assumed to be relevant to even a closely related species. This can be important where some local areas support several quite similar species (for example, of *Acacia, Prostanthera* or *Solanum*) not all of which are listed in local or regional records, and some of which possibly may have toxic qualities. It is strongly advised that the identity of samples of unfamiliar plants to be used for propagation should be confirmed by an authority such as a relevant State Herbarium, which will also advise whether the species is protected by legislation from collection from the wild.

- **Problems associated with excessive consumption.**

Digestive or other problems may be associated with the consumption of particularly excessive quantities of unripe or very acid fruits, for example some of the aspens (*Acronychia* species), some bush tomatoes other than the popular *Solanum centrale*, some lillypillies (*Syzygium* species) and unprocessed Davidson's plums (*Davidsonia* species) or to excessive use of very strongly flavoured, peppery and potentially irritant spices (for example, *Tasmannia* species).

- **Failure to follow recommended procedures during harvesting, handling, or preparation**

Varying harvesting, handling or preparation operations from traditional practices can result in harmful or toxic constituents not being removed and included in the end food product. Examples include contact with irritant parts during shucking of rosella calyces, or harvesting of Davidson's plums (*Davidsonia pruriens*) and native cashew (*Semecarpus australiensis*). It is also advisable for bushfood marketers to label their value-added products (and fresh material where practicable) with the name of the species used, and any advice as to requirements for cooking, removal of inedible parts, blanching, as described in section 2.2.15, and a recommended maximum intake in the case of strong spices.

4.3 Additional Information from the Analytical Study, and some Remaining Uncertainties

The analytical results have been generally reassuring . Although for many species there had been no previous analytical information, apart from standard nutritive values, the present research has not identified any potentially toxic concentrations of any class of bioactive compound in the leading commercial bushfoods that were examined. However, the limited range of analyses possible in a comprehensive study of this size could not exclude every possibility of inherent toxicity, and it is always possible that some unexpected allergic reaction, or a potentially harmful natural chemical variation between bushfood plants or provenances, may be reported and require particular analytical procedures.

It was not possible to conduct more than screening tests for the presence of alkaloids in the bushfoods. The results (Tables 3.6 & 3.7) tended to follow previous published results, where they existed, but often only inedible parts of plants had previously been tested. The relatively strong presence of alkaloids in most samples of bush fruits of the family Rutaceae - *Acronychia* and *Citrus* species - proved to be quite similar to that in commercial oranges and limes, leading to the implication that the alkaloids in these bushfoods are not likely to cause a health concern. It was, however, difficult to find previous published records of alkaloids in the fruits of most of these species.

Lemon and aniseed myrtle leaves contained the highest levels of oxalic acid (oxalate) recorded during the study (Table 3.3). No previous records had been located, and the results were higher than for warrigal spinach (*Tetragonia tetragonioides*) about which there have been concerns which indicated a need for their blanching , as described in Section 2.2.15, during preparation as greens. The level of soluble oxalate in the warrigal spinach (*Tetragonia tetragonioides*) samples was, however, less than has been generally reported in the literature, including values for hydroponically-grown material. The highest values of oxalate were from samples of lemon and aniseed myrtle leaves, for which no information had previously been located. However, the myrtles are used in small quantities as flavourings, whereas warrigal spinach is used as a leafy vegetable. The level of oxalates in a larger selection of samples of warrigal spinach would be expected to vary with provenance and season.

Safrole, which had been shown by Menary *et al.* (1999) to be present in highly variable quantities in a range of samples of *Tasmannia lanceolata,* was recorded for the commercial samples of berries and leaves at levels (Table 3.3) approximating the lowest recorded in that study.

Most of the bushfoods tested in this study for cyanogens, including all the frozen samples, gave results below the minimum level of detection (Tables 3.3 & 3.4). and for the remainder the results were well below a level which might cause concern if not reduced by suitable processing.

The results of essential oil analysis (Table 3.7) showed that the less desirable components estragole (methyl chavicol) and eucalyptol (1,8-cineole) were present in some of the mints, basil and aniseed myrtle leaves at levels of approximately 1% of dry weight. However, considering the, amount likely to be consumed following processing and drying, or extracted in infusions of fresh leaves, and use of the products as minor ingredients in dishes, it seems unlikely that exposure is likely to have adverse effects.

In general, the results of analyses for other potentially harmful constituents in the bushfoods were in accordance with previously published results, where these existed. Solanine alkaloids were identified and confirmed as present at relatively low levels in bush tomatoes (*Solanum centrale*), and in general decreased on ripening, but increased somewhat as water was removed during the drying process. The analysis supports the choice of *S. centrale* as the preferred and safest species for commercial use.

Lectins, some of which, if taken in quantity, can cause digestive difficulties, were not found in the bunya nut samples, despite their reported presence in edible South American nuts of the same genus.

The remaining uncertainties about bushfood chemistry are still numerous, and a reason for caution when commercialising bushfoods with no history of safe use and for which few or no analytical data are available. There have been some mostly unexplained adverse reactions to fruits and nuts of a number of native species which may resemble related, edible species but have no history of safe use. These include fruits of one or more of the *Dianella* species, some of which have produced neurological effects, and do not appear to have been part of traditional diets, some non-commercial *Macadamia* species which contain cyanogens (and possibly other toxins) to a level requiring active detoxification or complete avoidance . The also include some other members of the family Proteaceae and some of the bush tomato (*Solanum*) species which contain high levels of certain toxic solanine alkaloids.

A good rule-of-thumb is that if particular native species were used in Aboriginal diets, but are known to have required extensive preparation to reduce a potentially severe toxicity, they should not be considered for commercial use as bushfoods. Use in traditional medicine, even for external use or inhalations, is an indication that one or more strongly bioactive compounds – not necessarily desirable - are likely to be present.

4.4 Adding Bushfoods to Everyday Cuisine

From the information available, it appears that Australian bushfoods have been added rather more slowly to normal diets than might have been expected. As a general rule, the stronger-flavoured spicy and mint-type products may be used in increasing quantities as flavourings, and` the small quantities of undesirable essential oil constituents they contain are unlikely to present any toxicity problem. One might hope that bushfoods will join more familiar foods as a well-recognised alternative choice, as greater familiarity and strong quality control bring realisation of the guaranteed safety of bushfood products. There may still be problems with product recognition and consumer caution if the detail of bushfood ingredients on labels of value-added products is inadequate. While advice on uses and preparation may not be easily provided for fresh retail bushfoods, in the case of a particularly strongly flavoured, packaged product such as mountain pepper and native herbs such as mints and basils, it would be advisable to suggest maximum quantities to be used for particular purposes.

4.5 Recommendations to Prevent Hazardous Material Being Marketed

Actions which the industry could consider implementing to minimise the risk of hazardous material being marketed and to give greater confidence by buyers and consumers could include:

- Providing producers with user friendly information on plant identification including on a website as well as in bushfood publications.
- Documenting information on essential preparation practices for those bushfoods where blanching (as described in Section 2.2.15) boiling or baking are required to diminish undesirable components.
- Ensuring that comprehensive analysis of essential oils is obtained for all sources of plants used for flavouring that could have undesirable components.
- Setting shelf life limits and storage conditions for raw and processed bushfoods.
- Checking the most recent ANZFA food codes and any other relevant food regulations for the names of native and exotic plants which cannot be sold for use in foods. Currently these include kangaroo apples (*Solanum aviculare* and *S. lactinatum* - the latter assumed to be *S. laciniatum*) but the list is subject to ongoing review and should be checked in cases of doubt (see section 2.2.12).
- Encouragement of producers to label bushfood products both with botanical and standardised common names - ideally, together with suggestions for suitable quantities for use per meal.

4.6 Future Work

- Further chemotaxonomic investigation is required into the definition and recognition of chemical varieties (chemotypes) of species that contain a range of aromatic flavour compounds in very variable proportions, for example *Anetholea, Backhousia, Mentha, Ocimum, Prostanthera* and *Tasmannia* species, to enable selection of propagation material containing essential oils of the most desirable chemical composition.
- Documentation of any apparent adverse reactions to particular bushfoods, including allergic responses. Ideally, this would be done through a central registry as has been proposed for the macadamia industry. While it seems that adverse reactions to bushfoods may be rare, during the establishment days of the industry it would be as well to take note of and record, for possible future reference, any such anecdotal or other reports attributed to particular bushfoods.
- Standardisation, and effective promotion within the industry, of a total quality assurance system, such as a HACCP model, for individual bushfood species which include safe selection of raw materials, as well as subsequent guidelines for handling and processing to point of sale.

4.7 Conclusion

Some but not all of the commercial bushfoods mentioned in this report have a history of traditional Aboriginal use, and/or use by early European settlers. Detailed and reliable records of Aboriginal use of food plants are often few, scattered, and complicated by differences between Aboriginal and modern scientific criteria for distinguishing separate plant species. Some traditional bushfoods required lengthy preparation to improve palatability and in some cases to remove inherent toxicities. Bush fruits such as bush tomatoes (*Solanum centrale*) and seeds such as wattleseed (for example *Acacia victoriae*) have a reliable history of traditional use, and are especially favoured by the modern bushfood industry.

Products from native plants containing small percentages of essential oils of unusual and attractive flavour and aroma have been an important focus for bushfood promotion, although their history of traditional use for food purposes is often slight. Such products include lemon, aniseed and cinnamon myrtles, mountain pepper, and some of the native thymes and basils, some of which have had medicinal of other non-food uses. While there is already substantial analytical information on the essential oil composition of many of these latter species, information on other non-nutritional classes of components of bushfoods in general has been limited.

This study has located numerous records of the chemical composition and traditional usage of native plants as bushfoods. As bushfood preferences have become better defined during the course of the study, the range of species discussed in the report has been enlarged to include some recent additions. New analyses during the study have supported and extended the scant information available on the presence/absence in bushfoods of several of the larger classes of compound which include some toxic elements, and some individual, potentially toxic compounds Although a number of compounds such as cyanide and certain essential oil components are restricted, or in the case of safrole, banned by legislation for addition to foods, they are nevertheless naturally present in small quantities in many everyday commercial foods and spices, which are are not considered a hazard to human health due to the low level of consumption in normal use. The investigations reported here have not led to any unexpected or serious concerns regarding the normal use and intake of the commercial bushfoods which were studied, subject to the following reservations that:

- Bushfoods are consumed in normal quantities as part of a mixed diet
- As with other foods, some processing may be required before consumption to improve palatability and/or reduce levels of undesirable chemical constituents, such as cyanogens, soluble oxalates and bitter saponins.
- As with other commercial foods such as peanuts and wheat products, individual tolerances to particular chemical constituents of plant foods may differ. Therefore unfamiliar bushfoods should be introduced into the diet in small amounts.
- Relatively few samples of each species were analysed and hence the results cannot be considered an accurate representation of the range of chemical variation between individual plants or provenances.
- The chemistry of even the best-known food plants is incompletely documented, and so knowledge about recently commercialised species such as bushfoods is even more limited. Therefore the results of this study have been limited by the availability of published information and the results of a limited range of exploratory analyses.

The image and prosperity of the bushfood industry needs to be enhanced by development of formal quality assurance programs to standardise and assure the production and delivery of high quality products, but this must be coupled with a well-founded public acceptance of these products as attractive and safe to eat. This recognition, rather than considerations of nutritional value, will provide impetus for the future development of the industry into new markets. It is hoped that this study will provide producers and others with interests in the development of the industry with a range of useful information to assist the marketing and registration of their products.

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6. Appendices

Appendix 1: Nutritional information for some leading bushfoods

(Data from Brand Miller *et al.* (1993), and as noted below)

Bushfood (species)	**Nutritional values per 100g of edible portion, raw** energy (kJ)	water (g)	protein (g)	fat (g)	c'hydrate (g)	diet/fibre (g)	ash (g)
Wattle seed (*Acacia victoriae*, av of 6 samples)	1384	6.9	17.5	3.2	67.5 (T)	29.4	3.5
Aspens (Acronychia fruits, average of 2 species)	nd	av.70	0.9	1.9	nd	nd	nd
Finger lime (*Citrus a'asica* var. *a'asica* fruit)	411	65.5	2.5	4.9	11.7*	14	0.7
Finger lime (*Citrus a'asica* var. *sanguinea*) fruit	nd	76.7	nd	1.7	8.7*	12.6	0.7
Round lime (*Citrus australis*) fruit	277	74.8	2.2	bdl	15	6.7	0.8
Davidson plum (*Davidsonia pruriens*) av. of 5 samples	72	90.6	0.4	0.9	8.7(T)	5.3	0.4
Native rosella (*Hibiscus heterophyllus*) flower	204	85.7	1.4	bdl	11.2	nd	nd
Native rosella (*Hibiscus heterophyllus*) carpels	nd	86.7	1.4	0.3	nd	nd	nd
Illawarra plum (*Podocarpus elatus*) fruit	347	87.3	0.2	0.2	21*	4.4	0.3
Quandong (*Santalum acuminatum*) av. 4 fruit samples	335	68.5	2.3	0.2	21.0(T)	4.3	2.1
Bush plum (*Santalum lanceolatum*) av. 6 fruit samples	636	63.2	3.3	4.4	25.7(T)	2.5	1.
Bush tomato (*Solanum centrale*) av of 7 fresh fruit samples	570	61.9	3.8	0.6	31.9(T)	7.8	1.9
Bush tomato (*Solanum centrale*) av of 6 dried fruit samples	1174	12.5	8.5	3.8	67.3(T)	23.4	5.
Lillypilly (*Syzygium luehmannii*) fruit	325	82	0.9	0.4	18.4*	6.8	0.8
Kakadu plum (*Terminalia ferdinandiana*) av.10 fruit samples	247	76.2	0.8	0.5	17.2(T)	7.1	1.
Warrigal greens (*Tetragonia tetragonioides*) leaf	61	90.9	1.7	0.3	1.3	3.8	2.
Wild rosella (*Hibiscus sabdariffa*, dry calyx)	Values for several parts of the plant, from various studies overseas, shown ⇒						

* Method of Southgate
nd: not determined
T: Total carbohydrate
bdl: below level of detection

Vitamins			**Mineral composition**								
B1 (g)	B2 (g)	Vit C (g)	Na (mg)	K (mg)	Mg (mg)	Ca (mg)	Fe (mg)	Zn (mg)	Cu (mg)	P (mg)	ref.
nd	nd	nd	33	766	173	243	10.4	2.2	1.1	nd	1
0.06	0.04	<0.2	35	327	28	36	1.5	0.2	0.2	22	2
nd	nd	nd	9	290	31	50	0.8	0.3	0.4	nd	1
nd	nd	82	3	200	15	40	0.6	0.2	0.3	nd	1
nd	nd	nd	4	270	24	46	0.5	0.1	0.2	nd	1
bdl	bdl	bdl	2	150	14	12.1	1.2	0.5	0.1	nd	123
0.02	0.04	1	4	150	35	94	1.8	nd	0.1	nd	2
0.02	0.11	bdl	nd	nd	nd	nd	nd	nd	nd	nd	2
nd	nd	nd	5	100	9	19	0.3	0.2	0.2	nd	1
nd	nd	nd	62	703	34	53	1.2	0.5	0.5	nd	1
bdl	0.17	15	6	800	55	41	1.9	1.2	0.7	91	123
0.21	nd	19	52	448	34	40	2.9	0.1	2.8	nd	13
0.85	bdl	17	95	1918	97	90	11	1.4	0.5	140	123
nd	nd	nd	11	250	48	00	0.9	0.2	0.3	nd	1
0.05	0.04	2907	13	261	40	62	2.4	0.7	0.9	24	12
nd	nd	nd	590	180	80	38	2.6	0.5	0.5	nd	1
http://www.hort.purdue.edu/newcrop/duke_energy/Hibiscus_sabdariffa.html											4

SOURCES OF INFORMATION:

1-3 Databases presented by Brand Miller, James & Maggiore (1993*) Tables of Composition of Australian Aboriginal Foods*, Aboriginal Studies Press, Canberra.

4 As shown, or:http://www.hort.purdue.edu/newcrop/FamineFoods/ff_families/

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Appendix 2.2: Acknowledgment of providers of information relevant to commercial uses and safety of particular species

(including information provided during discussions or meetings, advice on suitable contacts and addresses, and/or other information or advice relevant to the study)

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Appendix 3: List of bushfood species mentioned in the text

Acacia species:
aneura, coriacea, , holosericea,
longifolia, murrayana, notabilis,
pycnantha, retinodes,sophorae,
tumida, victoriae
Acmena smithii
Acronychia species:
aberrans, acidula, baueri,
bauerlenii, imperforata, oblongifolia
pubescens, suberosa, wilcoxiana
*Aleurites moluccana (*as *ssp.moluccana)*
Anetholea anisata
Apium species:
insulare prostratum
Araucaria bidwillii
Backhousia species:
anisata (see *Anetholea*),
citriodora, myrtifolia
Brachychiton species
Citrus species:
australasica, australis,
garrawayae, glauca, gracilis,
inodora, maideniana
Correa alba
Davidsonia species:
jerseyana, johnsonii, pruriens
Davidsonia pruriens var jerseyana
*(*see *D.jerseyana)*
Diploglottis campbellii
Drimys species:
aromatica, lanceolata, stipitata,
winteri
*Eremocitrus glauca (*see *Citrus glauca)*
Eugenia species (see also *Syzygium*)
luehmannii, smithii
“Forest Berry herb"
Hibiscus species:
divaricatus, heterophyllus,
sabdariffa
Kunzea species:
ericoides, pomifera
Leptospermum species:
citratum, flavescens, petersonii
Macadamia species:
integrifolia, tetraphylla
Mentha species:
australis, diemenica, gracilis
grandiflora, satureioides
*Microcitrus (*see *Citrus* species*)*
Ocimum species:
americanum, anisodorum
basilicum , caryophyllinum
sanctum tenuiflorum
Podocarpus elatus
Prostanthera species:
incisa, lasianthos, rotundifolia
sieberi, sp. aff. *P. melissifolia*
Prumnopitys amara
Racospermum (see *Acacia*)
Santalum species:
acuminatum, album, murrayana,
spicatum
Semecarpus australiensis
Solanum species:
aviculare, centrale, chippendalei,
cleistoganum, coactiliferum,
diversifolium, ellipticum, esuriale
simile
Sundacarpus amarus
Syzygium species:
corynanthum, luehmannii,
*oleosum (*formerly
coolminianum), suborbiculare,
tierneyanum,
Tasmannia species:
insipida, lanceolata (=
Drimys aromatica), stipitata
Terminalia species:
catappa, ferdinandiana
grandiflora, latipes,
oblongata, prostrata
Tetragonia species:
expansa, tetragonioides, moorei