Chapter 9

# Health attributes of Indigenous Australian plants

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The composition of food items is vital to maintain a good health. Research over the last two decades has shown that the nutritional quality of our diet improves with a greater diversity of food items or food groups (Shimbo *et al*., 1994; Hatloy *et al*., 1998). An assessment of dietary composition in the USA showed that those who consumed a large proportion of their food items from meat, fish, poultry, and eggs were at an increased risk of colon cancer. This risk was significantly reduced with a greater reliance on plant foods (fruits, vegetables, seeds and nuts) (Slattery *et al*., 1997).

This chapter describes the composition of micronutrients in a range of Australian wild or near-wild (minimally genetically selected) foods, including:

### 1. Fruits:

**Kakadu or Kalari plum*** (*Terminalia ferdinandiana* Excell, Conmbretaceae)
**Davidson plum** (*Davidsonia pruriens* F. Muell., and *Davidsonia jerseyana* (F. Muell ex F.M. Bailey) G.J. Harden and J.B. Williams, Cunoniaceae
**Quandong** (*Santalum acuminatum*, A.D.C., Santalaceae)
**Riberry** (*Syzygium luehmannii* (F. Muell.) L.A.S. Johnson, Myrtaceae)
**Lemon aspen** (*Acronychia acidula* F. Muell, Rutaceae)
**Finger lime** (*Citrus australasica* F.Muell; Rutaceae)
**Australian desert lime** (*Citrus glauca* (Lindl.) Burkill; Rutaceae)
**Munthari** (*Kunzea pomifera* F. Muell., Myrtaceae)
**Illawarra plum*** (*Podocarpus elatus* R. Br. ex Endl., Podocarpaceae)
**Burdekin plum** (*Pleiogynium timorense* D.C. Leenh, Anacardiaceae)
**Cedar Bay cherry** (*Eugenia carissoides* F. Muell., Myrtaceae)

Kakadu or Kalari plums

### 2. Herbs:

**Mountain pepper*** (*Tasmannia lanceolata,* (Poir) A.C. Sm., Winteraceae)
**Lemon myrtle** (*Backhousia citriodora* F. Muell., Myrtaceae)
**Anise myrtle** (*Syzygium anisatum* (Vickery) Craven and Biffen, Myrtaceae)

### 3. Spices:

**Wattle seeds*** (*Acacia sp*. Mill., Fabaceae
**Tasmanian pepperberry*** (*Tasmannia lanceolata,* (Poir) A.C. Sm., Winteraceae)
**Bush tomato*** (*Solanum centrale,* J.M. Black, Solanaceae).

* Primarily or predominantly wild crafted

## Introduction

The main role of phenolic compounds in plants is protection of plant cells from oxidative deterioration and environmental stress (drought, high/low temperature, soil salinity, bacteria, fungi, insect and herbivores) (Veberic *et al*., 2005). The importance of identification and quantification of phenolic compounds levels arises from earlier findings that these compounds, especially flavonoids, hydroxycinnamic acids and proanthocyanidins, are the most common sources of antioxidant capacities of fruits and vegetables (Kahkonen *et al*., 1999), primarily responsible for their health-enhancing properties (Moskaug *et al*., 2005).

The research on composition of phytochemicals in Australian wild foods has only begun recently. The results described in this chapter are based on chemical analysis of solvent-based plant extracts, which means that to date only extractable phytochemicals have been researched. However, water- or solvent-based extraction applied in these studies leave behind fibre-associated, unextractable compounds which may also play a significant physiological role. This might be the case of polymeric tannins bound to fibrous tissue of Kakadu plum fruit. Therefore, the reported levels of phytochemicals in the fruit, as presented based on the analysis of alcohol-based extract, may be underestimated. The unextractable phytochemicals might be responsible for variations in physiological responses in vivo to plant extracts versus the whole foods. Further studies are needed to address this issue.

Vic Cherikoff comments: This is effectively part of a first glimpse at these functional nutrients with more work needed in a host of areas of understanding of the composition and health properties of wild foods. Even with this limitation, the results presented suggest that wild foods are indeed impressive from the perspective of functionality and health enhancement.

## Fruits

Table 1 presents the Total Phenolics (TP) which are one of the major groups of hydrophilic (water-soluble) natural compounds in plant-based foods. The levels in the food analysed are compared to those in blueberry, which is widely accepted as one of the richest sources of phenolic-based antioxidant compounds and recognised as a health-enhancing food.

Two out of eight Australian fruits, Kakadu plum and quandong, contained superior levels of phenolic compounds being 6-fold and 1.9-fold respectively, to that in the blueberry reference. The TP level of the Kakadu plum sample was 27.1 ± 2.1mg GAE/g FW. Further screening of 45 accessions of Kakadu plum collected across Australia revealed that the level of total phenolics may vary from 25.6 to 82.7mg GAE/g FW of edible portion (Konczak *et al*., 2014), therefore selection of accessions with significantly higher levels of total phenolics is possible.

Kakadu plum and quandong also exhibited superior total reducing capacities (FRAP values). These were 13.2 and 2.3 times higher respectively, than blueberry. The same two fruits possess an outstanding ORAC (quandong; 532µmol T Eq/g FW and Kakadu plum 430µmol T Eq/g FW) which is 8.1-fold and 6.6-fold that of the blueberry reference, respectively.

Lipophilic (fat-soluble) antioxidant compounds present in plant-based foods, such as carotenoids or tocopherols (vitamin E components) represent an equally important group of dietary phytochemicals as the hydrophilic (water-soluble) antioxidants. They are especially required for the protection of lipids. The presence of lipophilic antioxidants is a unique and valuable quality of the Australian wild fruits (from around 6 per cent to over 30 per cent of the total antioxidant capacity) and they are even higher in wild herbs and spices contributing up to nearly half the antioxidant capacity.

In protein-free, human plasma lipophilic antioxidants contribute from 30 to

**Table 1. Total phenolic content and antioxidant capacity of the edible portion of selected Australian fruits**

| Fruit | Total phenolics (mg GA E/ g FW) | Total reducing capacity (FRAP) (µmol Fe+2/ g FW) | ORAC-T (µmol T E/ gFW) | ORAC-H | | ORAC -L | |
|---|---|---|---|---|---|---|---|
| | | | | (µmol TE/gFW) | (%) | (µmol TE/gFW) | (%) |
| Desert Lime | 1.83 ± 0.07* | 34.8 ± 2.3 | 56.8 | 44.88 ± 5.13 | 79.04 | 11.90 ± 0.17 | 20.96 |
| Kakadu Plum | 27.1 ±2.1• | 690.5 ± 48.4** | 430.0 | 315.40 ± 33.7 | 73.34 | 114.64± 13.89 | 26.66 |
| Lemon Aspen | 1.62 ± 0.05 | 14.0 ± 2.4 | 184.8 | 131.49 ± 11.4 | 71.16 | 53.29 ± 0.50 | 28.84 |
| Davidson Plum *(D. pruriens)* | 2.6 ± 0.04** | 53.9 ± 4.0** | 100.9 | 83.10 ± 10.9** | 82.36 | 17.80 ± 0.17** | 17.64 |
| Davidson Plum *(D. jerseyana)* | 1.39 ± 0.04** | 41.6 ± 1.4** | 59.0 | 47.63 ± 7.62** | 80.7 | 11.36± 0.03** | 19.3 |
| Finger Lime (green) | 1.16 ± 0.06 | 12.6 ± 0.5 | 57.8 | 45.95 ± 6.6 | 79.49 | 11.86 ± 1.25 | 20.51 |
| Finger Lime (pink) | 1.56 ± 0.08 | 23.2 ± 0.8 | 88.8 | 65.09 ± 12.8 | 73.28 | 23.73 ± 0.75 | 26.72 |
| Riberry | 1.27 ± 0.11 | 33.2 ± 1.9 | 72.0 | 49.89 ± 6.4 | 69.25 | 22.15 ± 0.86 | 30.75 |
| Quandong (fresh) | 8.57 ± 0.61 | 123.0 ± 0.6 | 531.7 | 500.96 ± 64.0 | 94.21 | 30.77 ± 0.30 | 5.79 |
| Blueberry | 4.51 ±0.10 | 52.4± 2.78 | 65.5 | 65.2 | 99.51 | 0.36 | 0.49 |

* Values represent means ± SD, n=3; Total phenolic content is corrected for ascorbic acid.

• Values vary from 25.6 mg to 82.7 mg GAE/g FW of flesh [Source: Ref. 59; unpublished data]

mg GA E/g FW: mg gallic acid equivalents/g fresh weight; FRAP: Ferric Reducing Antioxidant Power; ORAC- H: Oxygen Radical Absorbance Capacity-hydrophilic compounds; ORAC-L: Oxygen Radical Absorbance Capacity-lipophilic compounds; ORAC-T : total ORAC; µmol TE/gFW: micromoles trolox equivalent in 1 g fresh weight.

40 per cent of the total antioxidant capacity (Prior *et al.*, 2003). The contribution to the antioxidant capacity of lipophilic compounds in the reference blueberry is approximately 0.5 per cent. In the fruits presented here this contribution varied from 5.8 to 30.7 per cent (Table 1). Kakadu plum has the highest level of lipophilic antioxidants (114.64 ± 13.89µmol TEq/g FW) and their contribution toward total ORAC is a high 26.7 per cent.

The total antioxidant capacities of other fruits evaluated in this study were significantly lower. However, the contributions of the lipophilic fractions are relatively high (Table 1). In this respect Australian fruits differ significantly from the blueberry reference as well as from other common fruits, such as apple (0.8 per cent), apricot (0.6 per cent) and blackberry (1.1 per cent) (USDA database, 2010).

## Australian herbs and spices

These represented another rich source of phenolics. Three of the common herbs and spices – mountain pepper, anise myrtle and lemon myrtle – were similar in phenolics to bay leaf. The average level of total phenolics per gram of dry bay leaf is 41.7mg/g DW (Shan *et al.*, 2005). The level of phenolic compounds in mountain pepper was 2.4-fold that of bay leaf, while both anise myrtle and lemon myrtle were comparable to it (Table 2).

Anise myrtle displayed the strongest total reducing capacity (FRAP assay; Table 2), and was followed by the mountain pepper and lemon myrtle. The TRC of anise myrtle was similar to that of Chinese star anise (2.685±0.04mMol Fe$^{+2}$/g DW), while reducing capacity of mountain pepper and lemon myrtle leaves were similar to that of perilla leaf and nutmeg (1113 and 1255µMol Fe$^{+2}$/g DW, respectively) (Liu, Qiu, Ding and Yao, 2008). The reducing capacity of pepperberry was 72.6 per cent of that of black pepper (Liu, Qiu, Ding and Yao, 2008). The Australian bush tomato's reducing capacity and total phenolic content appeared to be similar to Chinese Wolfberry fruit (known as goji berry; *Lycium barbarum* L.) (207µMol Fe$^{+2}$/g DW) (Liu, Qiu, Ding and Yao, 2008). Wattle

**Table 2. Total phenolic content and antioxidant capacity of selected Australian herbs and spices.**

| Sample | Total phenolic content (mg GA E/ g DW) | Total Reducing Capacity (FRAP) (µmol Fe+2/g DW) | ORAC-T (µmol TE/ gDW) | ORAC-H | | ORAC-L | |
|---|---|---|---|---|---|---|---|
| | | | | (µmol TE/ gDW) | (% of ORAC-T) | (µmol TE/ gDW) | (% of ORAC-T) |
| Pepperberry | 16.9 ± 0.7* | 332. 9 ± 19. 9 | 956.4 | 779.5 ± 82.6 | 81.50 | 176.9 ± 2.7 | 18.50 |
| Mountain pepper | 102.1 ± 1.23 | 1314.5 ± 67.9 | 4077.1 | 3504.4 ± 392.5 | 85.95 | 572.7 ± 27.6 | 14.05 |
| Anise myrtle | 55.9 ± 4.7** | 2158.0 ± 88.5 | 2565.8 | 2446.1 ± 242.1 | 95.33 | 119.7 ± 0.1 | 4.67 |
| Lemon myrtle | 31.4 ± 5.9 | 1225.3 ± 72.2 | 3359.9 | 1889.8 ± 206.6 | 56.25 | 1470.1 ± 171.9 | 43.75 |
| Bush tomato | 12.4 ± 0.9 | 206.2 ± 9.0 | 931.3 | 912.8 ± 117.7 | 98.01 | 18.6 ± 2.2 | 1.99 |
| Wattle seed | 0.8 ± 0.12 | 17.8 ± 1.2 | 61.5 | 53.4 ± 7.9 | 86.83 | 8.1 ± 0.4 | 13.17 |

*Values represent means ± SD, n=3;

**Total phenolic content is corrected for ascorbic acid;

mg GA Eq/g DW: mg gallic acid equivalents/g dry weight;

FRAP: Ferric Reducing Antioxidant Power;

ORAC-H: Oxygen Radical Absorbance Capacity-hydrophilic compounds;

ORAC-L: Oxygen Radical Absorbance Capacity-lipophilic compounds;

ORAC-T : total ORAC activity; µmol TEq/gDW: micromole trolox equivalent/g dry weight.

seeds displayed very low reducing capacity and in this respect are comparable to lotus seeds (10µMol $Fe^{+2}$/g DW) (Liu, Qiu, Ding and Yao, 2008).

The highest ORAC value was for mountain pepper, followed by lemon myrtle, anise myrtle, pepperberry, bush tomato, and wattleseed. With the exception of lemon myrtle, the main source of antioxidant capacity was the hydrophilic fraction. In the case of lemon myrtle, the hydrophilic fraction contributed 56.2 per cent and the lipophilic fraction 45.8 per cent of the total ORAC. The high values of ORAC-L were possibly due to the presence in lemon myrtle of an essential oil that displays a high antioxidant capacity (Ruberto and Baratta, 2000). The contribution of the lipophilic fraction to the total ORAC were mountain pepper 14.0 per cent, in pepperberry 18.5 per cent, bush tomato 2.0 per cent and wattleseed 13.2 per cent.

## Major Phenolic Compounds

Phenolic compounds are the ubiquitous phytochemicals in plant-based foods. The majority of them are hydrophilic (water soluble) compounds. On consumption, these compounds readily interact with enzymes of the gastrointestinal track, regulating the digestion process, and – depending on their molecular structure – are absorbed by the blood stream.

Studies over the last decade have shown that phenolic compounds from food are absorbed throughout the gastrointestinal tract and are able to cross the blood barrier making them available to all organs. However, different compounds can vary in their bioavailability. For example, 23 to 26 per cent of anthocyanins containing only one moiety of a simple sugar (galactose or glucose) were absorbed from the gastric lumen of rat within the first 30 minutes after injecting a blueberry extract into the rat's stomach. The uptake of anthocyanins with a disaccharide in the molecule (rutinose) was lower – only 8.4 per cent (Talavera *et al.*, 2003).

Researchers have shown that one hour after an oral administration of blueberry extract to a rat, unmodified anthocyanidins were identified in heart, kidneys, liver, lungs and skin of the animal (Aldo Chrisoni (Indena); oral presentation '*Vaccinum myrtillus* L.'; International Blueberry Conference, Tokyo, Japan, 2004). Moreover, blueberry supplementation enhanced memory and motor performance in aged animals and these effects have been attributed in large part to anthocyanins, which enter the brain and other organs (Casadesus *et al.*,

### Table 3. Major phenolic compounds in selected Australian fruits

| Fruit | Phenolic compound | Amount (mg/g DW) |
|---|---|---|
| Kakadu plum | Kaempferol/luteolin glycoside | P |
| | Quercetin/hesperitin glucoside | P |
| | Gallic acid | From 0.2 to 30.5 |
| | Ellagic acid | From 3.0 to 140.2 |
| | Hydrolysable tannins | 87.10[a] |
| Lemon aspen | Kaempferol/luteolin hexoside | P |
| | Quercetin hexoside | P |
| | Rutin | P |
| | Chlorogenic Acid | P |
| | Caffeic Acid | P |
| | Coumaric Acid | P |
| | Ferulic Acid | P |
| Davidson plum (*Davidsonia pruriens*) | Ellagic acid | 3.67 |
| | Ellagic acid derivatives* | 14.64 |
| | Delphinidin sambubiose | 22.70[b] |
| | Cyanidin sambubiose | 2.08 |
| | Peonidin sambubiose | 7.07 |
| | Pelargonidin sambubiose | T |
| | Malvinidin sambubiose | T |
| | Myricetin | P |
| | Rutin | P |
| | Quercetin hexoside | P |
| Davidson plum (*Davidsonia jerseyana*) | Delphinidin sambubioside | 19.98 |
| | Cyanidin sambubioside | 24.68 |
| | Petunidin sambubioside | 8.56 |
| | Peonidin sambubioside | 30.44 |
| Quandong (Fresh) | Cyanidin-3-glucoside | 5.76 |
| | Pelargonidin-3-glucoside | 1.18 |
| | Quercetin rutinoside | 2.29[c] |
| | Kaempferol | 2.6[c] |
| Quandong (commercial sample of dry fruit) | Cyanidin-3-glucoside | 0.523 |
| | Pelargonidin-3-glucoside Quercetin | 0.01 |
| | rutinoside | 2.22[c] |
| | Kaempferol | 1.65 |
| Riberry | Rutin | 0.65c |
| | Quercetin hexoside | 0.64c |
| | Cyanidin 3 – galactoside | 28.8 |
| | Cyanidin 3 – glucoside | 2.3 |
| | Myricetin hexoside | P |
| | Kaempferol/luteolin rutinoside | P |
| | Quercetin rhamnoside | P |
| | Cyanidin 3,5 – diglucoside | 4.2 |
| Cedar Bay cherry | Gallic acid | 0.10 |
| | Chlorogenic acid | 0.58 |
| | Catechin | 0.12 |
| | Epicatechin | 0.75 |
| | Flavonoids (total) | 13.0 |
| | Proanthocyanins | 7.25 |

Results presented in milligrams per 1 gram dry weight of fruit (edible portion) (mg/g DW). T: trace; P: possible/confirmation required;

* Calculated as ellagic aicd; a Gallic acid equivalent; b All anthocyanins calculated as cyanidin 3-glucoside equivalent; c Rutin equivalent; d Catechin equivalent

Riberries.

2004; Andres-Lacueva *et al*., 2005; Kalt *et al*., 2008). Following blueberry feeding to aged rats, anthocyanins have been identified in brain, especially hippocampus and neocortex, which are essential for cognitive function (Andres-Lacueva *et al*., 2005). The distribution of anthocyanins in the hippocampus correlated with increased neuronal signalling (Casadesus *et al*., 2004). These studies suggest that anthocyanins increase neuronal signalling in brain centres mediating memory function. Other studies have shown insulin-like and glitazone-like properties of anthocyanins, which improve metabolic function (Martineau *et al*., 2006; Tsuda, 2008) and reduction of the accumulation of fat (Kalt *et al*., 2008).

Commonly present groups of phenolic compounds in Australian wild foods, as identified from analysis of solvent-based plant extracts, were found to be phenolic acids (benzoic and hydroxycinnamic), flavonoids (flavonols, flavanones and anthocyanins) and hydrolysable tannins (Tables 3 and 4). The first two groups of phenolic compounds dominated and are a source of antioxidant capacity in many common fruits (Kahkonen *et al*., 1999). The composition of the hydrophilic extract of Kakadu plum is unique and requires special attention. It contains flavonoids, hydroxycinnamic acids and proanthocyanidins at trace amounts. The hydrophilic fruit extract may contain from 0.2 to 30.5mg/g DW of gallic acid and from 3.0 to 140.0mg/g DW of ellagic acid. A recent study suggested that the major components of Kakadu plum extract were hydrolysable tannins, possibly complex ellagitannins and galloylglucoses (Konczak *et al*., 2014).

Ellagitannins and their oligomers with increasing numbers of galloyl units are highly potent antioxidants, with activities higher than those of most flavonoids (Quideau *et al*., 2011). However, substitution of their hydroxyl groups with a sugar moiety decreases the antioxidant capacity in vitro (Landete, 2011). This may be altered in vivo as recent work showed that gut micro-flora improved the bioavailability of many antioxidants post-digestion.

Fresh quandong predominantly contained flavonoids: quercetin, keampferol and the anthocyanins; cyanidin 3-glucoside, pelargonidin 3-glucoside and trace levels of cyanidin 3-rutinoside. The total level of anthocyanin in quandong was 1.57μmol C3G E/g DW. Other components identified in the extract of fresh quandong included chlorogenic acid and potentially benzoic acids.

In the dry quandong sample, the level of anthocyanin was reduced to 0.12μmol C3G E/g DW suggesting significant degradation of anthocyanin during the drying process. (Konczak *et al*., 2010).

Anthocyanins were the major phenolic compounds detected in Davidson plum. The main anthocyanins were 3-sambubiosides of delphinidin, cyanidin, petunidin and peonidin, pelargonidin and malvidin. Delphinidin 3-sambubioside contributed 47.5 per cent of the anthocyanin mixture and was followed by petunidin (23.7 per cent), peonidin (14.7 per cent) and cyanidin (4.4 per cent). The levels of pelargonidin and malvidin 3-sambubiosides were below 3 per cent. Other components found in small amounts included myricetin, rutin and quercetin hexoside.

Anthocyanins were the major antioxidant compounds in riberry extract. The mixture consisted of cyanidin 3-galactoside (81.6 per cent), cyanidin 3,5-diglucoside (11.9 per cent) and cyanidin 3-glucoside (6.5 per cent) (Table 3). The fruit also contained notable amounts of other glycosides including quercetin and kaempferol rutinosides, myricetin and quercetin hexosides and quercetin rhamnoside (Konczak *et al*., 2010b).

The major groups of phenolic compounds detected in Australian herbs and spices were phenolic acids (benzoic and cinnamic), flavonoids (flavonols, flavanones and anthocyanins) and ellagitannins (Konczak *et al.*, 2010a; Sakulnarmrat, 2012) The phenolic composition of Tasmanian pepperberry comprised predominantly cyanidin 3-rutinoside and cyanidin 3-glucoside, chlorogenic acid, rutin and quercetin (Table 4). The characteristic feature of these molecules is the 'catechol' structure or presence of at least 2 HO- groups on a benzene ring that is responsible for the enhanced antioxidant properties of phenolic compounds (Rice-Evans *et al.*, 1996). The phenolic mixture of the mountain pepper was comprised of the same compounds. However, anthocyanins were present at a very low level (1.25mg C3G/g DW) and the mixture was dominated by cinnamic acids. Chlorogenic acid was the major compound, making up about 3 per cent of the sample's dry weight. A similarly high concentration of chlorogenic acid has been identified in the leaf of white birch (Ossipov *et al.*, 1996).

Hydrophilic extracts of anise myrtle and lemon myrtle contained hydrolysable tannins (ellagitannins) (Sakulnarmrat *et al.*, 2012). Ellagic acid glycosides were the dominant ellagic acid derivatives in the anise and lemon myrtle phenolic-rich fractions. The level of ellagic acid and derivatives in anise myrtle was higher than in lemon myrtle. This finding explains the high antioxidant capacity of anise myrtle identified in both, FRAP and ORAC assays (Table 2).

The anise myrtle extract also contained aglycone(s) of quercetin and/or hesperetin (Table 4). Other detected components in minor amounts include myricetin and chlorogenic acid.

Based on mass spectrometric evidence, bush tomato contained quercetin rutinosides, a quercetin hexoside and a kaempferol/luteolin hexoside present at low levels. Minor amounts of chlorogenic, caffeic, ferulic, coumaric and hydroxybenzoic acids were also detected in the extract (Table 3).

Phenolic compounds were present in minute quantities in the extract of wattleseeds. Compounds detected included rutin, quercetin and hexosides of kaempferol or luteolin aglycones. Trace levels of chlorogenic acid were also present.

## Carotenoids: β-carotene and Lutein

Mountain pepper contained β-carotene at the level of 200μg retinol equivalents/100gDW. This compound was not found in the other foods described in this chapter.

Another lipophilic compound identified in indigenous fruits, herbs and spices is lutein which plays an important role in eye health. It improves visual function and symptoms in atrophic age-related macular degeneration that is the leading cause of vision loss in aging process (Richer *et al.*, 2004). It also protects the retina from damage by inhibiting inflammation (Jun-Sub *et al.*, 2006).

**Table 4. Major phenolic compounds in native Australian herbs and spices (mg/gDW).**

| Compound | Tasmanian pepper | | Anise Myrtle | Lemon Myrtle | Bush Tomato | Wattle seed |
|---|---|---|---|---|---|---|
| | Berry | Leaf | | | | |
| Hydroxybenzoic acid | ND | ND | ND | ND | 0.3±0.1 | ND |
| Ferulic acid | ND | ND | ND | ND | 0.8±0.1 | ND |
| Chlorogenic acid | 1.5±0.1 | 30.0±0.2 | 7.8±0.1 | ND | 0.4±0.1 | T |
| Caffeic acid | 1.1±0.1 | ND | ND | ND | T | ND |
| *p*-Coumaric acid | ND | 15.3±0.5 | ND | ND | T | ND |
| Ellagic acid | ND | ND | 7.54±0.5 | 5.85±0.3 | ND | ND |
| Ellagic acid derivatives | ND | ND | 25.34±2.5 | 20.66±1.8 | ND | ND |
| Quercetin | 0.9±0.1 | 17.9±0.3 | ND | ND | ND | ND |
| Quercetin hexoside | ND | ND | T | ND | T | T |
| Quercetin pentoside | ND | ND | 3.4±0.1 | ND | ND | ND |
| Rutin | 2.1±0.2 | T | ND | ND | T | ND |
| Rutin hexoside | ND | ND | ND | ND | ND | T |
| Kaempferol/luteolin hexoside | T | ND | ND | ND | T | T |
| Myricetin | ND | ND | 4.1±0.1 | 3.6±0.1 | ND | ND |
| Hesperetin rhamnoside | ND | ND | ND | 3.8±0.1 | ND | ND |
| Hesperetin pentoside | ND | ND | ND | T | ND | ND |
| Hesperetin hexoside | ND | ND | ND | 4.2±0.1 | ND | ND |
| Cyanidin 3-glucoside | 23.9±1.4 | 1.3±0.1 | ND | ND | ND | ND |
| Cyanidin 3-rutinoside | 55.3±2.7 | ND | ND | ND | ND | ND |

T = trace, ND = not detected

**Table 5. Vitamin E, lutein and folates in the edible portion of Australian fruits.**

| Fruit | Lutein (mg/100g FW) | Vitamin E components (mg/100g FW) | | | Vitamin E (mg/100g FW) | Folates (µg/100g FW) |
|---|---|---|---|---|---|---|
| | | α-tocopherol | β-tocopherol | γ-tocopherol | | |
| Desert lime | 0.295±0.013 | **0.701 ± 0.177** | **0.081 ± 0.017** | ND | 0.783 | 82.22±8.2 |
| Kakadu plum | 0.185±0.010 | 0.727 ± 0.076 | 0.013± 0.008 | ND | 0.741 | 13.41±1.3 |
| Lemon aspen | ND | 0.282 ± 0.047 | 0.010± 0.003 | ND | 0.292 | 17.04±1.7 |
| Davidson plum | 0.082±0.008 | 0.037 ± 0.002 | 0.027±0.001 | 0.018 ± 0.001 | 0.083 | 2.85±0.3 |
| Quandong | ND | 1.165 ± 0.078 | 0.086±0.005 | 0.038 ± 0.005 | 1.289 | 28.0±2.8 |
| Riberry | ND | 0.228 ± 0.044 | 0.001 ± 0.0005 | ND | 0.231 | 9.70±0.9 |
| Finger Lime (green) | 0.401±0.027 | 0.517 ± 0.033 | 0.004± 0.0004 | ND | 0.521 | 89.88±8.9 |
| Finger Lime (pink) | 0.140±0.011 | 2.335 ± 0.233 | 0.025± 0.002 | ND | 2.360 | 80.84±8.0 |

**Table 6. Vitamin E, ascorbic acid, lutein and folates in Australian herbs and spices**

| Spice/Herb | Lutein (mg/100g DW) | Vitamin E components (mg/100g DW) | | | Total Toco-pherol (mg/100 g DW) | Ascorbic acid (Vitamin C) (mg/100g DW) | Folates (µg/100g DW) |
|---|---|---|---|---|---|---|---|
| | | α-tocopherol | β-tocopherol | γ-tocopherol | | | |
| Pepperberry | ND | 0.238 ± 0.087 | 0.025 ± 0.003 | 0.935 ± 0.096 | 1.198 | ND | 87 |
| Mountain pepper | 1.564 ± 0.036 | 17.407 ± 1.791 | 0.193 ± 0.059 | 0.235 ± ND | 17.835 | ND | 160 |
| Anise Myrtle | 20.862 ± 1.662 | 49.405 ± 0.875 | 1.629 ± 0.013 | 8.662 ± 0.023 | 59.696 | 66.7 ± 7.5 | 100 |
| Lemon Myrtle | 6.559 ± 0.402 | 20.208 ± 0.330 | 0.365 ± 0.017 | 0.358 ± 0.002 | 21.231 | ND | 71 |
| Bush Tomato | ND | 3.414 ± 0.727 | 0.501 ± 0.031 | 0.658 ± 0.036 | 4.573 | ND | 100 |

Kakadu plum, Davidson plum and Australian desert lime contained lutein (Table 5). The level of lutein in Kakadu plum (0.185mg/100g FW) was similar to that in rhubarb (0.170) and higher than raspberries (0.136) (USDA National Nutrient Database for Standard Reference). Davidson plum contained 0.082mg/100g FW of lutein, which was equal to the lutein level in banana (0.084mg/100gFW) and approximately 2.5-fold of that of apple (0.029mg/100g FW) (USDA National Nutrient Database for Standard Reference). Desert lime and finger limes contained higher levels of lutein than lemon and grapefruit juice (approximately 0.010mg/100g FW) (USDA National Nutrient Database for Standard Reference).

Anise myrtle, lemon myrtle and mountain pepper contained, 20.9, 6.6 and 1.6mg/100g DW) respectively (Table 6). Lutein was absent in bush tomato, wattleseeds and Tasmanian pepperberry.

## Vitamins

### Vitamin C

The Kakadu plum flesh was found to contain vitamin C at an average level of 2.37g/100g of the fresh weight (Table 7) or approximately 15 per cent of dry weight. However, as mentioned elsewhere in the book, a high variability exists among plum samples collected across the country with the levels of vitamin C varying from 0.5 per cent dry weight to 32 per cent dry weight (respectively, 0.1 and 53.0mg/g FW) (Konczak *et al.*, 2014).

Acerola (*Malpighia emarginata* DC) fruit contains around 1g/100g FW of vitamin C (Mezadri *et al.*, 2008).

**Table 7. Vitamin C in selected Australian fruits**

| Fruit (edible portion) | Vitamin C (mg/100 g FW) |
|---|---|
| Riberry | 290±31 |
| Brush cherry | 140 ± 13 |
| Kakadu plum | 2368.22 ± 838 |
| Davidson plum | ND |
| Quandong | ND |
| Australian desert lime | 188 ± 5.0 |
| Finger lime (green) | 26.0 ± 1.0 |
| Finger lime (pink) | 91.0 ± 2.0 |
| Finger lime (red) | 153 ± 41 |
| Finger lime (yellow) | 182 ±60 |
| Munthari | 59±16 |
| Burdekin plum | 54±23 |

Desert lime and yellow finger lime contained over 180mg/100g FW vitamin C, which is approximately twice the level in Californian orange (0.83mg/g FW; Vanderslice *et al.*, 1990) and 5-fold the level of vitamin C in fresh mandarins (0.38mg/g FW; Mitchell *et al.*, 1992). Among the finger limes, the yellow and red varieties contained more vitamin C than the pink and green varieties. Riberry collected in a Sydney park and brush cherry contained similar levels of vitamin C as the wild limes (Table 7).

*Vic Cherikoff comments: It should be noted that the maturity, length and condition of storage and handling of any fruits will influence the level of ascorbic acid measured by the assay used. It was also not reported in dehydroascorbic was measured to obtain total ascorbate levels. Additionally, as described in the main text of the book, vitamin C activity is a net result of a host of compounds working together with ascorbic acid and so these results are presented as a snapshot of potential values of the nutrients assessed.*

Vitamin C was detected in anise myrtle at the level of 66.7mg/100 g DW (Table 6), which was around 0.1 per cent of the dry weight of leaf.

### Vitamin E

Vitamin E is the term for a group of tocopherols and tocotrienols, of which α-tocopherol has been most researched as to vitamin E activity. The most common components of vitamin E are: α-tocopherol, β-tocopherol and γ-tocopherol.

The content of α-tocopherol, β-tocopherol and γ-tocopherol in Australian fruits is presented in Table 5.

Pink finger lime contained the highest level of tocopherols (2.36mg/100g FW), followed by quandong (1.29mg/100g FW), desert lime (0.78mg/100g FW) and Kakadu plum (0.74mg/100g FW). In the case of the Kakadu plum, α-tocopherol represented 98.1 per cent; and quandong, 90.4 per cent of vitamin E components. Similarly, in riberry it made up 98.7 per cent of the vitamin E components and in lemon aspen, 96.6 per cent.

These results were in agreement with an earlier study of Brand-Miller and coworkers, who detected relatively high levels of total fat in quandong and Kakadu plum (0.2 and 0.5mg/100g FW, respectively), although there can be a high variability among samples collected from different sites (Brand-Miller, James and Maggiore, 1993).

The composition of vitamin E components in Davidson plum was different with α-tocopherol contributing only 44.6 per cent, followed by γ-tocopherol (32.5 per cent) and β-tocopherol (21.7 per cent). Additionally, γ-tocopherol, which plays an important role in neutralisation of mutagens (Zingg and Azzi, 2004), was also found in quandong.

The levels of vitamin E in desert lime was higher than those reported for lemon and lime: 0.15mg/100g FW of edible portion, 0.25mg/100g FW of peels in lemon and 0.22mg/100g FW of edible portion of lime (USDA National Nutrient Database for Standard Reference).

Avocado is known as one of the richest sources of Vitamin E with α-tocopherol being the main component. Australian grown, Hass avocado contains from 1.40 to 2.65mg/100g FW vitamin E and α-tocopherol varies from 1.2 to 2.15mg/100g FW (Zabaras and Konczak I. 2010). Californian grown Hass avocado has similar levels of α-tocopherol: 1.63 to 2.76mg/100g FW with higher levels measured in fruit harvested later in the season (Lu *et al.*, 2009).

The level of vitamin E in Kakadu plum was approximately 25-50 per cent that of avocado adding to the total ORAC of this unique and nutritious fruit.

The leaves of anise myrtle, lemon myrtle and mountain pepper also contained high levels of vitamin E, being 59.7mg/100gDW, 21.2mg/100gDW and 17.6mg/100gDW, respectively (Table 6). α-Tocopherol was the main component of the tocopherol mixtures in these three sources, being 82.8 per cent, 95.2 per cent and 98.9 per cent respectively. Anise myrtle contained γ-tocopherol (14.5 per cent) and δ-tocopherol (2.7 per cent).

Wattleseed, bush tomato and pepperberry contain negligible amounts of vitamin E, being 5.3, 4.57 and 1.2mg/100gDW, respectively. α-Tocopherol was the main component of bush tomato and wattleseed tocopherol mixtures with 74.6 per cent and 87.9 per cent, respectively.

Interestingly, the main component of pepperberry vitamin E is δ-tocopherol, which contributed 78.0 per cent of the tocopherol mixture.

### Folate

Folate or folic acid are water-soluble vitamins collectively known as vitamin B9. It is another vitamin class that needs an entourage of other components to make it work and these include enzymes, the amino acids, serine or glycine and vitamin B3 or NADPH. Folate is essential in the synthesis, methylation and repair of DNA and for chromosome segregation (Duthie *et al.*, 2002). Adequate levels of folate, combined with the presence of Zn, Mg, Ca and vitamin B12 in the diet, can prevent genome damage that occurs due to oxidative stress, nutrient deficiency or calorie excess (Fenech and Ferguson, 2001; Fenech, 2001). Folate deficiency results in an increased risk of cardiovascular disease and dementia (Quinlivan *et al.*, 2002; Seshadri *et al.*, 2002).

The levels of folate in Australian fruits, herbs and spices corresponded with the levels of folate in common fruits.

Among the fruits presented in this chapter the wild limes contained the highest levels of folate (80.8 – 89.9µg/100g FW; Table 5), twice that in mango and eight times that in conventional lime juice (43µg/100g FW and 10µg/100g FW, respectively). They were equal to that in avocado (81µg/100g FW), (USDA National Nutrient Database for Standard Reference).

The level of folate in quandong is slightly higher than that in banana (20µg/100g FW); and that of riberry is similar to the folate level in blueberry (8µg/100g FW) (USDA National Nutrient Database for Standard Reference).

Mountain pepper had a higher level of folate (160µg/100g DW; Table 6) than anise myrtle, bush tomato and wattleseed (100µg/100g DW each), which was more that the level of folate in pepperberry (87µg/100g DW) and lemon myrtle (71µg/100g DW).

## Minerals

Minerals are essential regulators of physiological processes their deficiency negatively impacts human health (Bertini *et al.*, 2001). Individual food sources can have very different mineral contents depending on the plant source, its maturity, soil conditions, weather and agricultural practises (Mirdehghan and Rahemi, 2007). Knowledge on mineral composition of foods is necessary in the development of a balanced diet. This is especially important with regards of the redox-active elements (iron, copper, manganese) which, when present at higher levels than required exert toxic effects through the generation of free radicals and potentially damaging organic molecules including proteins, lipids or DNA (Kozlowski *et al.*, 2009).

Nutritionally, we can consider the following three groups of minerals:

1. biologically essential minerals required in amounts greater than 100mg/day – potassium (K), phosphorus (P), sulphur (S), calcium (Ca), magnesium (Mg), sodium (Na)
2. essential trace elements required in amounts lower than 100mg/day – iron (Fe), zinc (Zn), manganese (Mn), cobalt (Co), copper (Cu), nickel (Ni), molybdenum (Mo) and selenium (Se)
3. elements perceived as toxic at high levels (and whose physiological function has not been reported) – aluminum (Al), cadmium (Cd) and lead (Pb)

### Group 1

Quandong contained more potassium (K) per 100g dry weight than any other plant source evaluated in this study. This level is comparable to K levels in turnip, artichoke and carrot consumed in Finland but higher than K levels in any Finnish fruit (Ekholm *et al.*, 2007) as well as UK, German and Mexican fruits (apple, avocado, lime, mango, orange, papaya and pineapple) (Sanchez-Castillo *et al.*, 1998). Quandong also contained the highest level of sodium (Na) and as a dryland species and one tolerant of saline soils the high content of potassium and sodium in the fruit may not be unexpected.

The levels of K in other Australian fruits evaluated in this study were comparable to these in European fruits and vegetables (Ekholm *et al.*, 2007).

With regards to phosphorus (P), the majority of Australian fruits contained from 52.5 to 167mg/100g DW and in this respect were comparable to the fruits from UK and Mexico. The content of P in fruits consumed in Finland was from 30 to 360mg/100gDW (Ekholm *et al.*, 2007). The fruits consumed in UK and Mexico contained from 40 to 190mg/100g DW. These results indicate that the levels of P in Australian fruits are comparable with those in plant sources consumed in Europe and Mexico.

Sulphur is the sixth most abundant mineral in breast milk and the third most abundant mineral based on percentage of total body weight, representing about 0.25 per cent of the total body weight. However, its physiological function is not well studied. It is a component of six amino-acids (methionine, cysteine, cystine, homocysteine, homocystine and taurine).

Sulphur-containing compounds are thought to have clinical applications in the treatment of a number of conditions such as depression, fibromyalgia,

**Table 8. Mineral elements content (mg/100g DW) of Australian fruits, herbs and spices**

| Fruit | Fe | Cu | Mn | Zn | Ca | Mg | K | P | Se | Mo | Ni | Co | Na | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pepperberry | 5.2 | 0.846 | 33.8 | 3.5 | 147.8 | 142.2 | 1106.7 | 126 | <0.001 | 0.0023 | 0.387 | 0.004 | 27 | 130 |
| Mountain pepper | 11.4 | 0.619 | <0.001 | 6.565 | 495.1 | 212.1 | 837.9 | 106 | <0.001 | 0.0033 | 0.181 | 0.007 | 47 | 217 |
| Anise myrtle | 5.9 | 0.367 | 9.595 | 1.44 | 261.45 | 247.4 | 773.3 | 101 | <0.001 | 0.0026 | 0.117 | 0.006 | 52 | 186 |
| Lemon myrtle | 5.8 | 0.474 | 1.28 | 1.055 | 1583.2 | 188.3 | 1258.7 | 114 | <0.001 | 0.0055 | 0.147 | 0.009 | 19 | 145 |
| Bush tomato | 26.5 | 0.732 | 1.315 | 1.85 | 117.05 | 160.3 | 2251.0 | 257 | 0.007 | 0.0184 | 0.019 | 0.005 | 5 | 197 |
| Wattle seed | 10.9 | 0.835 | 2.955 | 3.105 | 434.4 | 255.1 | 1147.6 | 228 | 0.032 | 0.0251 | 0.062 | 0.015 | 44 | 240 |
| Desert lime | 4.7 | 0.641 | 0.877 | 1.060 | 384.2 | 94.5 | 1287.8 | 128 | <0.001 | 0.0077 | 0.048 | 0.004 | 2 | 119 |
| Kakadu plum | 4.0 | 0.303 | 3.500 | 0.574 | 282.4 | 203.8 | 1905.5 | 53 | <0.001 | 0.0185 | 0.036 | 0.005 | 10 | 63 |
| Lemon aspen | 13.3 | 0.834 | 10.02 | 3.925 | 133.3 | 147.6 | 1512.9 | 129 | <0.001 | 0.0128 | 0.443 | 0.008 | 45 | 145 |
| Davidson plum: *Davidsonia pruriens* | 1.2 | 0.638 | 19.55 | 0.426 | 217.3 | 138.1 | 1465.5 | 95 | <0.001 | 0.0109 | 0.016 | 0.003 | 2 | 68 |
| *Davidsonia jerseyana* | 2.4 | 0.919 | 30.15 | 0.965 | 193.6 | 208.7 | 1857.4 | 106 | <0.001 | 0.0136 | 0.031 | 0.06 | 10 | 86 |
| Quandong | 16.6 | 0.100 | 0.288 | 4.240 | 133.3 | 217.9 | 3456.2 | 97 | <0.001 | 0.0556 | 0.015 | 0.002 | 306 | 125 |
| Riberry | 4.3 | 1.135 | 22.75 | 1.315 | 307.7 | 189.0 | 1715.7 | 119 | <0.001 | 0.0107 | 0.128 | 0.008 | 47 | 137 |
| Finger Lime (green) | 7.3 | 0.715 | 0.450 | 0.848 | 352.7 | 139.5 | 1459.6 | 167 | <0.001 | 0.0104 | 0.035 | 0.002 | 11 | 112 |
| Finger Lime (pink) | 3.7 | 1.310 | 0.400 | 0.780 | 334.1 | 111.1 | 1242.6 | 142 | <0.001 | 0.0083 | 0.056 | 0.003 | 9 | 75 |
| Illawarra plum | 1.4 | 0.138 | 1.525 | 0.987 | 156.6 | 161.1 | 2730.1 | 79 | <0.001 | 0.0359 | 0.021 | 0.003 | 179 | 102 |
| UK fruits* | 0.4–4.4 | | | | 2-240 | 20-120 | ** | 40-150 | | | | | 10-40 | |
| German fruits* | | | | | 30-290 | 10-330 | *** | | | | | | 10-30 | |
| Mexican fruits* | 1.1-4.1 | | | | 20-390 | 30-170 | **** | 60-190 | | | | | 20-50 | |

* Fruits: apple, avocado, lime, mango, orange, papaya and pineapple.

** K level in UK fruits: 510-2740mg/100gDW.

*** K level in German fruits: 910-1740mg/100gDW.

**** K level in Mexican fruits: 710-2310mg/100gDW.

arthritis, interstitial cystitis, athletic injuries, congestive heart failure, diabetes, cancer and AIDS (Parcell, 2002).

Wattleseed and mountain pepper both contained above 200mg S per gram, dry weight, followed by bush tomato and anise myrtle, containing from 180 to 200mg/g DW.

Australian citrus were rich sources of Ca (above 330mg/100g DW) and were closely followed by riberry and Kakadu plum (308 and 282mg/100g DW, respectively). With regards to Ca level these fruits are comparable to the European redcurrant (Ekholm *et al.*, 2007). The Ca content in the remaining Australian fruits was above 150mg/g DW and was comparable to that in European berries and vegetables such as cauliflower, broccoli and onion (Ekholm *et al.*, 2007).

Zinc was present in quandong and lemon aspen at approximately twice the level of Zn in European raspberry (2.0mg/100g DW) and which was identified as the richest source of Zn among berries grown in Finland (Ekholm *et al.*, 2007). All other fruits contain similar levels of Zn to that in European fruits (Ekholm *et al.*, 2007).

Magnesium (Mg) was present in Australian fruits within the range of 94.5 to 218mg/100g DW (Table 8). These levels are simillar to or slightly higher than those in berries consumed in Finland (strawberry, blackcurrant, redcurrant and raspberry, 100–160 mg/100g DW) and within the same range as Finnish vegetables (80 to 265mg/100g DW) (Ekholm *et al.*, 2007). Selected fruits evaluated in Germany contained from 10 to 330mg/100g DW of Mg (Table 1). Lower levels of Mg were reported for fruits consumed in the UK (20–120mg/100g DW) and Mexico (30–170mg/100g DW) (Table 8).

## Group 2

Iron (Fe), an essential trace element functions in the haemoglobin of red blood cells, which transports oxygen from the lungs to the body's tissues, including the muscles and the brain. The highest levels of Fe (above 10mg/100g DW) were present in lemon aspen and quandong (Table 8). All other fruits contained from 1.24 to 7.29mg/100g DW and in this respect are comparable to fruits and vegetables consumed in Finland (Ekholm *et al.*, 2007) and richer in Fe than fruits consumed in the UK and Mexico (Table 8).

Selenium (Se) forms the active centre (coenzyme) of antioxidant enzymes, such as the glutathione peroxidise enzyme family, whose role is to protect the organism from oxidative damage. Subsequently, it provides antioxidant benefits and participates in the body's natural defences. Bush tomato and wattleseed were the only two sources that contained selenium at very low levels of 0.0067 and 0.0317mg/100gDW, respectively (Table 8).

Copper (Cu) is an essential trace element for humans. It possesses the ability to easily accept and donate free electrons and therefore plays an important role in scavenging free radicals and reducing the oxidative status (Linder *et al.*, 1996). Some studies suggest that Cu deficiency increases the risk of cardiovascular diseases (Jones *et al.*, 1997) while high levels of Cu might be a risk factor for Alzheimer's disease (Morris *et al.*, 2006; Kitazawa *et al.*, 2009).

Riberry, finger limes and lemon aspen contained the highest levels of copper (Cu) which were approximately twice the level of Cu in European fruits and vegetables with the exception of European squash (0.9mg/100g DW), celery root (1.2mg/100g DW) and artichoke (1.0mg/100g DW) (Ekholm *et al.*, 2007).

Relatively high levels of Mn (10.0 to 22.75mg/100g DW) were found in the fruits of Davidson plums, riberry and lemon aspen (Table 3). Similar Mn levels were reported for bilberry, lingonberry and cranberry consumed in Finland (Ekholm *et al.*, 2007). Other Australian fruits contained similar levels of Mn to those in other fruits consumed in Finland (Ekholm *et al.*, 2007).

Co and Ni are required by humans in minute amounts and are toxic at high levels. Australian fruits contained from 0.0016 (green finger lime) to 0.0084mg/100g DW (riberry, Table 3) of Co. These levels were comparable to the Co levels in fruits consumed in Finland (0.002 to 0.011mg/100g DW) (Ekholm *et al.*, 2007). The levels of Ni in Australian fruits varied from 0.0153mg/100g DW (quandong) to 0.0563mg/100g DW (pink finger lime) with the exception of lemon aspen that contained a higher level of 0.443mg/100g DW. The higher level of Ni in lemon aspen might be associated with the laterite deposits of Ni existing in areas of Queensland and New South Wales (Australian minerals, 2010). In fruits consumed in Finland the level of Ni varied from 0.007mg/100g DW (apple) to 0.088mg/100g DW (raspberry) (Ekholm *et al.*, 2007) which indicates that, with the exception of lemon aspen, the levels of Ni in Australian fruits were within the same range as the levels of Ni in fruits consumed in Finland.

Lead (Pb) is best known for its toxic properties and low levels are desirable. Australian fruits contained from 0.004mg/100g DW (green finger lime) to 0.208mg/100g DW (riberry). The level of Pb in vegetables consumed in Finland ranged from 0.002 (tomato) to 0.036mg/100g DW (radish) and in fruits from 0.005mg/100g DW (strawberry) to 0.016mg/100g DW (cranberry) (Ekholm *et al.*, 2007). In order to compare our results with these for Pb levels in Mexican fruits, the levels of Pb in Australian fruits were recalculated toμg/100g FW obtaining the following values: Australian desert lime: 0.91; Kakadu plum: 0.92, lemon aspen: 1.25; Davidson plum: 0.30, quandong: 5.41; green finger lime: 0.85; pink finger lime: 0.83 and riberry: 18.3μg/100g FW. According to Sanchez-Castillo and co-workers (Sanchez-Castillo *et al.*, 1998) the levels of Pb in Mexican fruits varied from 0 to 243μg/100g FW, with majority of fruits containing from 20 to 50μg/100g FW, which indicates that the levels of Pb in Australian fruits were many times lower than those in Mexican fruits.

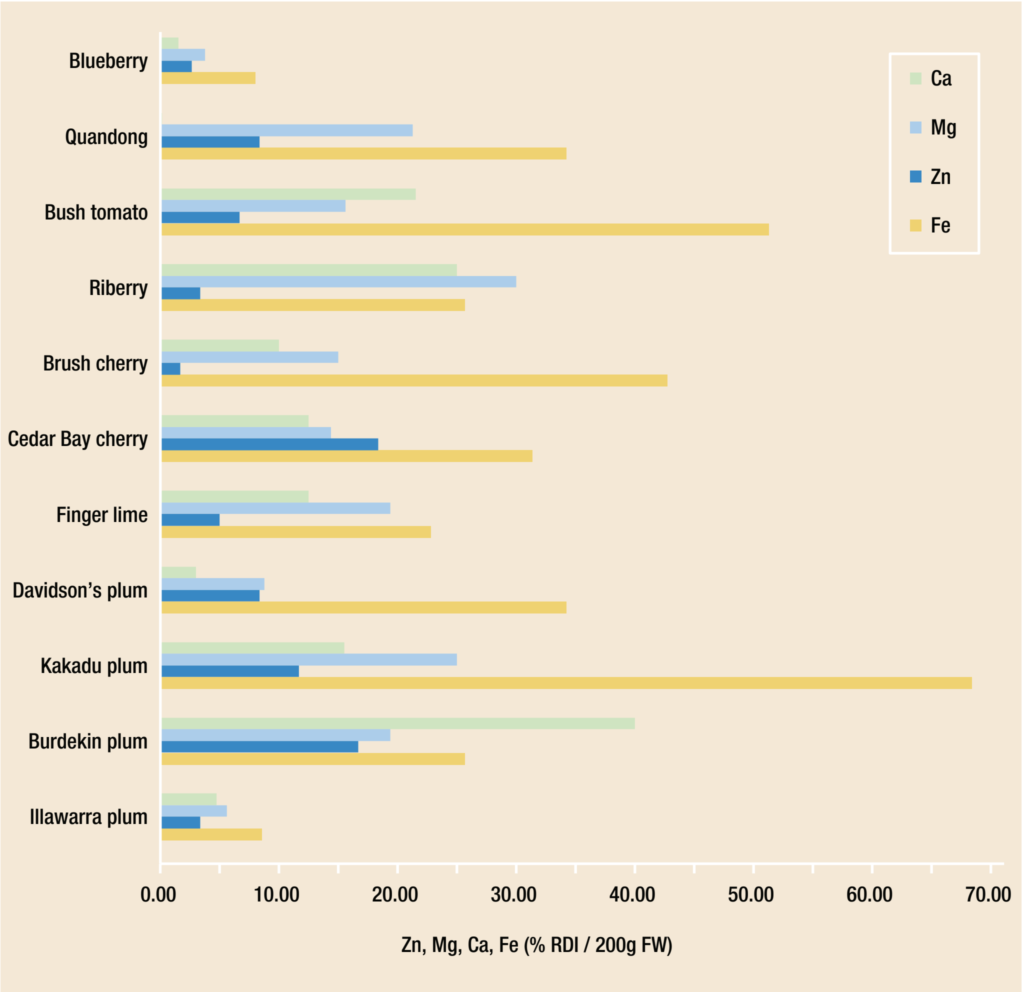
**Table 9. The content of mineral elements precived as toxic at higher levels: cadmium (Cd), lead (Pb) and aluminum (Al), which are precived as toxic at higher levels (mg/100g DW)**

| Fruit | Cd | Pb | Al |
|---|---|---|---|
| Pepperberry | 0.0071 | 0.007 | 7.86 |
| Mountain pepper | 0.0132 | 0.02 | 70.85 |
| Anise myrtle | 0.0007 | 0.004 | 9.51 |
| Lemon myrtle | 0.0007 | 0.004 | 4.11 |
| Bush tomato | 0.0032 | 0.013 | 32.41 |
| Wattleseed | 0.0022 | 0.028 | 0.34 |
| Desert lime | 0.0005 | 0.004 | 3.87 |
| Kakadu plum | 0.0011 | 0.007 | 0.52 |
| Lemon aspen | 0.0043 | 0.008 | 2.67 |
| Davidson plum *(D. pruriens)* | 0.0008 | 0.004 | 22.8 |
| Davidson plum *(D. jerseyana)* | 0.006 | 0.011 | 20.95 |
| Quandong | 0.0031 | 0.023 | 4.93 |
| Riberry | 0.0024 | 0.208 | 1.66 |
| Finger lime (green) | 0.0005 | 0.004 | 0.4 |
| Finger lime (pink) | 0.0004 | 0.004 | 0.64 |
| Illawarra plum | 0.0033 | 0.002 | 0.46 |

With the exception of Davidson plum and quandong, the levels of Al in Australian fruits were comparable to and slightly higher than these in Finnish fruits. Davidson plum had the highest level of Al (22.8mg/100g DW). This level was approximately 50 per cent lower than that in capsicum, paprica, anise, basil and rosemary grown in Turkey (Ozcan, 2004).

The Recommended daily intake (RDI) of minerals is a figure defined by the National Health and Medical Research Council (NH&MRC) of Australia defined as "the level of intake of essential nutrients considered adequate to meet the needs of practically all healthy people" (www.medicalonline.com.au/medical/nutrition/rdi.htm).

Figure 1 below shows the percentage of RDI of Ca, Mg and Zn for 19–64 year old adults in one fruit serving of 200mg fresh weight.



Burdekin plum and riberry, were good sources of Ca and a serve would provide 40 and 25 per cent of the RDI for Ca, respectively.

One serving of riberry, Kakadu plum and quandong would provide 30, 25 and 21.25 per cent of the RDI for Mg, respectively.

One serving of Cedar Bay cherry, Burdekin plum and Kakadu plum would provide from 11.7 to 18.3 per cent of the RDI for Zn.

Freshly consumed Kakadu plum fruits were a rich source of iron and would provide 68.5 per cent of the RDI for Fe.

In conclusion, the levels of minerals in Australian fruits are similar to those in a range of vegetables and fruits produced and consumed in Europe and Mexico.

## Organic Acids

Organic acids are important contributors to sensory qualities of plant-based foods and are responsible for the slightly acidic, refreshing taste of fruits. They are important as intermediates in metabolic processes and are directly involved in the development, maturation and senescence of fruits. The combinations and levels of organic acids change with fruit growth and maturation.

The major acids in fruits include citric, malic and tartaric acids and other acids in fruits are D-ascorbic, fumaric, oxalic and succinic acids. The presence of organic acids affects the pH of a plant cell and which subsequently may affect the colour. This is especially the case when anthocyanins are present and the colour can vary from bright red at low pH to purple or blue at high pH.

Citric and malic acids are among the more common organic acids present in fruits. Both are present in Australian fruits (Table 10) and ascorbic acid content is discussed above. Citric acid is present in all fruits in the Rutaceae family evaluated in this study in the following order: pink finger lime > green finger lime > lemon aspen > desert lime.

It was highest in finger limes and lemon aspen (with the level ranging from 58.8±1.7 (pink finger lime) to 32.9±1.6mg/g FW (lemon aspen) but not in the Desert lime, which contained predominantly malic acid (25.2±0.5mg/g FW).

Citric acid is commonly present in fruits and it is the main organic acid of kiwi fruit (9.85mg/g FW), banana (3.59mg/g FW) and strawberry (3.12mg/g FW) (Perez *et al.*, 1997).

Similarly to the Desert lime, malic acid was the dominant acid in sweet lime (Clements, 1963). Malic acid has been identified also in Davidson plum, riberry and fresh quandong.

Malic acid is the main organic acid of apple (4.12mg/g FW), it was detected in kiwi fruit (1.9mg/g FW), banana (2.89mg/g FW), peach (2.82mg/g FW) and strawberry (1.11mg/g FW) (Perez *et al.*, 1997).

Oxalic acid was identified in the fruits at negligible levels. In case of citrus fruits, peels could be the main source of this acid (Clements, 1963).

**Table 10. Organic acids (mg/g FW) in Australian fruits**

| Fruit | Citric acid | Malic acid | Oxalic acid | Tartaric acid | Succinic acid |
|---|---|---|---|---|---|
| Desert lime | 4.61 ± 0.19 | 25.24 ± 0.48 | 1.04 ± 0.10 | ND | ND |
| Kakadu plum | ND | ND | 1.03 ± 0.08• | ND | ND |
| Lemon aspen | 32.91 ± 1.60 | 2.33 ± 0.13 | 0.19 ± 0.01 | T | T |
| Davidson plum *(D. pruriens)* | ND | 32.9 ± 2.4• | 0.10 ± 0.01• | T | ND |
| Davidson plum *(D. jerseyana)* | ND | 30.8 ± 1.3• | 0.06 ± 0.02 | T | ND |
| Finger lime (green) | 46.81 ± 0.47 | ND | 0.08 ± 0.02 | T | ND |
| Finger lime (pink) | 58.82 ± 1.70 | ND | 0.20 ± 0.03 | ND | ND |
| Riberry | ND | 17.2 ± 0.34 | 0.23 ± 0.01 | ND | ND |
| Quandong | ND | 19.1 ± 1.33 | 0.40 ± 0.01 | ND | ND |

Data are means ±SE of 3 independent determinations; • ND: not detected; T: trace

In Australian herbs and spices, oxalic acid was present at negligible levels, with the exception of anise myrtle and lemon myrtle as in the table below.

**Table 11. Organic acids (mg/g DW) in Australian herbs and spices**

| Herb/spice | Citric acid | Malic acid | Oxalic acid | Tartaric acid | Succinic acid |
|---|---|---|---|---|---|
| Pepperberry | ND | ND | ND | ND | ND |
| Mountain pepper | ND | ND | ND | T | ND |
| Anise myrtle | 81.13 ± 2.61 | ND | 6.48 ± 0.94 | ND | ND |
| Lemon myrtle | ND | ND | 23.32 ± 1.39 | ND | ND |
| Bush tomato | ND | ND | 0.73 ± 0.01 | ND | ND |
| Wattleseed | ND | ND | 0.13 ± 0.01 | ND | ND |

ND: not detected; **T: traces

## Conclusion

The extracts of Australian wild fruits, herbs and spices emerged as good sources of micronutrients, including vitamins, minerals and phytochemicals, with numerous exhibiting potent antioxidant properties.

Lemon myrtle plantation.

While most of agricultured fruits predominantly contain hydrophilic (water soluble) antioxidants, Australian foods also contain a significant proportion of lipophilic antioxidants. Among these sources are Kakadu plum, lemon aspen, riberry, Davidson plum, desert lime, mountain pepper, pepperberry and lemon myrtle. This suggests greater protection from oxidative stress and possibly more pronounced health benefits.

Numerous sources, such as Kakadu plum, quandong, Davidson plum, lemon aspen and lemon myrtle provided the valuable minerals zinc, magnesium and calcium while bush tomato and wattleseeds are sources of selenium. Davidson plum was also a good source of anthocyanins.

Among the Australian wild fruits evaluated to date, Kakadu plum emerges as an exceptionally rich source of micronutrients with superior levels of vitamin C; phenolic compounds, especially hydrolysable ellagitannins; vitamin E; and essential minerals. This indicates potent physiological activities and pronounced health-enhancing properties which should be explored further.

This research suggests that adding Australian wild foods to our daily diet will enrich it with a variety of micronutrients potentially contributing to the prevention of diseases and the support of optimal metabolic processes.

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