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**ORIGINAL RESEARCH**

# *Buchanania obovata*: An Australian indigenous food for diet diversification

Selina A. FYFE,[1] Michael NETZEL,[2] Ujang TINGGI,[3] Eva M. BIEHL[4] and Yasmina SULTANBAWA[2]

*[1]School of Agriculture and Food Sciences, The University of Queensland, [2]Queensland Alliance for Agriculture and Food Innovation (QAAFI), Health and Food Sciences Precinct, The University of Queensland and [3]Queensland Health Forensic and Scientific Services, Brisbane, Australia; and [4]Technische Universität München, Freising, Germany*

**Abstract**

**Aim:** *Buchanania obovata* Engl., the Green Plum, is a small green fruit eaten by Australian Indigenous peoples of the Northern Territory and Western Australia that has had limited study and has potential as a source of food for diet diversification. Flesh and seed of the fruit are eaten and the plant is used as bush medicine.

**Methods:** Physical characteristics of the fruit were measured. The flesh and seed freeze dried powders were measured separately for proximates, mineral/trace element and heavy metals and folate analysis. Vitamin C was analysed in the flesh.

**Results:** The flesh is high in protein (12.8 g/100 g dry weight (DW)) and both flesh and seed are high in dietary fibre (55.1 and 87.7 g/100 g DW, respectively). The flesh is high in potassium (2274.7 mg/100 g DW), and is a good source of magnesium (570.5 mg/100 g DW), calcium (426.0 mg/100 g DW) and phosphorous (216.8 mg/100 g DW), whereas the seed is high in iron (8.15 mg/100 g DW). The flesh contains folate at 752.4 μg/100 g DW and the seed contains 109.5 μg/100 g DW as pteroylmonoglutamic acid equivalents.

**Conclusions:** The flesh and seed have good nutritional properties and the results support the use of the Green Plum for diet diversification and nutrition in Indigenous and non-Indigenous populations in Australia.

**Key words:** *Buchanania obovata*, food, folate, indigenous Australia, nutritional profile.



## Introduction

The Green Plum is the fruit of the tree *Buchanania obovata* Engl. and is a native Australian food eaten by Indigenous Australians. It grows and is wild harvested in the northern parts of Australia, in the Northern Territory and Western Australia,[1] and is also known as the wild plum, bush mango or wild mango. The Green Plum is a small green fruit, shown in Figure 1, the flesh is eaten raw from the tree and the flesh and seed are mashed into a paste and eaten.[2] The tree *B. obovata* grows to about 15 m high and has rough brown bark and branchlets. The leaves are alternate and their shape is obovate to oblong-obovate growing to 5–25 x 1.5–10 cm in size. The flowers are bisexual and are creamy white in colour.[3]

*Buchanania obovata* is in the family Anacardiaceae which contains well-known commercialised fruit including mango (*Mangifera indica*), cashew apple (*Anacardium occidentale*) and pistachio nuts (*Pistacia vera*).[4]

Studies of Australian native foods show they can have very good nutritional and functional properties. Indigenous foods of Australia have previously been underutilised but now have potential for wider availability and commercialisation. The Kakadu Plum (*Terminalia ferdinandiana*) has such high levels of ascorbic acid (vitamin C) and high-antioxidant capacity[5,6] that it is used in the dietary supplement industry[6] and a natural preservative is made from it for commercial dipping of prawns in Queensland, Australia, giving an extended shelf life.[7] Other Australian native foods have been shown to have high-antioxidant compounds, minerals and vitamins[8] indicating that further study of Australian native foods is warranted.

The Green Plum was selected for this study as it is used by Australian Aboriginal people as a food and the plant as bush medicine. The Green Plum is commonly eaten by many Aboriginal communities and is a favourite with children.[2,9] Aboriginal communities have names for it in their own languages, in Kija it is taluuny,[10] in Murinpatha it is kilen, in Jandjung it is djamuru,[2] in Rirratjunu it is

S. A. Fyfe, MFoodSciTech, Student
M. Netzel, PhD, Senior Research Fellow
U. Tinggi, PhD, Advanced Chemist
E. M. Biehl, BSc, Student
Y. Sultanbawa, PhD, Associate Professor
**Correspondence:** Y. Sultanbawa, Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Health and Food Sciences Precinct, 39 Kessels Rd, Coopers Plains, PO Box 156, Archerfield BC, Brisbane, QLD 4108, Australia.
Tel: 07 3443 2471.
Email: y.sultanbawa@uq.edu.au
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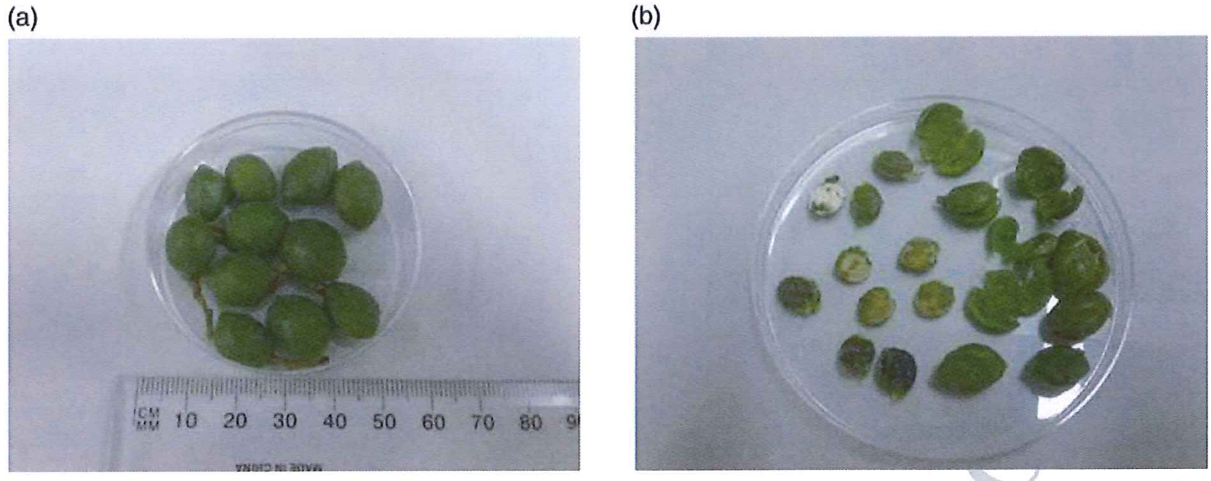



**Figure 1** Green Plums (a) whole and (b) flesh and seed separated.

dhurrpinda,[11] in Djambarrpuyngu it is munydjutj, in Burarra it is mulaagi, in Yanyuwa it is bigigee, in Garawa it is bikabaji, in Anindilyakwa it is mangkarrba, in Djinang it is yulwandi, in Alawa it is yulmuru, in Rirratjunu it is dhurrpinda[3] and the people of Groote Eylandt call it mangkarrkba.[12] Young stems, leaf ribs, inner bark from young branches and older stems have been used as bush medicine for their antiseptic and analgesic qualities to treat toothache, skin infections and conditions and as an eye lotion.[3,12]

Indigenous communities in Australia have had very poor quality diets for at least three decades.[13] Australian Aboriginals are at increased risk of malnutrition and chronic disease causing poorer levels of health than non-Indigenous Australians.[14] Diabetes, cardiovascular disease and tobacco-related illnesses account for half of the health gap in the Australian Indigenous population.[15] Diversity in national food system has been shown to increase human health and nutrition.[16] Indigenous traditional foods could add diversity in nutrition to the Australian food system and be a good source of nutrients and micronutrients. Wider availability and a better understanding of native Australian foods could lead to a higher intake by Australian Indigenous peoples providing better nutrition and health outcomes.

This is the first study of this kind on the Green Plum investigating so much of its nutritional properties for dietary purposes. The data presented in this study are novel except for a small number of proximate and inorganic constituents and vitamin C of the flesh which were published in 1993,[17] and mineral analysis which were done by Medley and Bollhöfer and provided as supplementary material in their study on the radium uptake in the tree.[9] Including the mineral analysis data in this study is important as their study focused on the tree whereas this study is investigating the flesh and seed of the fruit for dietary purposes and also analysed the proximates, vitamin C and folate, making the nutrition profile available to dietitians, nutritionists and the food industry. Vitamin C and folate were chosen as vitamins for testing in this initial screening of the Green Plum as vitamin C is a key vitamin in fruit, and folate, a critical vitamin, has previously been found in considerable amounts in a number of Australian native bush foods.[8]

## Methods

Chemicals used were from Sigma-Aldrich (St Louis, MO, USA) and Chem-Supply (Gillman, SA, Australia).

Approximately 800 individual *B. obovata* fruit were randomly picked slightly under-ripe from several tree's located near Darwin, Northern Territory, Australia, in 2015, with the assistance of the experienced Thamarrurr Rangers and Chris Brady from the Northern Territory. The fruit were picked under-ripe due to availability and ease of transportation. They were frozen and transported to Brisbane where they remained frozen at −20°C. Samples for physical properties and moisture content were randomly selected and thawed to room temperature before testing. From the sample, 554 g of composite whole fruit with the seed intact (approximately 700 Green Plums) were lyophilised in a Christ Gamma 1–16 LSC Freeze Drying Unit (John Morris Scientific, Osterode, Germany) and the flesh was ground to a powder in a kitchen food processor. The seeds were separated from the flesh powder with a sieve and finely ground in a hammer mill (Lab Mill, Christy and Norris Ltd. Chelmsford, England). The composite flesh powder and seed powder were stored at room temperature in separate air tight plastic containers, protected from light.

*Size of whole fruit*: Ten Green Plums were chosen at random and measured for length, width and depth (height lying on a bench) using 150 mm Digital Calliper (Craftright Engineering Works, Jiangsu, China).

*Weight*: Ten whole fruit were weighed on laboratory scales (Sartorius CP224S, Gottingen, Germany). The fruit were cut down one side with a knife and the flesh peeled off the seed, then weighed separately and the pulp/seed ratio was calculated.



 

*Colour*: Colour was measured with a Konica Minolta CR-400 Chroma Meter and DP-400 Data Processor (Osaka, Japan) on 10 Green Plums chosen for optimal testing. Two measurements were averaged for each result. The colour of the inside flesh of 10 pieces of fruit were measured, with both measurements from the same area of flesh. Lightness (L*), Chroma (C*) and hue angle (h) were recorded.

*Moisture Content*: Moisture content was determined using the AOAC Official Method on Analysis 920.151 (1990) in triplicate on pieces of flesh and seed. Flesh of 10 Green Plums were cut into small pieces and the seeds separated and broken up and approximately 0.5 g samples of flesh and seed were placed in a vacuum drying oven (Series RVT, Heraeus, Berlin, Germany) at pressure 200 Torr and temperature 70 °C, until constant weight.

Proximate analysis was performed on the freeze dried powders of both the flesh and seed of the Green Plum at Symbio Alliance, Eight Mile Plains, Queensland, Australia, a National Association of Testing Authorities (NATA) accredited laboratory that complies with ISO/IEC 17025:2005. The analysis were done according to the NATA approved in house methods or AOAC methods: protein by AOAC method 990.03 (AOAC, 1997); fat by AOAC method 991.36 (AOAC, 1999); saturated, mono-unsaturated, poly-unsaturated and trans fat by in house method CFH068.2; moisture by AOAC 934.01 (AOAC, 1990), ash by AOAC method 923.03 (AOAC, 2000); total sugar by CFH001.1, total dietary fibre by CF057; available carbohydrate by CF029.1; energy by CF030.1; crude fibre by AOAC 962.09 (AOAC, 1990) and dry matter by in house method CF006.1.

The methods used for analysis of minerals and trace elements/metals have previously been described in Carter *et al.*[18] The analysis was carried out in duplicate using a 7700 inductively coupled plasma (ICP)-MS (Agilent Technologies Australia Pty. Ltd., VIC, Australia) and ICP-OES (Agilent Technologies Australia Pty. Ltd., VIC, Australia) after microwave digestion (MarsXpress, CEM Corporation, Matthews, NC, USA).

**Table 1** Proximate results of the freeze dried Green Plum flesh and seed

| Proximate (g/100 g DW) | Flesh | Seed |
|---|---|---|
| Protein | 12.8 | 3.0 |
| Fat | 2.5 | 1.8 |
| Saturated fat | 0.5 | 0.6 |
| Mono-unsaturated fat | 0.7 | 0.3 |
| Poly-unsaturated fat | 1.2 | 0.8 |
| Trans fat | <0.01 | <0.01 |
| Moisture (air) | 2.2 | <0.1 |
| Ash | 6.1 | 0.8 |
| Total sugar | 2.9 | <0.10 |
| Dietary fibre (total) | 55.1 | 87.7 |
| Avail carbohydrate | 21.3 | 6.7 |
| Energy (kJ/100 g DW) | 1112 | 934 |
| Crude fibre | 7.7 | 55.3 |
| Dry matter | 97.8 | 100.0 |

Vitamin C was tested on the freeze dried flesh powder by Symbio Alliance using the AOAC Official Method 967.21 on HPLC.

Folate in the freeze-dried Green Plum flesh and seed powders were analysed in triplicate as outlined by Ringling and Rychlik[19] using a UHPLC-MS/MS (Shimadzu, Rydalmere, NSW, Australia) with a Raptor ARC-18 column (Restek, Bellefonte, PA, USA). The derivatives pteroylmonoglutamic acid (PteGlu), tetrahydrofolate (THF), 5-methyltetrahydrofolate (5mTHF), 5-formyltetrahydrofolate (5fTHF) and 10-formylpteroylglutamic acid (10f PteGlu) were measured by stable isotope dilution assays.

Data analysis and calculations were done using Microsoft Excel software, version 2013 (Microsoft Corporation, Redmond, WA, USA). Arithmetic means ± SDs are shown in text and tables.

## Results

Ten whole Green Plums were measured with the following characteristics: length 15.07 ± 1.14 mm, width 11.54 ± 0.90 mm and depth 9.14 ± 0.96 mm.

Ten whole Green Plums had an average weight of 0.75 ± 0.13 g. When the flesh was removed from the stone it separated easily by hand, with only a few small shards of flesh clinging to the seed. The flesh of each Green Plum averaged 0.39 ± 0.09 g and the seed 0.22 ± 0.04 g, the seed was 29.7% of the whole fruit by weight and the pulp/seed ratio was 1.75.

The outer skin colour was measured as L* 43.99 ± 2.62, C* 29.02 ± 2.41 and h 105.36 ± 2.12 (n = 10). The inner flesh was L* 49.70 ± 2.62, C* 35.83 ± 1.86 and h 105.28 ± 1.67 (n = 10). The Green Plum fruits are a dull colour with a yellow/green hue. The hue of the skin and the inside flesh is very similar, however, the flesh appears to be slightly more vivid then the skin and lighter in brightness.[19] Both the outer skin and inner flesh were fairly uniform in colour across all 10 Green Plums tested.

Moisture content of the Green Plum flesh was around 79% and of the seed around 35%.

The results of the proximate analysis on the lyophilised powders, as measured by Symbio Alliance, are shown in Table 1.

The minerals/trace elements and metal results of the flesh and seed powders are shown in Table 2.

Five different vitamers of folate were measured in the Green Plum flesh and seed powders with results in Table 3. Vitamin C was measured in the Green Plum flesh and the result is in Table 3.

## Discussion

The proximate results indicate that both the flesh and seed can be used as a source of total dietary fibre. The total dietary fibre % daily intake for a 100 g serve DW of an 8700 kJ diet is 184% for the flesh and 292% for the seed (Symbio Alliance nutrition information report received with results). The protein in the flesh is 26% of the daily intake

**Table 2** Minerals/trace elements and metal analysis of the Green Plum flesh and seed freeze dried powders

| Element (mg/100 g DW) | Flesh | Seed |
|---|---|---|
| Macro-minerals | | |
| Sodium | 188.1 | 55.6 |
| Potassium | 2274.7 | 285.1 |
| Calcium | 426.0 | 46.8 |
| Magnesium | 570.5 | 49.5 |
| Phosphorus | 216.8 | 45.5 |
| Trace elements | | |
| Selenium | 0.022 | 0.0044 |
| Zinc | 2.6 | 0.38 |
| Iron | 3.8 | 8.15 |
| Manganese | 1.5 | 0.32 |
| Copper | 0.54 | 0.72 |
| Nickel | 0.082 | 0.050 |
| Cobalt | 0.018 | 0.0030 |
| Chromium | 0.0038 | 0.067 |
| Vanadium | 0.0011 | 0.0031 |
| Boron | 1.4 | 0.23 |
| Molybdenum | 0.013 | 0.0074 |
| Strontium | 2.8 | 0.37 |
| Barium | 1.1 | 0.17 |
| Antimony | <0.001 | <0.001 |
| Silver | <0.001 | <0.001 |
| Aluminium | 0.59 | 0.36 |
| Heavy metals | | |
| Mercury | <0.001 | 0.01209 |
| Lead | 0.014 | 0.0043 |
| Cadmium | <0.001 | <0.001 |
| Arsenic | <0.001 | 0.0090 |

**Table 3** Vitamers in the Green Plum flesh and seed freeze dried powders

| Vitamer | Flesh | Seed |
|---|---|---|
| Folate Type (μg/100 g DW) | | |
| PteGlu | ND | 2.9 ± 0.8 |
| THF | 28.6 ± 0.4 | 12.3 ± 1.2 |
| 5mTHF | 505.8 ± 13.4 | 59.6 ± 1.5 |
| 5fTHF | 211.3 ± 0.5 | 29.6 ± 1.4 |
| 10f PteGlu | 6.7 ± 0.5 | 5.1 ± 0.2 |
| Total Folate | 752.4 ± 12.5 | 109.5 ± 0.4 |
| Vitamin C (mg/100 g DW) | 170 | NA |

ND, not detected; NA, not available. Folate derivatives measured: PteGlu, pteroylmonoglutamic acid; THF, tetrahydrofolate; 5mTHF, 5-methyltetrahydrofolate; 5fTHF, 5-formyltetrahydrofolate; 10f PteGlu, 10-formyl-pteroylglutamic acid, all reported as μg $kg^{-1}$ DW PteGlu Equivalents of means ± SD (n = 3).

per 100 g serve DW. Current remote Indigenous diets are low in protein contributing only 12.5–14.2% of energy, lower than the recommended 15–25%.[13] Through diet diversification the Green Plum can contribute to improvement in protein intake but is not a replacement for traditional sources of proteins.

The results in Table 2 show the Green Plum can be used as a dietary source of potassium and other macro-minerals and contains a variety of trace elements essential to the human diet. Compared to recommended daily intakes the Green Plum is a good source of many nutrients, particularly the flesh which is high in calcium, potassium, magnesium, phosphorous, zinc, selenium, copper and manganese.[20] The seed has lower amounts of most nutrients than the flesh but contains higher amounts of iron.

The study by Medley and Bollhöfer[9] on the uptake of radium by the *B. obovata* tree did a metals and trace elements analysis of flesh and seeds from seven different trees in seven different sites. Their results are similar to those in this study, with the potassium in the flesh slightly lower than in this study (average 1660.0 *vs* 2274.7 mg/100 g DW). he group II metals, calcium, barium, strontium and magnesium were all higher in their study in the flesh and seed, except for magnesium which gave similar results to these. Other Australian native foods also have high-mineral content. Of those studied by Konczak and Roulle,[21] the Green Plum flesh has higher levels of calcium, magnesium, phosphorous and selenium, and only the Quandong (3456.2 mg/100 g DW) has higher levels of potassium.

Vitamin C in the Green Plum flesh (170 mg/100 g DW) is similar to that of the mango (220 mg/100 g DW) (reported by the USDA ARS and calculated to DW using moisture content),[22] but is lower than the Kakadu plum which has levels of up to 22 490 ± 5290 mg/100 g DW.[6]

The flesh is much higher in folate then any of the Australian native fruit tested by Konczak *et al.* including the Australian Desert Lime (420 μg/100 g DW) and the seed has similar levels to the Kakadu Plum, Riberry and Lemon Aspen (around 110 μg/100 g DW).[8] The flesh has much higher folate levels than all of the foods measured using the same method by Ringling and Rychlik,[23] and the results are higher than all of those compiled by Saini *et al.* from USDA data.[24] However, some Asian green vegetables such as tatsoi (231 μg/100 g FW), and English spinach (213 μg/100 g FW), have higher levels than the Green Plum flesh (161 μg/100 g FW).[25] The low amounts of PteGlu found compared to the other vitamers is consistent with it not generally occurring naturally in food.[26]

Folate is a B vitamin that is synthesised in plants and is essential for human health due to its role in synthesising, repairing and methylating DNA.[24] Folate deficiency is associated with neural tube defects[24] non-alcoholic fatty liver disease and steatohepatitis,[27] and it is a risk factor for vascular disease.[28] The cells in the human body are unable to synthesise folate so there must be sufficient dietary intake.[24] Folate produced in plants is preferred over synthetic folic acid,[24] which may have negative side effects in humans.[29] The Green Plum is very high in 5mTHF which is the bioactive folate form in the body.[24]

There are challenges for Indigenous communities as the current food supply discourages healthy eating. Indigenous communities are remote and healthy food is relatively expensive compared to unhealthy choices.[30] The price difference of healthy food in remote Northern Territory can be



 

60% higher than in urban Australia.[31] The diets of many remote Aboriginal people are characterised by high fat and high-sugar processed foods that are cheap and have a 'long-life' including bread and tinned meat.[32]

Remote Australian Aboriginal communities have very poor dietary nutrition profiles, and many key nutrients come from poor-quality nutrient-fortified processed foods.[13] Lee *et al.* found that in two remote Aboriginal communities over 26 years there was an increase in the intake of folate from fortified bread, and an increase of niacin and thiamin from fortified breakfast cereals.[30] Brimblecombe *et al.* studied the diets of three remote Northern Territory Aboriginal communities and found that fortified white bread was a major source of fibre, protein, folate, sodium, calcium, potassium and other micronutrients in the diet in all of the communities. The overall diets in all communities were insufficient in fibre, potassium, magnesium and calcium for the weighted estimated average requirement due to the consumption of fortified processed foods and the minimal intake of traditional foods.[13]

The nutrients found in Australian Indigenous fruits could be used as a method of combatting dietary deficiencies and increasing the diversity and nutrition in the diet. Adding or increasing the availability of Green Plum in the food supply chain could increase the natural intake of folate, fibre, potassium and magnesium that are insufficient in the current diet.[13] Traditional foods are culturally important in Indigenous communities and are based on values and tastes.[33] They are seen as a way of achieving a balanced life, and the decreasing use of them is associated with deteriorating health in Indigenous cultures.[34] Australian native traditional foods could be part of the response needed in the preventive and curative efforts required for health gain in the Indigenous population.[15] They provide the 'balance' and 'freshness' that Indigenous Australians associate with 'good food'.[32] Increasing the availability of supply, and educating on the nutrients available in the Green Plum and other Australian native foods could lead to an increase in the nutrition and health in remote Indigenous communities, and possibly a replacement of bio-fortified foods. They can be a source of income for remote communities from the wild harvesting and processing of them in communities,[35] enabling them to be further used, and their health and nutritional properties more widely available for Aboriginal communities and non-Indigenous peoples of Australia. This work will be useful for commercialisation of the Green Plum, for use by dietitians and as a basis for further studies. As the fruit was picked only from one geographical location for this initial study, further studies should be done to assess variation in nutrients based on location and other environmental and genetic factors.

In conclusion, this initial study indicates the Australian native Green Plum has promising nutritional composition in both its flesh and seed. It is high in fibre, folate and potassium and contains essential minerals and trace elements which can contribute to diet diversification and have a beneficial impact on health in Aboriginal communities. However, further testing of the Green Plum is warranted to elucidate the full nutritional profile and dietary value for both the Aboriginal and wider communities.

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## Conflict of interest

The authors declare that they have no conflict of interest.

## Authorship

SAF was responsible for sample preparation, physical and chemical analysis, data interpretation and the writing of the manuscript. MN supplied editorial assistance. UT was responsible for analysis of Minerals/Trace Elements and Metals. EMB was responsible for the Folate analysis. YS was responsible for project concept, design and supervision. All authors are in agreement with the manuscript and declare that the content has not been published elsewhere. A conference abstract has been submitted to Tropical Agriculture 2017.

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