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Preliminary studies on the evaluation of nutritional composition of unripe and ripe 'Kundang' fruits (*Bouea macrophylla* Griffith)

Nithiya Shanmuga Rajan, *Rajeev Bhat and Karim, A. A.

Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang 11800, Malaysia

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Abstract

Unripe and ripe kundang fruits (*Bouea macrophylla* Griffith) is either consumed fresh or is cooked in Malaysia. In this study composition of unripe and ripe fruits (proximate, amino acids profile, minerals and heavy metal contents) were evaluated. Results obtained showed unripe kundang fruit to possess higher moisture, ash, crude lipid, crude fiber and crude protein contents than the ripe fruits. With regard to amino acid contents, unripe fruits had higher content of essential amino acids. The unripe and ripe fruits were found to be rich in essential minerals with potassium (K) to be in abundance. Heavy metals such as cadmium, nickel, mercury, lead and arsenic, were detected in trace amounts (< 5.0 mg/kg) in both unripe and ripe fruits. Through this investigation, it is concluded that both unripe and ripe fruits to posses' adequate amount of nutritionally important compounds beneficial to human health and can be explored for commercial purposes.

Introduction

Malaysia has a wide diversity of underutilized fruits that possess rich nutraceutical value. Most of the fruits (e.g. durian, rambutan, longan, mangosteen, etc) are preferred locally for their acceptable organoleptic properties and health promoting potentiality (Ikram *et al.*, 2009; Alothman *et al.*, 2009). Of course, today, it is a well-accepted fact that consumption of fresh fruits play an key role towards lowering the risk associated with chronic diseases such as cancer and cardio-vascular diseases, including that of aging (Joshipura *et al.*, 2001; Bhat *et al.*, 2012). Hence, providing in-depth details on these components are essential elements not only from the nutritional point of view, but also from economical aspects.

Bouea macrophylla Griffith or commonly known as kundang fruit (or Setar) in Malaysia (in English as Gandaria or Plum mango) belongs to the family Anacardiaceae. It is a tropical fruit tree native to Southeast Asia and commercially grown in the ASEAN regions (Malaysia, Thailand and Indonesia). Kundang tree produces fruits, which look alike, a small mango. The fruits are green in color when young and yellow when matured and encompass brightly colored purple seeds. The endosperm of the seed is bitter and is edible. Ripe fruits are consumed fresh or cooked into syrup or made into very delicious compote (dessert). On the other hand, young unripe fruits are consumed by traditional Malay population as an ingredient of 'sambal' (a chilli-based condiment), as 'asinan' (pickles) or as 'rojak' (traditional fruit and vegetable salad dish) (Rifai, 1992; Gajaseni and Gajaseni, 1999; Lim, 2012).

Based on this background, the present work was undertaken mainly to provide basic information on the proximate composition, amino acid profiles, minerals and heavy metal contents of the unripe and ripe kundang fruits. The results obtained are expected to provide useful data for future commercial exploitation as there are no detailed scientific reports available on the nutritional attributes of this fruit.

Materials and Methods

Sample collection

Kundang unripe and ripe fruits were collected from a local farm in Perak region of Malaysia. Fruits without any physical or insect damage were selected and all were of equal maturity. Fresh fruits were cleaned by washing with water to remove dust or soil particles followed by wiping and drying using a clean sterile cloth. Pulp and peel portions, devoid of seeds were cut into small pieces of equal sizes, followed by freeze-drying (temperature -46^{o}C and vacuum pressure 0.030 mBar; Model 7754511, Labconco Corporation, Kansas City, USA). Generally, fruits which go through freeze drying process cause no loss to nutrients and tend to retain the original flavor and sensory attributes of the fruits (Soceanu, 2010; Zhang *et al.*, 2014). Further, freeze dried samples were powdered using a kitchen mixer and sieved

*Corresponding author.
Email: *rajeevbhat1304@gmail.com / rajeevbhat@usm.my*
Tel: +60 4653 5212; Fax: +60 4657 3678

(250 µm).

Proximate analysis

The moisture content in fruit samples was determined by using moisture analyzer (IR-30, Denver Instrument, Colorado, USA). The crude protein, crude lipid, crude fiber and ash contents were determined using standard procedures of AOAC (1990). The crude carbohydrates (or the total Nitrogen-free extracts, NFE) and the gross energy were calculated using the following formula employed by Bhat and Sridhar (2008) :

$$\text{Total NFE (\%)} = 100 - [\text{Moisture (\%)} + \text{crude protein (\%)} + \text{crude lipid (\%)} + \text{crude fiber (\%)} + \text{total ash (\%)}]$$

$$\text{Gross energy (kJ } 100^{-1}) = (\text{protein} \times 16.7) + (\text{fat} \times 37.7) + (\text{NFE} \times 16.7)$$

Amino acid analysis

The amino acids composition of ripe and unripe kundang fruits was evaluated based on method described previously (Bhat *et al.*, 2008; Huda *et al*., 2010). Commercial and individual amino acid mixtures were used to prepare a calibration mixture. Further, amino acid score was determined using the FAO/WHO/UNU Expert Consultation (2007) patterns for children (age 3-10) and adults (18 years and above) by using the following formula:

$$\text{Amino acid score} = \frac{\text{Amino acid content in food protein}}{\text{Amino acid content in the FAO/WHO/UNU reference pattern}} \times 100$$

Minerals and heavy metal analysis

Acid digestion method described by AOAC (1990) was used to determine minerals and heavy metal contents in the samples. We used atomic absorption spectroscopy (Perkin Elmer, Beaconfiend, UK) equipped with deuterium hollow cathode lamp background correcting system for determining various minerals and heavy metals such as: potassium, calcium, sodium, iron, zinc, aluminium, cadmium, mercury, arsenic, etc. In addition, phosphorus and boron content were determined colorimetrically by spectrophotometer (DR 2800, Hach, USA).

Statistical analysis

All the data generated in this study are represented as means ± SD (n = 3) and Analysis of variance (independent t-test) were performed using SPSS VERSION 14.0. Level of significance was determined by using Duncan's new multiple range tests at a level of significance of $p < 0.05$.

Results and Discussion

Proximate composition

The results of proximate compositions of freeze-dried unripe and ripe kundang fruits are provided in Table 1. The proximate compositions differed significantly between unripe and ripe fruits, only with the exception of ash and crude lipid content. The moisture content of fresh unripe fruit was 85.64%, which was slightly lower (non–significant) than that of ripe fruits (86.03%). Unripe fruits had significantly higher moisture (dry weight), crude fiber and crude protein (7.16%, 6.39% and 0.64%, respectively), than the ripe fruit, but had a lower content of nitrogen-free extracts (88.62%) and Gross Energy (1571.14 kJ 100^{-1} g). The moisture content of food products can critically affect the growth rates of microbes as well as affect the biochemical reactions and texture quality (Bhat and Sridhar, 2008, Ovando-Martinez *et al*., 2009). Presence of low moisture content in both ripe and unripe kundang fruits can be beneficial to improve the shelf-life and can play an important role on the storage stability of dried food products developed using these fruits. The moisture content in these fruits were much lower than *Vitex doniana* (black plum) which is reported to have 16.66% moisture content (Vunchi *et al*., 2011), and lower than whole fruit and berries of *Baccaurea angulate* [belimbing dayak, 16.79 and 20.63% dry weight (d.w.), respectively] (Nurhazni *et al*., 2013).

Ash content in a food product is required to provide important data on nutritionally essential minerals. In the present study, even though ash content of ripe and unripe kundang fruits were low (2.19 g/100 g and 2.22 g/100 g, respectively), it was much higher than some of the other tropical fruits such as sweetsop (Silva *et al.*, 1994) and jackfruits (1.37% and 0.8%, fresh wet basis, respectively) (TACO, 2006; Rodriguez-Amaya *et al.*, 2008). Hence, higher ash content in kundang fruits (especially unripe fruit) can be nutritionally valuable as they encompass essential minerals.

With regard to the crude protein, it was relatively low in unripe (0.64 g/100 g) and ripe (0.47 g/100 g) kundang fruits compared to other fruits, such as: whole fruit of figs (12.3%) and guava (5.0%), and pulp portions of Chinese wampee (6.2%) and langsat (4.1%) (d.w.) (Huang *et al*., 2010). High protein is an indication as source of nutrient in food (Bhat and Sridhar, 2008). The crude lipid content of unripe and ripe kundang fruits were relatively low compared

Table 1. Proximate composition of freeze dried unripe and ripe Kundang fruits (n = 3 ± SD)

Composition	Unripe	Ripe
Moisture (%)	7.16 ± 0.04^b	6.00 ± 0.15^a
Ash (g/100 g)	2.22 ± 0.07^a	2.19 ± 0.05^a
Crude lipid (g/100 g)	2.14 ± 0.16^a	1.89 ± 0.09^a
Crude fiber (g/100 g)	6.39 ± 0.17^b	3.64 ± 0.15^a
Crude protein (g/100 g)	0.64 ± 0.01^b	0.47 ± 0.01^a
Crude carbohydrates (NFE)	88.62 ± 0.10^a	91.81 ± 0.27^b
Gross Energy (kJ 100 g^{-1})	1571.14 ± 5.74^a	1612.17 ± 2.0^b

Values in the same row with different superscript letter are significantly different from each other ($p < 0.05$). All the results reported are on dry weight basis.

to some of the common fruits [such as those in figs (7.8%), gardenia (15.9%), guava (3.2%) and rose myrtle (5.1%)] (all on d.w. basis) (Huang *et al*., 2010). Low level of crude lipids is very important especially when they need to be used as a food additive (Lintas, 1992). Owing to the low lipid contents, both unripe and ripe kundang fruits contained a high amount of NFE (88.62% and 91.81%, respectively) (see Table 1). Earlier, high NFE has been correlated to low lipid contents (Bhat and Sridhar, 2008).

Fibers, which are also known as non-digestible carbohydrates, are common in fruits. It has been indicated that, only lychee and cactus pear to be classified as low-fiber fruits (0.2% and 0.06% respectively) (Clerici and Carvalho-Silva, 2011). The crude fiber content of unripe and ripe kundang fruit (see Table 1) is notably higher than lychee and cactus pear, and this proved both unripe and ripe kundang fruits are good source of fiber.

Amino acids profile

Amino acids are important in human health and play a pivotal role as the building blocks of protein (Galili *et al*., 2008). Amino acids from naturally occurring food products have been established as a potential antioxidant, antimicrobial, anti-inflammatory and as an immune stimulating agent (Bernal *et al*., 2011; Nimalaratne *et al*., 2011).

Amino acids profiles of unripe and ripe kundang fruits are compared with FAO/WHO/UNU Expert Consultation (2007) patterns for children (age 3-10) and adults (18 years and above) (see Table 2). In addition, results obtained for amino acid score (AAS) was also compared (see Table 3). Results showed cysteine to be the dominant amino acid detected in unripe kundang fruit (13.59 g/100 g N), with methionine being the lowest (1.26 g/100 g N). In the ripe kundang fruit, alanine was found to be the dominant amino acid (7.52 g/100 g N), whereas tyrosine was detected to be the lowest amino acid (1.37 g/100 g N). Overall, the amino acids contents in unripe fruit were higher than the ripe fruit. This can be correlated to the higher protein content in unripe fruit compared to ripe fruits. Wood apple (*Limonia acidissima*) which is an underutilized tropical fruit

Table 2. Amino acid profile of unripe and ripe kundang fruits (g/100 g crude Nitrogen) (n = 3, mean ± S.D.)

Amino Acid	Amount (g/100 g)		FAO/WHO/UNU Pattern [y]	
	Unripe	Ripe	Children	Adults
Essential amino acid				
Isoleusine	2.21 ± 0.31^a	1.88 ± 0.09^a	3.1	3.0
Leucine	3.64 ± 0.66^a	2.81 ± 0.10^a	6.1	5.9
Phenylalanine	2.44 ± 0.39^a	1.85 ± 0.06^a		
Methionine	1.26 ± 0.34^a	4.63 ± 6.14^b		
Threonine	2.54 ± 0.45^a	2.54 ± 0.11^a	2.5	2.3
Valine	2.92 ± 0.53^a	2.44 ± 0.20^a	4.0	3.9
Histidine	1.76 ± 0.32^a	1.56 ± 0.15^a	1.6	1.5
Lysine	4.62 ± 0.81^a	3.75 ± 0.12^a	4.8	4.5
Tryptophan	ND	ND	0.66	0.6
Non-essential amino acid				
Alanine	3.87 ± 0.74^a	7.52 ± 0.12^b		
Proline	3.85 ± 0.71^a	4.43 ± 0.24^a		
Cysteine	13.59 ± 0.82^b	1.80 ± 0.16^a		
Tyrosine	1.94 ± 0.31^b	1.37 ± 0.08^a		
Aspartic Acid	4.79 ± 0.89^a	3.89 ± 0.20^a		
Serine	3.08 ± 0.54^a	4.30 ± 1.23^a		
Glutamic acid	6.95 ± 1.24^a	6.38 ± 0.14^a		
Glycine	2.73 ± 0.61^a	2.91 ± 0.51^a		
Arginine	3.48 ± 0.76^a	2.28 ± 0.12^a		
SAA [p]	14.85	6.43	2.4	2.2
AAA [q]	4.38	3.22	4.1	3.8

ND, Not detected in the samples
[y] FAO/WHO/UNU Expert Consultation (2007) patterns for children (age 3-10) and adults (18 years and above) [p] Sulphur amino acid: methionine + cysteine
[q] Aromatic amino acid: tyrosine + phenylalanine
Data with different superscript alphabets in the same row are significantly different from each other ($p < 0.05$)

Table 3. Amino acid scores (%) of ripe and unripe kundang fruits compared to the FAO/WHO/UNU Expert Consultation (2007) patterns for children (age 3-10) and adults (18 years and above)

Amino acid score (%)	Unripe		Ripe	
	Children	Adult	Children	Adult
Threonine	101.6	110.4	101.6	110.4
Valine	73.0	74.9	61	62.6
Isoleucine	71.3	73.7	60.6	62.7
Leucine	59.7	61.7	46.1	47.6
Lysine	96.25	102.7	78.125	83.3
Histidine	110.0	117.3	97.5	104.0
SAA [p]	618.8	675.0	267.9	292.3
AAA [q]	106.8	115.3	78.5	84.7

[p] Sulphur amino acid: methionine + cysteine
[q] Aromatic amino acid: tyrosine + phenylalanine

Table 4. Minerals and heavy metal contents of ripe and unripe kundang fruit

Element	Amount (mg/kg)	
	Unripe	Ripe
Minerals		
Potassium	7801.5 ± 145.81	10087.5 ± 29.70
Calcium	931.6 ± 21.35	561.4 ± 5.52
Magnesium	680.7 ± 12.45	422.6 ± 8.77
Sodium	101.9 ± 0.71	90.5 ± 0.99
Phosphorus	1200.0 ± 2.83	800 ± 0.00
Selenium	<2.5 ± 0.00	<2.5 ± 0.00
Chromium	<2.5 ± 0.01	<2.5 ± 0.00
Copper	16.3 ± 0.71	18.1 ± 0.28
Iron	35.5 ± 2.83	22.9 ± 0.71
Manganese	58.3 ± 2.55	25.2 ± 2.26
Zinc	13.5 ± 2.83	12.6 ± 1.13
Aluminium	10.6 ± 0.14	9.72 ± 0.62
Boron	<1.0 ± 0.00	<1.0 ± 0.00
Heavy metals		
Cadmium	<0.5 ± 0.00	<0.5 ± 0.00
Nickel	<5.0 ± 0.00	<5.0 ± 0.00
Mercury	<0.5 ± 0.00	<0.5 ± 0.00
Lead	<5.0 ± 0.00	<5.0 ± 0.00
Arsenic	<0.5 ± 0.00	<0.5 ± 0.00

has been reported to have negligible amounts of lysine, methionine, threonine, glutamic acid and serine amino acids. Furthermore, the leucine, glycine and arginine in wood apple fruits (1.76, 1.52 and 2.06 g/100 g) (Priyadarsini *et al.*, 2013) was found to be lower than the unripe and ripe kundang fruits, as reported in this study.

In comparison with FAO/WHO/UNU Expert Consultation (2007) of children pattern, essential amino acids (EAAs) such as phenylalanine, methionine, threonine and histidine of unripe kundang fruit were found to be higher, meanwhile in comparison to the adult pattern, EAAs such as phenylalanine, methionine, threonine, histidine and lysine for unripe fruit were found to be higher. Their AAS for children and adult pattern ranged from 101.6 to 618.8 and 102.7 to 675.0. Whereas in the ripe fruit, methionine and threonine were higher than the children pattern, but for the adult pattern, methionine, threonine and histidine were found to be higher. Their AAS varied from 101.6 to 267.9 for children pattern and 104.0 to 292.3 for adult pattern. Hence, this proved that unripe fruit is better source of protein than the ripe fruit.

Minerals and heavy metal contents

Table 4 illustrates the minerals and heavy metal contents in both unripe and ripe kundang fruits. Results showed, both unripe and ripe fruits to be rich with essential minerals such as potassium (7801.5 and 10087.5 mg/kg), phosphorus (1200 and 800 mg/kg), calcium (931.6 and 561.2 mg/kg), magnesium (680.7 and 422.6 mg/kg), and sodium (101.9 and 90.5 mg/kg), respectively. Selenium, chromium, copper, iron, manganese, zinc, aluminium and boron were some of the other trace elements detected. Selenium, chromium and boron were found in low amounts (<2.5 mg/kg), whereas, manganese, iron, copper, zinc and aluminium ranged between 9.72−25.2 mg/kg in ripe fruits. Whereas, in the unripe fruit, these trace elements ranged between 10.6−58.3 mg/kg. Amongst the minerals, potassium was found most abundantly in both unripe and ripe fruit, but was highest in ripe fruits (10087.5 mg/kg).

According to Siddhuraju *et al.* (2001), intake of high amount of potassium in our daily diet can be crucial for people who are suffering from hypertension and also for those suffering excessive defecation of potassium via body fluids. Potassium, magnesium, calcium and phosphorus are significant for intracellular and extracellular functions of human body as they form a primary part of structural components of the building blocks in the body. Magnesium and zinc are widely known to prevent muscle degeneration, cardiomyopathy, dermatitis, growth retardation, immunologic dysfunction, bleeding disorders, and congenital malformations, while trace elements such as iron and selenium play an important role as antioxidant compounds and help in strengthening immune system (Bhat and Sridhar, 2008; Bhat *et al.*, 2010). In addition, kundang (both unripe and ripe) fruits contained higher potassium content compared to fruits of *Rosa* species which ranged between 5467 to 7700 mg/kg (Ercisli, 2007) but was reported to have lower potassium content than strawberry fruit; 14909.08 mg/kg. The trace elements such as copper, iron, manganese and zinc in strawberry fruit (1.65, 12.15, 4.44, and 8.09 mg/kg) were lower than the unripe and ripe kundang fruits (Özcan and Haciseferoğullari, 2007). Despite the fact that minerals play a key role in human health, on the other hand, a significant quantity of heavy metals in food products above the recommended values could be fatal too. Rapid urbanization and industrialization can accelerate heavy metals deposition flow into water channels, which are subsequently used for irrigation purposes (Khan *et al*., 2008; Ping *et al*., 2011).

Due to high atomic weight of cadmium (Cd), Nickel (Ni), Mercury (Hg), lead (Pb) and arsenic (Ar), they are frequently referred as heavy metals (Toxicology Factsheet Series, 2009). Earlier, it is reported that fresh fruits can contain a maximum amount of 0.05 mg/kg Cd, 0.05 mg/kg Hg and 0.5 mg/kg Pb (Stefanut *et al*., 2007). Both unripe and ripe kundang fruits contained <0.5 mg/kg of Cd and Hg content, whereas the content of Pb in these fruits are <5.0 mg/kg N. However, for Ar and Ni, an Adequate Intake (AI) or Estimated Average Requirement (EAR) was not established (National Research Council, 2001). The content of these heavy metals in unripe and ripe kundang fruits were slightly higher than the recommended limit. However, the heavy metal toxicity degree in humans depends on their daily intake of these fruits and the body weight of an individual as well could influence the tolerance of the heavy metals consumption (Orisakwe *et al.*, 2012). Therefore, these unripe and ripe fruits with low heavy metals content can be considered safe for human consumption.

Conclusions

Results of this preliminary study clearly indicated unripe and ripe kundang fruits to posses' significant amounts of nutrients and can be explored for commercial purposes. Further research works are warranted to evaluate the health promoting properties as well as identify the bioactive compounds and volatile compounds in both unripe and ripe kundang fruits.

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