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Antioxidant and Nutritional Values of Selected Under-utilised *Mangifera* Species in Malaysia

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Antioxidant properties and nutritional constituents of selected *Mangifera* species namely, *M. caesia, M. foetida, M. laurina, M. longipetiolata, M. odorata, M. pajang, M. pentandra* besides some landraces and commercial clones collected from four different sites in Malaysia, were studied. Results showed that *M. caesia* was the most potential source of antioxidant as evidenced by its most active scavenging activity with 92.09 ± 0.22% radical inhibition or IC_{50} value of 8.14 ± 0.17 mg/ml. *M. pajang* showed the greatest amount of total phenolic (7055.65 ± 101.89 mg/100 g) and ascorbic acid (403.21 ± 46.83 mg/100 g) content. Highest protein content was observed in *M. odorata* var. Kuini KL with 6.02%, while the highest calcium content was found in *M. pentandra* and *M. odorata* var. Kuini KR with 140 mg/100 g. *M. pentandra* was also found to be the best source of potassium with 1930 mg/100 g. In addition to being the potential antioxidants, *M. caesia* and *M. pajang* also showed the highest magnesium (130 mg/100 g) and iron (7.31 mg/100 g) content, respectively. The present study indicates that underutilised *Mangifera* species are a potential source of antioxidants and nutrition with some of them being even better than common mango and other popular fruits.

Key Words: *Mangifera*, Underutilised, Antioxidant, Proximate, Mineral

Introduction

Malaysia possesses a rich diversity of many traditional under-utilised fruits that can be explored for their potential health and nutritional value. These fruits are usually grown in orchards and home gardens and some can be found in the wild and forests of Peninsular Malaysia, Sabah and Sarawak. In Malaysia, underutilised fruits are important for better nutritional status and food security especially for rural and farm communities. As they are usually maintained by cultural preferences and traditional practices, some of them are neglected in research and conservation. Low attention from formal research could be due to lack of knowledge of their potential value. Therefore, information about their health and nutritional components is critical to increase the value of neglected species and varieties and for sustaining and strengthening food, nutrition, health and livelihood security.

Information about food composition of different cultivars, regions and countries is extremely important and needs to be more widely disseminated in order to guarantee the preservation and sustainable use of biodiversity in enhancing food security and human nutrition programmes (de Menezes, 2009). The availability of compositional information will support countries in promoting their local species and varieties to improve health and nutrition status by increasing food diversity from the local surroundings and through planting more foods with higher micronutrient content (Stadlmayr *et al.*, 2011).

Mangifera belongs to the order Sapindales in the family Anacardiaceae which comprises 73 genera and about 830 species, mainly in tropical regions. Previous studies (Bompard and Schnell, 1997) indicate that the centre of origin and diversity of the genus *Mangifera* is mostly restricted to Southeast Asia. Yamanaka *et al.* (2006) listed 58 species in the genus *Mangifera*, with the highest diversity occurring in Malaysia, Java and Sumatra (Kostermans and Bompard, 1993) of which 12 were cultivated, of which eight were found in the wild. Salma *et al.* (2006) listed 30 cultivated and wild *Mangifera* species occurring in Malaysia with three endemic species.

M. indica L., the popular mango, is the most commonly studied by researchers and widely cultivated throughout the world. Mango is a popular and economically important tropical fruit due to its excellent

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eating quality and nutritional composition. Mango is also rich in antioxidants and is reported to contain various classes of polyphenols, carotenoids and ascorbic acid, which scavenge free radicals that have been associated with the beginning of many disorders, such as cancer and cardio- and cerebro-vascular diseases. Antioxidants, may therefore contribute to different health-promoting properties (Kim *et al.,* 2009).

While extensive research has been carried out on *M. indica*, there is lack of information on the other *Mangifera* fruit species. Other *Mangifera* fruit species, commonly referred to as wild and underutilised, are less popular even though they have consumption value. Ikram *et al.* (2009) reported that *M. foetida*, *M. odorata* and *M. pajang* had higher antioxidant capacity than *M. indica*. This finding has shown that underutilised fruits could be better sources of antioxidants than the popular commercial fruit and therefore, should not be neglected. Antioxidants have gained increasing interest in health, nutrition and food science in recent years due to their claimed health benefits (Stadlmayr *et al.,* 2011). Antioxidants scavenge reactive free radicals and oxidants which have been associated with the beginning of many disorders, such as cancer and cardio- and cerebro-vascular diseases (Liu *et al.,* 2000). Almost all organisms posses antioxidant defences and repair systems to protect them against oxidative damage. However, these systems are insufficient to prevent the damage entirely. Thus, exogenous addition of dietary antioxidants is beneficial in assisting the human body to neutralise free radicals, help reduce the harmful effects of oxidative damage and protect against various diseases (Mau *et al.,* 2002). However, scientific information on the antioxidant and nutritional value of other underutilised *Mangifera* fruit species and some of their landraces and commercial clones is still scarce. This information is pertinent in promoting these underutilised fruit species to the public.

Thus, the major objectives of this study were; (i) to evaluate the antioxidant properties and (ii) to determine proximate and mineral composition as indicators of nutritional values of the fruits of selected underutilised *Mangifera* species, landraces and clones collected from various locations in Malaysia.

Materials and Methods

Fruit Samples

Mangifera species, landraces and clones were collected from four different sites in Malaysia (Table 1). Only ripe *Mangifera* fruits were used in this study.

Table 1. *Mangifera* species and their collection sites in Malaysia

Species	Common name	Collection site
Mangifera caesia	Binjai	Papar, Sabah
M. foetida	Bacang	Yan, Kedah
M. laurina	Mempelam air	Papar, Sabah
M. longipetiolata	Sepam	Yan, Kedah
M. odorata	Kuini	Yan, Kedah
M. pajang	Bambangan	Kota Belud, Sabah
M. pentandra	Mempelam bemban	Bukit Gantang, Perak

Preparation and Extraction of Fruit Samples

Fruit samples were washed with running tap water before being weighed for the whole and edible portion parts. Then, the edible portions of the fruits were cut into small pieces and freeze-dried using a bench-top freeze dryer (Virtis, USA). The freeze-dried samples were finely ground and kept in an airtight container prior to extraction.

For antioxidant analysis, the samples were extracted using methanol (1:10) and shaken for approximately 1 h before centrifugation for 10 min. at 10,000 rpm. The residue was separated from the supernatant and the procedure was repeated twice. The two resulting supernatants were mixed together to obtain the crude extracts which were stored at -80°C prior to analysis.

For ascorbic acid analysis, the extraction was performed according to Yurena *et al.* (2006) and Patric *et al.* (2006) with some modifications. The freeze-dried fruit samples were weighed and mixed with extract buffer (100 µg/ml Tris (2-carboxyethyl)-phosphine hydrochloride (TCEP-HCl), 3% MPA, 8% acetic acid and 1 mM ethylenediaminetetraacetic acid disodium salt (EDTA). The mixture was homogenized in a Virtishear homogenizer (Virtis, USA) in ice for 1 min. and then centrifuged at 10,000 rpm (refrigerated at 4°C) for 10 min. The supernatant was filtered through a 0.45 µm cellulose membrane and stored at -80°C until further use.

Determination of Antioxidant Activity

2,2-diphenyl-1-picrylhydrazyl (DPPH) Free Radical Scavenging Assay

Scavenging activity of the fruit extracts on DPPH radicals was assayed according to Molyneux (2004) with some modifications. Various concentrations of the crude extracts in methanol were prepared to give

a final volume of 7 µl and were mixed with 280 µl of methanolic solution containing DPPH (Sigma, USA) radicals resulting in a final concentration of 0.06 mM. The mixture was vigorously shaken and left to stand for 30 min. in the dark. The absorbance was measured at 517nm and ascorbic acid (Sigma, USA) was used as the positive control. The assays were carried out in triplicate and the results were expressed as mean values ± standard deviations. The scavenging effect on DPPH free radicals was calculated as follows:

$$\text{Inhibition (\%)} = \frac{A_{Control} - A_{Extract}}{A_{Control}} \times 100\%$$

$A_{Control}$ is the absorbance of the control reaction (containing all reagents except the test compound), and $A_{Extract}$ is the absorbance of the test compound.

Determination of Total Phenolic Content

Total phenolic content of the extracts was estimated by a colorimetric assay as described by Singleton and Rossi (1965) with some modifications. Briefly, 50 µl of the crude extracts were mixed with 100 µl of Folin Ciocalteau's phenol reagent (Merck, Germany). After 3 mins, 100 µl of 10% sodium carbonate (Na_2CO_3) (Sigma-Aldrich, USA) was added to the reaction mixture and allowed to stand in the dark for 60 mins. The absorbance was measured at 725 nm and the total phenolic content was obtained from a calibration curve using gallic acid (0–10 µg/ml) as a standard reference. Estimation of the phenolic content was carried out in triplicate. The results were mean values ± standard deviations and expressed as mg gallic acid per 100 g samples. All procedures were carefully carried out with minimum exposure of light.

Determination of Total Flavonoid Content

Measurement of flavonoid concentration of the extracts was based on the method described by Kim *et al*. (2003) with some modifications. An aliquot of 100 µl of fruit extract was diluted with 400 µl of distilled water. Afterwards, 30 µl of 5% sodium nitrite ($NaNO_2$), (Sigma, USA) solution was added and allowed to react for 5 min. Following this, 20 µl of 10% aluminium chloride ($AlCl_3.6H_20$) (Sigma, USA) was added and left to stand for 5 min. Finally, 200 µl of sodium hydroxide (NaOH) (Sigma, USA) was added and the mixture was well-mixed with a vortex. All samples were analyzed in triplicate and the absorbance was measured immediately at 510 nm. Rutin (Sigma, USA) was used to calculate the standard curve and the results were expressed as mg rutin per 100 g samples.

Determination of Ascorbic Acid Content

The analysis was carried out using a Waters High Performance Liquid Chromatography (HPLC) system equipped with a Waters E600 pump controller and Waters 2996 PDA detector (Waters, USA) based on Yurena *et al*. (2006) Empowers software was used for controlling the analytical system and data processing. The separation was carried out on a symmetry C18 column (5 µm particle size, 250 × 4.6 mm I.D.) as a stationary phase with a symmetry C18 guard column. Detection wavelength was set at 200 to 700 nm of which the UV spectrum of ascorbic acid is 245 nm. The standard solutions and extract samples were filtered through a 0.45 µm nylon membrane before introduced onto the column through a Waters 717 plus autosampler. The mobile phase employed was a 25 mM phosphate buffer (pH 2.5) adjusted with orthophosphoric acid at 25°C. Flow rate of the mobile phase was 1 ml/min. and an injection volume of 10 µl was used for quantitative analysis. The commercial external standard, ascorbic acid was used to identify and quantify the level of ascorbic acid in the samples by comparing their spectral characteristics and retention time.

Determination of Proximate Composition

Protein, fat and ash contents were determined using the routine chemical analytical methods of the Association of Official Analytical Chemists (AOAC) official method (AOAC, 1984). Protein content was determined by weighing 0.2 g of homogenized sample into a Kjeldahl digestion flask of capacity 30–35 ml. Potassium sulphate (1.2 g), mercuric solution (1 ml) and concentrated sulphuric acid (2.5 ml) were added. The mixture was then heated on a top pan heater in a fume cupboard. After heating, 10 ml of alkali mixture was added, and the steam was passed through the apparatus until the volume of liquid was 50–100 ml. Finally, the liquid was titrated with 0.02 N HCl.

In the method described by Tee *et al*. (1986), fat content was determined by directly extracting 10–40 g of dried ground sample with 150 ml petroleum ether in a Soxhlet extraction apparatus. The residue in the extraction flask after solvent removal represented the fat content of the sample.

The ash content was determined by drying the homogenized sample in a dish in an oven at 130 °C for 24 h. The dried sample was charred until it ceased smoking. The dish was placed in a cold muffle oven until

the temperature reached 550 °C. Total ash content was obtained after the weight of the sample was constant.

The carbohydrate content was calculated by the formula: [100–(moisture+protein+fat+ash)]. Meanwhile, the energy was calculated as: Energy, kcal/100g = [Fat] × 9 + [Protein] × 4 + [Carbohydrate] × 4.

Determination of Mineral Content

Calcium (Ca), iron (Fe), potassium (K), magnesium (Mg) and zinc (Zn) content of the selected underutilised fruit species were determined using inductively coupled plasma-mass spectrometry (ICP-MS) according to AOAC official method (AOAC, 1990). The freeze-dried samples were sent to Technical Service Centre, MARDI for analysis.

Results and Discussion

Antioxidant Capacity of Selected Mangifera Fruit Species

Results of the antioxidant activity of the edible portions of selected underutilised *Mangifera* species are presented in Table 2. The antioxidant activity was determined by DPPH free radical scavenging assay (FRSA) which measures the ability of the extracts to scavenge the harmful free radicals. The results were compared to the popular mango, *M. indica*. Different *Mangifera* species were observed to have varying degrees of free radical scavenging activities. Two underutilised *Mangifera* species were found to exhibit higher FRSA as compared to *M. indica*. *M. caesia* was the strongest potential source of antioxidant as evidenced by its most active FRSA with 92.09 ± 0.22% radical inhibition or IC_{50} value of 8.14 ± 0.17 mg/ml. *M. longipetiolata* ranked second with 90.08 ± 0.15% radical inhibition or IC_{50} value of 8.33 ± 0.08 mg/ml. The antioxidant properties are inversely proportional to the IC_{50} values and values lower than 10 mg/ml are indicative of the effective antioxidant activity (Lee *et al.*, 2007).

Table 2. Free radical scavenging activity (FRSA) of selected *Mangifera* species as compared to *M. indica*

Species	% of inhibition at 15 mg/ml	IC_{50} (mg/ml)
Mangifera caesia	92.09 ± 0.22	8.14 ± 0.17
M. foetida	17.35 ± 0.10	43.22 ± 0.29
M. laurina	56.31 ± 0.03	13.32 ± 0.11
M. longipetiolata	90.08 ± 0.15	8.33 ± 0.08
M. odorata	37.19 ± 0.59	20.16 ± 1.31
M. pajang	19.77 ± 0.53	37.94 ± 1.29
M. pentandra	56.54 ± 1.36	13.27 ± 0.81
M. indica	73.44 ± 0.40	10.21 ± 0.32

Values are mean ± standard error mean (SEM) of mean of triplicate analyses; IC_{50}: inhibitory concentration at which 50% radicals are scavenged

Table 3 shows the total phenolic content (TPC), total flavonoid content (TFC) and ascorbic acid content (AAC) of the selected underutilised *Mangifera* species. From the results, *M. pajang* showed the greatest amount of TPC (7055.65 ± 101.89 mg/100g) as followed by *M. foetida* (2917.92 ± 155.35 mg/100g) and *M. caesia* (2637.35 ± 178.92 mg/100g). This is in accordance to Ikram *et al.* (2009) who reported that *M. pajang* and *M. foetida* showed higher TPC value than *M. indica*. It is also interesting to note that all the underutilised *Mangifera* fruits tested in this study demonstrated higher TPC than *M. indica*. Meanwhile, *M. caesia* was also observed to have the highest TFC (550.67 ± 19.78 mg/100g) as compared to other underutilised *Mangifera* species tested. This explained its strong free radical scavenging activity as mentioned earlier (Table 2). However, the TFC was not comparable to *M. indica*. Phenolics and flavonoids have been the main phytochemicals responsible for the antioxidant capacity of fruits. They are important for human health because of their activities as radical scavengers (Hertog *et al.*, 1993). On the other hand,

Table 3. Total phenolic content (TPC), total flavonoid content (TFC) and ascorbic acid content (AAC) of selected underutilised *Mangifera* species as compared to *M. indica*

Species	TPC (mg /100g)	TFC (mg/100g)	AAC (mg/100g)
Mangifera caesia	2637.35 ± 178.92	550.67 ± 19.78	270.22 ± 12.79
M. foetida	2917.92 ± 155.35	282.88 ± 71.75	122.13 ± 32.84
M. laurina	144.33 ± 23.88	176.71 ± 25.78	135.74 ± 30.33
M. longipetiolata	263.31 ± 35.53	129.11 ± 56.39	322.75 ± 32.55
M. odorata	257.17 ± 27.72	202.33 ± 32.19	47.32 ± 9.73
M. pajang	7055.65 ± 101.89	256.42 ± 17.52	403.21 ± 46.83
M. pentandra	676.24 ± 40.13	118.82 ± 24.83	400.94 ± 71.74
M. indica	125.21 ± 19.11	853.98 ± 24.53	125.23 ± 81.26

Values are mean ± standard error mean (SEM) of mean of triplicate analyses; TPC: total pehenolic content; TFC: total flavonoid content; AAC: ascorbic acid content

M. pajang was found to exhibit the highest AAC (403.21 ± 46.83 mg/100g) followed by *M. pentandra* (400.94 ± 71.74 mg/100g). Most of the underutilised *Mangifera* fruits were also shown to have higher AAC than *M. indica.* Ascorbic acid or commonly known as vitamin C is one of the important antioxidants found in fruits and important for human nutrition. The vitamin C content in *M. pajang* reported in the current study is also higher than the vitamin C content of oranges (171.4 mg/100g) (Mirfat *et al.*, 2009) and guava (322.33 mg/100g) (Mirfat *et al.*, 2010). Meanwhile, Yahia *et al.* (2011) demonstrated that oranges and guava had 142 mg/100 g and 270 mg/100g vitamin C content, respectively. These results, may therefore suggest that some of the underutilised fruits have strong antioxidant properties compared to the popular fruits.

Antioxidant Capacity of Selected Mangifera Fruit Species, Landraces and Commercial Clones

Table 4 shows the results of antioxidant capacity of selected of underutilised *Mangifera* species and their landraces and commercial clones collected from Yan, Kedah. It was observed that different fruit samples showed different trend in the antioxidant activity and properties. Even within the same species, the landraces and commercial clones were shown to exhibit great variability. From the results, the commercial clone *M. indica* var. Chokanan Arau showed the strongest antioxidant activity (95.29 ± 4.09%) as compared to other *Mangifera* species, landraces and commercial clones tested. Another commercial clone, *M. indica* var. Harumanis had the highest TFC (885.11 ± 19.82 mg/100g). On the other hand, *M. odorata* var. Kuini KL demonstrated the highest TPC (2688.24 ± 307.99 mg/100g). All these results are consistent with the earlier findings (Table 2 and 3) that *M. indica* fruit showed higher free radical scavenging activity (FRSA) and TFC as compared to *M. foetida* and *M. odorata.* The variation of the antioxidant capacity of the selected *Mangifera* species, landraces and commercial clones is in agreement with previous studies which reported that the variation of antioxidant properties of *Mangifera* are strongly affected by the type of fruit (species and variety within species) and cultivation conditions of the plant (environmental and cultivation techniques) (Ma *et al.*, 2011). Other contributing factors to the variations may be expected from different location, ripening stage, season (Kubola *et al.*, 2011), agronomical differences, genomics, method of extraction and standards used (Imeh and Khokhar, 2002).

Nutritional Constituents of Selected Mangifera Species, Landraces and Commercial Clones

Other than the antioxidant phytochemicals, fruits also provide other nutrients which are good for health. The proximate composition of selected *Mangifera* species, landraces and commercial clones was shown in Table 5. From the results, considerable differences were found among the fruit samples tested. The commercial clones of *M. indica* were revealed to be a good source of fat,

Table 4. Free radical scavenging activity (FRSA), total phenolic content (TPC) and total flavonoid content (TFC) of selected *Mangifera* fruit species, landraces and commercial clones collected from Yan, Kedah

Species/landraces/clones		FRSA (%)	TPC (mg /100g)	TFC (mg/100g)
Mangifera foetida				
Landraces	Lada	64.12 ± 2.11	916.77 ± 19.92	295.43 ± 0.48
M. odorata				
Landraces	Kuini KL	45.86 ± 5.6	2688.24 ± 307.99	568.16 ± 10.99
	Kuini KR	63.76 ± 1.32	722.75 ± 10.22	206.98 ± 42.5
M. indica				
Landraces	Ciku	41.00 ± 0.89	792.61 ± 13.21	111.16 ± 9.65
	Enam Kati	27.66 ± 1.25	774.94 ± 11.3	450.22 ± 12.16
	Paragon Bangkok	24.00 ± 6.77	902.88 ± 71.1	221.72 ± 1.55
	Pipi Merah	37.91 ± 2.23	799.98 ± 12.18	804.03 ± 16.73
	Sawa	22.45 ± 1.87	2140.92 ± 109.61	302.80 ± 10.76
	Tok Nus	47.49 ± 0.66	862.89 ± 12.45	479.71 ± 1.54
	Pedal Ayam	67.49 ± 1.45	813.66 ± 3.98	442.85 ± 17.87
Commercial clones	Chokanan Arau	95.29 ± 4.09	904.99 ± 11.32	30.07 ± 0.78
	Chokanan	68.82 ± 10.11	869.00 ± 17.91	155.38 ± 14.11
	Epal	45.27 ± 2.35	851.96 ± 46.11	575.53 ± 52.1
	Harumanis	22.58 ± 1.89	736.22 ± 9.87	885.11 ± 19.82
	Sala	42.32 ± 5.76	756.21 ± 61.12	442.85 ± 7.88

Values are mean ± standard error mean (SEM) of mean of triplicate analyses**;** FRSA: free radical scavenging activity; TPC: total phenolic content; TFC: total flavonoid content

carbohydrate and energy. *Mangifera indica* var. Sala contained the highest fat and energy with 2.21% and 421 kcal, respectively. Meanwhile, *M. indica* var. Chokanan Arau exhibited the highest carbohydrate content with 95.43% (Table 5). The contribution of energy content in fruits may come from fat, other than protein and carbohydrate (Umi Kalsum and Mirfat, 2014). The energy content of *Mangifera* species, landraces and commercial clones in this present study ranged from 312.04-421.00 kcal and was higher than that of avocado (145-198 kcal) and banana (81-185 kcal) (Yahia *et al.*, 2011). *Mangifera foetida* var. Lada was observed to have the highest ash content with 4.53%. Ash content is a direct indicator of the total amount of minerals present in fruits. The higher ash content may indicate the higher minerals in the fruits. Determination of the ash in foods is important for nutritional labelling, quality assessment, microbiological stability, nutrition aspect and processing (McClements and Decker, 2009). On the other hand, protein predominated in the *M. odorata* var. Kuini KL with 6.02%. Protein is also a major source of energy, as well as containing essential amino acids, such as lysine, tryptophan, methionine, leucine, isoleucine and valine, which are essential for human health (Umi Kalsum and Mirfat, 2014).

In addition to proximate, mineral composition is also important for reliable nutritional information and necessary to evaluate diets for nutritional adequacy. Minerals are also required for normal cellular function and provide additional protection to the human body. In this study, five selected major trace elements; calcium (Ca), iron (Fe), potassium (K), magnesium (Mg) and zinc (Zn) were determined (Table 6). Some of these minerals have a function in the mechanism of preventive defense against free radicals performed by antioxidant enzymes (Yahia *et al.*, 2011). From the results, both *M. pentandra* and *M. odorata* var. Kuini KR showed the highest Ca content with 140 mg/100 g. In addition, *M. pentandra* fruit species was also found to be the best source of potassium with 1930 mg/100g. This value is much greater than the popular potassium-enriched fruit, banana with only of 348-370 mg/100g (Yahia *et al.*, 2011). *M. caesia* and *M. pajang* which were earlier revealed to be good antioxidants had the highest Mg (130 mg/100 g) and Fe (7.31 mg/100g) content, respectively. Meanwhile, *M. foetida* showed the highest Zn content with 3.26 mg/100 g. The Fe and Zn content of *Mangifera* species, landraces and commercial clones in this study was notably higher than all the tropical and sub-tropical fruits tested by US Department of Agriculture (USDA,

Table 5. Proximate composition of selected *Mangifera* species, landraces and commercial clones collected from Yan, Kedah

Species/landraces/ commercial clones	Fat (%)	Ash (%)	Protein (%)	Carbohydrate (%)	Energy (kcal)
	(% dry basis)				
Mangifera caesia	0.82	2.25	4.12	75.35	325.21
M. laurina	0.33	2.44	1.89	80.55	332.72
M. pajang	0.28	2.38	3.24	74.15	312.04
M. pentandra	2.21	2.15	2.61	84.28	367.51
M. foetida					
Landraces					
Lada	0.43	4.53	3.43	91.43	383.29
M. odorata					
Landraces					
Kuini KL	1.22	2.48	6.02	89.71	393.87
Kuini KR	1.16	2.97	4.35	91.05	392.01
M. indica					
Landraces					
Ciku	0.59	1.58	3.06	94.43	395.29
Enam Kati	0.56	3.01	4.79	90.98	388.13
Paragon Bangkok					
Pipi Merah	0.28	1.87	2.75	87.74	364.48
Sawa	1.14	1.32	3.73	92.51	395.26
Tok Nus	0.68	1.70	2.46	94.15	392.54
Pedal Ayam	0.08	1.81	2.81	94.69	390.70
Commercial clones					
Chokanan Arau	0.78	1.76	1.72	95.43	395.66
Chokanan	0.29	2.95	4.07	92.37	388.37
Epal	1.02	2.14	2.79	93.09	392.75
Harumanis	0.97	1.87	3.26	93.49	395.73
Sala	6.08	1.79	3.58	87.99	421.00

2005). In particular, Fe and Zn content of the tropical and sub-tropical fruits ranged from 0.09-3.4 mg/100g and 0.06-0.64 mg/100g, respectively (Yahia *et al.*, 2011). The variations in the nutritional composition of these fruits may be attributed to maturity, climate, soil type, fertility and agricultural practices (Lee and Kader, 2000; Forster *et al.*, 2002). Even within a cultivar, there could also be large plant-to-plant and within plant variation in nutrient composition for fruit harvested from the same field (Shewfelt, 1990).

Conclusions

The present study indicates that underutilised *Mangifera* fruit species, landraces and commercial clones are potential sources of antioxidants and nutrition with some of them being even better than *M. indica* (mango) and other popular fruits. This information is also pertinent to help neglected species and varieties be valued for better health and nutritional status especially for rural and farm communities. More studies should be conducted to explore their functional and nutraceutical benefits. This study adds valuable information to the current knowledge of health and nutritional properties of the selected *Mangifera* species, landraces and commercial clones, serves as a guideline and selection criteria for their further consumption in diet and can inform potential product developments in the future.

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Table 6. Major mineral composition of selected *Mangifera* fruit species, landraces and commercial clones collected from Yan, Kedah

Fruit sample	Ca	Fe	K	Mg	Zn
			mg/100g		
Mangifera caesia	30	4.85	1060	130	1.23
M. laurina	130	4.38	1040	100	1.21
M. longipetiolata	90	5.06	1600	130	1.69
M. pajang	70	7.61	1120	110	2.27
M. pentandra	140	3.27	1930	90	1.54
M. foetida					
Landraces					
Lada	110	4.04	1600	120	3.26
M. odorata					
Landraces					
Kuini KL	50	2.08	610	80	1.64
Kuini KR	140	4.26	660	70	2.76
M. indica					
Landraces					
Ciku	30	1.83	480	40	2.48
Enam Kati	30	2.28	830	80	2.26
Paragon Bangkok	90	1.76	860	60	1.11
Pipi Merah	40	3.22	540	60	2.13
Sawa	80	2.76	370	40	2.04
Tok Nus	40	3.47	470	50	2.90
Pedal Ayam	30	2.52	610	40	1.42
Commercial clones					
Chokanan Arau	40	3.56	450	40	1.89
Chokanan	50	3.44	980	60	2.79
Epal	70	2.04	580	40	2.19
Harumanis	40	2.22	470	40	1.41
Sala	50	2.47	530	70	2.13

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