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FULL PAPER

Effect of pretreatment on nutrient content and antioxidant properties of *Mangifera odorata* L. peel and seed kernel powder

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Abstract

This study was carried out to investigate the influence of pretreatment, such as steaming and blanching, on the nutrient content and antioxidant properties of *Mangifera odorata* L. fruit peel and seed kernel powder. Results showed that steaming and blanching could increase the peel's powder calories, carbohydrate and vitamin A content. A similar trend was also observed on the dietary fibre content of the seed kernel powder. Conversely, the vitamin C and dietary fibre content of the peel powder were degraded after undergoing pretreatment. The protein content of the seed kernel powder had shown a decrement when blanching, indicating that the steamed samples had better retention of the protein content. It was observed that vitamin A and C were only detected in the peel powder, but fatty acids were only found in the seed kernel powder. Blanching had decreased 24% of stearic acid and 38% of methyl linolenate. Results of total dietary fibre showed that the values were 22-77% higher in the peel than the seed kernel powder. Meanwhile, the seed kernel showed higher antioxidant activity than the peel, although both samples showed EC_{50} values ≤ 1 mg/mL. These results might be useful to produce a powdered functional ingredient from *M. odorata* fruit wastes.

1. Introduction

Mangifera odorata L., locally known as kuini, is one of the underutilized local fruits among *Mangifera* spp. species. The fruit belongs to the family *Anacardiaceae* and has the same appearance and taste as mango (*Mangifera indica*), bacang (*Mangifera foetida*) and bambangan (*Mangifera pajang*). The unique criteria of *M. odorata* are its strong smell and fibrous texture compared with other *Mangifera* species. The flesh is orange–yellowish, hard texture, fibrous, sweet and sour, juicy, and has a pungent turpentine scent and flavour (Lim, 2012). The fruit is rich in nutrients, containing higher levels of protein and calcium than other *Mangifera* species, as well as a sufficient amount of carotenoids (Khoo *et al*., 2008; Mirfat *et al*., 2015).

Mangifera odorata is a seasonal crop and the fruit has a short shelf life when fully ripe. To reduce the risk of dumping and losses, *M. odorata* is processed into food products such as paste, puree, juices, cordial and chutney. However, the processing of *M. odorata* based products contributes to the dumping of the peels and seeds. Just like mangoes, the percentage of *M. odorata* wastes compared to the overall weight of the fruits consists of 15-20% peels and 20-60% seeds. While the kernel in the seeds contributes about 45-75% of the weight of the seeds (Ashoush and Gadallah, 2011). As fresh and ripe *M. odorata* is rich in nutrients, so is its peel and kernel. A previous study by Lasano, Hamid, Karim *et al.* (2019) showed that the freeze-dried *M. odorata* peel powder is rich in fibre and minerals, while the seed kernel is rich in protein and fat. The seed kernel also had the highest total phenolic content and total flavonoid content. It possessed excellent antioxidant capacity compared to peel and pulp of *M. odorata,* which is suitable to be used as a functional ingredient for the prevention of oxidative-stress related diseases. Moreover, Nur Baizura *et al*. (2019) found that the peel and seed kernel powder might have a prebiotic effect. Therefore, *M. odorata* peels and seed kernels have the potential to be used as functional ingredients.

Before drying, fruits and vegetables are usually subjected to physical or chemical pretreatment to reduce drying time and energy consumption and retain product quality (Yu *et al*., 2017). Thermal pretreatments such as steaming and blanching may stabilize product nutrients by inactivating or retard bacterial and enzyme action responsible for unacceptable darkening and off-flavours (Severini *et al*., 2005; Bai *et al*., 2013; Araujo *et al*.,

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2016), hence would prevent degenerating quality during storage. Blanching also might enhance the drying rates due to structure softening and cell wall destruction, leading to lesser resistance to moisture movement during drying (Severini *et al*., 2005; Leeratanarak *et al*., 2006). In some cases, pretreatments may enhance retention of the antioxidant compounds (Hong and Lu, 2012; Liu *et al*., 2015). Therefore, the objective of this study was to determine the effect of steaming and blanching, on nutrient content and antioxidant properties of *M. odorata* peel and seed kernel powder. Findings from this study may provide insight to promote the *M. odorata* fruit industrial wastes as a functional ingredient.

2. Materials and methods

2.1 Chemicals and reagents

All the chemicals and reagents used were of analytical grade purity. All fatty acids and ß-carotene standards, potassium dihydrogen phosphate, dipotassium hydrogen phosphate and sodium hydroxide solution (all analytical grade) were purchased from Sigma-Aldrich, UK. Hexane (GC grade), acetonitrile (Extra Pure), methanol (HPLC grade), ethanol, ethyl acetate, potassium hydroxide and sulfuric acid were purchased from Fisher Scientific. Folin–Ciocalteu reagent and gallic acid were purchased from Sigma–Aldrich (GmbH, Sternheim, Germany). Potassium ferricyanide, trichloroacetic acid, ferric chloride, 2, 2-diphenyl-1-picrylhydrazyl (DPPH), Trolox, ascorbic acid and other chemicals were purchased from Merck (Darmstadt, Germany). Distilled and deionized water was used throughout the experiment.

2.2 Preparation of Mangifera odorata peel and kernel powder

Mangifera odorata was obtained from the Malaysian Agricultural Research and Development Institute (MARDI), Sintok, Kedah, Malaysia. Approximately 30 kg of *M. odorata* fruits were collected. Fruit samples were washed, and the spoiled parts were removed. The cleaned fruits were then divided into three portions, namely control (no pretreatment), steaming (10 mins) and blanching (10 mins). Ten minutes of steaming and blanching was the optimum times which gave a significant difference in physico-chemical properties compared to control and was determined during the preliminary study (data was not shown). The samples were peeled, and the seed was separated from the pulp. The seed was cut in half to collect the kernel. The peel and seed kernel were sliced and dried in a hot air circulating dryer at 60°C (Memmert, Germany) until the moisture content reached <5% (between 20 to 27 hrs). The moisture content was tested from time to time using a moisture analyzer (SARTORIUS MA 35, Germany). Dried samples were ground into powder using a grinder (FRITSCH Universal Cutting Mill Pulverisette 19, Germany). The powder samples were packed in oriented polypropylene/ aluminium/polyethylene (OPP/Al/PE) packaging (22 × 30 cm) and kept at -18°C until further analysis.

2.3 Determination of proximate and dietary fibre composition

The moisture content, ash, fat, protein and dietary fibre (soluble and insoluble) analyses were conducted following the AOAC Official method of 934.01, 930.05, 991.36, 981.10, 993.19 and 991.42, respectively (AOAC, 2000). Meanwhile, the carbohydrate content was calculated from the sum of the percentage of crude protein, ash, fat and crude fibre, and subtracted from 100. The energy was calculated by multiplying the values obtained for protein, carbohydrates and fat by 4.00, 3.75 and 9.00, respectively, and reported as kcal/100 g dry basis (FAO/WHO/UNU, 1985).

2.4 Determination of vitamin A and vitamin C

2.4.1 Vitamin A

The determination of vitamin A of samples was conducted using the reverse-phase HPLC method (Amin and Fun, 2003). A Waters Alliance 2690 HPLC system, USA, equipped with column C18-Reverse phase (Waters, Spherisorb ODS 2) (5 µm packing) (250 × 4.6 mm id) was used and the mobile phase was acetonitrile: methanol: ethyl acetate (88:10:2, v/v/v), the flow rate of 1.3 mL/min and an injection volume of 20 µL. 10 g of sample was combined with 95% ethanol (4 times the weighted sample volume) and 20% potassium hydroxide (KOH) solution (volume equal to the weight of sample). The refluxing procedure was carried out for 30 mins. The hydrolysate was extracted three times with 50 mL hexane. The extract was then rinsed with distilled water before being washed again with anhydrous sodium sulphate. After that, the hexane extract was evaporated and resuspended in the mobile phase. Before being injected into the system, the extract was filtered via a 0.45 µm nylon syringe filter. For vitamin A quantification, ß -carotene standard curve was employed, and the results were represented in mg per 100 g dry sample.

2.4.2 Vitamin C

Vitamin C of *M. odorata* peel and kernel powder was quantified according to Courtois *et al*. (2009) by using HPLC (Waters Alliance 2690 LC system) using an isocratic gradient equipped with a reversed-phase C18 column (Waters, Spherisorb ODS 2) (5 µm packing) (250 × 4.6 mm id). The following conditions were used

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to extract ascorbic acid: injection volume 20 µL; oven temperature 30°C; solvent mixture dipotassium hydrogen phosphate (K_2HPO_4) (0.1 M), potassium dihydrogen phosphate (KH_2PO_4) (0.08 M), and methanol (55:25:20, v/v/v). The elution time was 10 min and the flow rate was 1.5 mL/min. An III-1311 Milton Roy fluorimeter (Ivyland, PA) with excitation = 350 nm and emission = 430 nm was used for detection. External ascorbic acid calibration was used for quantification. The ascorbic acid calibration curve ranged from 1 to 7 g/mL.

2.5 Fatty acid profile

The fatty acid analysis was performed in a Shimadzu GC with flame ionization detector (GC-FID) according to AOAC official method 969.33 (AOAC, 1995). Samples were trans-esterified to methyl esters using potassium hydroxide in methanol and *n*-hexane. A flame ionization detector with a 1: 30 split ratio injection mechanism and an autosampler were included in the gas chromatography. The compounds were separated using a 60-meter-long fused silica capillary column (CP-Sil 88) with a 0.25 mm internal diameter and 0.20 mm film thickness. The initial column temperature was set to 90° C, which was elevated to 195°C at a rate of 10°C/min for 4 mins before being held isothermally for 16 mins. The injector and detector were set to 230°C and 240°C, respectively. Compound identification was carried out using external standards of fatty acids methyl esters. Helium was used as a carrier gas with a flow rate of 0.5 mL/min and controlled initial pressure of 93.2 kPa at 120°C. Nitrogen and air were makeup gases. The injection temperature was 210°C, and the oven temperature was 120°C for 3 mins before increasing at a rate of 10°C/min to 220°C, holding at this temperature for 30 mins, increasing at a rate of 5°C/min to 240°C, followed by holding at 240°C for 30 mins. The split ratio was 100:1, the injection volume was 1 µL, and the detector temperature was 280°C. All fatty acid contents were given based on percentage area.

2.6 Determination of antioxidant properties

2.6.1 Sample extraction

The peel and seed kernel powders were extracted with distilled water at a ratio of 0.01 to 10 (w/v). The mixture was in a centrifuge tube and vortex for 1 min (SA-8 Stuart, United Kingdom) before being agitated at 100 rpm at room temperature in a shaker for 1 hour. The mixture was then centrifuged at 8500×*g* for 10 mins using Sigma 2-16K (Sartorius). The supernatant was filtered through Whatman no. 541 filter paper (Maidstone, UK) to obtain a clear extract. The filtrates were assayed for their total phenolic content and antioxidant activity assay, as described below. All experiments were run in triplicate.

2.6.2 Total Phenolic Content analysis

The total phenolic content (TPC) was determined using Folin-Ciocalteu's reagents according to Lim *et al*. (2006). A total of 0.3 mL of samples was inserted into the test tube followed by 1.5 mL of Folin-Ciocalteu's reagents (10% v/v) and 1.2 mL of sodium carbonate (75% w/v). The test tube was wrapped with aluminium foil before being shaken using a vortex (SA-8 Stuart, United Kingdom). The mixture was kept in the dark for 30 mins. The absorbance of the sample was read at a wavelength of 765 nm using a UV spectrophotometer (U -2800 Hitachi, Japan). The sample was disbursed to provide a reading value of less than 1. The total phenolic content is expressed alongside gallic acid (mg GAE/100 g). The curd is standardized in gallic acid at density 10, 25, 50, 75 and 100 mg/L.

2.6.3 Ferric reducing antioxidant power assay

The ferric reducing antioxidant power (FRAP) assay is determined by the ability of the extract to lower ferric ion free radicals (Fe^{3+}) to ferrous ions (Fe^{2+}). The conversion of Fe^{3+} yellow to Fe^{2+} blue was measured at a wavelength of 700 nm. The FRAP of *M. odorata* peel and seed kernel powder were determined according to the method of Lim *et al*. (2006) with slight modifications. The analysis was carried out by adding 2.5 mL of 0.2 M phosphate buffers (pH 6.6), 2.5 mL of potassium ferricyanide (1%) and 2.5 mL of trichloroacetic acid (10%) into 1 mL of extract. The mixture was infused in soaking water at a temperature of 50°C for 20 mins. Then, 2.5 mL of the mixture was taken and added with 2.5 mL of distilled water and 0.5 mL of 1% ferric chloride ($FeCl_3$). This mixture was kept at room temperature for 30 mins in dark conditions. Antioxidant activity was measured at a wavelength of 700 nm using the UV spectrophotometer (U-2800 Hitachi, Japan). FRAP values were expressed as mg $FeSO_4$ /100 g.

2.6.4 Free radical scavenging activity-DDPH test for EC_{50}

Free radical scavenging activity was determined using spectrophotometric assay according to Lu and Foo (2000) with a slight modification. 2,2-diphenyl-1-picrylhydrazyl (DPPH) was used as a reagent. About 100 µL of the extracts at concentrations ranging from 0.0781 – 5.0 mg/mL was added to 200 µL of 0.007% methanol solution of DPPH. Trolox and ascorbic acid (Vitamin C) were used as positive controls. The absorbance was read against a blank at 517 nm using a microplate reader (BIOTEK GEN5 EON Microplate Spectrophotometer, Winooski, Vermont, USA) after 40 mins of incubation period in a dark environment at room temperature. The

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percentage of the inhibition of free radical DPPH by the extracts was calculated as follows:

$$\text{Inhibition (\%)} = (A_{blank} - As_{ample}/A_{blank}) \times 100$$

Where A_{blank} is the absorbance of the control reaction (containing all reagents except the test compound), and A_{sample} is the absorbance of the test compound. Inhibition (%) was plotted against concentration and the EC_{50} was calculated graphically.

2.7 Statistical analysis

All experimental data were analysed using ANOVA and Tukey's test by MINITAB version 16 Sub100 (USA) software. A *p*-level <0.05 was used where values were described as being significant.

3. Results and discussion

3.1 Effect on proximate and dietary fibre

The proximate composition which consists of moisture, ash, fat, carbohydrate, protein and dietary fibre (soluble and insoluble) of *M. odorata* peel and seed kernel powder are depicted in Table 1. The peel powder presented higher moisture content (7.39 to 9.70%) compared with seed kernel powder (3.77 to 6.09%). Although the moisture content of samples was monitored to be <5% before cooling and grinding, the moisture content was found to increase after grinding into powder. This might be due to the increment of the surface area of samples particle size in a form of powder which has a smaller particle size (Tun Norbrillinda *et al*., 2020). Since the moisture content of the peel and seed kernel powder produced was <10%, we may conclude that the powder is chemically and microbiologically stable (Mercer, 2008). Hence, the powders might have longer shelf life due to low water activity which implies that there is less free water available for biochemical reactions (Tun Norbrillinda *et al*., 2020).

Steaming and blanching pretreatments were observed to have a significant effect (p<0.05) on the ash and carbohydrate content of the peel powder. The ash content of the peel powder had significantly decreased when samples underwent pretreatments. This result showed that steaming and blanching before drying might lower the ash content of the peel powder. Results suggested that steamed samples had better retention of the ash content than the blanched samples (lowest value) due to the leaching during the blanching process. Results from Table 1 showed that the fruit peel's ash content was higher than the seed kernel, suggesting that the *M. odorata* peel powder might be rich in mineral content than that of the seed kernel powder. These results were in line with a study of mango peel and seed kernel powder, which reported the ash content in the peel powder was higher than the seed kernel powder (Ashoush and Gadallah, 2011). Unexpectedly, the peel powder was observed to have higher carbohydrate content than the seed kernel powder, which the blanched sample was the highest. The carbohydrate content of the peel and seed kernel powders in this study was found to be higher than that reported by Lasano, Hamid, Karim *et al.* (2019) with freeze-dried *M. odorata* peel and seed kernel (22-43%). It could be concluded that the variation of the carbohydrate values might be due to the differences in the drying method, pretreatments and origin.

There were no differences (p>0.05) found in ash, CHO, and energy content of seed kernel powder between pretreated and control. Hence, it implies that this part of *M. odorata* fruits was highly stable to heat. However, the protein content of seed kernel powder showed a reduction in the blanched sample. Protein is a soluble nutrient substance, and therefore, the considerable loss of protein by dissolving or leaching into blanching water might occur, resulting in the decrement (Mukherjee and Chattopadhyay, 2007; Garba *et al*., 2015). The protein content of *M. odorata* peel powder was similar to previous reports on *M. pajang* (Hassan *et al*., 2011) and *M. indica* peels (Larrauri *et al*., 1996; Vergara-Valencia *et al*., 2007; Ajila *et al*., 2008). Fats are a concentrated source of energy, and they supply more than twice as many calories per gram, that is, 9 kcal/g (27.7 kJ/g) compared with proteins and carbohydrates (Eze *et al*., 2014). In this study, the fat content in peel and seed kernel powders was not significantly (p>0.05) affected by pretreatments, suggesting that the nutrient is heat stable. The seed kernel powder also presented the highest fat content with approximately 86.7-92.6% higher than the peel powder. Lasano, Hamid, Karim *et al*. (2019) also reported the same pattern, where the freeze-dried peel powder's fat content was lower than the seed kernel powder. It was observed that the fat content in both samples of peel and seed kernel in this study was higher than reported by Lasano, Hamid, Karim *et al*. (2019). Besides, the fat content of the *M. odorata* seed kernel powder in this study was higher than other dried samples such as *L. fruiticosa*, plantain, *Nypa fructicans* and *L. alata* (Onwuka and Onwuka, 2005; Ping *et al.*, 2013; Zhang *et al*., 2019; Tun Norbrillinda *et al*., 2020). Table 1 also showed that steaming and blanching increased the calorie of the peel powder (p<0.05) while the pretreatments significantly decreased the calorie of the seed kernel powder samples. Therefore, we may conclude that steaming and blanching might enhance the calorie of the *M. odorata* peel powder. Fresh fruits and vegetables contain high water content and fibre, and very low levels of fat which are <0.5%, thus having low

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calories and energy density (Chen *et al*., 2016). Subsequently, this study observed that the seed kernel powder had higher calories than the peel powder, which was associated with low moisture content and a high amount of energy-yielding nutrients consisting of fat and protein content (Lasano, Hamid, Karim *et al*., 2019). Lasano, Hamid, Karim *et al*. (2019) supported the results, which suggested the seed kernel could be an important source of energy and essential nutrients.

The total dietary fibre of *M. odorata* peel powder ranged from 42 to 58% (Table 1). The values were in a range as reported by Lasano, Hamid, Karim *et al.* (2019) in freeze-dried *M. odorata* peel powder (50.94%). The total dietary fibre of *M. odorata* peel powder found in this study was similar with *L. alata* (58-59%) (Zhang *et al*., 2019), but higher than the ripe apples (2.21%) (Li *et al*., 2002), wheat flours and whole grain cereals (3.65-24.63%) (Ragaee *et al*., 2006). Both pretreatments could lower the total dietary fibre in the peel powder, whereas increased the content in the kernel seed powder. Total dietary fibre in the peel powder showed that the values were 22-77% higher than the seed kernel powder (13 to 34%), which might be due to the content of soluble dietary fibre which was only found in the peel. The results are consistent with previous studies conducted by Lasano, Hamid, Karim *et al*. (2019), who reported that the soluble dietary fibre was only detected in the freeze-dried *M. odorata* peel powder. Research on mango also reported a similar trend, which found a high amount of total dietary fibres in mango peel and a very low amount of crude fibre in the mango seed kernel powder (Al-Farsi and Chang, 2008; Ajila *et al*., 2008; Ashoush and Gadallah, 2011). The values of total dietary fibre in the seed kernel powder obtained in this study were within the range reported by Lasano, Hamid, Karim *et al.* (2019). Furthermore, the values were also higher than that reported in the avocado seed and mango seed kernel powder (Ashoush and Gadallah, 2011; Morais *et al*., 2017).

3.2 Effect on vitamin A and C

Vitamin A and C are naturally occurring organic compounds with antioxidant properties found in plants. Results of vitamin A and C in *M. odorata* peel and seed kernel powder were shown in Table 1. It was found that both vitamin A and C were only traced in the fruit's peel. Vitamin A is soluble in oils and fats, not easily destroyed by heat but is readily oxidized where it is unaltered at moderate temperatures in the absence of air (ŠeregeIj *et al.,* 2020). The values of total vitamin A were between 12.69 to 20.75 µg/100 g. We may conclude that the pretreatment might enhance the vitamin A content as powder samples' total vitamin A activity increased about 61-64% (Table 1). This result might be due to the inactivation of peroxidase and lipoxidase activity (Lavelli *et al.,* 2007). Previous studies on carrots (Lavelli *et al.,* 2007), confirmed the effect of heat on the vitamin A content of many fruits and vegetables, where vitamin A was found to increase when subjected to thermal treatment.

The vitamin C content of *M. odorata* peel powder was between 168.51 to 296.94 mg/100 g. Both pretreatments resulted in the losses of about 42 to 43% of vitamin C compared with non-blanched samples (control). Garba and Kaur (2014) mentioned that vitamin C is a potent water-soluble antioxidant and prone to degradation due to heating, leaching and enzyme interaction. Since steaming and blanching involved

Table 1. Nutrient composition of peel and seed kernel powders of *Mangifera odorata* L.

Nutrient composition	Peel			Kernel		
	Control	Steam	Blanch	Control	Steam	Blanch
Energy (kcal/100 g)	381.71 ± 0.71^{dB}	388.67 ± 0.71^{cA}	389.79 ± 1.42^{cA}	428.14 ± 2.84^{aA}	424.32 ± 0.71^{abA}	420.29 ± 2.83^{bA}
Fat (g/100 g)	1.06 ± 0.30^{bA}	1.45 ± 0.05^{bA}	1.18 ± 0.09^{bA}	7.97 ± 0.35^{aA}	7.28 ± 0.33^{aA}	6.63 ± 0.55^{aA}
Protein (g/100 g)	4.07 ± 0.02^{cA}	4.23 ± 0.00^{cA}	4.20 ± 0.10^{cA}	5.17 ± 0.02^{aA}	5.21 ± 0.04^{aA}	4.90 ± 0.04^{bB}
Moisture (g/100 g)	7.39 ± 0.10^{bB}	8.02 ± 0.03^{bB}	9.70 ± 0.45^{aA}	3.77 ± 0.37^{dB}	6.09 ± 0.09^{cA}	5.78 ± 0.18^{cA}
Ash (g/100 g)	5.87 ± 0.18^{aA}	4.65 ± 0.01^{bB}	4.04 ± 0.06^{cC}	$2.89\pm0.11d^{dA}$	$2.98\pm0.13d^{dA}$	3.14 ± 0.20^{dA}
Carbohydrate (g/100 g)	89.00 ± 0.41^{bB}	89.67 ± 0.06^{abAB}	90.59 ± 0.70^{aA}	83.97 ± 0.06^{cA}	84.47 ± 0.40^{cA}	85.33 ± 0.50^{cA}
Soluble dietary fibre (g/100 g)	18.03 ± 1.51^{aA}	19.25 ± 1.28^{aA}	16.08 ± 2.01^{aA}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
Total dietary fibre (g/100 g)	58.47 ± 2.37^{aA}	47.41 ± 1.89^{bB}	42.89 ± 2.16^{bB}	13.52 ± 1.33^{e}	24.99 ± 2.02^{d}	33.59 ± 1.23^{c}
Insoluble Dietary fibre (g/100 g)	40.44 ± 0.86^{aA}	28.16 ± 0.61^{cB}	26.80 ± 0.15^{cdB}	13.52 ± 1.33^{e}	22.71 ± 1.47^{d}	33.59 ± 1.23^{b}
Total vitamin A activity (µg/100 g)	12.69 ± 0.59^{bB}	20.43 ± 0.03^{aA}	20.75 ± 2.10^{aA}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
Vitamin C (Ascorbic acid) (mg/100 g)	296.94 ± 7.08^{aA}	168.51 ± 7.07^{bA}	171.64 ± 7.10^{bB}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}

Values are presented as mean±standard deviation, n = 3. Values with the different uppercase superscripts within the same sample are significantly different by Tukey test at 5% while values with different lowercase superscripts within the different sample are significantly different by Tukey test at 5%.

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heating, it is suggested that vitamin C in the sample was degraded due to the high temperature. The result was consistent with the finding reported for broccoli, dried dill, Brussels sprouts, sweet pepper and carrots (Lin *et al*., 1998; Martinez *et al*., 2005; Viňa *et al*., 2007; Galoburda *et al*., 2012; Severini *et al*., 2016). However, some studies also reported the increment of vitamin C content when blanching such as in *L. fruticosa* whole fruit powder, black carrot, sweet pepper and dried dill (Martinez *et al*., 2005; Galoburda *et al*., 2012; Garba and Kaur, 2014; Tun Norbrillinda *et al*., 2020). According to Galoburda *et al*. (2012), blanching conditions are very important to achieve less loss in the nutrient content, such as blanching temperature and time.

3.3 Effect on fatty acid

The fatty acid constituents were only found in the seed kernel powder, which might probably be due to the value of fatty acids that exist in the peel powder being too low and cannot be detected. The peel powder had a 7.4-13.3% lower fat content than that of the seed kernel powder. The fatty acids profile of *M. odorata* seed kernel powder is shown in Table 2. Stearic acid (C18:0) and cis -oleic acid (C18:1N9C) are the dominant fatty acids in the *M. odorata* seed kernel powder with values ranging from 2.24 to 2.93 g/100 g and 2.55 to 3.06 g/100 g, respectively. Previous studies on mango also reported that these two constituents are the main fatty acids (Abdalla *et al*., 2007; Sonwai *et al*., 2007; Muchiri *et al*., 2012; Jahurul *et al*., 2014). Stearic acid is categorized as saturated fatty acid and cis-oleic acid is a monounsaturated fatty acid. Unsaturated fatty acids, particularly the essential omega-3 and omega-6, are essential for human health (Coimbra and Jorge, 2012). According to Mooz *et al*. (2012), oleic acid reduces the levels of total cholesterol, low-density lipoproteins (LDL), triglycerides, and high-density lipoproteins (HDL). Other types of fatty acids which include lauric, myristic, palmitic, linoleic, linolenic, methyl linolenate, caprylic acid methyl ester and capric acid were considered minor fatty acids which only represent <1 g/100 g. Steaming and blanching had shown no significant effect (p>0.05) on fatty acids, regardless stearic acid and methyl linolenate (p<0.05). Blanching had been shown to decrease the content of stearic acid (24%) and methyl linolenate (38%). Meanwhile, steaming showed better retention to preserve the seed kernel powder's stearic acid and methyl linolenate content. The loss might be due to the deterioration of the plant tissues during blanching (Zhuang *et al*., 1997). Murcia *et al*. (1999) also reported the degradation of fatty acid compounds during blanching for broccoli.

3.4 Effect on antioxidant properties

3.4.1 Total Phenolic Content analysis

The TPC levels ranged from 7 – 9 and 16 - 25 mg GAE/100 g for the peel and seed kernel powder, respectively (Figure 1). Steaming and blanching were found to have a significant effect (p<0.05) on the phenolic content of the peel and seed kernel powders. Reductions in TPC were rather similar in both parts of the fruit. In both parts of the fruits, the percentage reduction of phenolic content in steaming was 33-34% and blanching, 21%. From the results, blanching had shown better retention of phenolic content compared with steaming. The seed kernel powder was found to have 64% higher TPC than that in the peel powder. The same trend was also found in a previous study, where the TPC values were higher in the seed kernel powder than the peel powder (Lasano, Ramli, Hamid *et al*., 2019; Ismail *et al*., 2019). Studies on bambangan (*M. pajang*) and mango (*M. indica*) also found that the TPC was higher in the seed kernel compared with the peel powder (Ribeiro *et al*., 2008; Ashoush and Gadallah, 2011; Ismail *et al*., 2019). According to Ismail *et al*. (2019), the phenolic content of seed kernel would protect the seed

Table 2. Fatty acid profile for kernel powder of *Mangifera odorata* L.

Fatty acid	Control	Steam	Blanch
Lauric acid (C12:0) (mg/100 g)	110.0±40.0^{a}	100.0±20.0^{a}	130.0±0.0^{a}
Myristic acid (C14:0) (mg/100 g)	60.0±20.00^{a}	50.0±10.0^{a}	60.0±10.0^{a}
Palmitic acid (C16:0) (mg/100 g)	840.0±90.0^{a}	750.0±10.0^{a}	650.0±60.0^{a}
Stearic acid (C18:0) (mg/100 g)	2930.0±10.0^{a}	2710.0±80.0^{ab}	2240.0±170.0^{b}
Cis-oleic acid (C18:1N9C) (mg/100 g)	3060.0±100.0^{a}	2770.0±190.0^{a}	2550.0±260.0^{a}
trans-oleic acid (C18:1N9C) (mg/100 g)	100.0±30.0^{a}	190±50.0^{a}	390.0±10.0^{a}
Linoleic acid (C18:3N3) (mg/100 g)	630.0±30.0^{a}	520.0±110.0^{a}	440.0±60.0^{a}
Linolenic acid (C18:3N3) (mg/100 g)	70.0±10.0^{a}	50.0±10.0^{a}	50.0±20.0^{a}
Methyl linolenate (C18:3N6) (mg/100 g)	130.0±10.0^{a}	110.0±10.0^{a}	80.0±0.0^{b}
Caprylic acid methyl ester (C8:0) (mg/100 g)	20.0±10.0^{a}	30.0±10.0^{a}	30.0±10.0^{a}
Capric acid (C10:0) (mg/100 g)	10.0±0.0^{a}	10.0±0.0^{a}	20.0±10.0^{a}

Values are presented as mean ± standard deviation, n = 3. Values with different superscript within the same column are significantly different by Tukey test at 5% probability.

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kernel from damage caused by the oxidative process of oxygen molecules, which is essential for seed germination. High phenolic acid such as gallic acid, ferulic acid, ellagic acid and mangiferin, contribute to most phenolic content in mangoes and longan seeds (Soong and Barlow, 2004). Previous studies reported that *Mangifera* species such as *M. odorata* and *M. indica* had high mangiferin content (Dorta *et al*., 2014; Asif *et al*., 2016; López-Cobo *et al*., 2017; Lasano, Ramli, Hamid *et al*., 2019). Hence, the mangiferin compound might contribute the phenolic content of the peel and seed kernel powder.

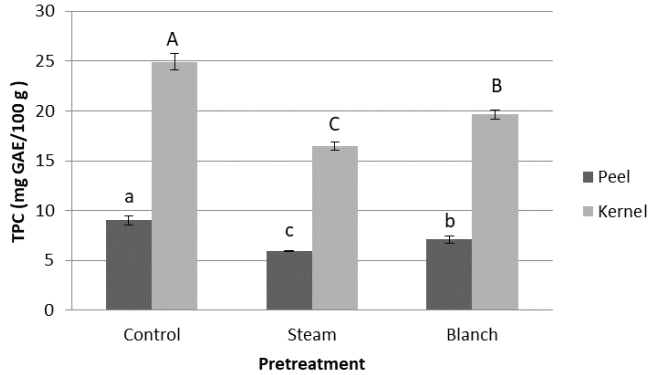

Figure 1. Total phenolic content of *M. odorata* peel and seed kernel powder. Values are presented as mean±standard deviation, n = 3. Bars with different notations are significantly different by Tukey test at 5% probability.

3.4.2 Ferric reducing antioxidant power assay

Ferric reducing antioxidant power assay (FRAP) is a method that focused on the antioxidant compounds acting as reducing agents donating a hydrogen atom to the ferric complex and causes the radical chain reaction to break down (Halliwell, 1991). Figure 2 shows the findings, which were expressed as mg $FeSO_4$/100 g. It was observed that there were significant (p<0.05) reductions in FRAP in the steamed peel powder with a 24% reduction, but the reduction in blanched peel powder was not significant (p>0.05). Thus, the effects of pretreatments were most severe for steaming and less for blanching. Previous studies done by Puupponen-Pimiä *et al*. (2003) found that blanching increased FRAP value by 9% for cabbage but reduced the antioxidant capacity by 23% for cauliflower. Meanwhile, no significant (p>0.05) effect was observed in the seed kernel powder for treated samples with values ranging from 29 to 36 mg $FeSO_4$/100 g. It was discovered that seed kernel powder has a stronger antioxidant potential with 82-87% higher than the peel powder. The effectiveness of reducing the capacity of Fe^{3+} ion by phenolic is related to hydroxylation and polyphenol conjugate bonding (Pulido *et al*., 2000). Hence, the higher levels for FRAP found in the seed kernel powder than that of the peel powder are likely a reflection of higher levels of TPC, which contributed to the antioxidant properties. The present study is in accordance with the study on 22 different vegetables by Wu *et al*. (2004) and Volden *et al*. (2009) who found a strong correlation between TPC and antioxidant capacity. The values of FRAP in blanched peel powder showed a pattern similar to the changes in TPC.

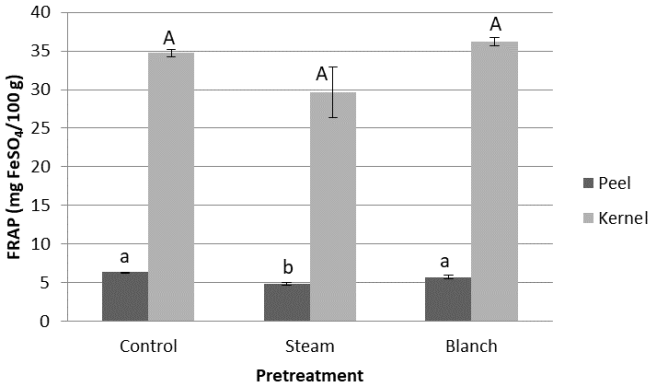

Figure 2. Ferric reducing antioxidant power of *M. odorata* peel and seed kernel powder. Values are presented as mean ± standard deviation, n = 3. Values with different superscript within the same column are significantly different by Tukey test at 5% probability.

3.4.3 Free radical scavenging activity - DDPH test for EC_{50}

The antioxidant properties assayed herein were summarized in Table 3 and the results were normalized and expressed as EC_{50} values (mg/mL). The antiradical activity is inversely proportional to the EC_{50} value. As a result, extracts with a strong scavenging capability for free radicals have a low EC_{50} value. All samples which include non-pretreatment samples showed the value of EC_{50} below 1 mg/mL, indicating that the samples have effective antioxidant activity (Lee *et al*., 2007). The seed kernel powder has 92-94% stronger antioxidant potential than the peel powder. These values are supported by Lasano, Ramli, Hamid *et al.* (2019) which reported values of 0.2862 - 0.5540 in the freeze-dried peel powder and 0.0206 – 0.0409 in the freeze-dried seed kernel powder. EC_{50} values of *M. odorata* seed kernel powder found in this study were very low (0.028 – 0.038) than *L. fruticosa* whole fruit powder (0.43-1.05) and *Hypsizigus marmoreus* mushroom ethanolic and hot water extract (2.85-18.85) (Lee *et al*., 2008; Tun Norbrillinda *et al*., 2020). Hence, the results showed that the *M. odorata* seed kernel powder had a high potential to be developed as a high antioxidant functional ingredient. According to Ashoush and Gadallah (2011), the higher the phenolic content, the more scavenging activity. Findings of free radical scavenging activity in mango peel powder and seed kernel powder also showed the same pattern (Ribeiro *et al*., 2008; Ashoush and Gadallah, 2011).

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Table 3. Antioxidant properties (EC_{50}) of *Mangifera odorata* peel and seed kernel powders

Sample	EC_{50} (mg/mL)
Control peel	0.476±0.014[c]
Steam peel	0.493±0.006[c]
Blanch peel	0.654±0.011[d]
Control seed kernel	0.028±0.001[a]
Steam seed kernel	0.038±0.001[b]
Blanch seed kernel	0.038±0.001[b]
Vitamin $C_{Positive\ control}$	0.0012±0.0001
$Trolox_{Positive\ control}$	0.0130±0.0010

Values are presented as mean ± standard deviation, n = 3. Values with different superscript within the same column are significantly different by Tukey test at 5% probability.

4. Conclusion

In conclusion, steaming and blanching affected most of the parameters investigated in *M. odorata* peel powder by significant losses from the peel to the treatment waters. However, steaming or blanching might also enhance the peel powder's carbohydrate, calorie and vitamin A activity. Antioxidant analyses showed that *M. odorata* seed kernel powder exhibited the best antioxidant activity with high values of TPC and FRAP and a lower value of EC_{50}. Therefore, agro-industrial *M. odorata* fruit wastes can be considered as a potential functional ingredients source of natural origin. The study offers a better understanding of the functional potential of these fruit species, which is important for potential product developments in the future. Furthermore, all this information is important to help wild and neglected species be valued for better nutritional status especially for farmers and health products entrepreneurs.

Conflict of interest

The authors declare no conflict of interest.

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