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FULL PAPER

Effects of cooking methods on physicochemical properties, antioxidant properties and sensory acceptability of purple sweet potato (*Ipomoea batatas*)

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Abstract

Purple sweet potato is commonly cooked by boiling, steaming, baking and microwaving. However, information on the effects of cooking methods on the physicochemical properties, antioxidants properties and sensory acceptability is limited. In this study, the effect of cooking methods (boiling, steaming, baking and microwaving) on the physicochemical properties, antioxidant properties and sensory acceptability of purple sweet potato were investigated. The results showed that the boiled sample was the softest (hardness of 933.39 g) and also had the highest total colour difference (18.56), while the steamed sample was the most adhesive (-92.35 g.s) and least cohesive (0.41). An increased moisture content caused a decrease in other proximate compositions in the samples. The baked sample had the highest antioxidant properties, with 232.20 mg GAE/100 g of total phenolic content, 2.05 mg cyaniding-3-glucoside/L of total anthocyanins, 61.95% of DPPH and 79.20% of ABTS radical-scavenging activity. The steamed sample was rated most acceptable by the panellists.

1. Introduction

Sweet potato (*Ipomoea batatas*) is a widely consumed tuber. It is originally from Central America and is now cultivated by many other countries in the world (Adepoju and Adejumo 2015). According to Alam *et al.* (2016), the sweet potato is a primary food crop for tropical and subtropical areas. Tang *et al.* (2015) reported that white-, yellow-, orange- and purple-coloured sweet potatoes could be commonly found in the market. Each has a unique chemical and nutritional composition. Sweet potato is a highly nutritive crop because it is rich in carbohydrates, fibre, minerals and phytochemical compounds such as phenolics and anthocyanins (Dincer *et al.*, 2011; Xu *et al.*, 2016). Phenolic is a natural antioxidant that contributed to sweet potato's main antioxidant properties (Donado-Pestana *et al.*, 2012). Anthocyanin is a natural purple pigment that also acts as an antioxidant in the purple sweet potato (Lee *et al.*, 2005). According to Hong and Koh (2015), purple sweet potato has a reddish-purple colour due to the high level of anthocyanins in its tissues and skins.

The most common and popular cooking methods used in cooking sweet potatoes are boiling, steaming, baking and microwaving (Xu *et al.*, 2016; Shariff *et al.*, 2017). According to Tian *et al*. (2016), different cooking methods will have different effects on the physicochemical and antioxidant properties of food. Furthermore, Adepoju and Adejumo (2015) reported that cooking may either be beneficial or detrimental to the nutritional composition. The cooking process can be beneficial to human health by improving organoleptic qualities and increasing the bioavailability of nutrients. For example, cooking can increase the antioxidant properties of the sweet potato, such as its total phenolic content, anthocyanins and antioxidant activities (Dincer *et al.*, 2011; Xu *et al.*, 2016). Cooking is also good for destroying the toxins, microorganisms and anti-nutritional factors in food. Moreover, cooking can increase digestibility. On the other hand, cooking will also have some negative effects on the chemical compositions of the food, such as micronutrient loss (Boekel *et al.*, 2010; Adepoju and Adejumo, 2015), and may result in the impairment of some functional compounds of sweet potato (Tang *et al.*, 2015; Lončarić *et al.*, 2016).

Although sweet potato is commonly consumed after cooking, most previous studies have only focused on the composition of macronutrients and micronutrients in a

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raw sweet potato (Sharrif *et al.*, 2017). There is limited information on the effects of different cooking methods on the physicochemical properties, antioxidant properties and sensory acceptability of cooked purple sweet potato. Many people are consuming purple sweet potato without knowing the quality changes after cooking using different cooking methods.

Cooking will also affect the sensory qualities of food products (Schnepf and Driskell, 1993). Sensory evaluation is important in determining the most acceptable cooking method based on the overall acceptability of consumers. The different sensory attributes are also important in determining the sensory acceptability of consumers. Good taste, cooking quality and flesh colour are the major characteristics of consumer acceptability. The sensory acceptability of consumers to the cooked purple sweet potato is a major concern because most consumers make good products their priority in choosing a food product. The sensory perception of consumers is a good indicator to determine the most acceptable cooking method to be used (Leksrisompong *et al.*, 2012).

The objectives of the present study are to determine the effect of different cooking methods on the physicochemical properties, antioxidant properties and sensory acceptability of purple sweet potato. This information can be used as a guideline in selecting a good cooking method and obtaining optimum nutrients from purple sweet potato. In addition, information on consumer acceptability of the purple sweet potato cooked by different cooking methods can contribute to the food industry in marketing the purple sweet potato, as well as increasing purple sweet potato consumption among the public due to its high nutritional contents.

2. Material and methods

2.1 Sample preparation

Approximately 40 kg of freshly harvested purple sweet potatoes (*Ipomoea batatas*) with an average size of 10×4×3.5 cm and weight of 130 – 140 g were purchased from Kampung Raja, Besut, Terengganu, Malaysia. The whole purple sweet potato tubers were washed and cleaned with tap water to remove dirt and dust without peeling off the skins and were subjected to four cooking methods as below.

2.1.1 Boiling

The purple sweet potatoes (6.0 kg) were boiled in 100°C boiling water for 25 mins in a stainless-steel pot according to Padda and Picha (2008) method until they could be pricked easily using a fork.

2.1.2 Steaming

The purple sweet potatoes (6.0 kg) were steamed using a steamer at 96.5°C for 30 mins according to a modified Tang *et al.* (2015) method until they could be pricked easily using a fork.

2.1.3 Baking

The purple sweet potatoes (6.0 kg) were wrapped with aluminium foil and baked in a convection combi oven (Jackie, Singapore) at 190°C for 30 mins according to a modified Padda and Picha (2008) method until they could be pricked easily using a fork.

2.1.4 Microwaving

The purple sweet potatoes (6.0 kg) were cooked in the microwave oven (Panasonic, Malaysia) of 1000 W for 8 mins according to a modified Padda and Picha (2008) method until they could be pricked easily using a fork.

2.1.5 Raw sample

Raw purple sweet potatoes were used as a control and analysed for all parameters except for sensory evaluation.

2.2 Texture profile analysis

Texture profile analysis (TPA) was performed on all samples at room temperature (28°C) using a TA.XT2 Texture Analyser (Stable Micro System, United Kingdom) according to a modified Chiavaro *et al.* (2006) method. The purple sweet potatoes were cut into cubes with equal sizes of 1.5 × 1.5 × 1.5 cm. Texture analysis was carried out to a 20% compression level and 20% strain with 36 mm a cylinder probe (P/36) and a 30 kg load cell. The data were analysed using the equipped software. The raw and cooked samples were analysed for their hardness, adhesiveness and cohesiveness.

2.3 Colour analysis

The colour attributes of samples were measured by Tristimulus colorimeter (Minolta. Co. Ltd, Japan) according to the modified Wang *et al.* (2011) method. The colour was expressed in Hunter values (L*, a*, b*), and the total colour difference (ΔE) was defined using the following equation:

$$\Delta E = [(L^*-L_0^*)+(a^*-a_0^*)+(b^*-b_0^*)^2]^{½}$$

Where L*, a*, and b* are the measured values of each of the cooked purple sweet potato, and L_0*, a_0* and b_0*are the values of the raw purple sweet potato.

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2.4 Proximate analysis

Proximate analysis of raw and cooked purple sweet potatoes was carried out according to AOAC (2005) methods. Moisture content was determined by heating the samples at 105°C in an oven (Chemopharm, Malaysia) overnight. Determination of ash was carried out by heating the samples at 550°C using a muffle furnace (Carbolite, Malaysia) overnight. Analysis of fat content was conducted using Labtec ST310 (Foss, Malaysia) with petroleum ether (Emsure, Germany) as an extraction solvent. Protein content was analysed using the Kjeldahl method with the Turbotherm digestion unit (Gerhardt, Malaysia) with a protein conversion factor of 6.25. Fibre content was measured using the Gerhardt Fibrebag method.

2.5 Antioxidant analysis

2.5.1 Antioxidant extraction

Extraction of the sample was carried out according to modified Lyimo *et al.* (2010) and Dincer *et al.* (2011) methods. The samples were chopped into small pieces and dried in a convection oven (Roller Grill, United Kingdom) at 40°C. The dried samples were ground into powder. The purple sweet potato powder (1 g) of each treatment was placed into a 50 mL centrifuge tube and mixed with 20 mL of aqueous methanol solution (80%; Emsure, Germany) The tubes were heated in a water bath (Memmert, Germany) at 80°C for 10 mins. After that, the tubes were shaken manually for 30 s, cooled to room temperature, and centrifuged using a high-speed centrifuge (HermLe, USA) at 6040 *g*, 4°C for 20 mins. Then, the supernatants were filtered using filter paper and transferred into a 25 mL volumetric flask and made up the volume to 25 mL with methanol (Emsure, Germany) solution. The methanol in the supernatants was evaporated using a rotary evaporator (Wilmad-LabGlass, USA) at 60°C for 3 mins. The extracts were used for total phenolic content, total anthocyanins, DPPH, and ABTS analyses.

2.5.2 Total phenolic content

Total phenolic content (TPC) levels of all samples were measured according to a modified Steed and Truong (2008) method. Each of the purple sweet potato extract solutions (0.25 mL) and standard solutions were mixed with 4 mL of distilled water and 0.5 mL Folin-Ciocalteu reagent (R&M Chemical, Malaysia) for incubation at room temperature for 3 mins. After that, 0.5 mL of 1 N sodium carbonate (Bendosen, Malaysia) solution was added and the mixture was incubated for 1 hr. The absorbance of the samples was measured at 725 nm using a UV/Vis spectrophotometer (Shimadzu, Japan). Distilled water (0.25 mL) was used as a blank and mixed with the same amount of distilled water for dilution, and a Folin Ciocalteu reagent and sodium carbonate solution. Gallic acid was used as standard (0 to 250 ppm). The TPC (mg GAE/100 g) was calculated through a linear regression equation obtained from the gallic acid standard calibration curve.

2.5.3 Total anthocyanins

Total anthocyanins in purple sweet potato extracts were measured according to Lee *et al.* (2005) method. The extract was diluted with a pH 1.0 buffer until the absorbance at 520 nm is within the linear range of the spectrophotometer (0.2 – 1.4 Abs). The dilution ratio was 1:4 (10 mL of extract and 40 mL of buffer solution) and two dilutions of the extract were prepared using the dilution factor of ¼, one with pH 1.0 buffer and the other with pH 4.5 buffer. The absorbance of extracts diluted with pH 1.0 buffer and pH 4.5 buffer were determined at both 520 nm and 700 nm using UV/Vis spectrophotometer (Shimadzu, Japan). The absorbance of extract within 20 – 50 mins of preparation was measured. Anthocyanins content was calculated and expressed in mg cyaniding-3-glucoside/L using the following equation:

$$\text{Anthocyanins} = \frac{A \times MW \times DF \times 1000}{\varepsilon \times l}$$

Where $A = (A_{520\,nm} - A_{700\,nm})$pH 1.0 $- (A_{520\,nm} - A_{700\,nm})$ pH 4.5, MW = molecular weight of cyanidin-3-glucoside chloride ($C_{21}H_{21}ClO_{11}$), DF = dilution factor (¼), Ɛ = molar absorptivity (26,900) and l = pathlength (cm)

2.5.4 DPPH radical scavenging activity

DPPH radical scavenging activity analysis was conducted according to Dincer *et al.* (2011) and Xu *et al.* (2016) methods. The purple sweet potato extract (100 µL) was mixed with 4 mL of freshly prepared DPPH (Sigma-Aldrich, Germany) solution (6×10^{-5} M in methanol) and incubated in dark condition at room temperature for 30 mins. The absorbance was read at 516 nm using a UV/Vis spectrophotometer (Shimadzu, Japan). Methanol with the same amount of DPPH solution was used as blank. The inhibition percentage of the DPPH radical was calculated using the following equation:

$$\text{DPPH Inhibition \%} = \frac{Ab - As}{Ab} \times 100$$

Where Ab = Absorbance of the blank sample and As = Absorbance of sample

2.5.5 ABTS radical scavenging activity

ABTS radical scavenging activity analysis was conducted according to Bellail *et al.* (2012) and Xu *et al.* (2016) methods. The ABTS solution was prepared by

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mixing 8 mM of ABTS with 3 mM potassium persulphate in 25 mL of distilled water. The ABTS solution was held in darkness at room temperature for 16 h before use. Then, the $ABTS^{\bullet+}$ solution was diluted with 80% methanol to obtain an absorbance between 0.8 – 0.9 at 734 nm using a UV/Vis spectrophotometer (Shimadzu, Japan). One hundred (100) µL of purple sweet potato extract was mixed with 1.9 mL of diluted $ABTS^{\bullet+}$ solution. The absorbance of blank (methanol) with the same amount of $ABTS^{\bullet+}$ solution and extract at 734 nm was read after 7 mins using a UV/Vis spectrophotometer (Shimadzu UV-1601, Japan). The inhibition percentage of the ABTS radical was calculated using the following equation:

$$\text{ABTS Inhibition \%} = \frac{\text{Ab} - \text{As}}{\text{Ab}} \times 100$$

Where Ab = Absorbance of a blank sample and As = Absorbance of sample

2.6 Sensory evaluation

Sensory evaluation of cooked purple sweet potato was carried out according to a modified Gilsenan *et al.* (2010) and Bolade *et al.* (2017) methods. The cooked purple sweet potatoes from different cooking methods were evaluated for their sensory qualities. The acceptance test was used to determine which of the cooked sample is most acceptable. The cooked purple sweet potatoes were rated by 35 panellists. Each panellist was asked to rate the samples based on colour, texture, odour, taste and overall acceptability using a seven-point hedonic scale (7 = extremely like; 4 = neither like nor dislike; 1 = extremely dislike).

2.7 Statistical analysis

All analyses were carried out in triplicate and data were presented as mean ± standard deviation. Statistical analysis was performed using IBM SPSS Version 20.0 (SPSS Inc., USA). One-way analysis of variance (ANOVA) and Tukey's Multiple Comparison Test was conducted for significant difference ($p<0.05$) determination between the treatments.

3. Results and discussion

3.1 Texture profile

An overall texture profile of raw and cooked purple sweet potatoes is shown in Table 1. The hardness of the raw purple sweet potatoes was significantly different ($p<0.05$) from all cooked purple sweet potatoes. However, there was no significant difference in hardness between cooked samples ($p>0.05$). The hardness of the purple sweet potatoes decreased in the order of raw, baked, microwaved, steamed and boiled samples. The boiled sample had the lowest hardness value among the cooked samples and in accordance with Nicoletto *et al.* (2017), who reported that boiled and steamed samples were softer than the raw sample. According to Nicoletto *et al.* (2017) and Yang *et al.* (2016), the hardness of purple sweet potato after cooking was mainly related to the moisture content. Steaming and boiling contributed to a softer texture due to the sample in contact with water, which leads to higher moisture content and causes the softening of cell tissues. On the other hand, baking and microwaving cooking methods contributed to firmer texture due to the dry heat causing the loss of moisture content, which leads to dehydration in cell tissues (Nicoletto *et al.*, 2017).

Hardness was defined as the peak force of the first compression cycle (Chiavaro *et al.*, 2006). It can also be explained as the force needed to break the food sample with the incisors during mastication (Yang *et al.*, 2016). A lower hardness value indicates the lower sample firmness and the lower force needed to break through the food sample (Chiavaro *et al.*, 2006). In the present study, the boiled purple sweet potato sample had the softest texture and needed the lowest force to be broken by the incisors.

The adhesiveness of the steamed sample in the present study was significantly increased ($p<0.05$) compared to the raw sample. However, there were no significant differences among the raw, boiled, baked and microwaved samples ($p>0.05$). The steamed sample had the highest adhesiveness value among the cooked samples. The findings of the present study are in accordance with García-Segovia *et al.* (2008), who reported that adhesiveness is mainly related to starch gelatinisation which causes an increase in adhesiveness

Table 1. Overall texture profile of raw and cooked purple sweet potatoes

Samples	Hardness (g)	Adhesiveness (g.s)	Cohesiveness
Raw	18938.04±1721.03^{a}	-1.65±0.14^{b}	0.79±0.02^{a}
Boiled	933.39±36.15^{b}	-75.31±52.80^{ab}	0.48±0.05^{b}
Steamed	1041.84±62.92^{b}	-92.35±45.84^{a}	0.41±0.01^{b}
Baked	1134.81±255.80^{b}	-38.53±12.28^{ab}	0.48±0.05^{b}
Microwaved	1100.34±159.40^{b}	-44.79±21.42^{ab}	0.44±0.06^{b}

Values are presented as mean±SD, n = 3. Values with different superscript letters in the same column are significantly different at $p<0.05$.

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after cooking. According to Chen (1990) and García-Segovia *et al.* (2008), adhesiveness is known to be highly related to starch gelatinisation, which occurs when starch granules are heated in the presence of water. The starch granules tend to swell above the gelatinisation temperature. The swollen starch granules will be separated and form a viscous paste that is sticky in texture. The sticky texture will increase the adhesiveness of a food sample.

The boiled and steamed samples were in contact with water during the cooking process. The samples contained higher moisture content which maximised starch gelatinisation and resulted in higher adhesiveness value. In contrast, baking and microwaving lowered the moisture content in the tissues of purple sweet potato, limiting the starch gelatinisation and resulting in a lower adhesiveness value. The steamed sample was the most adhesive and needed the highest force to be removed from the palate and teeth.

There was a significant difference ($p<0.05$) between raw and cooked samples in terms of cohesiveness. The cohesiveness decreased in the order of raw, baked, boiled, microwaved and steamed samples. However, there was no significant difference in cohesiveness between cooked samples ($p>0.05$). The result showed that the steamed sample had the lowest cohesiveness value among the cooked samples. The decrease in cohesiveness after cooking was in accordance with Alvarez and Canet (1998), who found that thermal processing reduces intercellular cohesion. According to Chen (1990), when the viscosity of the swollen starch granules increases during the continuing cooking process, the swollen starch granules are close together and cause movement restriction. The gradual increase in viscosity until they reach their viscosity peak will cause the cohesive force that holds the tissue cells to become extremely weakened and leads to loss of integrity in the starch granules. This was supported by van Marle *et al.* (1992), who reported that the cooking process will break down the pectin, which reduces the intercellular cohesion in the cells. The reduced intercellular cohesion will contribute to a smaller disintegration of the food sample, which decreases the degree to which the sample will deform (Chiavaro *et al.*, 2006; García-Segovia *et al.*, 2008).

A higher starch gelatinisation in boiled and steamed samples contributed to a higher viscosity and lower cohesiveness. This is because viscosity increases as starch gelatinisation increases. The steamed sample in the present study was the least cohesive sample and had the lowest degree to be deformed.

3.2 Colour

Table 2 shows the overall colour profile of the raw and cooked purple sweet potatoes. The lightness (L^*) of the raw was significantly ($p<0.05$) higher than the cooked purple sweet potatoes. The decrease in the lightness of the purple sweet potatoes after cooking was in agreement with previous studies by Hong and Koh (2015) and Yang *et al.* (2016) on purple sweet potatoes and potato tubers, respectively. According to Tang *et al.* (2015), the lower lightness value in the sample indicates a darker colour. In the present study, the lightness decreased in the order of raw, microwaved, baked, steamed and boiled.

The redness of the raw sample was also significantly higher ($p<0.05$) than the cooked samples. However, there was no significant difference between boiled, steamed and baked samples ($p>0.05$). The redness of the samples was in the order of raw, microwaved, baked, steamed and boiled samples. The microwaved sample had the highest redness value compared to other cooked samples. Hong and Koh (2015) reported that the purple pigment of anthocyanins in the sample contributed to the red colour of the purple sweet potato.

The yellowness of the raw sample was also significantly higher than the cooked samples ($p<0.05$). The cooking methods significantly affected ($p<0.05$) the yellowness of the samples. The yellowness order of the purple sweet potato was raw, microwaved, boiled, steamed and baked samples. According to Hong and Koh (2015), the increase in yellowness after cooking was mainly due to the formation of brown colour compounds by the Maillard reaction or reduction in redness during cooking. The total colour difference increased significantly in the order of microwaved, baked, steamed and boiled samples. The result showed that the boiled

Table 2. Overall colour profile of raw and cooked purple sweet potatoes

Samples	Lightness (L*)	Redness (a*)	Yellowness (b*)	Total Colour Difference (ΔE)
Raw	46.14±0.02^{a}	21.57±0.70^{a}	-1.18±0.38^{a}	-
Boiled	33.57±0.81^{e}	9.07±0.49^{c}	-6.67±0.32^{c}	18.56±0.70^{a}
Steamed	37.54±0.21^{d}	9.61±0.24^{c}	-7.80±0.16^{d}	16.16±0.22^{b}
Baked	40.68±0.20^{c}	10.09±0.14^{c}	-8.51±0.13^{e}	14.68±0.44^{c}
Microwaved	43.64±0.07^{b}	11.32±0.16^{b}	-4.89±0.01^{b}	11.19±0.51^{d}

Values are presented as mean±SD, n = 3. Values with different superscript letters in the same column are significantly different at $p<0.05$.

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sample had the highest total colour difference among the cooked samples. Boiling changed the colour of raw purple sweet potato the most.

3.3 Proximate composition

The proximate composition of the raw and cooked purple sweet potatoes is shown in Table 3. The results obtained in the present study were in accordance with Bembem and Sadana (2013) where an increase in moisture content in moist heat cooking methods (boiling and steaming) will decrease the percentage of the other parameters. The moisture contents of both the baked and microwaved samples were significantly lower than the raw sample ($p<0.05$). However, there was no significant difference observed in moisture contents among raw, boiled and steamed samples ($p>0.05$).

The boiled sample had the highest moisture content, whereas microwaved sample had the lowest moisture content. The insignificantly ($p>0.05$) increase in moisture content in boiled and steamed samples was in an agreement with Inocent *et al.* (2011), which is probably due to the samples being cooked in unpeeled form and the skin becoming a barrier for water absorption. The decrease in moisture content in baked and microwaved samples is probably due to the destruction of the cells which causes the removal of moisture content from the hot sample surface (Dincer *et al.*, 2011).

The ash content in the microwave sample was higher (1.46%) and followed by baked (1.35%), raw (0.93%), steamed (0.49%) and boiled (0.45%) samples. The ash content decreased significantly in boiled and steamed samples ($p<0.05$) and was in agreement with Elfaki and Abbsher (2010). The ash content decreased for moist heat cooking methods and increased for dry heat cooking methods, which was in agreement with Bembem and Sadana (2013).

The fat contents in the purple sweet potatoes ranged from 0.10% to 0.25%. The highest fat content was found in the microwaved sample whereas the steamed sample had the lowest crude fat content among the cooked samples. The results for steamed and baked samples in the present study were similar to Shariff *et al.* (2017) who reported that steamed and baked samples contained 0.15% and 0.32% of fat content, respectively. The fat contents decreased significantly in boiled and steamed samples and were in agreement with Elfaki and Abbsher (2010). Meanwhile, the fat contents in samples of the present study increased for dry heat cooking methods and in accordance with Bembem and Sadana (2013) on potato tubers.

The protein content in raw and cooked samples in the present study ranged from 0.52% to 0.93% and was comparable to Adepoju and Adejumo (2015) study where the protein content in their sweet potato ranged from 0.46 to 0.82%. The protein contents in boiled and steamed samples decreased significantly from the raw sample and similar to Elfaki and Abbsher (2010) study on sweet potatoes. The protein content in the purple sweet potato decreased in the moist heat cooking methods and increased in dry heat cooking methods. These findings are in agreement with Bembem and Sadana (2013).

According to BeMiller (2017), fibre is classified as a non-digestible polysaccharide in foodstuffs. The results showed that the fibre contents were significantly different among boiled and microwaved samples ($p<0.05$). However, there was no significant difference in fibre content among raw, steamed and baked samples ($p>0.05$). The microwaved sample had the highest fibre content whereas the boiled sample had the lowest crude fibre content among the cooked samples. The results obtained in the present study were similar to Dincer *et al.* (2011) on sweet potatoes (2.33 – 2.65%). The fibre content in the samples decreased for moist heat cooking methods and increased for dry heat cooking methods, and this was in agreement with Bembem and Sadana (2013).

The carbohydrate content in raw and cooked samples ranged from 21.79% to 25.31%. The results of the present study showed that the carbohydrate contents were significantly different among boiled, baked and microwaved samples ($p<0.05$). However, there was no significant difference observed in carbohydrate contents among raw and steamed samples ($p>0.05$). The results obtained in the present study were comparable with

Table 3. Proximate composition of raw and cooked purple sweet potatoes

Samples	Moisture	Ash	Fat	Protein	Fibre	Carbohydrate
Raw	72.77±1.37^{a}	0.93±0.01^{b}	0.16±0.02^{b}	0.84±0.05^{a}	2.68±0.06^{ab}	22.60±1.46^{ab}
Boiled	74.69±1.29^{a}	0.45±0.01^{c}	0.11±0.02^{bc}	0.52±0.00^{b}	2.43±0.18^{b}	21.79±1.29^{b}
Steamed	73.78±1.42^{a}	0.49±0.01^{c}	0.10±0.02^{c}	0.55±0.05^{b}	2.63±0.22^{ab}	22.45±1.28^{ab}
Baked	69.37±0.50^{b}	1.35±0.05^{a}	0.22±0.03^{a}	0.93±0.10^{a}	2.82±0.14^{ab}	25.31±0.48^{a}
Microwaved	69.16±1.22^{b}	1.46±0.08^{a}	0.25±0.02^{a}	0.87±0.00^{a}	2.98±0.09^{a}	25.28±1.13^{a}

Values are presented as mean±SD, n = 3. Values with different superscript letters in the same column are significantly different at $p<0.05$.

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Adepoju and Adejumo (2015) on sweet potatoes (26.84 – 33.37%). These findings showed that the baked sample had the highest carbohydrate content whereas the boiled sample had the lowest carbohydrate content among the cooked samples. The carbohydrate content decreased in boiled and steamed samples and was in accordance with previous studies on potatoes (Bahado-Singh *et al.*, 2006; Elfaki and Abbsher, 2010; Inocent *et al.*, 2011) due to the leaching of free sugars into the liquid medium during cooking. The increase in carbohydrates in baked and microwaved samples was due to the moisture content being lost during baking which concentrated the free sugars within the samples (Bahado-Singh *et al.*, 2006). The carbohydrate content decreased for moist heat cooking methods while the increased for dry heat cooking methods was in agreement with Bembem and Sadana (2013).

3.4 Antioxidant properties

The total phenolic contents (TPC) in the purple sweet potato in the present study were significantly different among raw samples and all the cooked samples ($p<0.05$; Table 4). The TPC in the raw and cooked sample ranged from 60.77 to 232.20 mg GAE/100 g. The TPC values of the cooked samples were higher than the raw sample and in agreement with Xu *et al.* (2016). Meanwhile, the baked sample had the highest TPC among the cooked samples. The increment of TPC in cooked samples was in agreement with Dincer *et al.* (2011), Bellail *et al.* (2012) and Xu *et al.* (2016) studies. The increase in the TPC was due to phytochemicals released from the matrix of the sample during the cooking process (Xu *et al.*, 2016). In addition, Dincer *et al.* (2011) stated that the increment of TPC was caused by the release of phenolics during the hydrolysis process of glycoside bonds during the cooking process and making them more available in the sample. The cooking process can also damage the sweet potato cell wall, allowing easy liberation of antioxidant components from the sweet potato (Bellail *et al.,* 2012).

Total anthocyanins were significantly different among raw and all the cooked samples ($p<0.05$). The increment in total anthocyanins after cooking was in agreement with Tokusoglu and Yildirim (2012) who reported that the cooking process causes the rupture of sweet potato tissues and thus releases more antioxidant components such as anthocyanins.

The DPPH and ABTS free radical-scavenging activities were also significantly different among raw and all the cooked samples ($p<0.05$). The increments in DPPH and ABTS activities after cooking were in agreement with Xu *et al.* (2016). The DPPH and ABTS activities were highly related to the antioxidant components such as total phenolic content (Bellail *et al.*, 2012) and anthocyanins (Tokusoglu and Yildirim, 2012) in the sample. The highest DPPH and ABTS antioxidant activities were observed in baked purple sweet potato due to its highest levels of phenolics and anthocyanins.

3.5 Sensory evaluation

Table 5 shows the overall sensory evaluation of cooked purple sweet potatoes. There was no significant difference in colour between all samples in the present study ($p>0.05$). In terms of texture, the boiled sample was significantly different from the steamed sample ($p<0.05$). However, there was no significant difference between boiled, baked and microwaved samples ($p>0.05$). The results showed that the texture of the steamed sample was most accepted by the panellists. The results of texture attributes by sensory evaluation were compared to the hardness of the samples measured using the instrumental method. The panellists accepted the hardness with the value of 1041.84±62.92 g from the steamed sample.

The odour attributes were not significantly different among the cooked samples ($p>0.05$). Meanwhile, the taste attributes were significantly different between steamed and microwaved samples ($p<0.05$). However, there were no significant differences in taste among the boiled, baked and microwaved samples ($p>0.05$). The taste of the steamed sample was the most accepted by the panellists. According to Gilsenan *et al.* (2010), the taste of the cooked purple sweet potato is verified as the sweetness and aftertaste obtained after cooking. The results obtained in the present study indicated that most of the panellists liked the sweetness and aftertaste of the

Table 4. Antioxidant properties of raw and cooked purple sweet potatoes

Samples	Total phenolic content	Total anthocyanins	DPPH (%)	ABTS (%)
Raw	60.77±1.09^{e}	0.17±0.10^{d}	42.41±0.07^{e}	66.04±0.37^{e}
Boiled	198.01±1.11^{b}	1.88±0.12^{ab}	53.98±0.32^{b}	73.83±0.27^{b}
Steamed	153.78±1.03^{c}	1.57±0.14^{bc}	51.90±0.54^{c}	72.75±0.28^{c}
Baked	232.20±2.22^{a}	2.05±0.12^{a}	61.95±0.38^{a}	79.20±0.28^{a}
Microwaved	148.80±0.15^{d}	1.49±0.16^{c}	48.73±0.34^{d}	67.74±0.18^{d}

Values are presented as mean±SD, n = 3. Values with different superscript letters in the same column are significantly different at $p<0.05$.

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Table 5. Overall sensory evaluation of cooked purple sweet potatoes

Samples	Colour	Texture	Odour	Taste	Overall acceptability
Boiled	5.71±1.13^{a}	4.77±1.55^{b}	5.23±1.06^{a}	4.91±1.44^{ab}	4.83±1.36^{b}
Steamed	5.40±1.38^{a}	5.69±0.99^{a}	5.34±1.28^{a}	5.63±1.19^{a}	5.66±0.97^{a}
Baked	5.43±1.14^{a}	4.89±1.39^{ab}	5.54±0.98^{a}	5.11±1.32^{ab}	5.14±1.35^{ab}
Microwaved	5.74±0.95^{a}	5.09±1.22^{ab}	5.43±1.09^{a}	4.63±1.21^{b}	4.89±1.18^{b}

Values are presented as mean±SD, n = 3. Values with different superscript letters in the same column are significantly different at $p<0.05$.

steamed sample. The overall acceptability attributes were significantly different among steamed, boiled and microwaved samples ($p<0.05$). However, there were no significant differences between boiled, baked and microwaved samples for overall acceptability ($p>0.05$). Overall, the steamed sample was most accepted by the panellists.

4. Conclusion

This study showed the effects of cooking methods on the physicochemical properties, antioxidant properties and sensory acceptability of purple sweet potato (*Ipomoea batatas*). Cooking reduced the texture (hardness and cohesiveness) and colour (lightness and redness) of the purple sweet potatoes. The boiled sample was the softest in texture, darker in colour and had the highest total colour difference, whereas the steamed sample was the most adhesive and least cohesive, compared to other cooked samples. In terms of proximate composition, an increase in the moisture content caused a decrease in other parameters. The moisture content in the boiled and steamed samples was higher than in the baked and microwaved samples. On the other hand, the ash, fat and protein contents in the baked and microwaved samples were higher than in the boiled and steamed samples. Meanwhile, the antioxidant properties (total phenolic content, total anthocyanins, DPPH and ABTS free radical-scavenging activities) of purple sweet potato were increased after cooking in the order of microwaved, steamed, boiled and baked samples. The baked sample had the highest antioxidant properties due to its highest contents of total phenolics and anthocyanins. For sensory evaluation, the steamed purple sweet potato had the highest score for texture and taste and was the most acceptable sample rated by panellists.

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References

Adepoju, A.L. and Adejumo, B. (2015). Some proximate properties of sweet potato (*Ipomoea batatas* L) as influenced by cooking methods. *International Journal of Scientific and Technology Research,* 4(3), 146-148.

Alam, M.K., Rana, Z.H. and Islam, S.N. (2016). Comparison of the Proximate Composition, Total Carotenoids and Total Polyphenol Content of Nine Orange-Fleshed Sweet Potato Varieties Grown in Bangladesh. *Foods,* 5, 64. https://doi.org/10.3390/foods5030064

Alvarez, M.D. and Canet, W. (1998). Rheological characterisation of fresh and cooked potato tissues (cv. Monalisa). *Z Lebensm Unters Forsch A,* 207, 55–65. https://doi.org/10.1007/s002170050295

AOAC. (2005). Official methods of analysis. 18th ed. Washington D.C., U.S.A: Association of Official Analytical Chemists.

Bahado-Singh, P.S., Wheatley, A.O., Ahmad, M.H., Morrison, E.Y.St.A. and Asemota, H.N. (2006). Food processing methods influence the glycemic indices of some commonly eaten West Indian carbohydrate-rich foods Food processing methods influence the glycaemic indices of some commonly eaten West Indian carbohydrate-rich foods. *British Journal of Nutrition,* 96(3), 476–481.

Bellail, A.A., Shaltout, O.E., Youssef, M.M. and Gamal, A.M.A.E. (2012). Effect of home-cooking methods on phenolic composition and antioxidant activity of sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars grown in Egypt. *Food and Nutrition Sciences,* 3, 490–499. https://doi.org/10.4236/fns.2012.34069

Bembem, K. and Sadana, B. (2013). Effect of cooking methods on the nutritional composition and antioxidant activity of potato tubers. *International Journal of Food and Nutritional Sciences,* 2(4), 26-30.

BeMiller, J.N. (2017). Carbohydrate Analysis. In Nielsen, S.S. (Ed.). Food Analysis. 5th ed, p. 334–350. Switzerland: Springer Nature.

Boekel, M.V., Fogliano, V., Pellegrini, N., Stanton, C., Scholz, G., Lalljie, S., Somoza, V., Knorr, D., Jasti, P.R. and Eisenbrand, G. (2010). A review on the

beneficial aspects of food processing. *Molecular Nutrition and Food Research,* 54(9), 1215–1247. https://doi.org/10.1002/mnfr.200900608

Bolade, M.K., Usman, M.A. and Da-Clarke, U. (2017). Proximate composition, colour characteristics, index of oiliness and estimated glycemic index of deep-fried bitter yam (*Dioscorea dumentorum*) chips. *International Journal of Sciences,* 6, 39–47. https://doi.org/10.18483/ijSci.1468

Chen, J.F. (1990). Effects of amylose and amylopectin on the functional properties of starch. USA: Iowa State University, MSc Thesis.

Chiavaro, E., Barbanti, D., Vittadini, E. and Massini, R. (2006). The effect of different cooking methods on the instrumental quality of potatoes (cv. Agata). *Journal of Food Engineering,* 77(1), 169–178. https://doi.org/10.1016/j.jfoodeng.2005.06.060

Dincer, C., Karaoglan, M., Erden, F., Tetik, N., Topuz, A. and Ozdemir, F. (2011). Effects of baking and boiling on the nutritional and antioxidant properties of sweet potato [*Ipomoea batatas* (L.) Lam.] Cultivars. *Plant Foods for Human Nutrition,* 66, 341–347. https://doi.org/10.1007/s11130-011-0262-0

Donado-Pestana, C.M., Salgado, J.M., Oliveira Rios, A., Santos, P.R. and Jablonski, A. (2012). Stability of carotenoids, total phenolics and in vitro antioxidant capacity in the thermal processing of orange-fleshed sweet potato (*Ipomoea batatas* Lam.) cultivars grown in Brazil. *Plant Foods for Human Nutrition,* 67, 262–270. https://doi.org/10.1007/s11130-012-0298-9

Elfaki, A.E. and Abbsher, A.M. (2010). Nutritional situation of potato (alpha) subjected to Sudanese cooking methods. *Journal of Applied Sciences Research,* 6(8), 980–984.

García-Segovia, P., Andrés-Bello, A. and Martínez-Monzó, J. (2008). Textural properties of potatoes (Solanum tuberosum L., cv. Monalisa) as affected by different cooking processes. *Journal of Food Engineering,* 88(1), 28–35. https://doi.org/10.1016/j.jfoodeng.2007.12.001

Gilsenan, C., Burke, R.M. and Barry-Ryan, C. (2010). A study of the physicochemical and sensory properties of organic and conventional potatoes (Solanum tuberosum) before and after baking. *International Journal of Food Science and Technology,* 45(3), 475–481. https://doi.org/10.1111/j.1365-2621.2009.02148.x

Hong, K.H. and Koh, E. (2015). Effects of cooking methods on anthocyanins and total phenolics in purple-fleshed sweet potato. *Journal of Food Processing and Preservation,* 40(5), 1054–1063. https://doi.org/10.1111/jfpp.12686

Inocent, G., Adelaide, D.M., Giséle, E.L., Solange, M.O.R., Richard, E.A. and Elie, F. (2011). Impact of three cooking methods (steaming, roasting on charcoal and frying) on the β-carotene and vitamin C contents of plantain and sweet potato. *American Journal of Food and Technology,* 6(11), 994–1001. https://doi.org/10.3923/ajft.2011.994.1001

Lee, J., Bames, K.W., Eisele, T., Giusti, M.M., Haché, J., Hofsommer, H., Koswig, S., Krueger, D.A., Kupina, S., Martin, S.K., Martinsen, B.K., Miller, T.C., Paquette, F., Ryabkova, A., Skrede, G., Trenn, U. and Wightman, J.D. (2005). Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: Collaborative study. *Journal of AOAC International,* 88(5), 1269–1278. https://doi.org/10.1093/jaoac/88.5.1269

Leksrisompong, P.P., Whitson, M.E., Truong, V.D. and Drake, M.A. (2012). Sensory attributes and consumer acceptance of sweet potato cultivars with varying flesh colors. *Journal of Sensory Studies,* 27 (1), 59–69. https://doi.org/10.1111/j.1745-459X.2011.00367.x

Lončarić, A., Svrakačić, B., Nedić Tiban, N., Kopjar, M. and Piližota, V. (2016). Effect of baking and steaming on physicochemical and thermal properties of sweet potato puree preserved by freezing and freeze-drying. *Croatian Journal of Food Science and Technology,* 8(2), 90–98. https://doi.org/10.17508/CJFST.2016.8.2.08

Lyimo, M.E., Gimbi, D.M. and Kihinga, T. (2010). Effect of processing methods on nutrient contents of six sweet potato varieties grown in Lake Zone of Tanzania. *Tanzania Journal of Agricultural Sciences,* 10(1), 55–61.

Nicoletto, C., Vianello, F. and Sambo, P. (2017). Effect of different home-cooking methods on textural and nutritional properties of sweet potato genotypes grown in temperate climate conditions. *Journal of the Science of Food and Agriculture,* 98(2), 574–581. https://doi.org/10.1002/jsfa.8499

Padda, M.S. and Picha, D.H. (2008). Phenolic composition and antioxidant capacity of different heat-processed forms of sweet potato cv. "Beauregard." *International Journal of Food Science and Technology,* 43(8), 1404–1409. https://doi.org/10.1111/j.1365-2621.2007.01663.x

Shariff, A.H.M., Wong, M.M., Yahya, A., Salleh, M.M., Iqbal, N., Kadir, W.R.W.A., Ahmad, R., Sharaani, S.M., Nordin, M.F.M. and Zakaria, M. (2017). Biochemical content of two sweet potatoes (*Ipomoea batatas*) cultivars under dry heat and moist heat

treatment. *Transactions on Science and Technology,* 4(3), 224 – 231.

Schnepf, M. and Driskell, J. (1993). Sensory attributes and nutrient retention in selected vegetables prepared by conventional and microwave methods. *Journal of Food Quality*, 17(2), 87-99. https://doi.org/10.1111/j.1745-4557.1994.tb00135.x

Steed, L.E. and Truong, V.D. (2008). Anthocyanin Content, Antioxidant Activity, and Selected Physical Properties of Flowable Purple-Fleshed Sweet potato Purees. *Journal of Food Science,* 73(5), 215–221. https://doi.org/10.1111/j.1750-3841.2008.00774.x

Tang, Y., Cai, W. and Xu, B. (2015). Profiles of phenolics, carotenoids and antioxidative capacities of thermal processed white, yellow, orange and purple sweet potatoes grown in Guilin, China. *Food Science and Human Wellness,* 4(3), 123–132. https://doi.org/10.1016/j.fshw.2015.07.003

Tian, J., Chen, J., Feiyan, L.V., Chen, S., Chen, J., Liu, D. and Ye, X. (2016). Domestic cooking methods affect the phytochemical composition and antioxidant activity of purple-fleshed potatoes. *Food Chemistry,* 197(Part B), 1264–1270. https://doi.org/10.1016/j.foodchem.2015.11.049

Tokusoglu, O. and Yildirim, Z. (2012). Effects of cooking methods on the anthocyanin levels and antioxidant activity of a local turkish sweet potato [*Ipomoea batatas* (L.) Lam] cultivar hatay kirmizi: boiling, steaming and frying effects. *Turkish Journal of Field Crops,* 17(1), 87-90.

van Marle, J.T., Clerkx, A.C.M. and Boekestein, A. (1992). Cryo-scanning electron microscopy investigation of the texture of cooked potatoes. *Food Structure,* 11(3), 209 – 216.

Wang, S.M., Yu, D.J. and Song, K.B. (2011). Quality characteristics of purple sweet potato *(Ipomoea batatas*) slices dehydrated by the addition of maltodextrin. *Horticulture Environment and Biotechnology,* 52(4), 435–441. https://doi.org/10.1007/s13580-011-0015-x

Xu, Y., Chen, Y., Cao, Y., Xia, W. and Jiang, Q. (2016). Application of simultaneous combination of microwave and steam cooking to improve nutritional quality of cooked purple sweet potatoes and saving time. *Innovative Food Science and Emerging Technologies,* 36, 303–310. https://doi.org/10.1016/j.ifset.2016.07.014

Yang, Y., Achaerandio, I. and Pujolà, M. (2016). Effect of the intensity of cooking methods on the nutritional and physical properties of potato tubers. *Food Chemistry,* 197(Part B), 1301–1310. https://doi.org/10.1016/j.foodchem.2015.11.028

