

Development of high fiber rich antioxidant biscuits from purple and orange sweet potato peels

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Abstract

Sweet potato peel (SPP), which consist of various natural bioactive compounds, could play an important role in ameliorating chronic diseases such as cancer, cardiovascular diseases, and other degenerative diseases and yet remained underutilized. The current study investigated the effect of orange or purple SPP powder at different level of substitution (2, 5, 10%) in the production of biscuits on the proximate, antioxidant potentials and consumer acceptance. Dietary fibre increased significantly ($P < 0.05$) with an increase in SPP powder, ranging from 2 to 2.3 g/100 g. The total phenolic content of the biscuits was between 101.21 and 147.7 GAE/mL, total flavonoid ranged from 22.7 to 42.2 RU/mL, ABTS radical content ranged from 2.7 to 42.2 ($\mu\text{g ascorbic/mL}$). Acceptable biscuits were obtained by incorporating 2% SPP powder. Thus, SPP powder could be used as a functional and nutraceutical ingredient in biscuit production.

1. Introduction

Tuber and root crops are significant sources of several natural compounds, such as saponins, phenolic compounds, glycoalkaloids, phytic acids, carotenoids, and ascorbic acid (Chandrasekara and Kumar, 2016). Several scientific investigations have mentioned that root crop extracts, especially yam and sweet potato have radical scavenging activities. These activities are due to its phytochemical content, including ascorbic acid, alpha-tocopherol, beta-carotene and polyphenols (Bhandari and Kawabata, 2004; Kalt, 2005; Rumbaoa *et al.*, 2009). These phytochemical compounds have attained a great interest in nutrition because of their ability in promoting human's health and preventing chronic diseases as antioxidants (Lampe, 1999). The nutritional management of different diseases has been usually attached with a diet rich in antioxidants and dietary fibres (Lattimer and Haub, 2010).

Peel from fruits, vegetables and tubers has healthy value content. Pear cultivar showed that the peel contains 25 times more amount of total phenolic content and high antioxidant rather than in flesh (Cruz-Bravo *et al.*, 2019). *Citrus sinensis*, which is a tropical fruit, is proceed into juice with 20% peels waste. This fruit wastes are prone to microbial growth and thus causing environmental pollution (Rafiq *et al.*, 2018). Earlier scientific reports have concluded that some of these peels are rich in

dietary fibre with good antioxidant properties (Serna-Cock *et al.*, 2016).

Dietary fibre has been identified as the indigestible part of plant which assist in the movement of bowel and waste efficiently (Mcrorie and Fahey, 2013). Fruits, vegetables and cereals are the major source of dietary fibre (Bakar *et al.*, 2015). However, low-fibre intake has been prominent in the current lifestyle, and therefore dietary fibres have been presented as a nutraceutical supplement. However, those supplements could not be used in conventional food, meal or diet. Therefore, incorporating dietary fibres into commercial food are encouraged to meet the recommended daily intake.

Purple and orange sweet potato have been known as a healthy food additive and a potential source of natural food colorants because of their high levels of anthocyanins. Ayamurasaki purple sweet potato contains 59 mg of anthocyanin for each 100 g. Anthocyanin derivatives such as peonidins and cyaidins have been reported to be responsible for the antioxidant activities in the peel of purple sweet potato (Han *et al.*, 2007). The concentration of these promising-healthy flavonoids is mainly found in the peels more than the inner cortex (Liu *et al.*, 2018).

Biscuits are one of the most common consumed food in the world. The affordable cost, good nutritional

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quality, availability in different tastes and long shelf-life are the main reasons for wide consuming (Boobier *et al.*, 2006). Currently, different types of cereals such as oat bran, wheat bran, rice bran are utilized in bakery production to increase the fibre content (Lebesi and Tzia, 2011). However, the nutritional quality of dietary fibres in vegetables and fruits have higher proportion of soluble dietary fibre and bioactive compounds than the cereals (Arslan *et al.*, 2019). Therefore, developing baking foods rich in fibre content by utilizing waste by-product is a healthy-promising approach and could decrease the negative environment effect. The aim of the present research is to develop biscuits rich in fibre and antioxidants from sweet potato peel, and to evaluate their physiochemical, biochemical and sensory characteristics.

2. Materials and methods

2.1 Materials

Wheat flour used in the study was purchased from the Universiti Tun Hussein Onn Malaysia market, Batu Pahat, Malaysia. Orange and purple sweet potato were harvested at maturity age from a commercial farmland located in Cameron Highlands, Pahang, Malaysia. The other reagents used in this study were of analytical grade.

2.2 Sample preparation

2.2.1 Preparation of sweet potato peel powder

The orange and purple sweet potato peel powder were prepared according to Ben Jeddou *et al.* (2017) with slight modification. The purple and orange sweet potato was washed with distilled water and peeled with a hand knife. After drying the peels with a hot air oven at 60°C for 24 hrs, the peels were grounded into powder which was cooled and sieved (150 µm mesh size) to obtain the orange and sweet potato peel flour. Then, the sweet potato peel flour was stored at 4°C inside airtight polyethylene packs prior to use.

2.2.2 Biscuits preparation

Normal biscuits were prepared as a control and compared with orange sweet potato peel (OSPP) and purple sweet potato peel (PSPP) biscuits. The normal biscuits were processed from dough containing 140 g flour, 45 g sugar, 125 g butter and 1 teaspoon of baking soda as described by Ajila *et al.* (2008) with slight modification. Purple and orange SPP biscuits were prepared separately. Dough biscuits were prepared according to three concentrations of SPP powder (2%, 5%, and 10%), like the following, 137.2 g of flour and 2.8 g of SPP, 133.0 g of flour and 7 g of SPP, and 126 g of flour and 14 g of SPP. The biscuits dough was sheeted to a thickness of 1 cm with a rolling pin. The biscuits were shaped in a circle with a 5 cm diameter and were

placed on a tray lined with baking paper and baked at 150°C for 15 mins in an electric oven.

2.3 Sample analysis

2.3.1 Proximate composition of orange and purple sweet potato peel biscuits

Fat, protein, carbohydrate, ash, moisture and dietary fibre content were analysed according to the method described by Analysis of Association of Official Analytical Chemistry (Association of Official Analytical Chemists, 2016). Total carbohydrate was calculated by difference (Dell and Reason, 1993).

2.3.2 Sample extraction for antioxidant and phenolic content assays

Methanolic extraction was performed according to Gull and his colleague (2018) with slight modifications. Briefly, each 2 g of samples were extracted with 10 mL of 80% methanol by using a magnetic stirrer located on the shaker for 2 hrs. Then, the mixture was filtered by a Newman filter paper. The filtered mixture was centrifuged at 3600 rpm for 15 mins (25°C) in a 30 mL plastic centrifuge tube. Then, the mixture was stored in a dried clean container for further analysis.

2.3.3 Total phenolic content

The extracted sample (200 µL) was mixed with 3 mL of distilled water and 0.5 mL of Folin-Ciocalteu reagent and left for about 3 mins. Around 20 g of sodium carbonate was dissolved in 100 mL of distilled water to obtain a 20% sodium carbonate solution. A volume of 2 mL of 20% (w/v) sodium carbonate was pipette into the same boiling tube before the sample was left for about 1 hr. All these steps were prepared in the dark. The sample was placed in the cuvette and the absorbance was measured at 650 nm by using UV-Vis Spectrophotometer (Model T60u, PG Instrument, USA). A standard solution of gallic acid was prepared by dissolving 0.1 g of gallic acid in 100 mL of distilled water. A serial dilution of 1.0, 2.5, 5.0 and 7.5mL was prepared. Next, 1 mL of each dilution was mixed with 4mL of sodium carbonate and 5mL of Folin-ciocalteu solution. The standard solution was left at 20°C for about 30 mins. Results were expressed as mg gallic acid per sample (Işik *et al.*, 2011).

2.3.4 Total flavonoid content

Total flavonoid content was determined by using colorimetric aluminium chloride method with slight modification. Briefly, 1 mL of the extracted sample was pipetted and 4 mL of distilled water was added into a test tube. Sodium nitrite (0.3 mL) was added to the solution. After six mins, aluminium chloride hexahydrate (0.3

mL) was added to the solution. 2 mL of sodium hydroxide (1M) was added. The mixture was vortex and immediately read at the absorbance of 510 nm against a blank reagent by using UV-vis spectrophotometer (Model T60u, PG Instrument, USA). Total flavonoid content was expressed as rutin equivalent in $\mu\text{g}/100\text{ g}$ of dry weight (Loizzo et al., 2012).

2.3.5 Antioxidant activity

2.3.5.1 DPPH assay

DPPH solution was prepared by dissolving 5.9 mg of DPPH with 100 mL of methanol in a dark place. The extracted sample (77 μL) was added into a test tube along with DPPH solution for 15 mins. After that, the samples were read by UV Vis Spectrophotometer (Model T60u, PG Instrument, USA) at 515 nm (Miliauskas et al., 2004).

$$\% \text{ Inhibition} = [(\text{Absorption of blank} - \text{Absorption of sample}) / \text{Absorption of blank}] \times 100$$

2.3.5.2 ABTS assay

Potassium persulfate (2.45 mM) was added into the ABTS stock solution to produce ABTS⁺ radical and stored in the dark room for 15 hrs. ABTS⁺ radical was then diluted with deionized water to obtain an absorbance value of 0.7 ± 0.2 at 734 nm. The sample extract (200 μL) was added into 2 mL of ABTS free radical solution and allowed to stand for 30 mins. A standard curve was calibrated by using ascorbic acid of 10 – 50 $\mu\text{g}/\text{mL}$. The absorbance of the standards and sample was measured at 734 nm by using UV-Vis Spectrophotometer (PG Instrument, Model T60u, USA). The test was conducted in triplicate and was calculated on average (Awika et al., 2003).

2.3.5.3 Ferric reduction antioxidant potential assay

The solution of FRAP was prepared by using 0.54g of FeCl_3 hexahydrate and was dissolved in 100 mL of deionised water. The buffer solution was prepared by dissolving 4mL of glacial acetic acid and 0.78g of sodium acetate in 250 mL of deionised water. TPTZ solution was prepared by mixing 0.34 mL of HCl in 100 mL of deionised water before adding 0.31 g of TPTZ powder. The extracted sample was diluted by dissolving 100 μL of the extracted sample with 300 μL of deionised water. Then, 100 μL of the sample was pipetted into the test tube before the addition of 2.5 mL of FeCl_3 , 2.5 mL of TPTZ and 25 mL of buffer solution into the same test tube. The sample was left for about 4 mins before the sample was read in the spectrometer (Model T60u, PG Instrument, USA) at 593 nm. The test was done in triplicates and calculated on average (Kwon et al., 2013).

2.3.6 Physicochemical test

2.3.6.1 Texture analysis

The hardness and fracturability of biscuits were measured by the bend or snap or known as the three-point break technique by using the Texture Analyser. The compression strength of biscuits was measured using the following conditions: Test mode: compression; pre-test speed: 1 mm/s; test speed: 3 mm/s; post-test speed: 10mm/s; target mode: distance; distance: 4mm; trigger force: 50 g; data acquisition rate: 500 PPS. Accessory: 3-Point Bending Rig (HDP/3PB) using 5 kg load cell, Heavy Duty Platform (HDP/90). The peak force (g) and the mean distance at break (mm) were recorded. The texture of biscuits was conducted by using Texture Analyser in triplicate.

2.3.6.2 Colour

The colour of biscuits was conducted by using Colour Spectrophotometer (Hunter Lab 4500L Model MiniScans E2, USA). The biscuits samples were placed into the petri dish and covered. The result L* (luminosity), A* (intensity of red colour) and B* (intensity of yellow colour) was measured and calculated automatically. The test was done in triplicate.

2.3.7 Sensory evaluation

The characteristic sensory of the orange and purple sweet potato was evaluated using five different attributes by fifty untrained panellists from Universiti Tun Hussein Onn Malaysia. The panellists were from both sexes, and from different ages, they were requested to taste each sample separately without comparing it with another sample. The evaluated sensory attributes were crispiness, aroma, taste, colour, hardness, appearance and overall acceptability. The panellists rated the quality characteristics of each sample on a nine-point hedonic rating as described by (Stefanowicz, 2013). The panellists were asked to drink water to neutralize the taste between samples tasting.

2.4 Statistical analysis

The experiments were carried out in triplicate and the results were reported as mean \pm SD and subjected to statistical analysis using Statistical Package of the Social Sciences (SPSS) version 19 using one-way analysis of variance (ANOVA) by using SPSS. Duncan's Multiple Range Test was performed to determine the difference of mean, and $p < 0.05$ was considered to be statistically significant.

3. Results

The proximate composition of sweet potato peel

biscuits compared with control biscuits is presented in Table 1. The results showed that adding SPP powder has increased carbohydrate from 56.26 to 56.92%, protein content from 5.7 to 6.1%, ash from 0.046 to 0.072% and total dietary fibre from 0.8 to 2.3%. Fat content was decreased from 34.8 to 34.2%. The total dietary fibre was significantly different in OSPP2% compared with PSPP10%.

The total phenolic and flavonoid content along with the antioxidant properties of sweet potato peel biscuits are presented in Table 2. The addition of OSPP increased the total phenolic from 101 to 111.24 $\mu\text{g GAE/mL}$, while PSPP increased the phenolic content from 126.26 to 141.02 $\mu\text{g GAE/mL}$. At 10% substitution of PSPP, the total phenolic content shows the highest value compared to OSPP 10%. Similarly, an increase in the substitution of OSPP and PSPP increased the total flavonoid content. The biscuits with 10% of PSPP had the highest total flavonoid content (42.9 $\mu\text{g RU/mL}$). However, OSPP at 5% and 10% concentration had similar value of total flavonoid content.

The antioxidant activities of SPP biscuits increased as the concentration of purple or orange sweet potato peel increased. The DPPH radical scavenging activity of 10% PSPP biscuit has the highest value (61.9%) followed by 10% OSPP biscuit (52.9%). The DPPH value was significantly ($P < 0.05$) different between 5% PSPP biscuits and 5% OSPP biscuits. FRAP values ranged from 40.8 to 177.8 (mM ferric reduced/g) for control and SPP biscuits, respectively. FRAP values demonstrated significant differences ($P < 0.05$) in all PSPP and OSPP biscuits. OSPP biscuits showed similar FRAP values at all concentrations ranging from 123 to 125.05 (mM ferric reduced/g), but PSPP biscuits had higher FRAP values than OSPP at all three concentrations. Similarly, the ABTS values showed a significant difference ($P < 0.05$) between control biscuits and SPP biscuits. The highest ABTS value was found at 10% PSPP biscuits (42.83 $\mu\text{g ascorbic/mL}$). The ABTS value of 10% OSPP biscuits (24.39 $\mu\text{g ascorbic/mL}$) was significantly similar to 5% PSPP biscuits (22.38 $\mu\text{g$

ascorbic/mL). Notably, the DPPH, FRAP and ABTS values for SPP biscuits followed a similar order of the total phenolic and total flavonoid contents.

Comparisons of the mean liking scores for the sensory attributes of the biscuits are presented in Table 3. The appearance value of all the biscuits was relatively similar, ranging from 6.4 to 7.12. The highest values of appearance were observed in PSPP 2% followed by OSPP 2%. The colour of 2% OSPP and 2% PSPP biscuits were more significantly acceptable ($P < 0.05$) than the other biscuits. Compared with the other biscuits, 2% PSPP had the highest value for taste and aroma. The crispiness values were significantly similar in the control biscuit (7.06), 2% OSPP (7.12), and 2% PSPP (7.12). At concentration of 2% of orange and purple sweet potato peel biscuits had the highest overall acceptability for sensory attributes.

The biscuits were measured by using texture analyser. The hardness values of SPP biscuits were lower than the control biscuits as shown in Table 4. The control biscuit has the longest distance which is 41.336 mm. Notably, as SPP powder concentrations increased, the brittleness of the biscuits raised up. Moreover, PSPP 10% biscuit has the shortest distance (37.847 mm) followed by OSPP 10% biscuit (39.829 mm).

The control biscuit had the highest brightness with 64.91 ± 0.29 for L^* , a^* is 9.40 ± 0.24 and b^* 39.23 ± 0.45 . The value of L^* for OSPP and PSPP biscuits decreased as the concentrations of peels increased as shown in Table 5. No specific trend is observed in the change in a^* value upon the addition of orange or purple sweet potato peel. As indicated by the b^* value, the yellowness of orange sweet potato peel biscuits was significantly higher than purple sweet potato peel biscuits.

4. Discussion

The moisture content of sweet potato peel biscuits was below 5% which support the shelf life against the microbial attack of any form of spoilage as mentioned by Calligaris *et al.* (2007) who suggested that less than 10%

Table 1. The proximate composition of orange and purple sweet potato peel biscuits comparing with control biscuits (g/100 g dry matter)

Nutritional content (%)	CB	OSPP2%	PSPP2%	OSPP5%	PSPP5%	OSPP10%	PSPP10%
Carbohydrates	56.21 ^d	56 ^d	56.26 ^d	56.52 ^c	56.75 ^b	56.88 ^b	56.92 ^a
Proteins	5.2 ^c	5.7 ^b	5.7 ^b	6.1 ^a	5.9 ^b	6.3 ^a	6.1 ^a
Fats	34.8 ^a	34.3 ^c	34.2 ^c	34.3 ^c	34.4 ^b	34.3 ^b	34.2 ^b
Ash	0.046 ^c	0.06 ^d	0.064 ^c	0.067 ^b	0.068 ^b	0.07 ^a	0.072 ^a
Moisture content	3.74 ^d	3.82 ^c	3.81 ^c	3.86 ^b	3.84 ^b	3.88 ^a	3.89 ^a
Total dietary fiber	0.8 ^d	2 ^b	1.7 ^c	2.2 ^b	1.9 ^b	2.5 ^a	2.3 ^a

CB: Control biscuits, OSPP: Orange sweet potato peel, PSPP: Purple sweet potato peel. Values are presented as mean \pm SD, n = 3. Values with the same superscript within the same column are not significantly different ($P > 0.05$).

Table 2. Total phenolic and flavonoid content, and antioxidant properties of sweet potato peel biscuits.

Samples	TPC ($\mu\text{g GAE/mL}$)	TFC ($\mu\text{g RU/mL}$)	%Inhibition DPPH	FRAP (mM ferric reduced/g)	ABTS ($\mu\text{g ascorbic/mL}$)
CB	75.25 \pm 0.40 ^c	8.16 \pm 0.30 ^d	5.9 \pm 0.125 ^d	40.82 \pm 0.06 ^c	0.57 \pm 0.009 ^e
OSPP2%	101.67 \pm 1.67 ^d	22.27 \pm 1.65 ^b	25 \pm 0.306 ^d	123.08 \pm 2.60 ^d	2.75 \pm 0.008 ^d
OSPP5%	102.87 \pm 0.22 ^d	30.41 \pm 0.05 ^a	48 \pm 0.165 ^b	125 \pm 0.09 ^d	19.50 \pm 0.001 ^b
OSPP10%	111.24 \pm 0.27 ^d	30.66 \pm 0.05 ^a	52.9 \pm 0.139 ^b	125.04 \pm 0.09 ^d	24.39 \pm 0.002 ^b
PSPP2%	126.26 \pm 2.14 ^c	13.31 \pm 7.03 ^c	39 \pm 0.280 ^c	139.09 \pm 1.23 ^c	8.57 \pm 0.006 ^c
PSPP5%	134.64 \pm 10.38 ^b	21.38 \pm 0.05 ^b	43.04 \pm 0.195 ^c	165.84 \pm 1.98 ^b	22.38 \pm 0.004 ^b
PSPP10%	141.02 \pm 2.96 ^a	42.9 \pm 0.09 ^a	61.9 \pm 0.090 ^a	177.73 \pm 0.16 ^a	42.83 \pm 0.001 ^a

CB: Control biscuits, OSPP: Orange sweet potato peel, PSPP: Purple sweet potato peel. Values are presented as mean \pm SD, n = 3. Values with the same superscript within the same column are not significantly different (P > 0.05).

Table 3. The mean and standard deviation of sensory evaluation for 7 samples of biscuits.

Attributes	CB	OSPP 2%	OSPP 5%	OSPP 10%	PSPP 2%	PSPP 5%	PSPP 10%
Appearance	6.9 \pm 1.3 ^a	6.96 \pm 1.3 ^a	6.4 \pm 1.44 ^b	6.66 \pm 1.6 ^b	7.12 \pm 1.2 ^a	6.7 \pm 1.2 ^b	6.58 \pm 1.5 ^b
Colour	6.86 \pm 1.4 ^a	6.98 \pm 1.5 ^a	6.32 \pm 1 ^b	5.98 \pm 1.6 ^c	6.94 \pm 1.2 ^a	6.52 \pm 1.1 ^b	6.4 \pm 1.3 ^b
Taste	6.84 \pm 1.6 ^c	7.12 \pm 1.5 ^b	5.96 \pm 1.7 ^c	6.16 \pm 1.8 ^c	7.36 \pm 1.3 ^a	6.62 \pm 1.1 ^d	6.18 \pm 1.3 ^c
Aroma	6.96 \pm 1.5 ^a	6.9 \pm 1.5 ^b	6.28 \pm 1.4 ^d	6.54 \pm 1.5 ^c	6.94 \pm 1.3 ^a	6.54 \pm 1.2 ^c	6.32 \pm 1.3 ^d
Hardness	6.96 \pm 1.7 ^b	7.1 \pm 1.5 ^a	5.28 \pm 1.8 ^d	6.04 \pm 1.5 ^c	7.26 \pm 1.1 ^a	6.24 \pm 1.1 ^c	5.66 \pm 1.3 ^d
Crispiness	7.06 \pm 1.6 ^a	7.12 \pm 1.3 ^a	5.3 \pm 1.8 ^c	6.0 \pm 1.6 ^b	7.12 \pm 1 ^a	6.06 \pm 1.2 ^b	5.66 \pm 1.3 ^c
Overall acceptability	7.18 \pm 0.4 ^b	7.4 \pm 1.3 ^a	5.7 \pm 1.8 ^c	6.34 \pm 1.5 ^c	7.42 \pm 0.9 ^a	6.44 \pm 1.1 ^c	6.08 \pm 1.3 ^d

CB: Control biscuits, OSPP: Orange sweet potato peel, PSPP: Purple sweet potato peel. Values are presented as mean \pm SD, n = 3. Values with the same superscript within the same column are not significantly different (P > 0.05).

Table 4. The hardness and fractur ability of sweet potato peel biscuits.

Samples	Force	
	Hardness (N)	Fracturability (mm)
CB	1983.419 ^a	41.336 ^a
OSPP 2%	1982.475 ^a	40.515 ^a
OSPP 5%	1842.888 ^b	40.286 ^a
OSPP 10%	1687.605 ^c	39.829 ^b
PSPP 2%	1898.072 ^b	40.302 ^a
PSPP 5%	1847.102 ^b	39.256 ^b
PSPP 10%	1840.306 ^b	37.847 ^c

CB: Control biscuits, OSPP: Orange sweet potato peel, PSPP: Purple sweet potato peel. Values are presented as mean \pm SD, n = 3. Values with the same superscript within the same column are not significantly different (P > 0.05).

moisture content was suitable for storage stability. By increasing the sweet potato peel, the total dietary fibre was increased which was in agreement with the report of Ben Jeddou and his colleagues (2017) who indicated that incorporating potato peel powder with cake dough improved the dietary fibre content and reduce the total calorie. However, the protein content of sweet potato peel biscuit slightly increased which was similar in another report where potato peel powder was added to cake (Ben Jeddou *et al.*, 2017).

Phenolic and flavonoid compounds are collectively considered a natural resource of antioxidants with a wide range of benefits for health (Brito *et al.*, 2014; Rafiq *et*

Table 5. The mean and standard deviation of color for sweet potato peel biscuits.

Samples	L*	a*	b*
CB	64.91 \pm 0.2 ^a	9.40 \pm 0.2 ^b	39.23 \pm 0.4 ^a
OSPP 2%	65.49 \pm 0.7 ^a	8.14 \pm 0.1 ^c	38.59 \pm 0.6 ^b
OSPP 5%	63.74 \pm 0.6 ^a	8.27 \pm 0 ^c	41.60 \pm 0.5 ^a
OSPP 10%	51.56 \pm 1.1 ^c	12.59 \pm 0.3 ^a	41.98 \pm 0.9 ^a
PSPP 2%	53.51 \pm 0.1 ^b	13.10 \pm 0.1 ^a	39.32 \pm 0 ^a
PSPP 5%	55.33 \pm 1.4 ^b	10.00 \pm 0.3 ^b	35.37 \pm 0.2 ^c
PSPP 10%	48.73 \pm 0.1 ^c	10.48 \pm 0.2 ^b	31.96 \pm 0.2 ^d

CB: Control biscuits, OSPP: Orange sweet potato peel, PSPP: Purple sweet potato peel. Values are presented as mean \pm SD, n = 3. Values with the same superscript within the same column are not significantly different (P > 0.05).

al., 2018). Previous studies reported the healthy benefits of incorporating citrus peel-rich polyphenols with bakery products (Rafiq *et al.*, 2018). The current study presented an increment in the total phenolic and total flavonoid content of sweet potato peel biscuits. However, the highest concentration was in purple sweet potato peel biscuit due to the high concentration of anthocyanin and its derivatives (Musilová *et al.*, 2017). Purple sweet potato flakes had increased the hepatic glutathione in rats fed with a high-cholesterol diet (Han *et al.*, 2007). Therefore, incorporating peels fruits and/or vegetables such as pomegranate peel with producing functional foods improve the antioxidant properties of biscuits or bread dough.

In the current study, purple and orange sweet potato peel had a DPPH free radical scavenging ability as shown in Table 2 which revealed that 10% of orange or purple sweet potato peel had the highest DPPH radical scavenging ability. The inhibitory activity of DPPH radicals for sweet potato peel biscuits was thought due to the high concentration of carotenoids and anthocyanins in orange and purple sweet potato respectively (Teow *et al.*, 2007). Since the Millard reaction is responsible for the brown pigments melanoidins during the baking process, it has been reported previously that melanoidins possess antioxidant activities (Wang *et al.*, 2011). Thus, Millard reaction could contribute to the antioxidant ability of orange and purple sweet potato peel biscuits produced.

The ability of orange and purple sweet potato peel biscuits in chelating Fe^{+2} is presented in Table 2. Orange or purple sweet potato peel biscuits were able to chelate Fe^{+2} in a dose-dependent manner. However, 10% purple sweet potato peel biscuits had the highest Fe^{+2} chelating ability. The presence of anthocyanin along with melanoidins may explain the antioxidant properties of purple sweet potato peel biscuits. It has been mentioned that soluble parts of Millard reaction compounds have metal chelating activity (Sharma and Gujral, 2014). ABTS assay was used to measure the radical scavenging activity by electron donation. In Table 2, the results showed that the oxidation of ABTS has been inhibited by orange and purple sweet potato peel compared with control biscuits. These results were in agreement with Kim and his colleagues (2019) who reported that caffeic acid and vanillic acid quantity were correlated with the antioxidant properties of potato peels.

Food performance is associated mainly with sensory quality which can be measured relatively by grading the biscuits. Currently, there are plenty of sensory evaluation methods which are applied for various purposes in the food industry. As shown in Table 3, the incorporation of orange and purple sweet potato peel powder at 2% concentration improved the overall accessibility of the biscuits compared with control biscuits. Moreover, few studies reported that the higher concentrations of dry extracts would disturb the development of the gluten matrix in the dough due to the presents of higher amounts of total solids and decreasing amount of gluten protein in content (Shewry *et al.*, 2002; Li *et al.*, 2012). Therefore, the presence of peel would affect the texture of biscuits. The colour of biscuits is influenced by cooking or baking due to brown pigments that occur because of browning and caramelization reaction and also due to temperature and cooking time (Rufián-Henares and Pastoriza, 2015). The orange sweet potato peel biscuit is slightly orange and red due to the presence

of beta carotene in the peel (Teow *et al.*, 2007). Purple sweet potato peel biscuit has purplish pigment due to the presence of anthocyanin (Liu *et al.*, 2018). In addition, sweet potato peel has polyphenol oxidase and peroxidase activities along with polyphenols which are substrates for these enzymes. Thus, the brightness and yellowness of the biscuits could be decreased due to the enzymatic browning.

4. Conclusion

The chemical composition of sweet and purple sweet potato peel biscuits provides a good source of phytochemicals and dietary fibres. Biscuits enriched with PSPP showed a higher polyphenol content and therefore, PSPP incorporated biscuits had significant antioxidant activity. Thus, orange or purple sweet potato peel, a by-product from the potato processing industry, could be utilized for the preparation of biscuits with improved functional and nutraceutical properties.

Conflict of interest

The authors herewith declare no conflict of interest.

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