ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 9
November 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2022; 22(9): 21476-21502 https://doi.org/10.18697/ajfand.114.22555

EFFECT OF PARTIAL SUBSTITUTION OF REFINED WHEAT FLOUR WITH PURPLE SWEET POTATO FLOUR ON THE PROPERTIES AND QUALITY OF NOODLES

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Volume 22 No. 9
November 2022
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ABSTRACT

Noodles are conventionally made with wheat or rice flour, but in order to improve their nutritional content, other crops have been successfully used. Purple sweet potatoes are an important food and phytochemical source world-wide and have the potential for partially substituting wheat or rice in making noodles. The substitution of part of the refined wheat flour in noodles with 5, 10, 15 or 20% of purple sweet potato flour (PSPF) in noodles was, therefore, tested which resulted in them having a darker appearance and an increase its green color. However, these noodles required shorter cooking times, but gave lower cooking yields, had higher cooking loss and a weaker structure in terms of their texture. These noodles also had a slightly increased pH and water activity than noodles made from 100% refined wheat flour as well as increased levels of fat, ash, carbohydrate, total anthocyanin content, total phenolic content and antioxidant capacity but reduced protein levels and moisture content. From the sensory evaluation panel, the addition of purple sweet potato flour (PSPF) to the flour had no significant effects on the color, taste and overall acceptability of the cooked noodles, although there was a significant indication ($p>0.05$) that the odor increased, elasticity, softness and smoothness all decreased with increasing substation of the refined wheat flour with purple sweet potato flour (PSPF). The sensory evaluation panel detected no significant differences ($p>0.05$) in the appearance of the noodles whatever the level of substation. In terms of microbial contamination, these noodles complied with Thai standards for microbiological regulations. The noodles preserved acceptable quality for at least 9 days of storage in refrigerator at 4±2^{o}C. Overall, it was concluded that enhancing the noodles by substituting 20% of the refined wheat flour with purple sweet potato flour (PSPF) would be acceptable to consumers, but would also improve their nutritional content.

Key words: Anthocyanin, Antioxidant activity, Purple sweet potato flour, Noodle, Sensory acceptability

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INTRODUTION

Sweet potatoes *(Ipomoea batatas L.)* are a major food staple grown throughout the world, and is the third most important root crop after potatoes and cassava [1]. In Asia, China, Indonesia, Vietnam, Philippines and Japan are major producers [2]. It plays an important role in food security as well as reportedly being a recommended healthy food [3, 4]. FoodData Central [5] gave the analysis of sweet potato per 100 g of flesh as: 89 calories, 20 g of carbohydrate, 1.57 g of protein, 0.05 g of fat, 3 g of fiber and 85.9 mg of beta-carotene. They gave vitamin A as 709 µg, vitamin B1, B2, B3, B5 and B6 as 0.078, 0.061, 0.557, 0.800, 0.209 mg, respectively. vitamin C as 2.4 mg and vitamin E as 0.26 mg. They gave the mineral content as calcium, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc as 30, 0.610, 25, 0.258, 47, 337, 55 and 0.30 mg, respectively. Four varieties of sweet potatoes are recognized based on flesh color: orange, yellow, white and purple [6] with the purple and orange varieties containing substantial amounts of anthocyanins, which is an important pigment that can prevent deterioration of cells and eyes, as well as decreasing of cardiovascular risk, decreasing of stroke, preventing blood clots, inhibiting pathogens and Escherichia coli in the gastrointestinal tract that can cause diarrhea and food poisoning [7,8].

The main ingredients of noodles are flour, eggs, salt, sodium bicarbonate and water, but there are many kinds of noodles in Thailand which include egg noodles, dried noodles, rice noodles and instant noodles [10]. Preparation is by mixing the ingredients then threshing and pressing the dough to 2-3 mm thick and cutting it into noodles [9]. Previous research has shown that other ingredients can be used to replace wheat flour including tamarind seed flour [11], quinoa flour [12] and yam flour [13]. Since sweet potato flour is potentially more nutritious than wheat or rice flour, which are conventionally used to make noodles, it was decided to test whether flour extracted from purple sweet potatoes could be successfully utilized to produce noodles that are acceptable to consumers since they would have a higher nutritional value and provide a healthy alternative for consumers. Have one statement here that captures statement of the problem specific to this study. The objectives of this research were therefore to investigate the physical quality, cooking quality, chemical composition, sensory characteristics and storage time of noodles made from refined wheat partially substituted with purple sweet potato flour at various ratios.

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MATERIALS AND METHODS

Material preparation

Purple sweet potatoes, grown in Chiang Mai, Thailand, were purchased in the local market, then washed thoroughly in flowing water to remove all the adhering soil, hand peeled, immersed in sodium chloride (1% concentration) and cut into 2 mm thick slices in a slicer machine. Slices were then soaked in a solution containing 1% sodium metabisulphite and 0.5% citric acid for 30 min, drained and washed in running tap water. Slices were then arranged on a wire rack and placed in an electric tray dryer at 60^{o}C until the moisture content was 7-8%, which took about 11 h. The dried slices were ground using an electric blender and sifted in a mechanical sieve with a mesh size of 80 mesh sieve (standard mesh size with a 180 µm nominal sieve opening with a typical wire diameter of 0.125 mm). The resulting flour was packaged in aluminum laminated bag and kept in room temperature at 25^{o}C until required.

Noodle preparation

The noodles were prepared according to the method of Uthai *et al.* [14] as follows. The control formula consisted of 200 g of refined wheat flour (United Flour Mill, Thailand), 70 g of pasteurized egg (CP brand, Thailand), 70 g of drinking water (Crystal, Sermsuk, Thailand), 3 g of sodium bicarbonate (Merck KGaA, Darmstadt, Germany) and 3 g of salt (Prung Thip, Thai Refined salt, Thailand). Four variations of this formula were prepared by diluting the refined wheat flour with 5, 10, 15, or 20% of the purple sweet potato flour (PSPF) described above. After mixing, each of the five doughs were allowed to rest for 30 min in separate mixing bowls covered with cling film. Then each dough was made into noodles by repeatedly passing them through a compact noodle hand machine (Marcato Atlas 150, Italy) with the distance between the rollers gradually reduced, All the noodles were then cut to the necessary length of 25 cm with a sharp knife.

Determination of color

The Hunter Lab spectrophotometer (Color Quest XE, USA) equipped with a D65 illuminant using the CIE, L* a* and b* system were used to measure the color of both the raw and cooked noodles for each of the five treatments. For these measurements, 30 g of each sample was spread on a glass plate and measured at 3 different places on different parts of each sample. The measurements of brightness L* (100=white; 0=black), redness a* (+, red; -, green), and yellowness b* (+, yellow; -, blue) were taken directly from the spectrophotometer. Color values were determined in triplicate.

Cooking analysis

Optimum cooking time

The optimum cooking time of noodles was determined using the American Association of Cereal Chemists (AACC) technique with slight modifications [15]. Briefly, 15 g of noodles were immersed in 500 mL of boiling water and they were tested throughout the boiling process by removing samples at intervals and squeezing them between two glass plates every 10 seconds until they were totally cooked or had no white or opaque wen. The tests were run in triplicate analyses.

Cooking yield

The cooking yield was calculated using the method of Chin *et al.* [16], where 10 g of noodles that had been immersed in 200 mL boiling water for 5 min, drained and rested for 15 min were weighed. Using equation (1), the cooking yield was estimated as a percentage of cooked noodles. The tests were run in triplicate.

$$\text{Cooking yield (\%)} = \frac{\text{weight of noodle after cooking} \times 100}{\text{weight of noodle before cooking}} \qquad (1)$$

Cooking loss

The method for measuring cooking loss, provided by AACC [15], was used and involved weighing 10 g of noodles, adding 200 mL of water in a measured beaker, boiling for 5 min and allowing to cool for 15 min. The noodles, together with the beaker containing the water, were placed in an air oven at 105°C (until the water had evaporated), after which they were weighed and the cooking loss was determined using equation (2) using triplicate analyses.

$$\text{Cooking loss (\%)} = \frac{\text{Residue in cooking noodle} \times 100}{\text{weight of noodle before cooking}} \qquad (2)$$

Texture determination

All the samples (uncooked and cooked noodles), were examined using TA-XT plus texture analyzer (England) described by Uthai *et al.* [14]. Before each measurement, with spaghetti tensile grips (A/SPR), a 5 kg load cell was used to calibrate the system to determine its tensile strength and elasticity. Tensile strength test mode was with a post-test speed of 5 mm/sec, a return to start distance of 100 mm, a pre-test speed of 3 mm/sec, a trigger type of 5 g, and a test speed of 3 mm/sec. Each sample was subjected to the analysis 5 times.

pH determination

pH was determined on raw noodle samples using the method of the Association of Official Analytical Chemists (AOAC) [17]. Each sample was ground thoroughly, and

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10 g was mixed with 100 mL of distilled water, stirred well for 30 sec, and left for 2 min. The top clear liquid of each sample was centrifuged at 1500 rpm at 25°C for 30 min, and a sample of the clear liquid was placed in a pH meter (SI Analytics Lab 855 pH Benchtop Meter, Germany) and the pH level recorded. Analyses were performed in triplicate.

Water activity determination
Water activity (Aw) of the raw noodles was determined using a Novasina water activity meter (Novasina, Switzerland) following the protocol and was calibrated with SALT-90 salts [18]. Analyses were performed in triplicate.

Chemical composition determination
Moisture content, protein, fat and ash of each sample of purple sweet potato flour (PSPF), noodle was determined using the method of the Association of Official Analytical Chemists (AOAC) [17]. The method of Darryl *et al.* [19] was utilized to determine carbohydrate. Triplicate analyses were carried out.

Anthocyanin, total phenolic content and antioxidant activity determination
Extraction method
2 g of each sample of the cooked noodles (containing 0, 5, 10, 15 or 20% PSPF with the balance being refined wheat flour) were extracted with 50 mL of methanol (95.5%) and cautiously mixed for 3 min, centrifuged at 4500 rpm for 10 min and stored at -20^{o}C until used in the following analysis indicated below.

- **Total Anthocyanin content**

Anthocyanin content of each sample of noodle was determined using the method of Lee *et al.* [20]. The samples were extracted in acidified (1% citric acid) methanol and then diluted in one of two buffers: potassium chloride-hydrochloric acid (KCl-HCl) (0.025 M) at pH 1.0 or sodium acetate-HCl (0.4 M $CH_3CO_2Na{\cdot}3H_2O$) at pH 4.5. With 20 mL HCl, the second solution was adjusted to 4.5 pH. An UV/Vis Spectrophotometer with a distilled water (as a blank) was used to measure the absorption of anthocyanin in 1 mL quartz cuvettes (in triplicate) at pH 1.0 and 4.5, both at 520 and 700 nm. The absorptions were measured within 20-50 min of preparation. The anthocyanin concentration in the samples was determined as cyanidin-3-glucoside (Cyd-3-Glu) equivalents (g/100 g) using equation 3.

$$\text{Anthocyanin (mg/L)} = \frac{\mathbf{A} \times \mathbf{MW} \times \mathbf{DF} \times \mathbf{10^3}}{\varepsilon \times \mathbf{l}} \qquad (3)$$

Where:

A = $A_{520} - A_{700})\text{pH } 1.0 - (A_{520} - A_{700})\text{pH}4.5$

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MW = (molecular weight) = 449.2 g/mol for Cyd-3-Glu
DF = dilution factor
Ɛ = 26,900 molar extinction coefficient, in l × mol^{-1} cm^{-1}, for Cyd-3-Glu
103 = factor for conversion from g to mg
l = path length of cuvette in cm

- **Total phenolic content**

Total phenolic content (TPC) of each sample was analysed using the Folin-Ciocalteu method described by Yun *et al.* [21] with minor modifications. A 0.5 mL sample was added to 5 mL of Folin-Ciocalteu and distilled water reagent (1:10) then vortexed and left for 5 min at room temperature (25^{o}C). 4 mL of 1 M sodium carbonate solution was used to balance the solution. An UV/Vis spectrophotometer (Model No. UV- 1800 Shimadzu, Japan) was used to measure the extract's absorbance at 765 nm after 10 min. Gallic acid was used to create the lineal standard curve, which was displayed at gallic acid concentrations of 0, 25, 50, 75, 100, and 125 µg. The results were calculated and expressed as milligrams of gallic acid equivalent per 100 g of sample (mg GAE/100g).

- **Determination of antioxidant capacity using ferric reducing antioxidant power**

The ferric reducing antioxidant power (FRAP) was used to determine the antioxidant capacity of each sample using the protocol described by Wu *et al.* [22] with slight modifications. The FRAP solution was made up with an acetate buffer (pH 3.6), 20 mM ferric chloride solution, and 10 mM TPTZ in 40 mM HCl in a 10:1:1 ratio at 37°C on the day of analysis. Then 0.15 mL of properly diluted sample was added to 2850 µL of FRAP solution in a test tube, vortexed, and incubated at 37°C in the dark for precisely 30 min and the absorbance of each sample at 593 nm was determined using an UV/Vis spectrophotometer. The antioxidant capacity of each sample was calculated using a Trolox standard curve made from 0-25 µg/mL Trolox methanolic stock solution, which was exposed in mg Trolox equivalent per 100 g sample (mg TE/100g).

- **Determination of antioxidant capacity using the 2,2 diphenyl- 1-picrylhydrazyl (DPPH) assay**

The antioxidant capacity was determined using the DPPH assay described by Wu *et al.* [22] with slight modifications. Firstly, 0.003 g of DPPH was dissolved in 50 mL ethanol to make the DPPH working solution, which was diluted by 1.5 mL (equivalent to the antioxidant standard), reacted with 1.5 mL DPPH, vortexed, and incubated in the dark for 30 min. An UV/Vis spectrophotometer was used to test the sample's absorbance at 517 nm. The antioxidant activity was calculated using a Trolox standard curve made from a 0-25 µg/mL Trolox methanolic stock solution. Results were expressed as mg Trolox equivalent per 100g sample (mg TE/100g).

- **Determination of antioxidant capacity using 2,2'-azino-bis (3-ethylbenzothiazoline-6-sul phonic acid) (ABTS)**

The antioxidant capacity of samples was determined using the ABTS assay described by Wu *et al.* [22] with slight modifications. A freshly prepared stock solution was made by reacting 7.4 mM ABTS with 2.6 mM potassium persulfate, then mixing the stock solution with potassium persulfate (1:1) and incubating it for 12 h in the dark at room temperature (25^{o}C). The mixture was diluted with 95.5% methanol to obtain an absorbance of 1.1±0.02 at 734 nm. The extract (0.15 mL) from 95.5% methanol was combined with the ABTS working solution (2.85 mL) in a test tube, vortexed, and stored in a dark room for 2 h before being analyzed at 734 nm using a UV/Vis spectrophotometer. Trolox was employed, and the antioxidant activity of the sample was calculated using 0-25 µg/mL Trolox methanolic stock solution, which was exposed in mg Trolox equivalent per 100 g sample (mg TE/100g).

Sensory evaluation

One hundred untrained panels were selected from universities and companies (50 females and 50 males, within the age range of 22 to 60 years) who were all accustomed with eating noodles, 2-3 times each week. Each panel member was given five samples to assess at the same time. Each sample weighed 15g, one each made from refined wheat flour blended with 0, 5, 10, 15 or 20% PSPF. All the samples had been cooked for 10 min in water and randomly labeled with a 3-digit code. The panelists carried out the evaluation in a well-lit room. Panelists were also given unsalted bread, a spit cup, napkins, and room-temperature drinking water for palate cleansing in between testing each sample. The panelists were asked to rate the cooked noodle on a 9-point hedonic scale (9 = extremely like, 8 = very much like, 7 = moderately like, 6 = slightly like, 5 = neither like nor dislike, 4 = slightly dislike, 3 = moderately dislike, 2 = very much dislike, 1 = extremely dislike) in terms of appearance, color, odor, elasticity, softness, smoothness, taste, and overall acceptability.

Microbial analysis

The uncooked noodle sample with the highest sensory acceptability scores was packed separately in sterile polyethylene bags, sealed, and stored in refrigerator (at 4±2°C) for 0, 3, 6, 9 or 12 days before being tested for microbiological contamination. Aerobic plate count, yeast, mold, *Staphylococus aureus, Bacillus cereus and Samonella spp.* were estimated in and presented in colony-forming

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units (CFU)/g, and Escherichia coli level was calculated in most probable number (MPN)/g. The methods used for all the samples examined were in accordance with the United States Food and Drug Administration, Bacteriological Analytical Manual FDA-BAM [23, 24, 25, 26, 27]. Each analysis was carried out in triplicate.

Statistical analysis

The experimental design was a completely randomized design (CRD) and a randomized completely block design (RCBD). The samples were analyzed in triplicates. For mean comparison, analysis of variance (ANOVA) and statistical methodology were tested using a Duncan's New Multiple Range Test at $p \leq 0.05$ in SPSS.

RESULTS AND DISCUSSION

Color characteristics of noodles

The color characteristics of noodles (raw and cooked) showed that increasing levels of PSPF in the noodles resulted in significantly increasing ($p<0.05$) L* (darkness) but significantly decreasing ($p<0.05$) a* (redness) and b* (yellowness) of both the raw and the cooked noodles (Figure 1 and Table 1). However, the noodles with PSPF became greener and darker although flour from which the PSPF was made was purple. This effect is confirmed by the report of Xiu-li *et al.* [28], who showed that purple sweet potatoes flour contained anthocyanins, which are compounds with a range colors from orange to purple and that the anthocyanin stabilization was changed in alkaline conditions, since the pH of the noodles was 7 and higher. This is confirmed by the findings of Khoo *et al.* [29] who showed that the color of the anthocyanin from the raw purple sweet potatoes remained purple at neutral pH. If the pH was higher (alkaline) the color of anthocyanin became blue to dark blue. These observations conform to the pH of the raw and cooked noodles with pH increasing to 9.0 or higher (Table 3), resulting in the color of anthocyanin turning blue. Moreover, some pasteurized egg was also added to the noodle flour, making it more yellow, thus making the appearance of green and also making it darker for both the raw and cooked noodles.

https://doi.org/10.18697/ajfand.114.22555

Figure 1: The appearance of dough (A1-A5), raw noodles (B1-B5) and cooked noodles (C1-C5) using purple sweet potato flour substituted at 0% (1), 5% (2), 10% (3), 15% (4) or 20% (5) with refined wheat flour

Cooking quality of noodles

The cooking quality of noodles was determined by water absorption or cooking yield, the cooking time and the loss of solids into the cooking water (Table 2). A high cooking yield, a short cooking time and low loss of solids were considered favorable attributes as previously reported [30]. The cooking time for control noodle was significantly higher ($p<0.05$) than the PSPF noodles, with times ranging from 80 to 120 sec. This effect was due to the decreasing gluten network resulting in faster moisture penetration and therefore leading to decreased optimum cooking time, as previously reported [31]. Also, the cooking loss of noodles containing PSPF were 4.80 to 7.53%, which was higher than the noodles made with no PSPF which was 4.40% (Table 2). Moreover, with increasing PSPF levels, the cooking yield decreased from 200.03 to 183.67%, which were lower than control noodles (205.3%). These results were closed to the findings of Sun *et al.* [13] who showed that the cooking loss of wheat flour noodles was significantly lower than the noodles prepared with wheat flour supplemented with Chinese yam powder. Also, Aukkanit and Sirichokworrakit [32] who used dried pumpkin powder for partial substitution of wheat flour in noodles, found that cooking loss increased with increasing dried pumpkin powder. Izydorczyk *et al.* [33] reported that when wheat flour was partially substituted with barley flour, the quality of the protein-starch matrix was reducing but the cooking loss in noodles increased. In addition, Phongramun *et al.* [34] studied wheat flour noodles substituted with Amaranth

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Volume 22 No. 9
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ISSN 1684 5374

(Amaranthus lividus) leaf powder. They found that cooking time and cooking yield were decreased while cooking loss was increased with added Amaranth leaf powder. It seems probable that the changes in cooking loss of the PSPF noodles could be due to the disturbance of the protein starch matrix through diluted gluten granules. It may, therefore, be concluded that increasing the amount of PSPF changed the cooking quality and other attributes because their gluten fraction was diluted, resulting in decreased water retention in noodles. Hence, increasing the PSPF levels affected the practical properties of noodles as well as their cooking ability.

Texture characteristics of noodles

Texture determination of raw and cooked noodles showed that when the PSPF level increased, the elasticity and tensile strength of both raw and cooked noodles were significantly decreased ($p<0.05$) (Table 3). The noodles that contained PSPF showed significantly ($p<0.05$) increased hardness and decreased elasticity compared to noodles made from 100% refined wheat flour, which may have reduced consumer acceptability, which confirms the findings of Ginting and Yulifianti [35]. Boonpichai and Sirivongpaisal [36] also showed that increasing the level of substitution of wheat flour in noodles with sweet potato flour increased their hardness. Khoo *et al.* [29] suggested that the reason for this effect was an inability to establish networks during dough formation, which damaged noodles, making them less soft and prone to breaking. By adding PSPF to noodles, the gluten level was diluted, agitation occurred and the noodle structure was intruded, resulting in the noodle being more easily torn.

Water activity and pH of uncooked noodles

The amount of free water in food, can be measured by its water activity and food with a high water activity may be more susceptible to spoiling. Water activity of the noodles (PSPF and control) in this experiment showed no significant differences ($p<0.05$) with levels of 0.94-0.95 (Table 3), which conforms to the findings of Li *et al.* [18] who reported Aw of 0.97 for wet yellow noodles and Murdinah and Wahyuni [37] who also reported Aw of 0.97 for wheat noodles incorporated with Caulerpa sp. seaweed. High levels of Aw in food can increase microbial development and was also linked to many enzymatic and chemical reactions as well as affecting its physical nature [38]. The range of pH levels in the noodle (9.32-9.48) showed significant difference ($p<0.05$), they could be classified as a normal noodle, since noodles generally has pH levels between 9 and 11. The flavonoids in wheat flour, which showed yellow color in an alkaline environment and increased with increasing pH values, therefore the pH a directly associated with the color of the noodles [39].

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Chemical compositions of purple sweet potato flour and uncooked noodles
The levels of moisture, carbohydrate, protein, fat and ash of purple sweet potato flour (4.39, 83.59, 0.59 and 2.35 g/100g, respectively) (Table 4) were similar to those reported by Hossain [40]. When PSPF was compared with refined wheat flour [41], the PSPF had considerably higher levels of carbohydrate and ash and lower in protein and fat. The lightness (L*), redness (a*) and yellowness (b*) of PSPF were close to those reported by Tang *et al.* [42]; however, comparison of PSPF and refined wheat flour, found that PSPF was darker (L*), redder (+a*) and bluer (-b*) than refine wheat flour.

Moisture content, protein and fat were slightly decreased when PSPF was added, while ash and total carbohydrate were slightly increased (Table 5). These results show that an advantage of the noodles with PSPF was increasing total carbohydrate and decreasing fat. This effect could indicate that consumption of these noodles could contribute to the reduced risk of disease such as heart attack, stroke and cancer [43].

Total anthocyanin content, total phenolic content and antioxidant activity
Uncooked noodles with PSPF substituted at 0 (control) and 20% had total anthocyanin content (TAC) which were 0 and 9.84 cyanidin-3-glucoside (Cyd-3-Glu) equivalents (g/100g) respectively, total phenolic content (TPC) values were 30.93 and 151.28 mg GAE/100g respectively, antioxidant activities by ferric reducing antioxidant power (FRAP) assays were 25.59 and 254.32 mg TE/100g respectively, 2,2 diphenyl-1-picrylhydrazyl assay (DPPH) assays had 10.95 and 158.70 mg TE/100g, respectively and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) assays had 17.69 and 156.98 mg TE/100g respectively, (Figure 2, 3 and 4). TAC, TPC and antioxidant activities in all assays increased as PSPF increased, with 20% of PSPF giving the highest anthocyanin, TPC and antioxidant activities while 0% PSPF was the lowest. Khumkhom [44] as well as Zhu and Sun [45] studied steamed bread with added with PSPF, and also observed that addition of PSPF increased the antioxidant activities, total polyphenol and anthocyanin contents. Aziz *et al.* [46] fortified biscuit with PSPF and observed that they had a higher antioxidant capacity compared to control as well as significantly higher levels of phenolic and anthocyanin.

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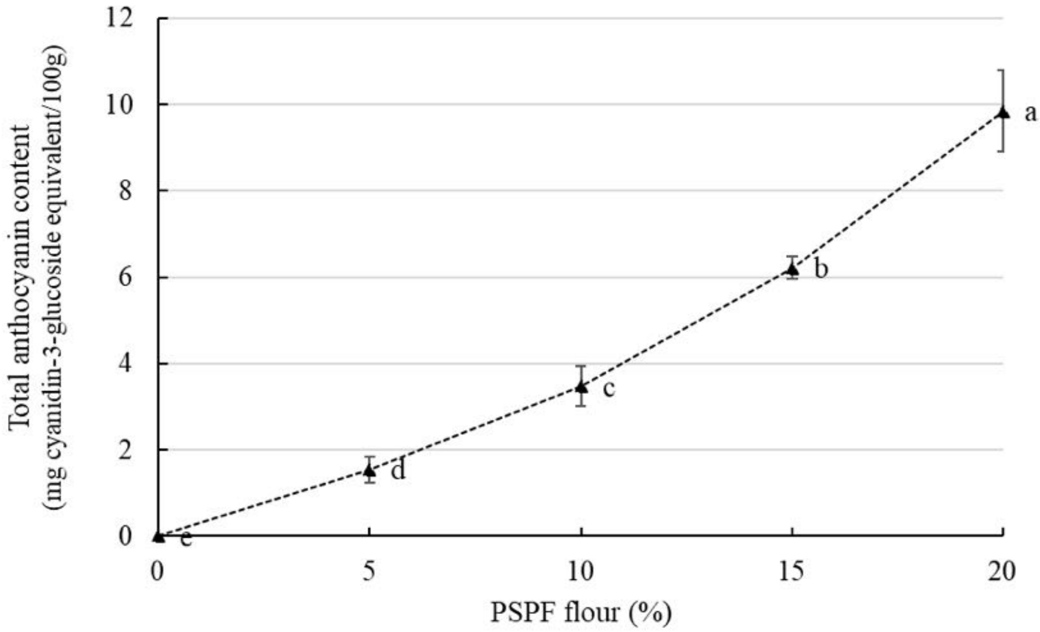

Figure 2: Total anthocyanin content of uncooked noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

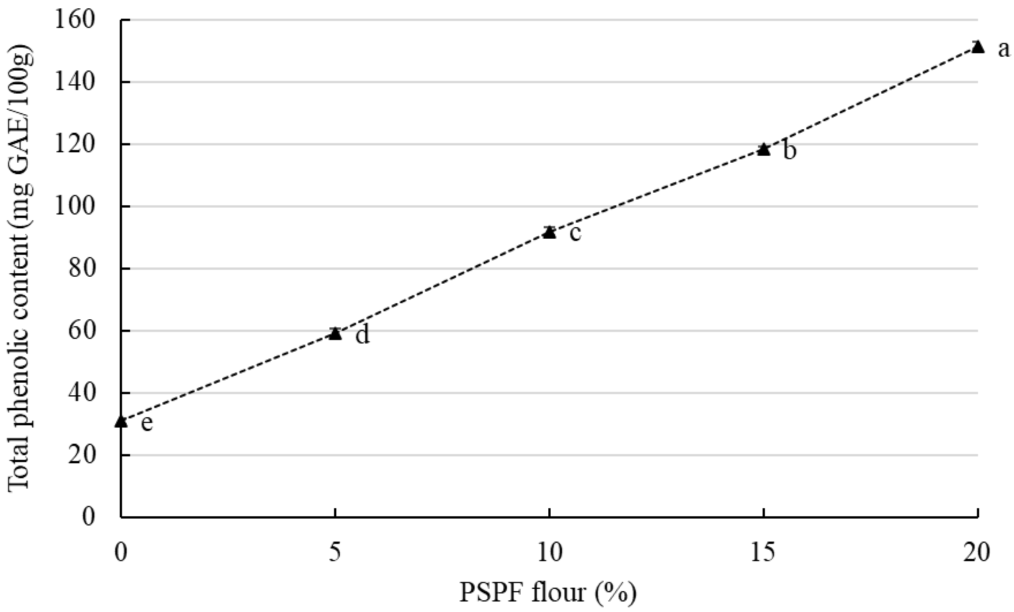

Figure 3: Total phenolic content of uncooked noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

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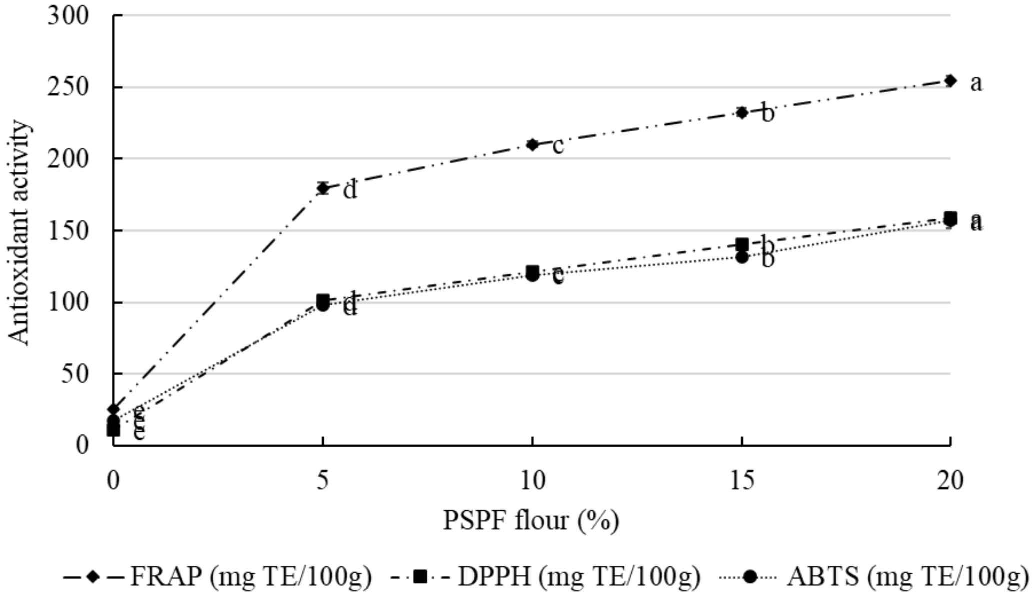

Figure 4: Antioxidant activity of uncooked noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

Sensory analysis

The sensory characteristics of the cooked noodles showed that all attributes were slightly decreased when PSPF added to the refined wheat flour (Table 6). The addition of PSPF at all the levels tested significantly ($p<0.05$) decreased elasticity, softness and smoothness, but the appearance, color, taste and overall acceptability were not significantly different ($p<0.05$) from the control in the noodles. The odor could be significantly ($p<0.05$) increasing their acceptance to consumers, it may because sweet potatoes contain volatile compounds (floral odor, floral sweet odor, sweet odor and potato odor) [47].

Effect of storage time on microorganism of uncooked noodles

It is crucial for consumer health that levels of Microbial infection are minimized in food [48]. As expected, the levels of total plate count, yeast and mold increased during refrigerator (4±2°C) storage in all treatments, but *Escherichia coli, Staphylococcus aureus, Bacillus cereus*, and *Samonella spp.* remained undetectable throughout the storage period (Table 7). According to the Department of Medical Science, Ministry of Public Health, Thailand, Guide Lines for Fresh Noodles (No.3/2017) [49], total plate count should be less than $5×10^5$ CFU/g, yeast and mold should be less than 500 CFU/g, Escherichia coli should be less than 10 MPN/g, *Staphylococcus aureus, Bacillus cereus* should be less than 100 and 1,000 CFU/g, respectively, and *Samonella spp.* should be undetected in 25 g.

https://doi.org/10.18697/ajfand.114.22555

From this study, even after 9 days of storage, these noodles complied with Thai standards for microbiological contamination [49].

CONCLUSION

It was concluded that although partially substituting refined wheat flour with purple sweet potato flour, resulted in measurable changes in their color, lightness, cooking times, cooking yields, cooking loss, texture and water activity, they remained acceptable to the sensory evaluation panel. These changes were also compensated by increases in levels of carbohydrate, ash, anthocyanin, phenolic compounds and antioxidant capacity. Also, no detrimental microbial contamination could be detected in the noodles after storage. It is recommended that substituting wheat flour with up to 20% purple sweet potato flour would have beneficial effects for consumers.

ACKNOWLEDGEMENTS

Thanks to Prof. Dr. Anthony Keith Thompson for correcting the English.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 9
November 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Color characteristics of uncooked and cooked noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

PSPF substitute wheat flour (%)	Uncooked noodles			Cooked noodles		
	L*	a*	b*	L*	a*	b*
0	68.45±0.71[a]	2.05±0.16[a]	24.32±0.97[a]	65.81±0.99[a]	0.65±0.20[a]	18.56±0.59[a]
5	46.96±0.83[b]	-1.97±0.11[b]	11.69±0.16[b]	42.32±1.01[b]	-2.52±0.38[b]	9.79±0.48[b]
10	44.87±0.70[c]	-4.31±0.31[c]	10.78±0.74[b]	37.98±0.85[c]	-3.59±0.27[c]	8.19±0.61[c]
15	38.33±0.93[d]	-7.32±0.57[d]	9.08±0.82[c]	35.17±0.54[d]	-5.46±0.15[d]	6.08±0.78[d]
20	35.78±0.80[e]	-9.21±0.54[e]	8.16±0.68[c]	31.22±0.88[e]	-7.29±0.16[e]	5.02±0.75[e]

[a-e] Mean ± SD The different letters in each column indicate significant difference ($p<0.05$)

ajfand SCHOLARLY, PEER REVIEWED
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ISSN 1684 5374

Table 2: Cooking time, cooking loss and cooking yield of noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

PSPF substitute wheat flour (%)	Cooking quality		
	Cooking time (sec)	Cooking loss (%)	Cooking yield (%)
0	120	4.40±0.92[a]	205.03±4.97[a]
5	110	4.80±0.60[a]	200.23±4.40[a]
10	100	5.20±0.53[b]	196.60±5.31[bc]
15	90	6.53±0.46[b]	190.17±5.60[bc]
20	80	7.53±0.42[b]	183.67±5.75[c]

[a-c] Mean ± SD The different letters in each column indicate significant difference ($p<0.05$)

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Volume 22 No. 9
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ISSN 1684 5374

Table 3: Water activity, pH and texture characteristics of noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

PSPF substitute wheat flour (%)	Uncooked noodles	Uncooked noodles	Uncooked noodles	Cooked noodles
	Water activity* [ns]	pH	Tensile strength (g)	Tensile strength (g)
0	0.94±0.01	9.32±0.07[b]	28.80±1.96[a]	20.80±2.55[a]
5	0.94±0.00	9.30±0.02[b]	26.22±1.56[b]	19.40±2.65[ab]
10	0.94±0.01	9.28±0.01[b]	24.86±1.47[b]	18.03±1.16[bc]
15	0.95±0.00	9.46±0.02[a]	22.01±1.02[c]	17.21±1.22[bc]
20	0.95±0.02	9.48±0.01[a]	20.82±1.14[c]	16.52±0.99[c]

[a-c] Mean ± SD The different letters in each column indicate significant difference ($p<0.05$)
[ns] The different letters in each column indicate non-significant difference ($p>0.05$)

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ISSN 1684 5374

Table 4: Chemical compositions and color characteristics of purple sweet potato flour (PSPF) and refined wheat flour (FWF)

Sample	Moisture content (%)	Carbohydrate (g/100g)	Protein (g/100g)	Fat (g/100g)	Ash (g/100g)	L*	a*	b*
PSPF 1	9.08	83.59	4.39	0.59	2.53	51.87	24.44	-7.72
PSPF 2	6.45	85.80	2.17	0.55	1.85	49.25	23.83	-9.56
RWF 3	11.10	74.60	12.00	1.70	0.56	86.15	0.56	6.85

PSPF 1 = purple sweet potato flour (This study), PSPF 2 = purple sweet potato flour [40, 42], RWF 3 = refined wheat flour [41]

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Table 5: Chemical compositions of uncooked noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

PSP substitute wheat flour (%)	Uncooked noodles substituted with PSPF				
	Moisture content (%)	Ash (g/100g)	Protein (g/100g)	Fat (g/100g)	Total carbohydrate (g/100g)
0	39.57	2.02	8.89	2.05	46.99
5	38.78	2.09	8.56	1.99	47.44
10	37.01	2.12	7.89	1.95	47.96
15	36.35	2.15	7.37	1.87	48.40
20	36.17	2.20	6.69	1.81	49.01

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
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Table 6: Sensory acceptability of cooked noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% purple sweet potato flour

PSPF substitute wheat flour (%)	Appearance* ns	Color* ns	Odor	Elasticity	Softness	Smoothness	Taste* ns	Overall* ns acceptability
0	8.12±0.99	7.76±0.81	7.54±0.73[b]	8.18±0.81[a]	8.58±0.75[a]	8.16±1.04[a]	7.70±0.78	8.52±0.73
5	8.16±1.08	7.86±0.89	7.74±1.25[ab]	8.00±0.85[ab]	8.22±0.90[b]	7.88±0.65[ab]	7.74±1.02	8.46±0.78
10	8.08±0.74	7.96±0.92	7.76±0.97[ab]	7.92±0.87[ab]	8.20±0.92[b]	7.86±0.89[ab]	7.78±0.61	8.34±0.76
15	7.92±0.52	8.00±0.60	7.88±0.82[ab]	7.80±0.60[bc]	7.94±0.70[bc]	7.84±0.93[ab]	7.90±0.83	8.42±0.67
20	8.04±0.80	8.04±1.00	8.08±1.02[a]	7.64±1.05[c]	7.82±0.99[c]	7.74±0.77[b]	7.98±0.81	8.40±0.87

[a-c] Mean ± SD The different letters in each column indicate significant difference ($p<0.05$)

[ns]The different letters in each column indicate non-significant difference ($p>0.05$)

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
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November 2022
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ISSN 1684 5374

Table 7: Microbial count of uncooked noodles made from refined wheat flour substituted with 20% purple sweet potato flour during storage at 4±2°C for 0, 3, 6, 9 or 12 days

Storage time (days)	Total plate count (CFU/g)	Yeast and mold (CFU/g)	*Escherichia coli* (MPN/g)	*Staphylococcus aureus* (CFU/g)	*Bacillus cereus* (CFU/g)	*Salmonella spp.* (in 25 g)
0	3.4×10^{2}	ND	ND	ND	ND	ND
3	4.1×10^{2}	ND	ND	ND	ND	ND
6	5.7×10^{3}	3.2×10^{2}	ND	ND	ND	ND
9	5.5×10^{4}	4.1×10^{2}	ND	ND	ND	ND
12	6.4×10^{5}	5.3×10^{3}	ND	ND	ND	ND

ND = not detected

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Volume 22 No. 9 November 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

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