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EFFECT OF PARTIAL SUBSTITUTION OF WHEAT FLOUR WITH TAMARIND SEED FLOUR ON PHYSICAL, CHEMICAL, ANTIOXIDANT AND SENSORY PROPERTIES OF NOODLES

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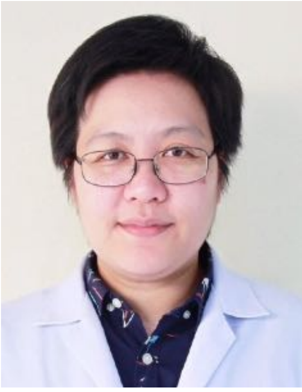

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ABSTRACT

Tamarind (*Tamarindus indica* L.) fruit are a major crop of Thailand and many other countries. Tamarind fruit are used in food processing, but their seeds, which constitute about 34% of each fruit, are largely a wasted byproduct. Production of fresh noodles, using flour made from tamarind seed (TSF) as a partial substitute for wheat flour, was tested. The proportion of TSF in the flour was varied from 0, 5, 10, 15 and 20%, with the balance being white wheat flour. Results showed that with increasing the levels of TSF in the flour there was a concomitant increase in their carotenoid content, but 15% resulted in negative responses from the sensory evaluation panel due mainly to darkening and browning of the color of the noodles and making them less soft and less elastic. These perceptions by the panelists were reflected in the measurement of $L*$, $a*$ and $b*$ and the tensile force of dough and tensile strength of cooked noodles. When the noodles made from 10% TSF plus 90% wheat flour were tested, their moisture content, protein, total carbohydrate, fat and ash were 70.6, 6.26, 21.5, 1.08, 0.490 g/100g and calories was 121 kcal/100g, respectively and their mineral contents were calcium, magnesium, phosphorus, potassium and sodium at 16.0, 14.4, 45.3, 27.2 and 130 mg/100g, respectively. Total phenolic content and antioxidant activity also progressively increased with increasing levels of TSF in the flour. The total phenolic content from noodles made from 10% TSF plus 90% refined wheat flour were 7.92 mg GAE/g, antioxidant activity was 29.6 mM TE/g by ferric reducing antioxidant power, 17.1 mM TE/g by 2,2 diphenyl-1-picrylhydrazyl assay and 3.84 mM TE/g by 2,2'-azino-bis (3-ethylbenzothiazo line-6-sulphonic acid). The descriptive analysis of eight trained panelists discovered 16 individual attributes of cooked noodles made from 10% TSF plus 90% wheat flour. These attributes were yellowness, turbidity, egg odor, flour odor, tamarind flour odor, roasted tamarind seed odor, alkaline odor, egg flavor, flour flavor, tamarind flour flavor, roasted tamarind seed flavor, bitter taste, wetness, smoothness, softness and elasticity. The descriptive analysis showed that the cooked noodles containing 10% TSF had similar characteristics to cooked noodles made from 100% wheat flour except for roasted tamarind seed odor, tamarind flour flavor and roasted tamarind seed flavor that were unique characteristics, as would be expected.

Key words: Antioxidant activity, Chemical properties, Noodle, Sensory attributes, Tamarind seeds flour

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INTRODUCTION

Tamarind trees (*Tamarindus indica* L.) are grown in more than 50 countries for their edible fruit. Producing countries include Bangladesh, India, Indonesia, Sri Lanka, Thailand and also several countries in Africa and the Americas. Thailand produces about 76,144 tonnes of tamarind fruit a year, mainly in Phetchabun province. However, there is only one company who processes the seeds into flour. The same company also makes gellose from tamarind flour, which is similar to pectin and able to use in the food industry for many products including tamarind jelly, jelly powder, fruit coating film and specifically for the ice cream industry [1, 2]. The tamarind fruit is comprised of about 55% pulp, 34% seeds and 11% shell [3]. The shell is minutely scaly, light greenish in color eventually turning brown and brittle, fibrous and broken easily when pressed. The pulp is thick firm soft and blackish-brown in color and is an ingredient and flavor component in commercially produced chutneys (including Worcestershire sauce), pickled fish and curry dishes and is used to make a sweet syrup flavoring for ice cream and soft drinks [4]. Tamarind polysaccharides and gum obtained from their seeds can be used to produce gels that can be used as an alternative to fruit pectin in the food industry. Besides being used to a limited extent in the food industry, tamarind seed extract is also used as adhesive filler in the plywood industry, as a stabilizer for making sawdust briquettes and as a thickener for some explosives [5] It is clear that much of the seed that is produced goes to waste; therefore, any new uses could be beneficial to growers and processors.

Noodles have been used as a staple food in Asia, together with rice, for over 2,500 years. Noodles are normally made from refined wheat flour, salt, alkali solution, eggs, water and/or food coloring by mixing, rolling into sheets and cutting [6]. Nevertheless, fresh noodles are generally low in nutrients, dietary fiber and minerals, which are often supplemented during commercial processing [7, 8]. Tamarind seeds have high amounts of fiber and other nutrients and could be processed to make flour that could be used as a partial substitute for refined wheat flour in noodles [9]. El-Gindy *et al.* [10] successfully tested biscuits made from a mixture of wheat flour and tamarind seed flour (TSF) at a ratio of wheat flour to TSF of 100:0, 97:3, 94:6, 91:9, 88:12 and 85:15. The nutritional level of the biscuits was affected by the level to tamarind seed flour and results were 10.55, 14.63, 21.01, 25.23 and 28.87 mg GAE 100 mL^{-1} for total phenolic content and 4.12, 5.22, 6.95, 8.33, 10.01 and 11.13 mg GAE 100 mL^{-1} for total antioxidant activity, respectively. Also, Natukunda *et al*. [11] incorporated tamarind seed powder into mango juice (1.5%) and cookies (6%) and reported that these levels enhanced their nutritional properties and were accepted by a sensory evaluation panel.

It is clear that blending wheat flour with flour from tamarind seeds could improve the nutritional content of noodles. The objective was therefore to ascertain the optimum processes required to produce cooked noodles from TSF as a partial substitute for refined wheat flour and determine the acceptability of these noodles, made from this mixture, to consumers.

MATERIALS AND METHODS

Raw material preparation

Tamarind seed flour was purchased from the Pinphet Company in Phetchabun province of Thailand. The standard formula of the noodles was made by the method described by Uthai *et al.* [12] by mixing 200 g of medium protein refined wheat flour, 3 g of sodium chloride (NaCl), 3 g of sodium carbonate (Na_2CO_3), 55 g of egg and 70 mL of drinking water in a kitchen mixer (Kenwood Elite XL KVL6320S, Thailand) at medium speed for 5 min. The selection of these ingredients had been established to provide a product that is acceptable to consumers in terms of texture, flavor and overall liking. The mixture was varied by substituting tamarind seed flour for refined wheat flour at 0 (control), 5, 10, 15 or 20%. After mixing the dough was wrapped in a commercially available food wrap, made from polyvinylchloride film, and left for 30 min at room temperature (about 25°C) then placed in a noodle maker (Marcato Atlas 150, Italy) also at room temperature. The noodles were then boiled in water at 100°C for 90 sec (Figure 1).

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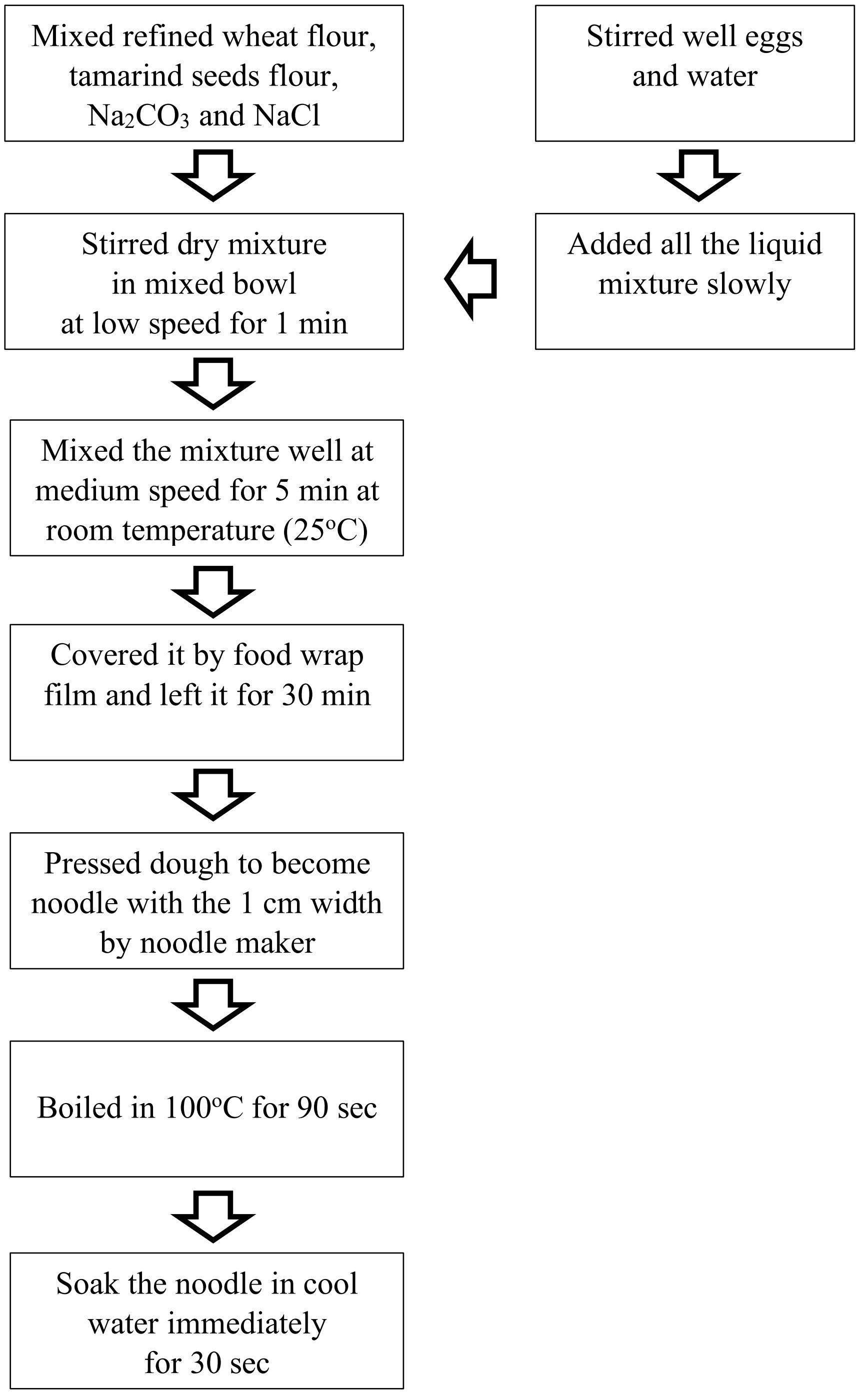

Figure 1: Flow chart of the process used for noodle production in the experiments

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Chemicals and reagents
The chemicals, 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), 2,2 diphenyl-1-picrylhydrazyl (DPPH), 6-hydroxy-2, 5, 7, 8-tetramethylchroman-2-carboxylic acid (trolox), 2,4,6-tripyridyl-s-triazine (TPTZ), gallic acid monohydrate, iron (III) chloride hexahydrate, quaiacol and Folin-Ciocalteu reagents, were purchased from Sigma Aldrich Corp., St. Louis, USA. Potassium persulfate, sodium acetate trihydrate, sodium carbonate, ethanol (96%) and methanol (95.5%) were purchased from Merck KGAA, Darmstadt, Germany. Acetic acid and hydrochloric acid were purchased from RCI Labscan Co., Ltd., Bangkok, Thailand. All chemicals and reagents were of analytical grade.

Determination of color (dough and cooked noodles)
The color of both the dough, before cooking, and the cooked noodles were analyzed for their surface color using a Chroma-meter (Minolta CR400, Japan) to measure L^*, a^* and b^* using the CIE system. For this, 30 g of each sample was spread out on a glass plate and measured in 3 different places on different parts of each sample.

Determination of texture (dough and cooked noodles)
The texture of both the dough and cooked noodles were analyzed using a Texture Analyzer (TA-XT plus, England) following the method reported by Uthai *et al.* [12], using a Kieffer dough and gluten extensibility rig at a speed test of 3 mm/sec, a distance of 100 mm and 30 mm and the trigger type was auto 5 g. The analysis was repeated 5 times on each sample.

Determination of total phenolic content and antioxidant activity

Samples preparation
Samples (2g) of the cooked noodles, containing 0, 5, 10, 15 or 20% TSF, with the balance refined wheat flour, were extracted with 50 mL of methanol (95.5%) and carefully mixed for 3 min, centrifuged at 4500 rpm for 10 min and preserved at -20^{o}C until used in the following analyses:

***Total phenolic content* (TPC)**
The TPC analysis conformed that of Yun *et al*. [13] with slight modifications. TPC was determined according to Folin-Ciocalteu method, the solution from 5 mL of Folin-Ciocalteu and distilled water reagent (1:10) was added to 0.5 mL sample, vortexed and leaved for 5 min at room temperature (25^{o}C). The solution was balanced with 4 mL of 1 M sodium carbonate solution. After 10 min the absorbance of the extract was performed by an UV/Vis spectrophotometer (Model No.UV-1800 Shimadzu, Japan) at 765 nm. Gallic acid was used to set up the lineal standard curve and plotted in gallic acid of 0, 25, 50, 75, 100 and 125 µg and the results were calculated as gallic acid equivalent per 1 g of sample (mg GE/g).

***Determination of antioxidant capacity using Ferric Reducing Antioxidant Power* (FRAP)**
The measurement of antioxidant capacity using FRAP assay was accordance with the procedure of Wu *et al*. [14] with slight modification. The FRAP solution was composed

of acetate buffer (pH 3.6), 20 mM ferric chloride solution and 10 mM TPTZ in 40 mM HCl in a balance of 10:1:1, respectively at 37°C freshly made on the day of analysis then added 0.15 mL of properly diluted sample with 2850 µL of FRAP solution in the 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 performed by an UV/Vis spectrophotometer. A Trolox standard curve was prepared from a 1 mM Trolox methanolic stock solution and used to calculate the antioxidant capacity of the sample, which was revealed in mM Trolox equivalent per g sample (mM TE/g).

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

The antioxidant capacity was analyzed by using DPPH assay as following Wu *et al*. [14] with slight modification. The DPPH working solution was prepared by dissolving 0.003 g of DPPH in 50 mL ethanol. The sample was diluted by 1.5 mL (the same amount as the antioxidant standard) was reacted with 1.5 mL DPPH, vortexed and incubated for 30 min in the dark. Absorbance of the sample was at 517 nm was measured with an UV/Vis spectrophotometer. A Trolox standard curve was prepared from 1 mM Trolox methanolic stock solution for calculating the antioxidant activity, which was revealed in mM Trolox equivalent per g sample (mM TE/g).

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

The antioxidant capacity of samples was analyzed using the ABTS assay following the method of Wu *et al*. [14] with slight modification. Freshly prepared stock solution which was produced by the reaction between 7.4 mM ABTS and 2.6 mM potassium persulfate, then the stock solution was mixed with potassium persulfate (1:1), incubated in the dark at room temperature for 12 h. Then the mixture was diluted with 95.5% methanol such that an absorbance of 1.1±0.02 at 734 nm to obtain. The extraction (0.15 mL) from the 95.5% methanol was added with the ABTS working solution (2.85 mL) in a test tube, vortexed, stored in a dark place for 2 h and its absorbance at 734 nm was measured with an UV/Vis spectrophotometer. Trolox was used as standard substance. Trolox methanolic stock solution (1mM) was prepared and used for calculating the antioxidant activity of the sample, which was revealed in mM Trolox equivalent per g sample (mM TE/g).

Determination of chemical composition and minerals

Samples of the cooked noodles, which had been made from the TSF for 0, 5, 10, 15 and 20%, were analyzed founded on AOAC [15] for moisture content, fat, protein and ash using sub components 925.10, 922.06, 981.10 and 923.03, respectively. Total carbohydrate and energy were used with the method described by Darryl *et al.* [16]. Several key minerals (Calcium, Magnesium, Phosphorus, Potassium, and Sodium) were also analyzed AOAC [15] using sub components 984.27, 984.27, 985.01, 984.27 and 984.27, respectively.

Sensory acceptability of cooked noodles

Sensory evaluation of the cooked noodles, which had been made from the refined wheat flour substituted with 0, 5, 10, 15 or 20% TSF, were evaluated by 100 panelists selected from university faculties, government departments and companies. With each 15 g serving of noodles, each panelist received a spit cup for expectoration, paper napkins and drinkable water at room temperature (25°C). The panelists were asked to test for parameters: appearance, color, odor, elasticity, smoothness and overall liking using 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).

Sensory descriptive analysis of cooked noodles

Panel Selection

Eight panelists were between 25 and 35 years old and chosen from 18 food science post graduate students in the Faculty of Agro-Industry of King Mongkut's Institute of Technology Ladkrabang and students of Rajamangala University of Technology Krungthep, who could attend all of the programs and had experience and knowledge of sensory evaluation. Before becoming a panelist each candidate was tested in order to confirm that he/she could respect taste (bitter, sweet, salty and sour) and odor (apple, banana, chocolate, coffee, orange, strawberry, tea and vanilla), explain all attributes exactly and clearly rank the intensity of tastes (bitter, sweet, salty and sour). Only panelists could describe about 80% of the stimuli and their characteristics as recommended by Meligaard *et al.* [17].

Training

The panelists that had been selected used the technique to complete sensory descriptive analysis which was explained by Meilgaard *et al.* [17] and Stone and Sidel [18] where a 0 to 15 cm scale (one significant digit) was used to score attributes. This training program took 3 months and was divided to 3 sessions of 180 h in total. In the first training session, all panelists received noodle samples, a spit cup for expectoration, paper napkins and drinkable water at room temperature (25°C), and then described the appearance, odor, flavor and taste characteristics of the noodle samples, which were used to create product qualities. These attributes were identified and reference standards for rating were made by general agreement of the panelists. In the next session, all panelists reconsidered the terms and estimated the intensity scores needed to generate a reference standard for each attribute and deliver general agreement for scores in order to each reference standard. For the last session, panelists reconsidered the reference standards and appraised all of the noodle samples by the referable limit of reference standards therefore they had concurrence. Their scales were then adjusted the standard deviation (SD) of scores until it was less than 1.0. Every panelist was calibrated with warm-up samples on every training day by using 0 to 15 numerical scale ballots for evaluating the sample.

Sample preparation

Samples, 10 g each of seven brands of commercially produced noodles available in Thailand, made from 100% refined wheat flour, were prepared by placing them in a pot of boiling water at a ratio of noodles to water of 1:10 (w/v) (following the instructions on the packages for 1-3 min), then placing them in cool water for 60 sec, allowing them to dry and immediately serving them to panelists on ceramic plates.

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Sample evaluation

After finishing all sessions of the training program, each panelist was given 15g of the cooked noodles on a ceramic plate and asked to appraise in terms of appearance, odor, flavor and taste each sample in triplicate then explained all the above attributes. Every noodles sample was coded with random numbers in three-digits then served to the panelists, one sample each time, with a 5 min break between each sample and a one hour break half way through the evaluation (4 samples) then continuing the evaluation for the others (4 samples). Each panelist received a spit cup for expectoration, paper napkins and drinkable water at room temperature (25°C) during their evaluations.

Statistical analysis

The experimental designs used were the completely randomized designs (CRD) and the randomized completely block design (RCBD). The analyses of the samples were conducted in triplicate. Analysis of variance (ANOVA) and statistical protocol by the Duncan's new multiple range test ($p \leq 0.05$) using SPSS were used in the analyses.

RESULTS AND DISCUSSION

Color of dough, raw noodles and cooked noodles

The appearances of dough (line A which had A1-A5), raw noodles (line B which had B1-B5) and cooked noodles (line C which had C1-C5) are shown in Figure 2.

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

The color characteristics of both the dough and cooked noodles containing TSF are shown in Figure 1 and Table 1. With increasing levels of Tamarind seed flour (TSF) in the refined wheat flour noodles there was significantly (p<0.05) increasing darkening (L*) and redness (a*) but decreasing yellowness (b*) of both the dough and the cooked noodles. TSF was previously reported to contain leucoanthocyanidin pigment that can increase the light-brown color [19]. This change in color could affect its acceptance by consumers since it can give noodles an unnatural appearance. A similar effect on the L*, a* and b* of noodles was shown by Ekthamasut [20] when wheat flour was partially substituted with Bambara groundnut (*Vigna subterranean*) flour. This effect was accounted for by the presence of the color pigment flavonoids and anthocyanins in the groundnut flour, which increased redness and decreased lightness. Another cause that could result in the color change could be the actual process of making the noodles. For example, the color pigment from flavonoids, quercetin and rutin of buckwheat flour particles can be leached from the flour into the water, during boiling and steaming, leading to reduced brightness (L*) and increased redness (a*) [21].

Texture of dough and cooked noodles

The textural characteristics of dough and cooked noodles prepared from a mixture of TSF and refined wheat flour showed that all blends had significantly higher (p>0.05) tensile force of dough and tensile strength of cooked noodles than the control (Table 2). However, the maximum tensile force and distance of dough for the mixture of 20% TSF with 80% refined wheat flour were 177.82 g and 13.67 mm, which were significantly higher (p>0.05) than the other blends including control which were 86.16 g and 32.35 mm. This indicates that noodles containing increasing amounts of TSF were tougher and more easily torn. After boiling, the tensile strength of the cooked noodles decreased with increasing TSF substitution at 5, 10, 15 or 20%, which were all significantly different (p>0.05) from the control. The control had a maximum tensile strength of 19.8 g while the tensile strength of the others, 5, 10, 15 and 20%, were 16.53, 15.64, 14.48 and 13.25 g, respectively. This effect could be due to gluten of wheat flour giving the noodles a strong network however, increasing TSF, non-gluten flour, in the structure of noodles reduced the gluten of the wheat flour and disturbed the overall structure of noodles. In term of consumer acceptance, increasing TSF level resulted in the noodles being less soft, with lower elasticity and lower firmness. Suwannaporn and Wiwattanawanich [22] investigated quality and texture of fresh noodles using white rice flour to partially substitute wheat flour. With increasing proportions of rice flour, gluten levels in the noodles decreased and were less elastic. They found that this effect on elasticity was due to the protein from rice flour, having no glutenin and gliadin, which did not form three dimensional networks and therefore resulted in noodles with a weakened structure and that tore easily. Also, Sirichokworrakit *el al.* [23] reported that the tensile strength of noodles increased while breaking length reduced when flour from the rice cultivar ‘Riceberry’ was used to partially substitute wheat flour, giving those noodles higher hardness and lower elasticity. This effect may be because wheat flour contained glutenin and gliadin which can form three-dimensional networks. Hence, noodles made from wheat flour had higher elasticity than the other kinds of flour. This was confirmed by Tanasombun *et al.* [24] who analyzed the texture of fresh noodle, where palmyra palm (*Borassus flabellifer*) powder had been used to partially substitute wheat flour. They showed that elasticity/tensile strength decreased with increased palmyra palm powder because wheat flour contains greater density protein that gives the noodles their elastic characteristic. These results confirm that increased non-gluten or low gluten flour in noodles can decrease their elasticity.

Total phenolic content and antioxidant activity

Figure 3 and 4 show that cooked noodles with TSF substituted at 0, 5, 10, 15 or 20% had TPC values of 2.24, 4.12, 7.92, 9.79 and 13.06 mg GAE/g respectively, antioxidant activities by FRAP assays 21.03, 25.48, 29.60, 34.10 and 37.83 mM TE/g respectively, DPPH assays 10.58, 13.90, 17.11, 19.39 and 22.11 mM TE/g respectively and ABTS assays 0.77, 2.08, 3.84, 5.92 and 7.86 mM TE/g respectively. Therefore, TPC and antioxidant activities in all assays were increased as the level of TSF was increased with 20% of TSF, the highest and 0% TSF the lowest. Previously, Natukunda *et al*. [11] tested the total antioxidant activity (TAA) total phenolic content (TPC) and when tamarind seed powder (TSP) was added to mango juice in the range of 0 to 2.5% and cookies in the range of 0 to 10% then found a progressive increase in TAA and TPC with progressive increases in TSP, in both products. El-Gindy *et al.* [10] reported similar effects on total antioxidant capacity (TAC) and total phenolic content (TPC) of ground tamarind seed (GTS) on biscuits made from a combination of wheat flour and GTS, with GTS content ranging from 0 to 15%. The result exhibited greater the TPC and TAC when increasing of ground tamarind seeds. Other workers have shown that blending wheat flour with other flours can affect products. For example, Oniszczuk *et al.* [25] showed that blending wheat flour with flour made from chestnuts over the range of 0 to 50% affected the total phenolic content and antioxidant activity of pasta and showed that they increased as the level of chestnut flour increased with the highest at 50% and the lowest at 0%.

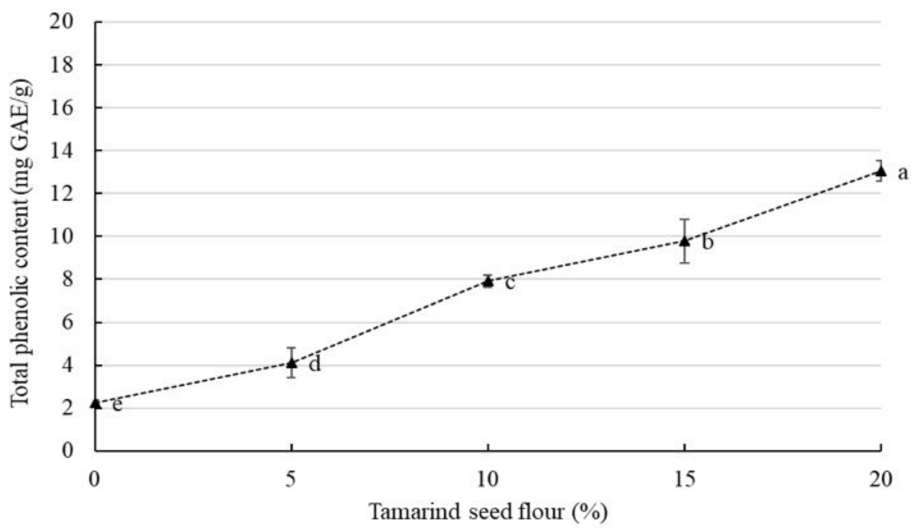

Figure 3: Total phenolic content of noodles after prepared from refined wheat flour containing 0, 5, 10, 15 or 20% tamarind seeds flour

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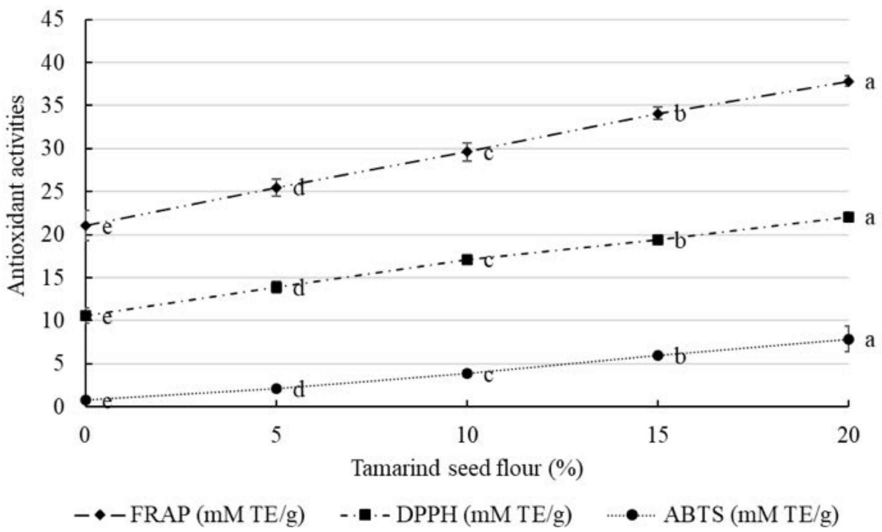

Figure 4: Antioxidant activity of noodles after prepared from refined wheat flour containing 0, 5, 10, 15 or 20% tamarind seeds flour

Determinations of chemical and mineral compositions

The protein, total carbohydrate, fat, ash and energy and the mineral compositions (calcium, magnesium, phosphorus, potassium and sodium) of cooked noodles substituted with tamarind seed flour were shown in Table 3A and 3B. All the chemical compositions increased with increasing levels of TSF except total carbohydrate. This is because refined wheat flour has higher total carbohydrate content than TSF and the other compositions were less than TSF [26, 27, 28]. The moisture contents of all samples were about 70% while cooked noodles containing 20% TSF had the highest contents in protein, fat, ash, energy and all of mineral contents [26, 27].

Sensory acceptability of cooked noodles

From the sensory acceptability of the noodles made from refined wheat flour substituted with 0, 5, 10, 15 or 20% TSF, evaluated by 100 panelists who normally consume noodles 3-4 times per month (Table 4), substituting refined wheat flour with 5 or 10% TSF did not result in significant differences ($p>0.05$) in appearance, color, odor, texture and overall liking of cooked noodles, but 15 and 20% TSF significantly decreased ($p<0.05$) all the above attributes, the attributes of 10% TSF cooked noodles in appearance, color, odor, texture and overall liking. Noodles containing 10% TSF had the highest scores from the panel but were not different from the control. Therefore, noodle made from 10% TSF was selected for sensory descriptive analysis of the product.

Descriptive analysis of cooked noodles

The 16 different attributes quoted by the descriptive analysis panel (yellowness, turbidity, egg odor, flour odor, tamarind flour odor, roasted tamarind seed odor, alkaline odor, egg flavor, flour flavor, tamarind flour flavor, roasted tamarind seed flavor, bitter taste, wetness, smoothness, elasticity and softness) were also presented in the seven commercial brands cooked noodles that were evaluated except for tamarind flour odor, tamarind seed roasted odor and tamarind seed flour flavor, which were found only in the cooked noodles made from 10% TSF 90% refined wheat flour (Tables 5, 6). However, Suwonsichon *et al*. [29] described 13 attributes of seven commercial cooked noodles produced in Thailand as: yellowness, translucency, shininess, egg odor, alkaline odor, wetness, elasticity, stickiness, firmness, toothpull, cohesiveness, adhesiveness and chewiness. The intensity and comparison between reference standards, cooked noodles containing TSF and commercial cooked noodles for appearance of yellowness and turbidity were similar, however egg odor and egg flavor were slightly different. This slight difference may have been due to the quantity of eggs used in the noodles containing TSF and commercial noodles being different. In addition, the intensity of flour odor and flour flavor were also slightly different because cooked noodles containing TSF had more tamarind flour odor, roasted tamarind seed odor, tamarind flour flavor and roasted tamarind seed flavor, which would have affected its flavor and odor. Alkaline odor was found to be from the water used for boiling and was the same for both of the noodle samples. The intensity of bitter taste was higher for the samples containing TSF than those containing only refined wheat flour, which may be because of they contained higher levels of tannins, which is consistent with the findings of Natukunda *et al*. [11] for tamarind seed powder used as an ingredient of cookies. Wetness of the noodles was not affected by the inclusion of TSF in the flour. The other attributes, softness, smoothness and elasticity were higher for the noodles without TSF than those containing TSF which may be related to gluten [30], since wheat flour contains glutenin and gliadin that can form three dimensional networks, which can affect the structure of noodles making them more soft and elastic [22]. However, on balance the attributes of the cooked noodles from TSF were similar to those of refined wheat flour noodles. The most outstanding difference was, as expected, tamarind flour odor, roasted tamarind seed odor and tamarind flour flavor that were absent in refined wheat flour noodles.

CONCLUSION

The partial substitution of refined wheat flour with tamarind seed flour (TSF) during processing of noodles increased their chemical compositions and minerals, total phenolic content and antioxidant activity, but the substitution could clearly be detected by a sensory analysis panel using descriptive analysis. The panel's overall liking was therefore affected and TSF substitution of up to 10% was accepted, but 15% and especially 20% received very low scores. These scores were reflected in the color and textural measurements, because as TSF levels increased there was a progressive reduction in lightness of both dough and noodles, also the texture became less soft. It was therefore concluded that up to 10% substitution of refined wheat flour with TSF could be successfully used for noodles, which would modestly increase their nutritional value without detrimentally affecting their acceptability and could provide an additional income to tamarind growers and processors.

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Table 1: The color of dough and cooked noodles in *L, *a** and *b** values which used TSF to substitute refined wheat flour at 0, 5, 10, 15 or 20%**

TSF (%)	Color values of dough			Color values of cooked noodles		
	*L**	*a**	*b**	*L**	*a**	*b**
0 (control)	74.52±0.47[a]	2.16±0.15[d]	24.54±0.56[a]	64.46±0.41[a]	0.26±0.12[c]	18.78±0.52[a]
5	73.89±0.41[ab]	2.56±0.11[b]	23.83±0.39[ab]	63.34±0.49[a]	0.24±0.07[c]	17.76±0.32[ab]
10	73.32±0.37[bc]	2.39±0.12[bc]	23.32±0.35[b]	61.34±1.17[b]	0.37±0.05[c]	17.37±0.86[b]
15	72.44±0.38[c]	2.68±0.25[b]	22.37±0.35[c]	60.37±0.38[b]	0.52±0.05[b]	15.82±0.34[c]
20	68.06±0.78[d]	3.54±0.23[a]	22.27±0.68[c]	58.71±0.37[c]	0.68±0.06[a]	15.10±0.98[c]

[a-c]mean ± SD, the different letter in each column demonstrate significant difference ($p<0.05$)

Table 2: Texture measurement of dough and cooked noodles which used TSF to substitute refined wheat flour at 0, 5, 10, 15 or 20%

TSF (%)	Texture measurement		
	Dough		Cooked noodles
	Tensile force (g)	Distance (mm)	Tensile Strength (g)
0 (control)	86.16±2.92[e]	32.35±6.32[a]	19.80±0.97[a]
5	105.65±9.78[d]	24.61±4.98[b]	16.53±1.59[b]
10	127.33±1.65[c]	19.84±2.41[b]	15.64±0.46[bc]
15	165.66±6.28[b]	19.64±3.03[b]	14.48±0.86[cd]
20	177.82±8.79[a]	13.67±1.01[c]	13.25±0.60[d]

[a-e]mean ± SD, the different letter in each column demonstrate significant difference ($p<0.05$)

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Table 3A: Chemical compositions of cooked noodles which used TSF to substitute refined wheat flour at 0, 5, 10, 15 or 20%

TSF (%)	Chemical compositions (g/100g)					
	Moisture content	Protein	Total carbohydrate	Fat	Ash	Energy
0 (control)	70.3	5.45	23.0	0.840	0.414	121 Kcal
5	70.6	5.87	22.1	1.01	0.483	121 Kcal
10	70.6	6.26	21.5	1.08	0.490	121 Kcal
15	70.6	6.68	21.0	1.15	0.581	121 Kcal
20	70.2	7.14	20.7	1.23	0.670	123 Kcal

Table 3B: Mineral compositions of cooked noodles which used TSF to substitute refined wheat flour at 0, 5, 10, 15 or 20%

TSF (%)	Mineral compositions (mg/100g)				
	Calcium	Magnesium	Phosphorus	Potassium	Sodium
0 (control)	12.6	12.0	44.8	10.1	125
5	15.0	13.3	45.0	22.1	127
10	16.0	14.4	45.3	27.2	130
15	17.5	14.9	46.0	33.2	134
20	18.4	15.3	46.8	36.7	136

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Table 4: Sensory acceptability by 100 panelists, using a 9-point (0 = low and 9 = high) hedonic scale, of cooked noodles made from refined wheat flour blended with 0, 5, 10, 15 or 20% of TSF

TSF (%)	Appearance	Color	Odor	Texture	Overall liking
0 (control)	7.26±0.92[a]	6.92±1.12[a]	6.56±1.30[a]	7.30±0.81[a]	7.70±0.71[a]
5	7.02±1.04[a]	6.62±1.37[a]	6.16±1.33[a]	7.08±1.14[a]	7.40±0.90[a]
10	7.04±1.07[a]	6.54±1.28[a]	6.12±1.52[a]	6.84±1.15[a]	7.42±1.09[a]
15	5.96±1.24[b]	5.52±1.18[b]	5.06±1.86[b]	5.38±1.77[b]	5.88±1.38[b]
20	5.26±0.80[c]	5.52±1.07[b]	4.66±0.87[b]	4.38±0.92[c]	4.08±1.01[c]

[a-c] mean ± SD, the different letter in each column demonstrate significant difference (p<0.05)

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Table 5: Descriptors and definitions used by the eight trained panelists to describe sensory attributes of cooked noodles made from 90% refined wheat flour and 10% TSF

Descriptor	Definition
Appearance	
Yellowness	The intensity of yellowness from light yellow to dark yellow
Turbidity	The intensity of turbidity from clear to thick
Odor	
Egg odor	The aromatics related to boil egg
Flour odor	The aromatics related to cooked bread
Tamarind flour odor	The aromatics related to tamarind flour
Roasted tamarind seed odor	The aromatics related to roasted tamarind seed
Alkaline odor	The aromatics related to boil noodles
Flavor	
Egg flavor	The aromatic and taste related to boil egg
Flour flavor	The aromatic and taste related to wheat flour
Tamarind flour flavor	The aromatic and taste related to tamarind flour
Roasted tamarind seed flavor	The aromatic and taste related to roasted tamarind seed
Taste	
Bitter	A basic taste constituent of paracetamol in water is typical
Texture	
Wetness	The texture related to moisture on surface
Smoothness	The texture related to smoothness on surface
Elasticity	The texture related to force and distance value
Softness	The texture related to surface of softness

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Table 6: References standard and intensity scores given by eight trained panelists in the descriptive analysis of cooked noodles made from flour containing 90% refined wheat flour and 10% TSF

Descriptor	Reference standards	Intensity reference standard	Intensity commercial cooked noodles (SD)	Intensity TSF cooked noodles (SD)
Appearance				
Yellowness	- Munsell book scales		14.1(0.55)	14.4(0.48)
	- 5Y8/2	0	-	-
	- 5Y8/4	7.5	-	-
	- 5Y8/6	15	-	-
Turbidity	- Distilled water	0	7.5(0.85)	7.6 (0.86)
	- Wheat flour solution 10g: 100mL water	9	-	-
Odor				
Egg odor	- Boiled egg	7	4.5(0.51)	3.5(0.62)
Flour odor	- Wheat flour	7	10.3(0.85)	8.4(0.83)
	- Cooked noodles	10		
Tamarind flour odor	- Wheat flour	7	0	3.5(0.59)
	- Tamarind seed flour	15		
Roasted tamarind seeds odor	- Roasted tamarind seeds	15	0	2.9(0.41)
Alkaline odor	- Distilled water	0	0.5(0.28)	0.8(0.33)
	- Boiled water	3		
Flavor				
Egg flavor	- Boiled egg	7	5(0.77)	3.5(0.66)
Flour flavor	- Cooked noodles	10	9.5(0.89)	8.6(0.85)
Tamarind flour flavor	- Tamarind seed flour	15	0	3.4(0.61)
Roasted tamarind seed flavor	- Roasted tamarind seeds	15	0	2.8(0.39)
Taste				
Bitter	- Paracetamol solution 0.5g: 100 mL water	10	0	3.4(0.59)
Texture				
Wetness	- a piece of fresh carrot	5	9.3(0.95)	9.2(0.77)
	- a piece of watermelon	15		
Smoothness	- Cotton cloth	5	12.1(0.88)	10.6(0.63)
	- A4 paper	15		
Elasticity/Resilience	- Rice noodle (Kanom jeen)	5	11.9(0.87)	9.3(0.71)
	- Instant noodle (Mama)	15		
Softness	- Soybean tofu	7	12.3(0.87)	9.1(0.80)
	- Egg tofu	15		

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