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*Original Article*

# Physicochemical properties and potential of lotus seed flour as wheat flour substitute in noodles

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## Abstract

Thai lotus seeds are rich in nutrients and antioxidants, which makes them interesting substitutes in food products. Lotus seeds can be produced into flour, which can be further processed to pre-gelatinized lotus seed flour (PLF) from the native lotus seed flour (NLF). The physical properties of these flours had no significant differences in swelling power or solubility, whereas NLF had higher viscosity and higher protein, fiber, and phenolic contents than PLF ($p<0.05$). Among noodles with 5, 10, and 15% of lotus seed flour, the noodles with 5% PLF were most similar to the control noodles with respect to consumer acceptance. Moreover, they had higher fiber content (0.823%db), ash content (0.903%db), and phenolic content (0.019 mg GAE/100mg) than the control noodles (0.393%db, 0.805%db, and 0.007%db fiber, ash, and phenolic contents, respectively) with significant differences ($p<0.05$).

**Keywords:** flour, lotus seeds, noodles, phenolic content, physical properties

## 1. Introduction

Noodles are among the most popular foods in the world. Generally, noodles are produced from wheat flour and are rich in carbohydrates and are good sources of energy. Unique noodles can be made by adding local or nutritional ingredients. Jirukkakkul (2014) reported that adding 30% pumpkin improved the fiber content, tensile strength, and elongation of the noodles. Moreover, the acceptance score for the pumpkin noodle was improved. Because of the network of gluten, adding KonjacGlucomannan (KGM) to replace partly (1-5%) wheat flour increased cooking yield of wheat noodles. Noodles with 3% KGM had a high acceptance level among consumers. Moreover, the textural defects of noodles were improved by KGM (Zhou *et al.*, 2013). Compared to control samples, the substitution of 10% banana flour (for wheat flour) in the noodles resulted in less lightness and yellowness, while giving a higher tensile strength and elasticity (Saifullah, Abbas, Yeoh, & Azhar, 2009). For example, adding 30% cassava starch improved cooking properties and texture of the noodles because cassava starch can decrease the reactions of amylose and amylopectin that soften the noodles (Charles *et al.*, 2007). With respect to healthy alternatives for consumers, the focus has been on creating highly nutritious noodles. Choo and Aziz (2010) added 30% banana flour in wheat flour of wheat noodles and the antioxidants (phenolic compounds) inhibited peroxidation. Wheat noodles prepared with 30% jackfruit seed flour were the most similar to plain wheat noodles. However, they exhibited a higher cooking yield and fiber content than the wheat noodles. Furthermore, they were accepted by consumers (Jirukkakul, 2016).

Lotus (*Nelumbonucifera*) seeds are a source of antioxidants. Thai lotus seeds especially have 6 times more antioxidants than Chinese lotus seeds. Lotus seeds are popular and widely consumed. Lotus seed flour has a high amylose content and gelatinization temperature, but has a lower swelling power than lotus stem flour. Lotus seeds have higher levels of proteins, amino acids, non-saturated fatty acids, and ash than lotus stem (Man *et al.*, 2012). Thai lotus seed contained more crude protein, crude fiber and ash but less crude lipid than Indian lotus seed (Paiyarach & Punbusayakul, 2009). However, processing may affect the nutritional value

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of lotus seeds, as well as physical properties of lotus seed flour. Radiation causes higher levels of ash and carbohydrates in lotus seeds. Thus, lotus seeds have great potential for commercial products due to the fact that the nutrients are retained when radiation is used (Bhat & Sridher, 2008). Ultra-high pressure affects the size and structure of lotus seed flour by a change from B to C form, and their swelling power & solubility are reduced at 85ºC and 95ºC (Guo *et al.*, 2015). Pre-gelatinized lotus seed flour exhibited stronger antioxidant activities than raw lotus seed flour (Yen, Duh & Su, 2005). Antioxidants from lotus seeds could be applied to sausage products to effectively retard lipid oxidation (Qi & Zhou, 2013). The seend also have high levels of calcium and unsaturated fatty acids. Lotus seed flour could be used in wheat flour (at up to 10%) in cookie products and this was the most acceptable formula (Paiyarach & Punbusayakul, 2009). This suggests lotus seed flour as a possible alternative source of nutrition and a functional ingredient. Thus, the addition of lotus seeds in noodles gives new products with high nutritional value and antioxidants to promote human health. Noodles were selected because they are a popular food. The aims of the experiments were as follows: 1) to determine the physical properties of native lotus seed flour (NLF) and pre-gelatinized lotus seed flour (PLF) and 2) to study the physical properties, sensory evaluation, and phenolic content of noodles in which lotus seed flour had been substituted.

## 2. Materials and Methods

### 2.1 Flour preparation

The lotus (*Nelumbonucifera*) seeds were purchased from a local market in NongKhai, Thailand. The initial moisture content of fresh lotus seeds was 70.61%. The hard seed coat was removed with a sharp knife. The cotyledon portion was then divided to prepare pre-gelatinized seeds as an alternative to the raw seeds. The seeds were gelatinized by boiling them in water at 100ºC for 10 min with the seed: water ratio of 1:4 (w/v) (Jirukkakul, 2016). Then both types of seeds were dried at 60°C for 8 h. The moisture content of dried lotus seed was 8.25%. After that, the seeds were ground in a hammer mill with mesh size 80. The pre-gelatinized lotus seed flour (PLF) and native lotus seed flour (NLF) were kept in plastic ziplock bags at room temperature (25-30°C) until further use.

### 2.2 Swelling power and solubility of flour

The suspension with 0.6 g (db) flour in 30 ml of water was heated to 80°C for 30 min while stirring. It was then centrifuged (Centrifuge Model EBA 8S, Hettich, Germany) at 2500 rpm for 20 min. The supernatant was separated and evaporated at 105ºC for 24 h and was then weighed (A) and then the sediment was weighed (B). The swelling power is the mass ratio of wet sediment to initial dry starch (B/0.6). The solubility is the mass ratio of dried supernatant to initial dry starch (A/0.6) (Guo *et al.*, 2015).

### 2.3 Pasting properties of flour

The pasting properties of the flours were measured using a Rapid Visco Analyzer (Model 4, Newport Scientific Pvt. Ltd., Australia). To prepare a suspension, about 3 g of accurately weighed flour with 14% moisture content was added to about 25 ml of distilled water. The flour solution was kept at 50ºC for 1 min and then was heated up to 95ºC and was held for 2.5 min. It was then cooled to 50ºC and a final isothermal step was carried out at 50ºC. The obtained RVA curve was used to determine the peak, trough, breakdown, and final viscosities, and setback, all in Rapid Visco Units (RVU), and peak time in min.

### 2.4 Noodle preparation

The noodle recipe was that according to Jirukkakul (2014). The lotus seed flours (PLF &NLF) were added to wheat flour in the noodle recipe (5%, 10% and 15%). The formulated flour with wheat flour and no lotus seed flour served as the control. The mixed ingredients were kneaded for 10-15 min and were then rested for 30 min. The dough was pressed into thin sheets, cut into 3 mm wide strips by cutting blades, and was then placed in plastic bags for testing. During processing, wheat flour was strewn to prevent sticking (Table 1).

Table 1. Formulations of noodles.

| Samples | Wheat flour (g) | PLF (g) | NLF (g) | Water (ml) | Egg | Salt (g) |
|---|---|---|---|---|---|---|
| 5% PLF noodle | 190 | 10 | - | 50 | 1 | 3 |
| 10% PLF noodle | 180 | 20 | - | 50 | 1 | 3 |
| 15% PLF noodle | 170 | 30 | - | 50 | 1 | 3 |
| 5% NLF noodle | 190 | - | 10 | 50 | 1 | 3 |
| 10% NLF noodle | 180 | - | 20 | 50 | 1 | 3 |
| 15% NLF noodle | 170 | - | 30 | 50 | 1 | 3 |
| Control noodle | 200 | - | - | 50 | 1 | 3 |

### 2.5 Cooking properties of noodles

The cooking yield and cooking loss were determined following Lu, Guo, and Zhang (2009). The noodle strands were weighed (A) and cooked and stirred in 400 ml of boiled water for 3 min. Then the cooked noodles were rinsed in cold water and drained before weighing (B). For each sample, the water was collected from cooking and from rinsing and was then evaporated in an oven at 105°C to determine the constant weight (C). The cooking yield (CY) of the cooked noodles was calculated as the percentage of increased weight in weight of uncooked noodle, CY= (B-A)/A ×100. The cooking loss (CL) was calculated as the percentage of residue weight to the weight of uncooked noodles, CL= C/A × 100. All tests were replicated 3 times.

### 2.6 Texture profile analysis of noodles

The noodles were prepared similarly as for the cooking properties above. The texture profile analysis (TPA) was done using a Texture Analyzer (TA-XTS, Micro Stable Systems, Godalming, UK). Three strands of noodles, measuring 6 cm long, were plated parallel on a flat metal plate with a 0.5 cm space between them. Samples were compressed twice with a 5.0 g force of P/50R probe to 25% of their original thickness, and three replicates were done. The TPA curve was summarized with four parameters: hardness, adhesiveness, springiness, and cohesiveness.

### 2.7 Color analysis of noodles

The cooked noodles were measured using a color meter (Color meter, JS555, China). Measurements were made in triplicate for each sample. The RGB values were converted and are reported as lightness (L*), redness (a*), and yellowness (b*).

### 2.8 Sensory evaluation of noodles

To conduct the sensory evaluation, cooked noodles were prepared and served with soup. The noodles with PLF and NLF were compared to wheat flour noodles (the control). The 30 panelists were students at the Nong Khai Campus of Khon Kaen University. The panelists evaluated the cooked noodles with soup in terms of appearance, color, odor, taste, texture, and overall acceptability. The noodles were evaluated using a 9-point hedonic scale (1= dislike extremely to 9 = like extremely).

### 2.9 Phenolic content of flour and noodles

The phenolic content of the flour types and the noodles was determined according to Bhat & Sridhar (2008) with some modifications. Briefly, the cooked noodles were extracted by using 5 ml of 95% ethanol in a water bath at 95°C for 10 min. Then 0.5 ml of extract was mixed with equal amount of distilled water and was treated with 2 ml of $Na_2CO_3$ (in 0.1 N NaOH). After 10 min, 0.2 ml of Folin-Ciocalteu's reagent (diluted with water 1:1) was used to determine the phenolic content, which is expressed in gallic acid equivalents (GAE).

### 2.10 Proximate analysis of flour and noodles

The fat, protein, ash, fiber, and moisture contents of the cooked noodles and flour were determined according to AOAC (2000). All determinations were replicated 3 times.

### 2.11 Statistical analysis

The experiments followed a randomized complete block design (RCBD) and Analysis of variance (ANOVA) was used to determine the significant differences between the samples. The differences in the mean values were subjected to Duncan's Multiple Range Test at $p<0.05$.

## 3. Results and Discussion

### 3.1 Swelling power, solubility and proximate analysis of flour

Swelling power depends on particle size and structure, as well as on physical and chemical properties. Swelling power and solubility inform about the extent of interactions between starch chains in amorphous and crystalline domains of the starch granules (Guo *et al.*, 2015). The crystal structure was destroyed by gelatinization, making it easy to hydrogen bond water with the hydroxyl of amylose (Zeng *et al.*, 2015). The swelling power and solubility of PLF and NLF are presented in Table 2. The PLF had lesser swelling power and solubility than the NLF. The lower swelling power of PLF was due to rearrangements of amylose with strong bonding forces, such as in the double helix that plays an important role in limiting starch hydration and swelling (Guo *et al.*, 2015). In the NLF, the hydrogen bonds of crystalline starch were partly destroyed by water penetrating into the starch. The melting of the crystalline structure, loss of birefringence and disruption of starch granules increased with time during pre-gelatinization. The decreased swelling power and solubility of PLF were attributed to the re-association of amylose and amylopectin, which increased the rigidity of PLF. The re-association of amylose is a major contributor to changes in the hydration properties of a starchy flour. Thus, the PLF exhibited lesser swelling power and solubility than the NLF (Lai, 2001).

The NLF contained more fiber, protein, and ash than the PLF because the composition of lotus seeds was affected by pre-gelatinization. The results are in agreement with Paiyarach & Punbusayakul (2009) who reported on lotus seed protein (30.54-30.71%), fiber (4.04-4.27%), and ash (5.3-5.6%) contents. The protein content of lotus seeds is higher than in parboiled rice (7.7%), wheat (8.55%), or egg (12.6%) (Statens Livsmedelsverk, 1988), as well as in Chinese lotus seeds (18.7%) (Wu *et al.*, 2007). The phenolic content has been reported to have antioxidant properties, which vary by extraction solvent used. Lotus seeds are reported to contain high amounts of polyphenolic compounds that exhibit antioxidant properties (Bhat & Sridher, 2011). The phenolic compounds in lotus seeds have been proposed to be gallic acid, ρ-hydroxybenzoic acid, chlorogenic acid and caffeic acid (Yen, Duh & Su, 2005). The phenolic content of PLF was lower than in NLF because the active components that are water soluble may have been extracted during pregelatinization (Yen, Duh, & Su, 2005).

### 3.2 Pasting properties of the flour

The pasting properties of the flours are shown in Table 3. The viscosity of PLF was lower than that of NLF. Compared to NLF, PLF was more stable and more resistant to shear stress, and had stronger starch aggregates and a lower retrogradation tendency (Guo *et al.*, 2015). The PLF was limited in swelling power and viscosity because the pre-gelatinization had decreased bonding forces between starch molecules (Zhang, Doehlert, & Moore, 1997). The results of this current study match theirs in swelling power and solubility.

Table 2. Swelling power, solubility and proximate analysis of lotus seed flour.

| Samples | Solubility (%) | swelling power | Moisture content (%) | Protein (% db) | Fat (% db) | Fiber (%db) | Ash (%db) | Phenolic (mg GAE/100mg) |
|---|---|---|---|---|---|---|---|---|
| PLF | 22.98±0.57$^{b}$ | 42.12±0.60$^{b}$ | 10.56±2.23$^{ns}$ | 28.18±0.20$^{b}$ | 0.02±0.00$^{ns}$ | 4.10±0.16$^{b}$ | 5.80±0.06$^{b}$ | 0.22±0.02$^{b}$ |
| NLF | 26.93±0.73$^{a}$ | 47.51±1.14$^{a}$ | 10.97±1.21$^{ns}$ | 30.85±0.45$^{a}$ | 0.02±0.00$^{ns}$ | 5.51±0.31$^{a}$ | 7.81±0.68$^{a}$ | 0.39±0.01$^{a}$ |

Note: In each column, different superscripts represent significant differences ($p \leq 0.05$).
ns means no significant difference ($p \geq 0.05$).
GAE means gallic acid equivalents

Table 3. Pasting properties of lotus seed flours.

| Samples | Peak (RVU) | Trough (RVU) | Breakdown (RVU) | Final Viscosity (RVU) | Setback (RVU) | Peak Time (min) | Pasting Temperature (ºC) |
|---|---|---|---|---|---|---|---|
| PLF | 5.00±0.71$^{b}$ | 2.96±0.30$^{b}$ | 2.04±1.00$^{b}$ | 4.58±0.00$^{b}$ | 1.625±0.29$^{b}$ | 4.33±3.39$^{b}$ | 80.10±0.10$^{ns}$ |
| NLF | 20.30±0.18$^{a}$ | 16.585±0.12$^{a}$ | 3.71±0.06$^{a}$ | 29.17±1.65$^{a}$ | 12.59±1.53$^{a}$ | 6.74±0.09$^{a}$ | 79.90±0.10$^{ns}$ |

Note: In each column, different superscripts represent significant differences ($p \leq 0.05$).

### 3.3 Cooking quality of the noodles

Cooking quality is an important determinant of the acceptability of noodles by consumers. The standards of high quality noodles require low cooking loss and high cooking yield. The starch granules in the dough can begin to swell and rupture, and thereby can also affect the uptake of water during heating (Zhou *et al.*, 2013). The cooking yield is mainly attributed to the gelatinization of starch and swelling of the gluten network (Majzoobi, Ostovan, & Farahnaky, 2011). The cooking quality of the noodles is shown in Table 4. With respect to the cooking yield and cooking loss of the noodles, PLF and NLF at all tested levels gave no significant differences to the control noodles. However, the cooking loss was lower than that of noodles made with sweet potato starch (7-18%) (Silva, Birkenhake, Scholten, Sagis, & Linden, 2013) or with KonjacGlucomannan (5-6%) (Zhou *et al.*, 2013). The low cooking loss of noodles suggests enhanced water binding capacity of the protein-starch matrix. Weak starch-protein complexes allow for a greater amount of water-soluble components (Zhou *et al.*, 2013).

### 3.4 Color of the noodles

The PLF noodles exhibited high L* and b*, but low a* compared with the NLF noodles (Table 4). The noodles with lotus seed flour showed lower L* and b*, but higher a* than the control noodles, due to the pigments in lotus seed flour (Saifullah *et al.*, 2009). There were no significant differences in the L* and a* with 5% PLF when compared to the control noodles ($p>0.05$). These results were confirmed in the sensory evaluation.

### 3.5 Texture profile analysis of the noodles

The texture profile analysis of cooked noodles made from lotus seed flour is summarized in Table 5. The hardness of lotus seed flour noodles was higher than that of the control noodles, because of increased flour solubilization and leaching of amylose that then interacted with the amylopectin fraction by hydrogen bonds, resulting in a stronger network (Charles *et al.*, 2007). Adhesiveness and cohesiveness were unaffected by lotus seed flour incorporation. Yet, when the lotus seed flour concentration was increased, there was a decreasing trend. The flour can hydrate and imbibe water producing high viscosity, and the porous structure of noodle strands having a soft gluten network transforms into a compressed solid network (Zhou *et al.*, 2013). However, the measured parameters showed no significant differences ($p>0.05$); the cases were similar in hardness, adhesiveness, cohesiveness, and springiness.

### 3.6 Sensory evaluation of the noodles

The sensory evaluation of cooked noodles in soup resulted indicated acceptability to consumers. The panelists evaluated each of the following attributes: 1) color, 2) odor, 3) flavor, 4) texture, and 5) overall acceptability, as shown in Figure 1. Because the color was darker, noodles made with NLF had lower acceptance than noodles made with PLF, due to appearance. The control noodles had the highest scores in all attributes. In terms of color, flavor, texture, and overall acceptance ($p>0.05$), the score of 5% PLF noodles was clearly close to the control noodles. The results differ from those with added banana flour and pumpkin flour, which can be used as a substitute (at up to 30%) in 0wheat flour noodles (Choo & Aziz, 2010; Jirukkakul, 2014). However, noodles made with KonjacGlucomannan (3%) were deemed acceptable to consumers (Zhou *et al.*, 2013).

### 3.7 Proximate analysis and phenolic content of the noodles

The 5% PLF noodle was selected for proximate analysis and testing of phenolic content due to its properties and consumer preferences. The mean values from the proximate analysis of the noodles are shown in Table 6. The protein content showed no significant differences ($p \geq 0.05$).

Table 4. Cooking quality and color of noodles.

| Samples | Cooking yield$^{ns}$ (%) | Cooking loss$^{ns}$ (%) | L* | a* | b* |
|---|---|---|---|---|---|
| 5% PLF noodle | 58.44±5.18 | 3.79±0.72 | 55.34±0.26$^{a}$ | 4.71±0.09$^{d}$ | 15.34±0.36$^{cd}$ |
| 10%PLF noodle | 56.08±1.89 | 3.54±0.59 | 52.86±0.35$^{b}$ | 5.88±0.32$^{c}$ | 16.11±0.59$^{bc}$ |
| 15%PLF noodle | 58.22±1.24 | 3.63±1.24 | 52.16±0.28$^{b}$ | 6.32±0.08$^{c}$ | 17.57±0.18$^{a}$ |
| 5%NLF noodle | 55.71±0.60 | 2.97±0.35 | 49.52±0.99$^{c}$ | 7.05±0.26$^{b}$ | 14.37±0.59$^{de}$ |
| 10%NLF noodle | 56.07±3.99 | 3.58±0.55 | 41.45±0.19$^{d}$ | 8.47±0.16$^{a}$ | 14.71±0.45$^{de}$ |
| 15%NF noodle | 54.60±2.78 | 3.90±0.30 | 40.54±0.57$^{d}$ | 8.09±0.10$^{a}$ | 14.00±0.05$^{e}$ |
| Control noodle | 53.33±2.16 | 3.52±1.22 | 56.45±1.29$^{a}$ | 4.42±0.74$^{d}$ | 16.91±1.40$^{ab}$ |

Note: In each column, different superscripts represent significant differences ($p \leq 0.05$).
ns means no significant difference ($p \geq 0.05$).

Table 5. Texture profile analysis of noodles$^{ns}$.

| Samples | Hardness (g) | Adhesiveness (g×s) | Cohesiveness | Springiness |
|---|---|---|---|---|
| 5% PLF noodle | 2.76±0.70 | 0.12±0.02 | 0.99±0.28 | 1.30±1.04 |
| 10%PLF noodle | 3.41±0.43 | 0.06±0.02 | 0.95±0.10 | 1.04±0.07 |
| 15%PLF noodle | 2.23±0.16 | 0.02±0.01 | 0.79±0.02 | 0.52±0.08 |
| 5%NLF noodle | 3.00±0.55 | 0.17±0.10 | 1.00±0.30 | 2.11±1.40 |
| 10%NLF noodle | 2.47±0.40 | 0.17±0.09 | 0.73±0.17 | 0.90±0.10 |
| 15%NLF noodle | 3.37±0.81 | 0.10±0.03 | 0.76±0.02 | 0.79±0.26 |
| Control noodle | 2.25±1.13 | 0.05±0.03 | 0.67±0.10 | 0.86±0.08 |

Note:ns means no significant difference ($p \geq 0.05$).

Table 6. Proximate analysis and phenolic content of noodles.

| Samples | Moisture content (%wb) | Protein (%db) | Fat (%db) | Fiber (%db) | Ash (%db) | Phenolic content (mg GAE /100 mg) |
|---|---|---|---|---|---|---|
| 5% PLF noodle | 64.32±0.60$^{b}$ | 17.13±0.09$^{ns}$ | 0.01±0.00$^{b}$ | 0.82±0.25$^{a}$ | 0.90±0.01$^{a}$ | 0.02±0.00$^{a}$ |
| Control noodle | 67.66±0.01$^{a}$ | 17.10±1.34$^{ns}$ | 0.02±0.00$^{a}$ | 0.39±0.08$^{b}$ | 0.81±0.01$^{b}$ | 0.01±0.00$^{b}$ |

Note: In each column, different superscripts represent significant differences ($p \leq 0.05$).
ns means no significant difference ($p \geq 0.05$).
GAE means gallic acid equivalents

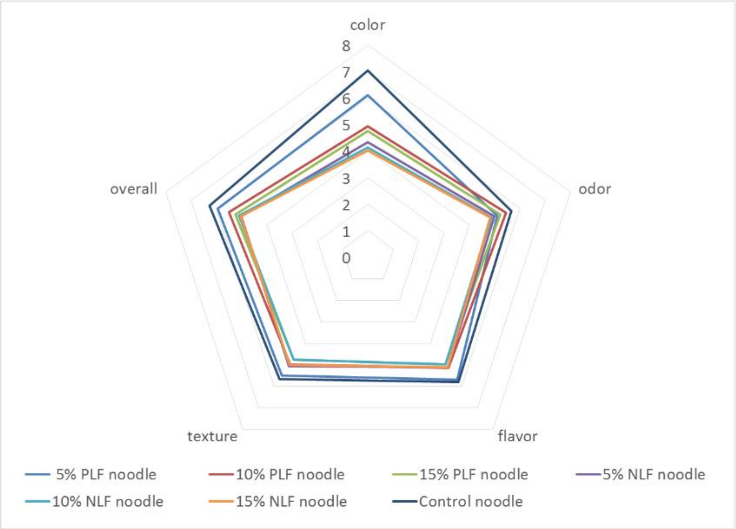


Figure 1. Sensory evaluation of noodles.

The fiber, ash, and phenolic contents of the 5% PLF noodles were significantly higher than in the control noodles, due to the composition of the flour. The ash content depends on the quality of the flour (Choo & Aziz, 2010). Because the lotus seed flour is high in fiber, ash and phenolic contents, this caused the high fiber, ash, and phenolic contents of the noodles prepared with it. In contrast, the fat content of 5% PLF noodle was half that of the control noodles due to the low fat content in the lotus seed flour (0.02%) relative to the wheat flour (2%). Moreover, the amylose-lipid complexation also reduces the fat content during heat treatment of the flour (Choo & Aziz, 2010).

Because lotus seeds are rich in phenolics, the phenolic content of the 5% PLF noodles was significantly higher than in the control noodles ($p<0.05$). The experiment confirmed that antioxidants remained in the obtained product. The phenolic content with 5% PLF was 3 times greater than in the control noodles.

## 4. Conclusions

Compared to PLF, NLF had greater solubility and swelling power, as well as higher protein, fiber, ash, and phenolic contents. In the cooking quality of NLF and PLF containing noodles there were no significant differences ($p>0.05$). The preferred noodles with 5% PLF were close to the control noodles. At 5%, PLF can be included in the noodle recipe giving noodles with reduced fat content, as well as elevated fiber, ash, and phenolic contents. Therefore, these modified noodles could become a new alternative product with health benefits for consumers.

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