Physical, Chemical, Textural and Sensory Properties of Dried Wheat Noodles Supplemented with Unripe Banana Flour

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ABSTRACT

Unripe banana flour is a starchy food that contains a high proportion of indigestible compounds such as resistant starch, and non-starch polysaccharides, which are included in the dietary fiber content. The objective of this study was to use unripe banana flour as an ingredient to make dried noodle products of high nutritional quality with low carbohydrate digestibility and rich in resistant starch. The effect of wheat flour substitution with unripe banana flour was investigated in terms of the physicochemical, textural, cooking and sensory qualities of dried noodles. Five additional dried noodles were prepared by substituting wheat with 10, 20, 30, 40, and 50% banana flour. The optimal ratio of noodle from banana flour was investigated using sensory qualities in comparison with the control (100% wheat flour). The results of noodle formula development indicated that as the amount of banana flour increased, the stickiness of the noodles decreased and the appearance became darker. The optimum formula consisted of 20.45% banana flour, 47.72% wheat flour, 20.45% water, 2.04% salt, 1.02% sodium carbonate, 6.82% egg powder, 0.14% polyphosphate and 1.36% propylene glycol. Banana flour was used to replace 30% of the total wheat flour in the formula. Uncooked dried noodles were composed of 13.7% protein, 0.12% fat and 4.8% dietary fiber (including 2.8% resistant starch). The optimal cooking time and cooking loss were 14.5 min and 11.15%, respectively. The tensile strength and breaking length of cooked noodles were 16.4 g and 67.2 mm, respectively. The results of consumer evaluation showed that the overall liking of uncooked and cooked dried noodles were at the moderate level. The present study indicated that unripe banana flour is a potential source of fiber when substituted for wheat flour in dried noodle products. The incorporation of 30% unripe banana flour in the noodle ingredients significantly increased their total dietary fiber and resistant starch content.

Keywords: dried noodles, unripe banana flour, resistant starch, supplement

INTRODUCTION

Noodle products are a staple food in many parts of Asia. Asian noodles made from wheat may be divided into two general classes based on the ingredients used: white salted noodles (WSN) made from flour, sodium chloride and water, and yellow alkaline noodles (YAN) made from flour, alkaline salts (such as sodium and potassium carbonate) and water (Asenstorfer et al., 2006). The type of salt, properties of the flour and the manufacturing process lead to a wide array of

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noodle types (Martin et al., 2008). Traditional noodles are claimed to lack other essential nutritional components such as dietary fiber, vitamins and minerals, which are lost during wheat flour refinement. Thus, noodle products which represent a major end-use of wheat, are suitable for enhancing health after incorporating sources of fiber and essential nutrients (Choo and Aziz, 2010). The development of new products is a strategic area of the food industry. Consumers are demanding foods that show two main properties, with the first dealing with the traditional nutritional aspects of the food, whereas, as a second feature, additional health benefits are expected from its regular ingestion. These kinds of food products are often called nutraceutical foods. In a rapidly changing world, with altered food habits and stressful lifestyles, it is more and more recognized that a healthy digestive system is an essential factor in determining the overall quality of life (Brouns et al., 2002).

Several studies have suggested that consumption of unripe bananas exerts a beneficial effect on human health, associated with the indigestible components. Unripe bananas are a good source of carbohydrates and nutritionally interesting bioactive compounds. However, there is an excess of production and large quantities of fruit are lost during commerce as a consequence of deficient postharvest handling. New economic strategies are therefore being considered for bananas as a food ingredient (Ovando-Martinez et al., 2009). According to the literature, green bananas are very rich in starch and the flour may provide 61.3–76.5 g/100 g of starch with a fiber content of 6.3–15.5 g/100 g. Moreover, a great part of the starch found in green banana flour is the resistant starch type 2 (RS2) from 52.7 to 54.2 g/100 g (Tribess et al., 2009). Resistant starch (RS) has attracted interest because of its positive effects in the human colon and implications for health. It can be found in both processed and raw food materials. According to various RS types, RS2 is found in the native uncooked granules of some starches such as those in raw potatoes and green bananas, whose crystallinity makes them barely susceptible to hydrolysis (Englyst et al., 1992).

Some research has been recently carried out to improve the nutritional properties of food products adding to its supplements from unripe banana flour. Choo and Aziz (2010) reported that green banana flour has potential as a source of fiber when substituted in yellow alkaline noodle products. The incorporation of 30% banana flour significantly increased the total dietary fiber of noodles, the resistant starch, total starch and some essential minerals, including phosphorus, magnesium, potassium, and calcium. Aparicio-Saguilán et al. (2007) found that a resistant starch-rich powder prepared from banana starch was a potential ingredient for bakery products containing slowly digestible carbohydrates. Ovando-Martinez et al. (2009) reported that pasta products containing banana flour exhibit a low rate of carbohydrate enzymatic hydrolysis and they could help broaden the range of low-glycaemic index foods available to consumers. However, there is no information on the use of unripe banana flour in dried noodle making. Therefore, the objective of this study was to use unripe banana flour as an ingredient to make dried noodle products of high nutritional quality with low carbohydrate digestibility that were rich in resistant starch. The effect of wheat flour substitution with unripe banana flour was investigated in terms of the physicochemical, textural, cooking and sensory qualities of the dried noodles.

**MATERIALS AND METHODS**

**Banana flour preparation**

Unripe banana (*Musa paradisiaca* L.) fruit was purchased from a local market in Kanchanaburi province, Thailand. Unripe banana flour was prepared using the procedure described by Ovando-Martinez et al. (2009). Fruits were
peeled and cut into 3 mm slices and immediately rinsed in sodium metabisulfite (0.25% w/v). The slices were dried at 50 °C, ground using a commercial grinder and stored at 25 °C in sealed plastic containers prior to further analyses. The commercial wheat flour used for this study was also obtained from the local market.

**Dried noodle processing**

Noodles were prepared in the laboratory following the procedures of Bui and Small (2007). The basic ingredients used for making dried noodles were: 100.0 g flour, 30.0 g water, 10.0 g egg powder, 3.0 g salt, 2.0 g propylene glycol, 1.5 g sodium carbonate, and 0.2 g polyphosphate. Control dried noodles were prepared from 100% wheat flour. Five additional dried noodle samples were prepared by substituting wheat with 10, 20, 30, 40 and 50% banana flour.

The different formulations were processed into noodles using a Kenwood mixer and a small spaghetti maker (Imperia brand, Italy) consisting of two rolls with adjustable gap settings and a cutting roll attachment. In brief, salt, egg powder, propylene glycol, sodium carbonate, and polyphosphate were dissolved in the water and this solution was added to the flour in the mixer (set at speed 1). After that, the speed of the mixer was increased. The resultant dough had a crumbly consistency similar to that of moist breadcrumbs. The dough was first formed into a dough sheet by a process of folding and passing the crumbly dough through the rollers of the noodle machine several times. Then, this combined sheet was allowed to rest in a plastic bag at room temperature for 30 min. The sheet was cut into strands 2.0 mm wide using the cutting roll attachment of the noodle machine. The noodle strands were then cut to 25 cm in length before steaming over boiling water for 2 min. Subsequently, the steamed noodles were dried in an oven at 50 °C for a total drying time of 1.5 h.

**Chemical analysis**

The chemical proximate compositions of unripe banana flour, wheat flour and different raw dried noodle samples were determined as follows. The moisture content was determined by gravimetric heating (130 °C for 2 h) using a 2–3 g sample. Ash and protein were analyzed according to American Association of Cereal Chemists methods 08-01 and 46-13, respectively (AACC, 2000). Total dietary fiber (DF) was evaluated using Official Methods of Analysis 985.29 (AOAC, 1999). Resistant starch was measured by the method proposed by Goñi et al. (1996). All analyses were performed in triplicate.

**Cooking qualities**

The qualities of the cooked dried-noodles, cooking time and cooking loss were evaluated according to Chillo et al. (2008). Optimal cooking time was evaluated by observing the time of disappearance of the core of the noodle strand during cooking (every 30 s) by squeezing the noodles between two transparent glass slides. The cooking loss was determined by measuring the amount of solid substance lost to cooking water. A 10 g sample of noodles was placed into 300 mL of boiling distilled water in a 500 ml beaker. Cooking water was collected in an aluminum vessel which was placed in an air oven at 105 °C and evaporated to dryness. The residue was weighed and reported as a percentage of the starting material. For each optimal cooking time and cooking loss value, five determinations were performed to obtain the mean values.

**Noodle color analysis**

The color of the dried noodle sheets and the optimally cooked noodle samples were measured with a Chroma-meter (Minolta, Tokyo, Japan) equipped with a D65 illuminant using the CIE L*a*b* system. The L*, a* and b* readings were obtained directly from the instrument and provided measures of lightness, redness and
yellowness, respectively. All measurements were performed in triplicate.

**Noodle texture analysis**

Noodles were optimally cooked, cooled for 1 min under running distilled water, drained, stored for exactly 10 min at 25 °C as described by Kruger et al. (1994) and submitted to tensile testing using the TA-XT2i texture analyzer (Lu et al., 2000). Instrument settings were extension mode; trigger type, auto-0.5 g; pretest speed 2.0 mm/s; post test speed 10 mm/s; test speed 3.0 mm/s; and trigger distance 80 mm. From force-distance curves, two texture parameters were obtained: tensile strength (maximum force; g) and breaking length (distance at maximum force; mm). Three replicates of cooked noodles at each level of unripe banana flour were determined.

**Sensory evaluation**

All dried noodle samples were prepared for sensory evaluation. The samples were boiled using tap water for the optimum cooking time. The samples were then stored for not more than 30 min in tightly covered plastic food containers before testing. Optimally cooked noodles with soup were evaluated for appearance, flavor, taste, texture and overall liking of the samples by 30 untrained panelists using nine-point hedonic scales, where 9 = extremely like and 1 = extremely dislike. Each panelist evaluated six samples (identified by unique three-digit codes) in a balanced sequential order. The optimal ratio of banana flour in the noodles was investigated using sensory qualities in comparison to the control noodles.

**Consumer evaluation**

Dried noodle samples prepared from the optimal ratio of mixtures of banana flour per wheat flour were analyzed by the consumers in a central location. One hundred consumers aged between 18 and 40 y with no previous experience in sensory analysis were recruited from Mahidol University, Kanchanaburi Campus, Thailand. Each consumer evaluated samples of both raw dried noodles and optimally cooked noodles with soup using the same nine-point hedonic scales. The attributes for the raw noodle samples were color, texture and overall liking, whereas the attributes of appearance, flavor, taste, texture and overall liking were used for the cooked noodles. The consumers were briefed on how they should perform the evaluations. In addition, they were asked to give their purchase intentions and overall impression of the dried wheat noodles supplemented with unripe banana flour.

**Statistical analysis**

The means and standard deviations were determined for all the physicochemical, textural, cooking and sensory qualities studied. The significant difference of mean values was assessed with one-way analysis of variance (ANOVA) followed by Duncan’s test using SPSS software at a significance level of \( P < 0.05 \).

**RESULTS AND DISCUSSION**

**Chemical compositions of raw noodles, banana and wheat flours**

The chemical compositions of raw dried noodles with added banana flour, the control raw dried noodles and their respective flour compositions (banana and wheat flour) are presented in Table 1. It can be observed that the moisture content of dried noodles decreased when the level of banana flour in the noodles increased. As described by Ovando-Martinez et al. (2009), this pattern is related to the decrease in the protein content with the increase in the amount of banana flour in the noodles where the network produced by the gluten is reduced; consequently, the separation of water during the drying is higher. Low-moisture content is important in the shelf-life of food products. The fat content did not change with the addition of banana flour, but the
ash content increased when the banana flour amount in the noodles increased. The ash content depends on the quality of the flour and thus corresponds to the higher mineral content, especially potassium (Kim, 1996). Banana contains high amounts of potassium (400 mg/100 g pulp) and magnesium (34 mg/100 g edible portion contents) (McCance and Widdowson, 2002).

Important increases in the dietary fiber (DF) and resistant starch (RS) levels were obtained in the noodles with the addition of banana flour. The control sample showed the lowest value of DF (3.70%) and RS (0.40%), while the noodles containing 50% banana flour possessed the highest values of DF (5.94%) and RS (4.71%), which were related to the high DF and RS contents of banana flour (7.8% and 56.17%, respectively). Faisant et al. (1995) reported that unripe bananas are the natural product with the highest RS content. RS values of 57.2% and 47.3% were determined in unripe banana flour using two different methods.

### Cooking qualities

The cooking time and cooking loss of dried noodles supplemented with banana flour are shown in Table 2. The degree of cooking can be observed either by eye or image analysis (Sozer et al., 2007). In the present study, it was determined by the disappearance of the core of the noodle strand during cooking. The optimum cooking times of all noodle samples ranged from 13.0 to 14.5 minutes.

#### Table 1 Chemical composition of raw materials and raw dried noodles supplemented with banana flour (%).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Dietary fiber (%)</th>
<th>Resistant starch (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% BF noodle</td>
<td>11.10±0.00</td>
<td>4.98±0.01</td>
<td>16.46±0.03</td>
<td>0.04±0.01</td>
<td>3.70±0.01</td>
<td>0.40±0.05</td>
</tr>
<tr>
<td>10% BF noodle</td>
<td>10.07±0.04</td>
<td>4.98±0.02</td>
<td>15.75±0.02</td>
<td>0.04±0.03</td>
<td>4.44±0.06</td>
<td>2.13±0.13</td>
</tr>
<tr>
<td>20% BF noodle</td>
<td>10.31±0.03</td>
<td>5.20±0.00</td>
<td>14.87±0.02</td>
<td>0.22±0.09</td>
<td>4.51±0.05</td>
<td>2.76±0.02</td>
</tr>
<tr>
<td>30% BF noodle</td>
<td>9.42±0.01</td>
<td>5.31±0.02</td>
<td>13.68±0.02</td>
<td>0.12±0.03</td>
<td>4.77±0.03</td>
<td>2.77±0.15</td>
</tr>
<tr>
<td>40% BF noodle</td>
<td>9.98±0.00</td>
<td>5.44±0.00</td>
<td>13.40±0.03</td>
<td>0.16±0.01</td>
<td>4.98±0.05</td>
<td>3.62±0.05</td>
</tr>
<tr>
<td>50% BF noodle</td>
<td>8.67±0.02</td>
<td>5.35±0.01</td>
<td>12.35±0.02</td>
<td>0.14±0.01</td>
<td>5.94±0.13</td>
<td>4.71±0.00</td>
</tr>
<tr>
<td>BF</td>
<td>7.58±0.01</td>
<td>3.31±0.04</td>
<td>3.18±0.02</td>
<td>0.38±0.08</td>
<td>7.80±0.06</td>
<td>56.17±1.50</td>
</tr>
<tr>
<td>WF</td>
<td>11.86±0.05</td>
<td>0.59±0.00</td>
<td>11.64±0.02</td>
<td>1.14±0.01</td>
<td>3.00±0.07</td>
<td>0.45±0.01</td>
</tr>
</tbody>
</table>

Values are shown as mean ± SD; n = 3.

Different superscript letters in a column indicate significant differences (P ≤ 0.05).

BF = banana flour; WF = wheat flour.

#### Table 2 Cooking time and cooking loss of noodles supplemented with banana flour (%).

<table>
<thead>
<tr>
<th>Noodles</th>
<th>Cooking time (min)</th>
<th>Cooking loss† (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% BF</td>
<td>13.0</td>
<td>9.35±0.12</td>
</tr>
<tr>
<td>10% BF</td>
<td>13.5</td>
<td>8.71±0.06</td>
</tr>
<tr>
<td>20% BF</td>
<td>14.0</td>
<td>9.31±0.09</td>
</tr>
<tr>
<td>30% BF</td>
<td>14.5</td>
<td>11.15±0.00</td>
</tr>
<tr>
<td>40% BF</td>
<td>13.5</td>
<td>11.09±0.02</td>
</tr>
<tr>
<td>50% BF</td>
<td>13.0</td>
<td>11.49±0.08</td>
</tr>
</tbody>
</table>

Cooking loss values are shown as mean ± SD; n = 5.

†Different superscript letters in a column indicate significant differences (P ≤ 0.05).

BF = banana flour.
14.5 min. The cooking loss is the amount of dry matter in the cooking water of optimally cooked noodles. An increase in the cooking loss with noodles containing banana flour (Table 2) may have been due to weakening of the protein network by the presence of banana flour. This may allow more solids to be leached out from the noodles into the cooking water (Rayas-Duarte et al., 1996). These results are in agreement with Ovando-Martinez et al. (2009) who reported that partial or complete substitution of durum wheat semolina with fiber material can result in negative changes to pasta quality, including increased cooking loss.

**Color characteristics**

Color is a key quality trait (Mares and Campbell, 2001) because of the visual impact at the point of sale. It provides some indication of the quality of the starting materials and, in some cases, the age of the product. Asian customers prefer bright yellow, alkaline noodles that retain a stable color for 24–48 h after preparation and consider red or dull grey noodles as undesirable (Asenstorfer et al., 2006). Factors controlling color stability, which include alkaline formulation, flour refinement and enzymatic browning associated with polyphenol oxidase, have been extensively investigated (Hatcher et al., 2008).

Color characteristics of raw sheet and optimally cooked noodles supplemented with banana flour are shown in Table 3. The results indicated that as the amount of banana flour increased, the appearance of the raw sheet and the cooked noodles supplemented with banana flour grew darker. The darkness of the both raw sheet and the cooked noodles supplemented with banana flour is a product of the Maillard reaction between reducing sugars and proteins (Mohamed et al., 2010). The redness (a*) and yellowness (b*) values were also significantly different between all samples. The redness values significantly increased relative to the banana content, while the yellowness values significantly decreased. These results were similar to the report on yeast leavened banana-bread by Mohamed et al. (2010). They found that samples with more banana powder will be darker due to excess sugar.

**Noodle texture analysis**

Instrumental texture tests on cooked noodles have been well reviewed by Ross (2006). Despite profound differences in the “test” environments, repeated studies have shown the ability of instrumental texture tests of a variety of types to correlate closely with related sensory texture attributes. Tensile tests used to measure elasticity and related attributes are amenable to interpretations of the raw time/force data that can be used to determine fundamental rheological parameters (Ross, 2006). Tensile parameters,
tensile strength and breaking length of cooked noodles made from wheat flour and supplemented with banana flour are compared in Figure 1. The tensile strength of cooked noodles was significantly different, while the breaking length of noodles was not significantly different with the variation of banana flour content. The tensile strength decreased when the banana flour content increased. Notably, the addition of banana flour, a non-gluten flour, in the fabrication of dried noodles diluted the gluten strength of the wheat flour and interrupted as well as weakened the overall structure of the noodles. These results are in line with Kovacs et al. (2004) who reported that about 80% of the total protein of wheat flour is gluten. Gluten proteins are composed of gliadins and glutenins, which are responsible for gluten or dough extensibility (viscosity) and strength (elasticity), respectively. Therefore, removal of wheat flour would impair the gluten matrix, hence leading to the weakening of noodle texture.

**Sensory evaluation**

Asian consumers normally purchase noodle products daily from either convenience stores or local manufacturers, basing their purchasing decisions upon their initial assessment of noodle quality by its visual appearance, that is, color, brightness and the absence of undesirable specks (Hatcher et al., 2009). In the present study, the sensory evaluation of optimally cooked noodles supplemented with banana flour was carried out with the objective to select the best-suited banana flour (by percentage) for the preparation of the noodles. The means sensory liking scores for appearance, flavor, taste, texture and overall liking of optimally cooked noodles supplemented with banana flour are shown in Figure 2. Most panelists scored the optimally cooked noodles supplemented with 10%, 20% and 30% banana flour to be equally acceptable as the control noodles. No statistically significant difference could be found for any of the sensory attributes. It is noted that the sensory liking scores for the flavor and taste attributes of noodles were not significantly different with variation in the banana flour content. In order to make dried noodle products of high nutritional quality with low carbohydrate digestibility and rich in resistant starch, the noodles supplemented with 30% banana flour were selected and subsequently used for the consumer test.

One hundred consumers (22 males and 78 females) participated in the consumer test. Consumers were asked to complete a short questionnaire following the preference test. This

![Figure 1](image-url) **Figure 1** Effect of banana flour (%) on: (a) tensile strength; and (b) breaking length of optimally cooked noodles supplemented with banana flour. The same letter above columns indicates there is no significant difference ($P > 0.05$). The vertical bars on each column indicate the standard deviation.
A questionnaire asked for demographic information and examined the respondents’ consumption habits with regard to yellow alkaline noodles. Analysis of the results indicated that 88% of the consumers accepted the product and 61% of the consumers were willing to purchase it. The overall liking scores of uncooked and cooked dried noodles were at the moderate level (Figure 3). According to this consumer test, the category of invention and health product was the main reason for the consumption.

Figure 2 Effect of banana flour (%) on sensory liking scores for: (a) appearance; (b) flavor; (c) taste; (d) texture; and (e) overall liking of optimally cooked noodles supplemented with banana flour. The same letter above columns indicates there is no significant difference ($P > 0.05$). The vertical bars on each column indicate the standard deviation.
Figure 3  Average sensory liking scores of: (a) raw dried noodles and (b) cooked dried noodles prepared from the optimal ratio of mixtures of banana flour per wheat flour. The vertical bars on each column indicate the standard deviation.

of dried noodles supplemented with banana flour.

CONCLUSION

Banana flour could be added to dried noodles up to the level of 30% without any significant change in organoleptic characteristics. Dried noodles made from 30% banana flour were considered as most acceptable organoleptically and nutritionally as they contained appreciable amounts of protein (13.7%), fat (0.12%) and dietary fiber (4.8%, including 2.8% resistant starch). The development of such functional foods not only improves the nutritional status of the general population but also helps those suffering from degenerative diseases associated with today’s changing life styles and environment.

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LITERATURE CITED


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