The Effect of Partial Wheat Flour Substitution by Unripe Banana Flour and Particle Sizes on the Physical, Chemical Properties and In Vitro Digestibility of Instant Noodles

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บทคัดย่อ

วัตถุประสงค์ของการศึกษานี้เพื่อพัฒนาบะหมี่กึ่งสำเร็จรูปที่มีคุณสมบัติเชิงหน้าที่ โดยการทดแทนแป้งสาลีบางส่วนด้วยแป้งกล้วยดิบ การศึกษาได้ดำเนินการเพื่อแสดงให้เห็นถึงการปรับปรุงโดยพิจารณาจากขนาดอนุภาคของแป้งกล้วย ผลของการเติมแป้งกล้วยดิบที่มีขนาดอนุภาคต่างกัน (อนุภาคหยาบ ขนาด 80 μm และอนุภาคละเอียด 250 μm) ทดแทนแป้งสาลีบางส่วน (0%, 10%, 20%, and 30%) ต่อคุณภาพทางกายภาพ เคมี และคุณสมบัติการย่อยได้ในหลอดทดลอง จากผลการวิจัยแสดงให้เห็นว่าการใช้แป้งกล้วยดิบที่ระดับการทดแทน 30% สามารถลดปริมาณน้ำมันและค่าพลังงาน และเพิ่มปริมาณความชื้นและเส้นใยอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) เมื่อปริมาณแป้งกล้วยที่ทดแทนแป้งสาลีเพิ่มขึ้น ลักษณะปรากฏของผลิตภัณฑ์จะมีความคล้ำขึ้น และความเหนียวของเส้นบะหมี่ลดลงเมื่อเทียบกับตัวอย่างควบคุม การเติมแป้งกล้วยดิบที่มีอนุภาคหยาบ 30% ส่งผลให้ระดับแป้งที่ย่อยได้ช้าเพิ่มขึ้นอย่างเห็นได้ชัดในบะหมี่กึ่งสำเร็จรูป แม้จะมีการเปลี่ยนแปลงคุณลักษณะด้านสี และเนื้อสัมผัสของผลิตภัณฑ์ แต่ความสามารถในการย่อยได้ของตัวอย่างบะหมี่กึ่งสำเร็จรูปแสดงให้เห็นว่าแป้งกล้วยดิบสามารถใช้เป็นส่วนผสมในการเตรียมบะหมี่กึ่งสำเร็จรูปที่มีคุณค่าทางโภชนาการมากขึ้น

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ABSTRACT

The objective of the study was to develop instant noodles with functional properties by partial wheat flour substitution with unripe banana flour. The study was undertaken to show the extent of improvement based on the size counterparts of the flour. The effect of addition of mechanically fractionated flours (fine fraction; 80 μm and coarse fraction; 250 μm) from unripe banana flour as a partial substitute (0%, 10%, 20%, and 30%) for wheat flour on the physical, chemical and in vitro digestibility properties was investigated. The results indicated that use of unripe banana flour at 30% substitution level significantly decreased the oil content and energy caloric value and increased the moisture and fiber ($p<0.05$). As the amount of banana flour increased, the appearance became darker and the stickiness of the noodles decreased when compared to the control sample. Addition of 30% coarse banana flour resulted in a marked increase in resistant and slow digestible starch levels in the instant noodles. Despite the change in color and texture of the product it presented, the digestibility of the instant noodle samples showed that unripe banana flour produced from a mechanical fractionation can be used as a promising functional ingredient to prepare instant noodles with greater nutritional value prospects.

Keywords: Unripe banana, Dietary fiber, Resistant starch, Instant noodle, Particle size

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INTRODUCTION

Instant noodle is considered a staple food item of Asian countries which corresponds to nearly 80% of instant noodle consumption and consumed worldwide in 2019 with approximately 106.4 billion servings. Demand is due to instant noodles low cost and convenience in preparation, cooking, and delivery [1]. However, instant noodles are a deep-fried product that contain high residual oil content, and claimed to lack other nutritional components such as dietary fiber, vitamins, minerals, and bioactive compound [2]. Thus, there is an effort to develop healthier instant products by incorporating sources of fiber and essential nutrients. Several studies have reported the replacement of some food ingredients to instant noodle for the production of functional foods, including sorghum [3], corn starch [4-5] or corn flour [6], pigeon pea and rice [7], amaranth flour and cassava starch [8], purple sweet potato and carrot [9] and green banana flour [10] have been incorporated.

It well known that green or unripe banana has potential as a source of dietary fiber, resistant starch and bioactive compounds [11]. Kumar et al. [12] reported that unripe banana flour contains a large proportion of resistant starch (52.7–54.2%), which shows a reduction in the caloric content and a positive impact on glucose homeostasis in healthy volunteers. Resistant starches are not digested within 120 minutes in the human small intestine, but are fermented by probiotics in the large intestine, producing short chain fatty acids which may have beneficial effects on health such as reduction of the glycemic and insulinemic responses to food, hypocholesterolemic action and protective effects against colorectal cancer [13]. Due to these characteristics, banana flour has been utilized as a functional ingredient in mostly starch-based food products such as spaghettis [14], pasta [15], dried noodles [16], snacks [17] and bread [18-19]. Use of a raw material for different food products, the particle size of flour is the intrinsic properties and are important for quality attributes such as oil holding, hydration and emulsifying properties and therefore affecting the quality of the final food products [20]. According to de la Hera et al. [21], cake development by using rice flours with coarse particle size showed a significant decrease in cake volume and texture. However, to the best of our knowledge, the use of banana flour with different particle sizes as an ingredient in instant noodle has not been studied.

Generally, noodles are made of a gluten network of wheat flour that is high in starch, which increases its glycaemic response. This may be related to rapidly digested starch (RDS) which is digested within 20 min and rapidly absorbed in the duodenum, leading to rapid elevation of blood glucose and significantly correlated to postprandial glycaemic index (pGI). On the contrary, slow digestible starch (SDS) is defined for starch digested and converted to glucose between 20 to 120 min [22]. It would be desirable if the rate of ingestion and absorption of the carbohydrates in noodles were reduced by addition of green banana pulp flour with higher content of SDS and RS compared to RDS. The slow rate of SDS and RS digestion would assist in controlling metabolic

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disorders such as obesity, diabetes, hyperlipidemia and cardiovascular diseases [23]. Although there are some reports on the effect of replacement of wheat flour with green banana flour on noodle properties [10, 16, 24-25] in vitro studies inspecting the digestibility of starch in this model are lacking.

In this way, our hypothesis was that the use of flour obtained from unripe bananas with an optimum particle size could: (1) improve the nutritional features of instant noodles while remaining its physicochemical attributes and (2) minimize the waste of banana culls. Therefore, the aim of this research was to investigate the effect of wheat flour substitution (10, 20 and 30%) by unripe banana flour with two different particle sizes [80 μm (fine) and 250 μm (coarse)] on the physical, chemical properties and the digestibility of instant noodles containing unripe banana flour.

MATERIALS AND METHODS

1. Banana flour preparation

Unripe banana fruits (*Musa sapientum* L., ABB group, cv. Kluai 'Namwa') were collected from a commercial grower in the Damnoen Saduak District, Ratchaburi Province, Thailand. The bananas were harvested on 115–120 days after bloom, which defined as ripening stage 2 (total soluble solids approximately 7.0±1.0° Brix). Unripe banana flour was prepared according to Segundo et al. [20] with some modifications. The fruits were peeled and soaked in 0.5% (%w/v) citric acid solution for 10 min, to prevent enzymatic browning. Then, the peeled bananas were grounded in a juicer (HR7761, Philips, Netherland) at speed 2 for 3 min. The banana paste was poured onto a tray and dried in tray dryer at 60 °C for 24 h. The dried paste was grounded in a Waring laboratory blender (Waring Laboratory Science, Winsted, USA) and subsequently sieved through two different mesh screens to obtain a fine (80 μm) and coarse fractions (250 μm). The different banana flour fractions were sealed in airtight plastic packs and stored at 4 °C until used for the instant noodle production. The proximate composition of the two fractions of banana flours and wheat flour (g/100 g db) were as follows: fine flour (moisture 7.85, protein 3.15, lipid 0.39, ash 3.64, carbohydrates 84.97); coarse flour (moisture 8.22, protein 4.21, lipid 0.43, ash 5.24, carbohydrate 81.90); wheat flour (WF) (moisture 11.45, protein 10.50, lipid 1.15, ash 0.73, carbohydrate 76.17).

2. Instant noodle production

Instant noodle preparation was conducted as described by Vernaza et al. [10] with slight modifications. The ingredients of instant noodle consisted of 70 g wheat flour, 2 g salt and 0.22 g guar gum and 27.78 g water. Treatments were prepared with 10, 20 and 30% (w/w) substitution of fine and coarse unripe banana flour, which together with the control (100% wheat flour) gave 7 formulations. Firstly, salt and guar gum were dissolved in the water (brine solution) used for noodle making. Then, wheat flour was mixed with banana flour for 1 min at speed 2 in the Kitchen Aid Artisan Mixer (St. Joseph, Michigan, USA) followed by the addition of brine solution for 10 min at speed 9 until smooth clotted dough was formed. The dough was divided into small batches and then

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passed through the rollers of the noodle making machine (Itop Kitchen Equipment Co., Ltd., Guangzhou, China) several times to obtain completely sheeted dough and then allowed to rest for 10 min. After that, the dough sheets were cut into 2 mm wide strands with the noodle cutting rolls. Finally, the noodles were steamed in a convotherm steam oven (Welbilt Inc., Munich, Germany) for 5 min and fried in palm oil at 150 °C for 90 sec followed by cooling at room temperature. The samples were stored at room temperature in sealed plastic containers for further analyses.

3. Instant Noodle Chemical Properties

The chemical properties of instant noodle samples were determined following AACC [26] methods for moisture content (44.15.02), protein (46.11.02), lipids (30.25.01), ash (08.12.01). The carbohydrate content (%) was calculated by difference method. The energy value was calculated by sum of the percentage of proteins and carbohydrates multiplied by a factor of 4 (kcal/g) and lipids multiplied by a factor of 9 (kcal/g).

Total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) contents were analyzed in following the methods 32.07.01 (AACC, 2000). Briefly, 1 g dried samples were subjected to sequential enzymatic digestion by heat-stable α-amylase, protease and amylogluco-sidase. IDF was filtered and then washed with warm distilled water and dried. SDF was precipitated with EtOH and then filtered dried and weighed. TDF value was corrected for protein and ash contents.

4. Color Analysis

The color of instant noodle samples was determined by colorimeter (Ultrascan VIS, Hunterlab, VA, United States). The CIELAB system was used to quantify the color of the samples, where L* is the brightness value between 0-100, positive a* values indicate redness and negative a* values indicate greenness, positive b* values indicate yellowness and negative b* values indicate blueness.

5. Texture Analysis

The measurement was performed using the TA-XT2i texture analyzer (Stable Microsystems, Surrey, UK). Instant noodle was rehydrated with boiled water for 3 min, drained for 10 minutes, and cooled at room temperature. The noodle strips length 5 cm for 10 strips were taken for examination. Each strip of instant noodle was put under 35 mm cylinder probe (P/35) of the texture analyzer to evaluate for hardness and adhesiveness. The hardness is defined as maximum force and is expressed in grams while the adhesiveness is defined as the negative force area and expressed in gram sec [27].

6. In Vitro Starch Digestibility Tests

The in vitro digestibility of instant noodle substitute with banana flour was determined by the method of Sharma et al. [28], with some modifications, in brief, 100 mg of samples were incubated with 0.2 mL α-amylase (100 mg/mL in KCl–HCl buffer) and 0.2 mL pepsin solution (5 mg/mL in 0.02 M HCl, pH 1.5) at 37°C for 30 min with shaking. Then samples were mixed with pancreatin and amyloglucosidase (300 U/mL) prepared in 0.2 M

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sodium acetate buffer (pH 6.0) and incubated at 37°C for 2 h. The released glucose at different times (0, 0.5, 1, 1.5, 2 and 3 h) was measured using glucose oxidase–peroxidase reagent (GOPOD). The values of rapidly digestible starch (RDS) and slowly digestible starch (SDS) were calculated.

Total starch content was measured by the Goñi's method [29]. The amount of 100 mg of dried ground samples were incubated with 2 M KOH at room temperature for 30 min. Solubilized starch was then incubated with 60 μL amyloglucosidase at 60°C and pH 4.75 for 45 min in a shaking water bath and determination of released glucose with glucose oxidase peroxidase (GODPOD) assay by absorbance at 510 nm against the reagent blank.

Total resistant starch was determined following Menezes et al. [30]. This method reports the sum of native indigestible fractions, retrograded fractions, and a substantial part of physically inaccessible starch. In short, 100 mg of instant noodle samples was incubated with pancreatic α-amylase/amyloglucosidase in maleate buffer (50 mM, pH 6) at 37°C for 3 h. After hydrolysis, samples were added with ethanol and centrifugation, the pellet was further digested with 4 M KOH. Digested pellet and supernatant were separately incubated with amyloglucosidase at 50°C for 20 min in a water bath. Resistant starch content was measured by GODPOD assay at 510 nm and calculated as mg of glucose × 0.9.

7. Statistical Analysis

All experiments were carried out in triplicate and values are expressed as mean and standard deviation (SD). Data analysis was conducted using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test ($p<0.05$) to identify significant differences among treatments, using the statistical software SPSS.

RESULTS AND DISCUSSION

1. Chemical Properties of Instant Noodle

The chemical compositions of the instant noodles with added banana flour, along with the control sample, are shown in Table 1. Moisture content increased ($p<0.05$) when increasing unripe banana flour level in instant noodle samples compared to the control sample. This result might be related to fibers in product, providing high water retention of samples as a result of hydrophilic sites in the fiber [31]. This finding is in agreement with Gomes et al. [18] who reported that the addition of green banana flour showed higher moisture content of the breads. The protein content was significantly lower in instant noodles that added unripe banana flour in comparison to the control sample ($p<0.05$). This could be due to unripe banana flour has lower protein content than wheat flour, as shown in the proximate composition of the raw material. Similar results were observed by Vernaza et al. [10] in which the protein content of instant noodles decreased when added with 10% green banana flour. Substitution in the coarse fraction of banana flour showed higher moisture and protein content than the fine fraction since the coarse fraction has higher moisture and protein content in raw material. Furthermore, this was expected since the large particles composed of dietary fiber and protein associated with the

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banana pulp, which attached to the granule surface and filling the intergranular space within the particle [20]. The fat content demonstrates a similar trend to protein content, where the fat content decreased with increasing the addition of banana flour. This result was consistent with Anggraeni and Saputra [16] who used banana flour in dried noodles and indicated that the raw banana flour had low-fat content when compared to wheat flour. There was no significant difference in fat content between the instant noodle made with fine and coarse banana flours. This result is supported by Savlak et al. [32] who reported that there was not a significant correlation between particle size and oil holding capacity. Ash content in the instant noodle was directly proportional to the addition of banana flour both of fine and coarse fractions. High ash content in the instant noodle substituted with banana flour is demonstrative of the presence of high mineral components, especially potassium in bananas [31]. Similar patterns were found in dried noodle [16], spaghetti [14] and bread [18-19] prepared with different ratios of unripe banana flour. As for the particle size, banana instant noodles with coarse fraction showed a higher ash content which is due to the coarse particles having higher ash content (5.24%) than the fine particles (3.64%) in raw banana flour and higher content of dietary fiber of coarser fractions of banana flour. The carbohydrate content of different instant noodle samples varied from 57.85 to 65.25 g/100 g (Table 1). The variations in carbohydrate content among samples may result from the difference in moisture, protein, fat, ash content of wheat flour and banana flour. Total dietary fiber (TDF) content of the instant noodles added with banana flour was found to be significantly higher than that of the control noodles ($p<0.05$) and this amount increased when the concentration of banana flour increased in the formulation. This pattern is related to the high fiber content present in green banana flour due to high levels of hemicellulose in the fruit [16]. This result was in accordance with the study by Ritthiruangdej et al. [24] who reported the dietary fiber content in raw noodles added with processed banana flour had a higher level of dietary fiber than those of wheat noodle. In this case, the coarse fractions of green banana flour had a higher amount of dietary fiber, which was also related to large particles composed of fiber content from the banana pulp as mentioned above. Regarding the energy value (EV), it can be observed that higher content of TDF resulted in decline of EV in the final product and the highest reduction of EV was observed in the instant noodles with 30% coarse banana flour (7.60%). The findings of chemical composition indicated that the instant noodles made with banana flours has more nutritional value than the wheat instant noodle with a decrease in protein content. In addition, the moisture content complied with the criterion standard (<8%) for instant noodles established by TISI 271-2563, however the fat content is slightly higher than the standard (<20%).

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Table 1 Chemical composition properties of instant noodle substituted with banana flour (g/100 g).

Sample	Moisture	Protein	Fat	Ash	Carbohydrate	TDF	EV (Kcal/100g)
Control	3.51 ± 0.12^{g}	11.94 ± 0.24^{a}	26.05 ± 0.21^{a}	0.65 ± 0.13^{g}	57.85 ± 0.10^{d}	3.65 ± 0.22^{g}	513.61 ± 0.20^{a}
Fine 10	3.62 ± 0.15^{f}	6.82 ± 0.17^{f}	22.23 ± 0.23^{d}	2.09 ± 0.19^{f}	65.25 ± 0.15^{a}	5.12 ± 0.12^{f}	488.31 ± 0.17^{b}
Fine 20	3.74 ± 0.20^{e}	6.86 ± 0.21^{f}	22.41 ± 0.26^{c}	2.21 ± 0.15^{e}	64.78 ± 0.12^{b}	5.35 ± 0.13^{e}	488.25 ± 0.21^{b}
Fine 30	3.87 ± 0.25^{d}	7.04 ± 0.18^{e}	22.65 ± 0.15^{b}	2.46 ± 0.12^{d}	63.98 ± 0.11^{c}	5.47 ± 0.11^{d}	487.93 ±0.18^{c}
Coarse 10	4.74 ± 0.21^{c}	7.67 ± 0.22^{d}	22.24 ± 0.18^{d}	3.18 ± 0.09^{c}	62.17 ± 0.09^{e}	5.62 ± 0.07^{c}	479.52 ± 0.19^{d}
Coarse 20	5.45 ± 0.18^{b}	8.03 ±v 0.26^{c}	22.43 ± 0.24^{c}	3.32 ± 0.11^{b}	60.77 ± 0.12^{f}	5.85 ±0.10^{b}	477.07 ± 0.22^{e}
Coarse 30	6.13 ± 0.26^{a}	8.36 ± 0.11^{b}	22.68 ± 0.32^{b}	3.58 ± 0.13^{a}	59.25 ± 0.13^{g}	6.16 ± 0.08^{a}	474.56 ± 0.15^{f}

Values are presented as mean ± SD (n = 3), dry weight basis. Different superscript letters in the same column indicate significant difference (p<0.05). TDF, total dietary fiber; EV, energy value.

2. Color and Texture Characteristics

Color is an important aspect of food products, as it indicates quality and consumer acceptance [33]. Table 2 demonstrates the color values of instant noodles prepared from banana and wheat flour. Overall, the addition of banana flour showed a significant (p<0.05) lower in the lightness value (L*) of the instant noodles when compared to the control sample. The instant noodle samples containing more banana flour were darker. This result could be related to excess sugar in the banana flour that caused the Maillard Reaction to occur between reducing sugars and proteins [34]. This is in agreement with the findings of Cheok et al. [15], who indicated that pastas added with high level of banana flour presented lower in the lightness. The instant noodle made with fine banana flour showed higher value for lightness than coarse flour. Ahmed et al. [35] reported that the increase of L* values with reduced particle size resulted from an increase in surface area that allows more reflection of light. In parallel, the incorporation of banana flour also significantly (p<0.05) increased the redness value (a*) and decreased the yellowness value (b*) of the instant noodles. These results were in concordance with the report from Mohamed et al. [36], that yeast leavened banana-bread samples with more banana powder will be darker due to bananas containing excess sugar and high levels of polyphenol oxidase leading to enzymatic oxidation of monophenols and the release of *o*-quinones which results in the formation of dark color. As for different banana flour fraction, it was found that the instant noodle prepared with fine particles had a* and b* values lower than the instant noodle from coarse particles. Ahmed et al. [37] mentioned that the decrease in a* and b* values of finer particles was caused by the loss of pigment during the milling process. Moreover, the reduction in yellowness of smaller particle sizes may correlated with a decline in protein content [32].

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Table 2 Color and texture qualities of instant noodle substituted with banana flour.

Sample	Color			Texture	
	L*	a*	b*	Hardness (g)	Adhesiveness(g.sec)
Control	73.36 ± 0.43[a]	2.14 ± 0.21[f]	22.75 ± 0.38[a]	45.31 ± 0.81[e]	78.16 ± 3.52[a]
Fine 10	70.85 ± 0.61[b]	4.36 ± 0.23[e]	18.46 ± 0.31[b]	64.16 ± 1.32[d]	58.61 ± 2.16[b]
Fine 20	69.46 ± 0.55[c]	5.52 ± 0.19[d]	17.23 ± 0.25[c]	67.25 ± 1.25[c]	57.20 ± 1.63[b]
Fine 30	68.67 ± 0.60[cd]	6.55 ± 0.14[c]	16.15 ± 0.36[d]	68.37 ± 1.23[c]	53.18 ± 2.46[c]
Coarse 10	68.52 ± 0.76[cd]	5.64 ± 0.25[d]	17.26 ± 0.32[c]	73.08 ± 1.33[b]	45.22 ± 1.09[d]
Coarse 20	68.04 ± 1.02[d]	6.89 ± 0.20[b]	15.87 ± 0.45[e]	75.62 ± 1.41[a]	44.79 ± 2.27[d]
Coarse 30	67.51 ± 0.83[e]	7.22 ± 0.16[a]	14.61 ± 0.30[f]	76.37 ± 1.45[a]	39.53 ± 1.42[e]

Values are presented as mean ± SD (n = 3), dry weight basis. Different superscript letters in the same column indicate significant difference ($p<0.05$).

Texture plays an important role in determining the final acceptance by the consumer, and it is one of the predominant criteria for assessing noodle quality [34]. The values of hardness and adhesiveness of cooked instant noodle prepared from flour of banana and wheat are presented in Table 2. Increasing the level of banana flour substitution significantly ($p<0.05$) increased hardness. A similar trend was found by Osorio-Díaz et al. [14] who reported that the increase on percentage substitution of unripe banana flours into spaghetti formulation showed the hardness values increased. However, the noodles prepared from banana flours showed lower adhesiveness values compared to the wheat noodle. The result was similar to the previous study of Cheok et al. [15] who discovered that the adhesiveness value of pasta was lower with addition of banana flour into the pasta formulation compared to the commercial pasta. These results might be related to the high amount of fiber in banana flour (Table 1), resulting in the covalent and noncovalent interactions between protein and dietary fiber that can cause higher molecular mass polymerization and increasing the hardness of cooked noodles. Also, smaller dietary fiber particles can fill in the gaps of the gluten network structure, increasing noodle stiffness [38]. While the decrease in the adhesiveness could be related to dietary fiber exerting binding steric hindrance, resulting in a negative impact on gluten malleability [39]. For considering the banana powder particles, the instant noodle containing coarse flour resulted in higher hardness but lower in adhesiveness value than the noodle prepared from fine flour. The results were due to the fiber content of coarse flour is much greater when compared to fine flour so the possibility of water absorption becomes larger, leading to gluten network weakened by dietary fiber, as well as being associated with amylose leaching during cooking [40]. This relation was supported by Cadden [41] who stated that finer particles of wheat bran decreased water-holding capacity, owing to the disintegrate of fiber matrix.

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4. Starch Digestibility Analysis

It is well established that a diet high in resistant starch (RS) and slowly digestible starch (SDS) can help reduce glycemic index, postprandial blood glucose and insulin response whereas rapidly digestible starch (RDS) releases glucose to blood at a fast rate [22]. The results of in vitro starch digestion properties are shown in Table 3. The amount of RS in the instant noodle increased significantly ($p<0.05$) with the addition of banana flour compared to wheat flour (1.58%), with the noodles that added 30% coarse banana flour having the highest percentage (7.62%). The results were similar to previous studies of noodles [25], spaghetti [14] and bread [42] prepared with banana flour. The instant noodle made with fine flour had RS content lower compared to noodles made with coarse flour. The result was possibly the consequence of the lesser amount of RS in the fine flour compared to the coarse flour. Resistant starch as a part of dietary fiber is a type of indigestible saccharide [43], so it is possible that the increment in the RS was associated with the increase of dietary fiber from the substitution of green banana flour. In this study, a higher amount of dietary fiber was found for the instant noodle made with coarse fractions of unripe banana flour, as shown in Table 1. The RS found in banana flour is type 2 (RS2). RS2 is a native starch type that limits the accessibility of digestive enzymes by its crystalline granular structure, making it resist hydrolysis [22]. According to the recommended daily intake of RS for prebiotic effect, the effective dosage of RS is considered 6–12 g/d [13]. Hence, having a 100 g of instant noodle substituted with 30% coarse banana flour can promote health benefits. An increase in SDS was observed when the amount of banana flour increased in the instant noodle ($p<0.05$) (Table 3). It has been mentioned that during cooking the starch structure becomes loosen and some long external chains of amylopectin and the starch structure amylose are depolymerized, but during the cooling phrase the starch restructuring is performed and this structure leads to a slower digestion by digestive enzymes [44]. This result was comparable to that reported in cookies created with unripe banana flour (30%), where control sample had an SDS content of 8.3 g/100 g and unripe banana flour cookies had 9.3 g/100 g [45]. Instant noodles added with unripe banana flour had lower RDS than the control and RDS decreased when banana flour increased in the instant noodles ($p<0.05$) (Table 3). During cooking the semicrystalline structure of native starch is disrupted and is readily hydrolyzed by digestive enzymes [44]. However, the presence of indigestible carbohydrates from unripe banana flour produces a dilution effect decreasing the RDS. The result is comparable to that reported by de la Rosa-Millan et al. [46]. Thus, the results of this study on the use of unripe banana flour as a food ingredient to reduce starch digestibility and increase RS and SDS in the food product may be of importance for the food industry.

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Table 3 Starch digestibility of instant noodle samples (g/100 g db).

Sample	RS (%)	SDS (%)	RDS (%)	TS (%)	RS:TS (%)
Control	1.58 ± 0.08^{f}	10.15 ± 1.18^{f}	58.64 ± 1.52^{a}	68.53 ± 2.52^{e}	2.31 ± 0.13^{e}
Fine 10	2.22 ± 0.15^{e}	11.53 ± 1.15^{e}	56.18 ± 2.16^{b}	69.04 ± 3.18^{e}	3.22 ± 0.17^{d}
Fine 20	3.54 ± 0.13^{c}	13.21 ± 1.21^{d}	56.23 ± 2.23^{b}	$70.65 \pm 3.45d^{e}$	5.01 ± 0.18^{c}
Fine 30	5.21 ± 0.17^{b}	15.44 ± 1.17^{b}	51.14 ± 1.53^{d}	72.18 ± 2.61^{c}	7.22 ± 0.14^{b}
Coarse 10	3.26 ± 0.11^{d}	13.66 ± 1.25^{c}	56.21 ± 2.35^{b}	71.06 ± 3.37^{d}	4.59 ± 0.17^{c}
Coarse 20	5.28 ± 0.18^{b}	15.48 ± 1.22^{b}	53.16 ± 2.27^{c}	73.25 ± 3.52^{b}	7.21 ± 0.18^{b}
Coarse 30	7.62 ± 0.21^{a}	17.67 ± 1.26^{a}	50.06 ± 2.02^{e}	75.72 ± 3.92^{a}	10.06 ± 0.20^{a}

Values are presented as mean ± SD (n = 3), dry weight basis. Different superscript letters in the same column indicate significant difference ($p<0.05$). RS, resistant starch; SDS, slow digestible starch; RDS, rapidly digestible starch; TS, total starch.

CONCLUSIONS

In this study, it can be concluded that the use of unripe banana flour (at ripening stage 2) up to 30% in substitution for wheat flour significantly increased total dietary fiber and ash content in the instant noodles. However, the instant noodles made with banana flour exhibited darker color and changed in some texture characteristics compared to the control noodle sample. The addition of 30% of unripe banana flour in the instant noodle brought about a product with the pronounced percentage of resistant starch and slowly digestible starch. As for the different particle size, coarse flours provided instant noodles with higher amount of dietary fiber, ash, resistant starch, and slowly digestible starch contents than those made with the fine counterparts. Therefore, banana coarse flours would be more useful in application and the 30% unripe banana flour addition could be considered as functional instant noodles containing prebiotic dosage (RS:TS = 10.06%). Further studies are recommended to use other hydrocolloids in the formulation of instant noodles for improving their final texture. Current findings are evidence that green banana flour might be a nutritional alternative source with many benefits to the food industry and consumers.

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REFERENCES

[1] World Instant Noodle Association. (2020). Global Demand for Instant Noodles. [Online] Available from http://www.instantnoodles.org/noodles/expanding-market.html. [Accessed May 19, 2021]

[2] Choo, C.L. and Aziz, N.A.A. (2010). Effects of banana flour and β-glucan on the nutritional and sensory evaluation of noodles. Food Chemistry. 119(1): 34-4.

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[3] Liu, L., Herald, T.J., Wang, D., Wilson, J.D., Bean, S.R. and Aramouni, F.M. (2012). Characterization of sorghum grain and evaluation of sorghum flour in a Chinese egg noodle system. Journal of Cereal Science. 55: 31-36.

[4] Yuan, M.L., Lu, Z.H., Cheng, Y.Q. and Li, L.T. (2008). Effects of spontaneous fermentation on the physical properties of corn starch and rheological characteristics of corn starch noodle. Journal of Food Engineering. 85: 12-17.

[5] Yousif, E.I., Gadallah, M.G. E. and Sorour, A.M. (2012). Physico-chemical and rheological properties of modified corn starches and its effect on noodle quality. Annals of Agricultural Science. 57(1): 19-27.

[6] Padalino, L., Mastromatteo, M., Lecce, L., Cozzolini, F. and Del Nobile, M.A. (2013). Manufacture and characterization of gluten-free spaghetti enriched with vegetable Flour. Journal of Cereal Science. 57: 333-342.

[7] Yadav, B.S., Yadav, R.B. and Kumar, M. (2011). Suitability of pigeoan pea and rice starches and their blends for noodle making. LWT-Food Science and Technology. 44: 1415-1421.

[8] Fiorda, F.A., Soares Jr., M.S., da Silva, F., Grosmann, M.V.E. and Souto, L.R.F. (2013). Microstructure, texture and colour of gluten-free pasta made with amaranth flour, cassava starch and cassava bagasse. LWT-Food Science and Technology. 54: 132-138.

[9] de Souza, I.G., da Silva Oliveira, W., Chang, Y.K., Godoy, H.T., Schmiele, M., Campelo, P.H. and Clerici, M.T.P.S. (2021). Root and tuber flours to improve nutritional quality in instant noodles. Research, Society and Development. 10(4): 1-13.

[10] Vernaza, M.G., Gularte, M.A. and Chang, Y.K. (2011). Addition of green o banana flour to instant noodles technological rheological and technological properties. Ciência e Agrotecnologia. 35(6): 1157-1165.

[11] Pragati, S., Genitha, I. and Ravish, K. (2014). Comparative study of ripe and unripe banana flour during storage. Journal of Food Processing and Technology. 5(11): 1-6.

[12] Kumar, P.S., Saravanan, A., Sheeba, N. and Uma, S. (2019). Structural, functional characterization and physicochemical properties of green banana flour from dessert and plantain bananas (*Musa* spp.). LWT - Food Science and Technology. 116: 108524.

[13] Amini, A., Khalili, L., Keshtiban, A.K. and Homayouni, A. (2016). Resistant starch as a bioactive compound in colorectal cancer prevention. In R.R. Watson and V.R. Preedy (eds.), Probiotics, Prebiotics, and Synbiotics: Bioactive Foods in Health Promotion (pp. 773-780). Academic Press, Cambridge, MA, USA.

[14] Osorio-Díaz, P., Islas-Hernández, J.J., Agama-Acevedo, E., Rodríguez-Ambriz, S.L., Sánchez-Pardo, M. E. and Bello-Pérez, L.A. (2014). Chemical, starch digestibility and sensory characteristics of durum wheat/unripe whole banana flour

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[2] Culinary Industry, School of Culinary Arts, Suan Dusit University, Bangkok, 10300 Thailand

blends for spaghetti formulation. Food and Nutrition Sciences. 5: 264-270.

[15] Cheok, C.Y., Sulaiman, R., Manan, N.A., Zakora, A.J., Chin, N.L. and Hussain, N. (2018). Pasting and physical properties of green banana flours and pastas. International Food Research Journal. 25(6): 2585-2592.

[16] Anggraeni, R. and Saputra, D. (2018). Physicochemical characteristics and sensorial properties of dry noodle supplemented with unripe banana flour. Food Research. 2(3): 270-278.

[17] Wang, Y., Zhang, M. and Mujumdar, A.S. (2012). Influence of green banana flour substitution for cassava starch on the nutrition, color, texture and sensory quality in two types of snacks. LWT - Food Science and Technology. 47: 175-182.

[18] Gomes, A.A.B., Ferreira, M.E. and Pimentel, T.C. (2016). Bread with flour obtained from green banana with its peel as partial substitute for wheat flour: Physical, chemical and microbiological characteristics and acceptance. International Food Research Journal. 23: 2214-2222.

[19] Rahman, T., Akter, S., Sabuz, A. A. and Rana, R. (2021). Characterization of wheat flour bread fortified with banana flour. International Journal of Food Science and Agriculture. 5(1): 7-11.

[20] Segundo, C., Román, L., Gómez, M. and Martínez, M.M. (2017). Mechanically fractionated flour isolated from green bananas (*M. cavendishii* var. nanica) as a tool to increase the dietary fiber and phytochemical bioactivity of layer and sponge cakes. Food Chemistry. 219: 240-248.

[21] de la Hera, E., Martínez, M., Oliete, B. and Gomez, M. (2013). Influence of flour particle size on quality of gluten-free rice-cakes. Food and Bioprocess Technology. 6: 2280-2288.

[22] Raigond, P., Ezekiel, R. and Raigond, B. (2015). Resistant starch in food: A review. Journal of the Science of Food and Agriculture. 95(10): 1968–1978.

[23] Yao, W., Liu, C., Xi, X. and Wang, H. (2010). Impact of process conditions on digestibility of pea starch. International Journal of Food Properties. 13(6): 1355-1363.

[24] Ritthiruangdej, P., Parnbankled, S., Donchedee, S. and Wongsagonsup, R. (2011). Physical, chemical, textural and sensory properties of dried wheat noodles supplemented with unripe banana flour. Kasetsart Journal (Natural Science). 45(3): 500-509.

[25] Tiboonbun, W., Moongngarm, A. and Preparation, A.S. (2011). Effect of replacement of unripe banana flour for rice flour on physical properties and resistant starch content of rice noodle. International Journal of Nutrition and Food Engineering. 5(9): 608-611.

[26] AACC. (2000). Official methods of the American Association of Cereal Chemists. St. Paul, MN, USA: AACC.

[27] Yildiz, Ö., Yurt, B., Baştürk, A., Toker, Ö.S., Yilmaz, M.T., Karaman, S. and Dağlioğlu,

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O. (2013). Pasting properties, texture profile and stress–relaxation behavior of wheat starch/dietary fiber systems. Food Research International. 53: 278-290.

[28] Sharma, B., Gujral, H.S., Solah, V. (2017). Effect of incorporating finger millet in wheat flour on mixolab behavior, chapatti quality and starch digestibility. Food Chemistry. 231: 156-164.

[29] Goñi, I., Garcia-Alonso, A., Saura-Calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. Nutrition Research. 17: 427–437.

[30] Menezes, E.W., Tadini, C.C., Tribess, T.B., Zuleta, A., Binaghi, J., Pak, N., Vera, G., Dan, M.C.T., Bertolini, A.C. and Cordenunsi, B.R. (2011). Chemical composition and nutritional value of unripe banana flour (*Musa acuminata*, var. Nanicão). Plant Foods for Human Nutrition. 66: 231-237.

[31] Campuzano, A., Rosell, C.M. and Cornejo, F. (2018). Physicochemical and nutritional characteristics of banana flour during ripening. Food Chemistry. 256: 11-17.

[32] Savlak, N., Türker, B. and Yeşilkanat, N. (2016). Effects of particle size distribution on some physical, chemical and functional properties of unripe banana flour. Food Chemistry. 213: 180-186.

[33] Selani, M.M, Bianchini, A., Ratnayake, W.S., Flores, R.A., Massarioli, A.P. and de Alencar, S.M. (2016). Physicochemical, functional and antioxidant properties of tropical fruits co-products. Plant Foods for Human Nutrition. 71(2): 137-144.

[34] Khoozani, A.A., Birch, J. and Bekhit, A.E.D.A. (2019). Production, application and health effects of banana pulp and peel flour in the food industry. Journal of Food Science and Technology. 56(2): 548-559.

[35] Ahmed, J., Al-Jassar, S. and Thomas, L. (2015). A comparison in rheological, thermal, and structural properties between Indian Basmati and Egyptian Giza rice flour dispersions as influenced by particle size. Food Hydrocolloids. 48: 72-83.

[36] Mohamed, A., Xu, J. and Singh, M. (2010). Yeast leavened banana-bread: Formulation, processing, colour and texture analysis. Food Chemistry. 118: 620-626.

[37] Ahmed, J., Taher, A., Mulla, M.Z., Al-Hazza, A. and Luciano, G. (2016). Effect of sieve particle size on functional, thermal, rheological and pasting properties of Indian and Turkish lentil flour. Journal of Food Engineering. 186: 34-41.

[38] Zhou, Y.J., Li, M.Q. and Li, C.R. (2015). Effects on noodle quality by the SDF or IDF of wheat bran and SEM graphs. Food and Fermentation Industries. 41: 128-133.

[39] Fan, L., Ma, S. and Wang, X.X. (2016). Improvement of Chinese noodle quality by supplementation with arabinoxylans from wheat bran. International Journal of Food Science and Technology. 51: 602-608.

[40] Fochia, M., Peressini, D. and Sensidoni, A. (2015). How combinations of dietary

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fibres can affect physicochemical characteristics of pasta. LWT - Food Science and Technology. 32: 1-6.

[41] Cadden, M.A. (2006). Comparative effects of particle size reduction on physical structure and water binding properties of several plant fibers. Journal of Food Science. 52(6): 1595-1599.

[42] Juarez-Garcia, E., Agama-Acevedo, E., Sáyago-Ayerdi, S.G., Rodríguez-Ambriz, S.L. and Bello-Pérez, L.A. (2006). Composition, digestibility and application in breadmaking of banana flour. Plant Foods for Human Nutrition. 61: 131-137.

[43] Sayago-Ayerdi, S.G., Tovar, J., Benitez, F.J.B. and Bello-Perez, L.A. (2011). Resistant starch in common starchy foods as an alternative to increase dietary fibre intake. Journal of Food and Nutrition Research. 50(1): 1-12.

[44] Magallanes-Cruz, P.A., Flores-Silva, P.C. and Bello-Perez, L.A. (2017). Starch structure influences its digestibility: A review. Journal of Food Science. 82: 2016-2023.

[45] Agama-Acevedo, E., Islas-Hernández, J.J., Pacheco-Vargas, G., Osorio-Díaz, P. and Bello-Pérez, L.A. (2012). Starch digestibility and glycemic index of cookies partially substituted with unripe banana flour. LWT - Food Science and Technology. 46: 177-182.

[46] de la Rosa-Millan, J., Agama-Acevedo, E., Osorio-Díaz, P. and Bello-Perez, L.A. (2014). Effect of cooking, annealing and storage on starch digestibility and physicochemical characteristics of unripe banana flour Revista Mexicana de Ingenierıa Quımica. 13(1): 151-163.

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