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Effect of Replacement of Unripe Banana Flour for Rice Flour on Physical Properties and Resistant Starch Content of Rice Noodle

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Abstract**—**This work was conducted to improve the level of resistant starch (RS) in a rice noodle using unripe banana flour and to investigate the effect of substitution of unripe banana flour for rice flour on the physical properties of rice noodle. In order to prepare rice noodles, the unripe banana flour were replaced the rice flour with different degrees of substitutions including 0, 20, 40, 60, 80, and 100%. The results indicated that substitution of unripe banana flour was significantly affected the viscosity properties of noodle flour, color, cooking loss, RS and total starch content of noodle. It was found that the noodle prepared from 100% unripe banana indicated the greatest changes on the viscosity properties and color profiles. It also showed the highest values of cooking loss (2.53%), tensile strength (129.03%), and RS content (13.15%).

Keywords**—**Banana flour, Rice noodle, Resistant starch, Unripe banana flour

I. Introduction

RICE noodle is one of the most popular foods in Asian countries and widely consumed in Southeast Asia [1]. According to the study of Zhang et. al. [2] and Surojanametakul et. al. [3], the major chemical compositions of rice noodle was carbohydrate (91.72%) and the remaining compositions were protein, fat, and ash with the amount of 7.20%, 0.84%, 0.24%, respectively. Currently, consumers are interested in functional foods produced from natural materials and foods lowering in glycemic index. There are several means to produce low glycemic foods. Production of foods containing high level of RS is one of the methods to lower the glycemic index. RS, by definition, is a fraction of the starch that is not broken down by enzymes in the small intestine of human. It is then enters the large intestine where it is partially or wholly fermented by microorganism. RS is generally considered to be one of the components that make up total dietary fiber (TDF). In this study, rice noodle was chosen, to produce a functional rice noodle by improving the RS content using unripe banana flour as a source of RS.

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Sajilata et al. [4] reported that banana flour produced from green banana contained mainly starch, which approximately 53.30% was RS. The study of reference [5] on the replacement of unripe banana flour for wheat flour in pasta indicated that RS content of pasta was significant improved. However, the replacement of unripe banana flour for rice flour may influence the physical properties of noodle apart from increasing the RS content.Therefore, this study was conducted to investigate the effect of substitution of unripe banana flour for rice flour on physical and physicochemical properties and resistant content of both noodle flour and rice noodle.

II. Materials and Methods

A. Sample Preparation

1. Unripe Banana Flour Preparation

Green banana fruits [*Musa sapientum* Linn., ABB group, Kluai Namwa], at first stage of maturation (approximately 110-120 days after bloom) were purchased from the Mahasarakham Agriculture and Technology College, Mahasarakham, Thailand. Fruits were peeled and cut into 0.2 cm slices and immediately rinsed in citric acid solution (0.3% w/v). The slices were dried at 50°C in a hot air oven to obtain moisture content below 10% and then ground and sifted through 100-mesh screen and stored at 25 °C in sealed plastic containers until use [4].

2. Rice Flour Preparation

Broken rice (*Oryza sativa* cultiva Leuang 11) was purchased from Kalasin province, Thailand. The broken rice was cleaned and washed before soaked in water for 3 hour with (rice to water ratio: 1:1). The soaked rice was ground using the wet milling process. The starch slurry was filter pressed and dried by hot air at 50°C for 15 hours. The milled flour was ground and sifted through 100-mesh screen before stored at 4°C in sealed plastic containers until use [6].

3. Rice Noodle Preparation

The noodle preparation was done by following the method reported by [6] with some modifications. The mixture contents of rice noodle and the degree of substitution were indicated in Table 1. Rice flour was mixed with water, placed in trays (20x30 cm) and steam for 5 min. The cooked rice sheet was taken out and cooled down to room temperature before cut into size 2.5x30 cm strips. The fresh rice noodle was obtained and then divided into two parts. The first portion was applied for the measurement of a cooking loss, pasting properties, color, and tensile strength.The second part was dried, ground, stored at 4°C, and used for chemical analyses which all aspects were expressed as dry weight basis.

TABLE I
MIXTURE CONTENTS OF RICE NOODLE SUBSTITUTED WITH DIFFERENT LEVELS OF UNRIPE BANANA FLOUR

Mixture	Substitution Content (% of Banana Flour)					
	0% (Control)	20%	40%	60%	80%	100%
Rice Flour	28.06	22.45	16.84	11.23	5.61	0.00
Banana Flour	0.00	5.61	11.23	16.84	22.45	28.06
Tapioca Flour	7.42	7.42	7.42	7.42	7.42	7.42
Water	64.08	64.08	64.08	64.08	64.08	64.08
Vegetable Oil	0.44	0.44	0.44	0.44	0.44	0.44
Total	100	100	100	100	100	100

B. Cooking Loss Measurement

The noodle (5 g) was boiled in 130 ml distilled water for 4 min. Cooked samples were washed with 20 ml distilled water then drained for 5 min the cooking water was evaporated and dried at 105 °C to a constant weight. Cooking loss calculated by using (1) [7].

$$\text{cooking loss} = \frac{(\text{weight of dry matter})}{(\text{weight of dried noodle})} \times 100$$

C. Pasting Properties Measurement

The pasting properties were determined using a Rapid Visco Analyzer (RVA, 4D, Newport Scientific, Australia) [8].

D. Color Measurement

The color of rice noodle was measured by a Chromameter (Minolta CR-300, Japan). The color was defined numerically in terms of lightness or L* value, (0=black, 100=white), a* value (greenness 0 to –100, redness 0 to +100) and b* value (blueness 0 to -100, yellowness 0 to +100).

E. Texture Analysis

The tensile strength analysis was measured using a texture analyser (TA-XT2i, Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) equipped with spaghetti / noodle tensile grips (A/SPR). The noodle strand was winded two, three or four times around parallel friction roller of the grip to anchor the samples and avoid slippage. The distance between the parallel rollers was 40mm. The mode was measure force in tension. Pre-test and test speeds were 3.0 mm/s, post-test speed was 3.0 mm/s. Distance was 100mm. The trigger type was auto with a trigger force of 5 g. The data acquisition rate was 200 pps. The maximum force required to break down the strand was termed tensile force (g) [9].

F. Resistant Starch Determination

Resistant starch (RS) was measures by the method of Megazyme International Ireland.

G. Digestible Starch Determination

Digestible starch (DS) was measures using the method of Megazyme International Ireland.

H. Total Starch Determination

Total starch (TS) was determined by the method of Megazyme International Ireland.

I. Statistical Analysis

Values were obtained as the means ± standard deviation of three determinations. Data was analyzed by analysis of variance (ANOVA) and Duncan's multiple-range test or *t*-test. Differences among samples were considered significant at $p \leq 0.05$.

III. RESULTS AND DISCUSSION

A. Pasting Properties

The pasting properties of flour samples and noodle flour mixtures with different degree of substitutions, namely, peak viscosity, trough, breakdown, final viscosities, setback, pasting time, as well as the pasting temperature are shown in Table II and Table III. In Table II, the highest value of pasting properties was found in rice flour (0% unripe banana flour), while the lowest was found in unripe banana flour. Similarly, the pasting properties of noodle flour mixture, prepared from 100% rice flour, were highest in peak viscosity, trough, final viscosity, setback and pasting time (340.17, 223.67, 363.78, 139.11 RVU, and 5.54 min, respectively), while the noodle flour containing 100% of unripe banana flour showed the lowest values of pasting properties (257.70, 182.14, 267.94, 85.80 RVU, and 4.93 min, respectively). The values of pasting properties were gradually decline with higher levels of substitution with unripe banana flour.

TABLE II
COMPARISON OF PASTING VISCOSITY OF DIFFERENT FLOURS USED TO PREPARED RICE NOODLE

Pasting Viscosity (RVU)	Starch		
	Rice Flour	Banana Flour	Tapioca Flour
Peak Viscosity	350.50±14.60[a]	236.92±24.79[b]	352.50±4.15[a]
Trough	243.36±10.40[a]	174.17±24.56[b]	152.86±3.46[b]
Breakdown	123.80±49.67[b]	62.75±1.52[c]	199.64±3.16[a]
Final Viscosity	422.75±3.48[a]	251.92±21.58[b]	230.00±2.53[b]
Setback	179.39±11.63[a]	77.75±4.13[b]	77.14±4.18[b]
Peak Time (min)	6.09±0.16[a]	4.96±0.08[b]	3.65±0.04[c]
Pasting Temperature (°C)	80.22±0.43[a]	75.90±0.85[b]	67.80±0.05[c]

[a], [b], [c]… Means within columns followed by the same letter are not significant different at $p > 0.05$

TABLE III
PASTING VISCOSITY OF NOODLE FLOURS OBTAINED FROM UNRIPE BANANA FLOUR SUBSTITUTED FOR RICE FLOUR AT DIFFERENT LEVELS

Pasting Viscosity (RVU)	Substitution (% of Banana Flour)					
	0	20	40	60	80	100
Peak Viscosity	340.17±13.99[a]	320.17±1.20[ab]	308.47±13.43[ab]	314.83±10.07[ab]	293.17±25.04[b]	257.70±31.01[c]
Trough	223.67±7.53[a]	202.83±3.55[b]	188.91±2.50[ab]	189.33±6.43[ab]	184.28±12.47[ab]	182.14±18.11[c]
Breakdown	116.50±18.90[a]	117.33±4.53[a]	119.56±11.01[a]	125.50±3.85[a]	108.89±12.58[a]	75.56±12.97[b]
Final Viscosity	363.78±2.8[a]	330.19±1.88[b]	307.53±8.46[bc]	303.61±9.31[bc]	288.58±21.08[cd]	267.94±27.27[d]
Setback	139.11±5.27[a]	127.36±3.59[b]	118.61±6.02[bc]	114.28±2.88[cd]	104.30±8.86[d]	85.80±9.65[e]
Peak Time (min)	5.54±0.12[a]	5.31±0.08[b]	5.05±0.04[c]	4.87±0.00[de]	4.78±0.04[e]	4.93±0.07[cd]
Pasting Temperature (°C)[ns]	69.42±11.17	73.45±0.00	74.15±1.57	73.72±0.46	73.48±0.08	75.10±0.80

[ns] = Not significant (p>0.05; [a], [b], [c]… Means within columns followed by the same letter are not significant different at $p > 0.05$

B. Color

The color of rice noodle are shown in Table IV. The levels of banana flour replacement was significantly increased the a* and b* values of rice noodles and significantly reduced L* values (p≤0.05). The highest of L* values was found in rice noodle prepared from 0% of banana flour or 100% of rice flour and gradually decreased in noodle replaced with 20%, 40%, 60%, 80% and 100% of banana flour. The a* value was highest in 100% of banana flour with the value of 12.84 and the highest b* value was found in 60% of banana flour (12.56). These results obtained were similar to that reported by [10]. The dark color of banana flour was caused by phenolic compounds. When the banana pulb is exposed to air, the polyphenol oxidases (PPO) enzymes such cresolase, catechlase, and o-diphenol oxidases will react with phenolic compounds and yield a dark color.

TABLE IV
COLOR PARAMETERS OF RICE NOODLE SUBSTITUTED WITH DIFFERENT LEVELS OF UNRIPE BANANA FLOUR

Substitution Content (% of Banana Flour)	Color		
	L*	a*	b*
0	78.78±1.47[a]	2.88±0.32[d]	1.75±0.66[e]
20	67.73±1.40[b]	6.85±0.42[c]	7.71±0.48[d]
40	61.72±1.78[c]	10.08±1.09[b]	10.38±0.33[b]
60	58.52±0.76[d]	10.11±1.29[b]	12.56±0.15[a]
80	55.28±0.67[e]	9.62±1.34[b]	10.56±0.25[b]
100	47.82±1.59[f]	12.84±1.55[a]	9.77±1.15[c]

[a], [b], [c]… Means within columns followed by the same letter are not significant different at $p > 0.05$

C. Tensile Strength

Tensile strength increased when banana flour content increased. The tensile strength of rice noodle (0% of banana flour) was lowest (88.96 g) whilst the noodle contained 100% of unripe banana flour showed significantly highest value (129.03 g) (p≤0.05) (as shown in Table V.)

D. Cooking Loss

The cooking loss increased when banana flour content increased (Table V). The rice noodle with 0% of banana flour had lowest cooking loss (1.00%), while the highest value was found in rice noodle contained 100% of unripe banana (2.53%). These results were similar to the previous study by reference [4], who found that cooking loss values of spaghetti samples added with banana flour were higher than those of wheat spaghetti.

TABLE V
TENSILE STRENGTH AND COOKING LOSS OF RICE NOODLE SUBSTITUTED WITH DIFFERENT LEVELS OF UNRIPE BANANA FLOUR

Substitution Content (% of Banana Flour)	Tensile Strength (g)	Cooking Loss (%)
0	88.96±4.30[c]	1.00±0.23[c]
20	99.27±17.98[bc]	1.55±0.05[bc]
40	118.89±33.56[ab]	1.79±0.24[b]
60	125.78±11.33[a]	2.03±0.43[ab]
80	129.03±34.49[a]	2.10±0.37[ab]
100	129.03±34.49[a]	2.53±0.38[a]

[a], [b], [c]… Means within columns followed by the same letter are not significant different at $p > 0.05$

E. Resistant Starch, Digestible Starch and Total Starch Content of Noodle Flour

The raw flours for rice noodle preparation had significantly different levels of resistant starch (RS), digestible starch, and total starch (Table VI). The highest content of resistant starch was observed in banana flour (42.82%), followed by that of tapioca flour and rice flour (12.44% and 1.85%, respectively). In this study, it can be seen that unripe banana flour is the natural product with highest RS content [4]. The highest level of digestible starch and total starch was found tapioca flour 78.02% and 90.46% (p≤0.05).

TABLE VI
RESISTANT STARCH, DIGESTIBLE STARCH, AND TOTAL STARCH CONTENT OF DIFFERENT FLOURS USED IN NOODLE PREPARATION

Type	RS (%)	DS (%)	TS (%)
Rice Flour	1.85±0.01[c]	69.70±3.66[b]	71.56±3.65[b]
Banana Flour	42.82±0.63[a]	30.01±0.16[c]	72.82±0.56[b]
Tapioca Flour	12.44±0.25[b]	78.02±2.74[a]	90.46±2.94[a]

[a], [b], [c]… Means within columns followed by the same letter are not significant different at $p > 0.05$

F. Resistant Starch, Digestible Starch and Total Starch Content of Rice Noodle

An increase in RS content was observed in rice noodle that substituted with unripe banana flour (Table VII). The control (0% of unripe banana flour) indicated lowest amount of RS (7.94%), whilst the rice noodle containing 100% of unripe banana flour had significantly highest content of RS (13.15%) ($p \leq 0.05$). This is related to the high RS content of banana flour, similar to that studied by references [4], [11]. The RS values of the noodle samples added with unripe banana flour (3-4.60%) were higher than those found in noodle without unripe banana flour added [12]. It was also found that the digestible starch (DS) content in rice noodle decreased with degree of substitution of unripe banana flour for rice flour, but there was no significant difference ranged between 63.52% and 66.86%. Ovando-Martinez et. al. (2009) [4] reported that DS values of the spaghetti sample with banana flour added were lower than those reported in spaghetti without banana flour (67.36-69.70%). An increase in total starch (TS) content was obtained in rice noodle with substitution of unripe banana flour. The noodle contained 0% of unripe banana flour had lowest amount of TS (74.80%), while the rice noodle contained 80% and 100% of unripe banana flour had highest values of TS (76.67%). These results were comparable to that reported by reference [4].

TABLE VII
RESISTANT STARCH, DIGESTIBLE STARCH, AND TOTAL STARCH CONTENT OF RICE NOODLE

Substitution Content (% of Banana Flour)	RS (%)	DS (%)[ns]	TS (%)[ns]
0%	7.94±0.12[e]	66.86±1.66	74.80±1.54
20%	8.91±0.11[d]	66.86±0.94	75.76±1.00
40%	9.97±0.16[c]	65.83±1.54	75.79±1.38
60%	12.71±0.11[b]	63.68±0.52	76.39±0.63
80%	13.14±0.07[a]	63.54±0.86	76.67±0.90
100%	13.15±0.25[a]	63.52±3.33	76.67±3.21

[ns] = Not significant ($p>0.05$; [a], [b], [c]… Means within columns followed by the same letter are not significant different at $p > 0.05$

IV. CONCLUSIONS

The replacement of unripe banana flour for rice flour significantly affected the physical properties and RS content of rice noodle. The increasing of degrees of substitution by unripe banana flour reduced the viscosity properties of noodle flour but enhanced the cooking loss, tensile strength, and color intensity of the noodle. The replacement of unripe banana flour for rice flour could be applied to improve the RS content of rice noodle, the higher the degree of substitution, the higher the level of RS content. However, when the degree of replacement of unripe banana flour was greater than 80%, it adversely affected the cooking loss, tensile strength, and the whiteness of noodle. Therefore, the optimization of several factors affecting the overall quality of rice noodle, incorporated with unripe banana, is important to obtain the best possible cooking and eating quality of rice noodle, as well as to achieve health benefits of the high RS rice noodle.

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