Effect of red Jasmine rice replacement on rice flour properties and noodle qualities

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Abstract This study aimed to assess flour and noodle qualities after substituting Phitsanulok rice flour (PH) with red Jasmine rice flour (RJ). Blended rice flours were prepared by replacing PH with RJ at various ratios [100:00 (0RJ), 75:25 (25RJ), 50:50 (50RJ), 25:75 (75RJ), and 00:100 (100RJ)]. Some quality improvements were observed in the blended rice flour in terms of chemical and pasting properties at the replacement ratio of 75:25 ($p < 0.05$). At the same ratio, total phenolic contents, antioxidance activities, and some textural and sensory properties of noodle were developed ($p < 0.05$). However, increasing values of some undesirable properties including cooking loss and rehydration were also observed ($p < 0.05$). The noodle made from 100RJ showed the highest level of acceptability but not significantly different compared with others ($p > 0.05$). Thus, RJ could be used to improve the nutritional value of rice flour, and it could be used for development of health benefits in rice noodle.

Keywords Amylose · Red Jasmine · Rice flours · Replacement · Noodle

Introduction

Rice is commonly used as a raw material in food industry, famously for rice noodle manufacturing, which is widely consumed throughout Southeast Asian countries (Cham and Suwannaporn, 2010). Traditionally, high amylose ($> 25\%$) white rice varieties (e.g., Suphanburi90, Suphanburi1, Phitsanulok) are used for preparing rice noodle because it contains the desirable qualities needed (Luo et al., 2015). Phitsanulok white rice flour has amylose content in the range of 28.6–36.7%, and it is widely used for forming rice noodle due to providing the acceptable texture, and sensory properties (Chungcharoen et al., 2015). According to Boers et al. (2015) amylose provides stability to rice flour gel, and it also gives chewiness and elasticity to rice noodle texture because of its low swelling capacity. Unfortunately, there are also some detrimental consequences to white rice consumption. It is understood to raise blood glucose levels (glycemic index; GI) that can contribute to the development of chronic metabolic diseases (Sumczynski et al., 2016).

Lately, preferences for functional and nutraceutical foods have been growing due to consumer health concerns. Consequently, food product manufacturers have been moving towards colored/pigmented rice that contains higher bioactive compounds and nutrients than white rice (Muntana and Prasong, 2010). Additionally, the compounds in pigmented rice such as red, black, and brown have been reported to prevent/delay the prevalences of Alzheimers, cardiovascular diseases, and colon cancer (Hu et al., 2017). It is reported that pigmented rice retards free radical reactions that can damage biological molecules in the human body (e.g., lipids, proteins, DNA) and cause oxidative stress (Wichamanee and Teerarat, 2012). Pereira-Caro et al. (2013) also described that biochemical

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compounds in colored rice including brown rice such as tocopherols, tocotrienols, γ -oryzanols, and polyphenolic compounds can improve immune system and mRNA generating in rats. Likewise, diabetes and obesity could be delayed by consuming colored rice thanks to reduced GI, decelerating rate of glucose molecules released into blood stream (Boers et al., 2015).

Red Jasmine rice is a famous pigmented rice variety in Thailand due to its unique fragrant smell. Rice flour is applied for manufacturing several foods and desserts such as puddings, cakes, and noodles. In Thailand, red rice has been applied for its clear health benefits. However, pigmented rice generally has low amylose content (< 20%), giving low cooking and texture qualities, resulting in lower consumer acceptance (Wang et al., 2016). Thus, this study aims to assess noodle qualities when substituting Phitsanulok rice flour (high amylose) with red Jasmine rice flour.

Materials and methods

Raw materials and rice flour preparation

In this study, two varieties of Thai rice (*Oryza sativa* cv.) which are Phitsanulok; white rice (PH) and Hom Mali Dang or known as red Jasmine rice (RJ) were used. PH rice grains were provided by Urmatt Ltd. (Chiang Rai, Thailand). RJ grains were purchased from Siam Organic Food Products Co., Ltd. (Bangkok, Thailand). Rice flour was prepared by grinding the two rice grain into powder with a hammermill (CMC-20, CMC Biotech Co., Ltd., Bangkok, Thailand) and then passed through a 60 mesh sieve (250 μ m).

Blended rice flour preparation, PH was substituted with RJ at the ratios of 100:00 (0RJ), 75:25 (25RJ), 50:50 (50RJ), 25:75 (75RJ), and 00:100 (100RJ).

Proximate analysis of blended rice flour

The contents of moisture, ash, crude protein ($N \times 5.95$), crude fat, and crude fiber were determined based on AOAC (2000); method 934.01, 945.46, 992.15 (39.1.16), 954.02, and 978.10, respectively. Carbohydrate content was calculated by subtracting the total percentage of the other components from one hundred.

Amylose content of blended rice flour

Amylose content was measured by using a colorimetry method (Juliano, 1971). The blended rice flours (100 mg) were added with 95% ethanol (1 mL) and 2 M NaOH (9 mL). The mixtures were added with 0.2% iodine solution (2 mL) and adjusted to 100 mL with distilled water.

The absorbances of the solutions were measured at 620 nm (Genesy 10S UV-Vis spectrophotometer, Thermo Fisher Scientific, Massachusetts, USA). The amylose content was estimated by referring to a calibration standard curve that was prepared by amylose from potato (CAS: 9005-82-7, Merck, Darmstadt, Germany).

Total dietary fiber (TDF) content of blended rice flour

TDF was assessed by using a TDF assay kit (K-TDFR-100A, Megazyme International Ireland, Wicklow, Ireland) based on AACC (2000) method 32-05.01 and AOAC (2000) method 985.29. In brief, blended rice flours were gelatinized (at 100 °C for 30 min) with a heat-stable α -amylase (CAS:9000-90-2/9000-85-5, EC 3.2.1.1, Megazyme International Ireland, Wicklow, Ireland) at a pH of 6. Then, the solutions were digested sequentially with protease (CAS:9014-01-1, EC 3.4.21.62, Megazyme International Ireland, Wicklow, Ireland) at pH 7.5 (at 60 °C for 30 min) and amyloglucosidase (CAS:9032-08-0, EC 3.2.1.3, Megazyme International Ireland, Wicklow, Ireland) at pH 4.5 (at 60 °C for 30 min), removing protein and starch. TDF was precipitated with 95% ethanol. The samples were dried at 105 °C overnight. TDF was computed using the following equation:

$$\text{TDF (\%)} = \frac{[(R_{\text{sample}} - P_{\text{sample}} - A_{\text{sample}}) - B] / \text{SW}}{\times 100} \quad (1)$$

where $B = R_{\text{blank}} - P_{\text{blank}} - A_{\text{blank}}$, R = average residue weight (mg), P = average protein weight (mg), A = average ash weight (mg), SW = average sample weight (mg).

Pasting properties of blended rice flour

A rapid visco analyzer (RVA 4500, Perten Instruments, Hägersten, Sweden) was used for determining pasting properties. The blended rice flours (3 g, 14% moisture basis) were placed in a canister and added with distilled water (approximately 25 mL, 14% moisture basis). The suspensions were held at temperature of 50 °C for 1 min and then raised up to 95 °C over 3.8 min and held for 2.5 min. Subsequently, they were cooled to 50 °C within 3.8 min and held for 1.4 min.

Rice noodle preparation

Rice noodles were prepared based on method of Wandee et al. (2015). Blended rice flours (40 g, dry weight basis) were mixed with distilled water (60 g), and the resulting slurry was spread on stainless trays at a thickness of 1 mm.

It was then steamed for 3 min. Subsequently, rice noodle sheets were peeled off and dried at 70 °C for 10 min. They were kept at room temperature for 3 h (covered with cheesecloth) and cut into strands 3 mm wide. Noodle strands were further dried at 40 °C for 4 h, decreased moisture content to 10–12%, (Thai industrial standards institute; TISI).

Color contributes of rice noodle

Rice noodle color was determined by using a colorimeter (Miniscan EZ, HunterLab, Virginia, USA). Color parameters were L^* ($L^* = 0$, black and $L^* = 100$, white), a^* ($-a^* = \text{greenness}$ and $+a^* = \text{redness}$), and b^* ($-b^* = \text{blueness}$ and $+b^* = \text{yellowness}$). The colorimeter was calibrated with a white calibration tile.

Total phenolic contents (TPC) and antioxidant activities of rice noodle

The noodles were extracted according to the method of Abdel-Aal et al. (2006). The ground noodles (1.0 g) were mixed with 85% methanol (10 mL) and stirred with a magnetic stirrer at room temperature for 30 min. The mixtures were centrifuged (AVANTI J-30I, Beckman, Krefeld, Germany) at 2500 g for 10 min. Supernatants were collected and kept in the dark at 4 °C for further analysis.

TPC contents were determined based on method of Chan et al. (2012). The extracted solutions (0.1 mL) were mixed with 0.5 mL of 10% (v/v) Folin-Ciocalteu reagent and 0.4 mL of 7.5% (w/v) sodium bicarbonate solution. The mixtures were left in the dark, at room temperature for 1 h. The reaction mixtures (200 μL) were placed into a 96-well plate. The absorbances of the solutions were measured at 765 nm with a microplate reader (Multiskan Go, Thermo Scientific, Vantaa, Finland). Gallic acid was used as a standard. The TPC was expressed in milligrams gallic acid equivalents (mg GAE/g dry weight basis (DW) sample).

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activity was estimated based on Chan et al. (2012). The extracted solutions (50 μL) were added with 1950 μL of DPPH methanolic solution (0.1 mM), and then let sit in the dark for 1 h at room temperature. The absorbances of the solutions were measured at 540 nm with a microplate reader. Trolox (TE) was used as a standard. The results were expressed as μg TE equivalent/g DW sample.

The 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) or ABTS radical scavenging activity was determined by using the method of Chatatikun and Chiabchalard (2013). The extracted solutions (50 μL) were mixed with

ABTS working solution (950 μL) and allowed to stand in the dark for 6 min, at room temperature. The absorbance of the solutions was measured at 734 nm by using a microplate reader. The results were expressed as μg TE equivalent/g DW sample:

$$\text{Scavenging activity (\%)} = 100 \times \left[\frac{\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}}}{\text{Abs}_{\text{control}}} \right] \quad (2)$$

Ferric reducing antioxidant power (FRAP) was measured based on Corral-Aguayo et al. (2008). The extracted solutions (20 μL) were mixed with a FRAP reagent (180 μL) and incubated at 37 °C for 30 min in the dark. The absorbances of the solutions were measured at 630 nm with a microplate reader. Ferrous sulfate was used as a standard, and the results were expressed as ferrous equivalent (Fe(II)) in $\mu\text{M}/100$ g DW sample.

Optimal cooking time of rice noodle

Rice noodle cooking time was executed according to the method reported in Wu et al. (2015). The noodle strands (5 g) were cut into strands 6 cm in length and then cooked with boiling distilled water (200 mL). The optimal cooking time was set when the noodle core was no longer visible. To observe the noodle core, one rice noodle strand was squeezed between two glass plates every 30 s.

Cooking loss and percent rehydration of rice noodle

Cooking loss and rehydration were determined under the same conditions as cooking time described above. The cooked rice noodles were rinsed with distilled water (50 mL). The cooking and rinsing waters were collected and dried at 105 °C until constant weights were achieved. The cooking loss was calculated by using the following equation:

$$\begin{aligned} \text{Cooking loss (\%)} &= \frac{\text{Weight of dry matter in cooking water (g)}}{\text{Weight of dry noodles (g)}} \times 100 \end{aligned} \quad (3)$$

The cooked noodles were taken out and the excess water was removed from their surfaces by using paper towel. The percentage of rehydration was estimated by using the following equation:

$$\begin{aligned} \text{Rehydration (\%)} &= \left[\frac{(\text{Weight of cooked noodles (g)} - \text{weight of uncooked noodles (g)})}{\text{Weight of uncooked noodles (g)}} \right] \times 100 \end{aligned} \quad (4)$$

Texture properties of rice noodle

The properties were measured with a texture analyzer (model TA. XT. Plus, Stable MicroSystems Ltd., Godalming, England) based on Ye and Sui (2016). The rice noodle strands were cooked for the optimal cooking duration. The cooked noodle strands were compressed with a hemispherical probe (P/0.5HS) at a test speed of 2.0 mm/s with 30% strain, to obtain hardness (g), adhesiveness (g sec), cohesiveness, springiness, and chewiness (g mm). Tensile strength (g) and extensibility (mm) were examined with a pair of spaghetti/noodle tensile grips at a cross head velocity of 3.0 mm/s.

Sensory evaluation of rice noodle

The assessment was performed according to the method of Purwandari et al. (2014). The samples were cooked for the optimal cooking times and then served with chicken soup (1:2 g/g) for 30 untrained panelists. The sensory evaluation was carried out by using a 9-point hedonic scale (9 = extremely like and 1 = extremely dislike).

Statistical analysis

An analysis of variance (ANOVA) was completed. The mean comparison was performed by Duncan's Multiple Range Tests (DMRT). The significance of difference was defined at $p < 0.05$. The analysis was performed by using an SPSS package (SPSS 17.0 for window, SPSS Inc, Chicago, 180 IL).

Results and discussion

Proximate composition of blended rice flour

The ash, fat and protein contents in RJ were higher than that of PH ($p < 0.05$), thanks to containing higher outer layer of RJ where those particular contents are mostly located (Wichamanee and Teerarat, 2012). Consequently, increasing of ash ($\approx 66\%$), fat ($\approx 37\%$), and protein contents (about 8%) (Table 1) were initially observed when PH was replaced with RJ at the ratio of 75:25 ($p < 0.05$). Accordingly, replacing RJ with PH could improve the blended rice flour nutritional value. At the same ratio, decreased carbohydrate content (almost 2%) was also found ($p < 0.05$). Lower carbohydrate content for RJ (73.84%) could be the cause of this phenomenon.

Table 1 Chemical properties of the blended rice flours and the blended rice noodle

Chemical properties	Blended rice flour				
	0RJ	25RJ	50RJ	75RJ	100RJ
Proximate composition					
Moisture (%)	11.63 $\pm$ 0.08	11.39 $\pm$ 0.08	11.12 $\pm$ 0.38	10.22 $\pm$ 1.01	10.13 $\pm$ 1.13
Ash (%)	0.26 $\pm$ 0.09 ^c	0.77 $\pm$ 0.03 ^{bc}	0.72 $\pm$ 0.01 ^{bc}	1.12 $\pm$ 0.31 ^b	1.70 $\pm$ 0.29 ^a
Crude fat (%)	0.72 $\pm$ 0.43 ^c	1.15 $\pm$ 0.21 ^b	2.19 $\pm$ 1.14 ^{ab}	2.74 $\pm$ 0.56 ^{ab}	3.83 $\pm$ 0.40 ^a
Crude fiber (%)	1.62 $\pm$ 0.05	1.75 $\pm$ 0.23	1.72 $\pm$ 0.68	1.80 $\pm$ 0.22	2.17 $\pm$ 0.45
Crude protein (%)	6.96 $\pm$ 0.02 ^b	7.60 $\pm$ 0.01 ^a	7.65 $\pm$ 0.03 ^a	7.60 $\pm$ 0.02 ^a	7.69 $\pm$ 0.18 ^a
Carbohydrate (%)	78.23 $\pm$ 0.39 ^a	76.70 $\pm$ 0.04 ^{ab}	75.96 $\pm$ 0.80 ^{ab}	75.88 $\pm$ 1.46 ^{ab}	73.84 $\pm$ 1.87 ^b
Amylose (%)	30.05 $\pm$ 0.35 ^a	27.18 $\pm$ 0.88 ^b	22.05 $\pm$ 1.41 ^c	20.93 $\pm$ 1.59 ^c	17.93 $\pm$ 0.88 ^d
Total dietary fiber (%)	2.42 $\pm$ 0.37 ^c	3.64 $\pm$ 0.09 ^d	4.81 $\pm$ 0.06 ^c	5.39 $\pm$ 0.06 ^b	6.05 $\pm$ 0.17 ^a
Total phenolic content and antioxidant activities					
The blended rice noodle					
	0RJ	25RJ	50RJ	75RJ	100RJ
TPC (mg GAE/100 g DW sample)	394.88 $\pm$ 5.87 ^e	419.40 $\pm$ 5.91 ^d	451.76 $\pm$ 4.02 ^c	480.98 $\pm$ 3.44 ^b	548.93 $\pm$ 1.50 ^a
DPPH (μ M TE/100 g DW sample)	20.41 $\pm$ 1.53 ^c	38.88 $\pm$ 2.69 ^d	45.52 $\pm$ 1.62 ^c	152.63 $\pm$ 2.18 ^b	189.15 $\pm$ 1.39 ^a
FRAP (μ M Fe(II)/100 g DW sample)	1.20 $\pm$ 0.03 ^d	1.33 $\pm$ 0.11 ^{cd}	1.77 $\pm$ 0.08 ^c	2.15 $\pm$ 0.19 ^b	2.87 $\pm$ 0.04 ^a
ABTS (μ M TE/100 g DW sample)	10.45 $\pm$ 1.80 ^d	17.19 $\pm$ 4.29 ^d	71.48 $\pm$ 4.43 ^c	96.67 $\pm$ 3.13 ^b	121.13 $\pm$ 3.22 ^a

All values are means of triplicates $\pm$ standard deviation

^{a-c}Means with the same superscript letters within a row are not significantly different at $p < 0.05$ level

The ratios of Phitsanulok and red Jasmine rice flours were 100:00 (0RJ), 75:25 (25RJ), 50:50 (50RJ), 25:75 (75RJ), and 00:100 (100RJ)

However, the replacement had no effect on moisture and crude fiber contents because the initial values of these two contents in PH and RJ were not significantly different ($p > 0.05$).

Differences in rice flour chemical composition resulted in varying quality attributes in rice noodles. Ye and Sui (2016) reported that differences in rice noodle qualities, including cooking, texture, and sensory properties, are dependent on various proximate compositions such as protein, lipid, and fiber. Differences in lipid and protein contents also have been reported to have an impact on rice noodle rehydration (Ahmed et al., 2015). Hence, the changes of chemical composition in blended rice flour by RJ replacement might affect the quality attributes of rice noodle.

Amylose content and total dietary fiber of blended rice flour

Low amylose content in RJ (17.93%) brought about an overall sharp decrease of amylose to the blended rice flours ($p < 0.05$). The results showed that substituting PH with RJ in the ratio of 75:25 decreased amylose content from 30.05 to 27.18% (Table 1). Amylose is an important component for providing desirable qualities (firmness and crispness) to noodle texture by three-dimensional network development (Wang et al., 2016). Han et al. (2011) found that noodles made of high amylose rice varieties (Chenmaai and YR24088 Acp9) had desirable cooking and texture properties. Consequently, decreasing amylose content in blended rice flour due to substitution may cause some undesirable texture properties.

Contrariwise, increasing TDF in blended rice flour was found when increased the amount of RJ in blended rice flours ($p < 0.05$). TDF was increased (about 33%) when PH was replaced with RJ at the ratio of 75:25 ($p < 0.05$). This could be because TDF is largely found in the higher outer layer of RJ (Wandee et al., 2015). Increasing TDF

content refers to a greater potential health benefit, such as the preventions of diverticular disease and colorectal cancer as it relieves constipation (Sumczynski et al., 2016). Furthermore, TDF also stimulates growth of health promoting bacterias (e.g. bifidobacteria) in colon, in which the bacterias generate short-chain fatty acids and stimulate immune system (Anderson and Baird, 2009). Consequently, RJ could be used as health promoting material.

Pasting properties of blended rice flour

The significant increases of peak (from 1618 cP to 1789 cP), trough (from 1405 cP to 1565 cP), breakdown (from 198 cP to 527.5 cP), and final viscosities (from 2807 cP to 3288 cP) in blended rice flour were initially observed when PH and RJ were blended at the ratio of 75:25 ($p < 0.05$) (Table 2). Whereas, reducing setback was noticed (from 1557 cP to 1499.5 cP).

Low amylose content in RJ (17.93%) led to increasing peak, trough, and breakdown viscosities ($p < 0.05$). Higher values of those pasting properties contribute to softer texture, because of a good capability of rice starch granules to engage water molecules (Pracham and Thaiudom, 2016). Therefore, RJ could be used for noodle texture quality development as it improves rice flour peak, and breakdown viscosities.

Greater final viscosity refers to better stability of rice flour gel that supported by larger protein content in RJ ($p < 0.05$), improving rice flour gel strength through protein network formation (Wu et al., 2015).

Amylose is the foremost component that supports setback value due to its good ability to induce starch molecule re-arrangement by hydrogen bonding upon cooling (Wandee et al., 2015). Oppositely, low amylose content in RJ is a cause for reducing setback in the blended rice flours ($p < 0.05$) because of decelerating rate of starch molecule re-arrangement (Ye and Sui, 2016). This effect might have

Table 2 Pasting properties of the blended rice flour

Pasting properties	Blended rice flour				
	0RJ	25RJ	50RJ	75RJ	100RJ
Peak viscosity (cP)	1618.0 ± 16.97 ^d	1789.0 ± 14.14 ^b	1725.0 ± 19.79 ^c	1731.50 ± 10.61 ^{bc}	2349.0 ± 15.55 ^a
Trough (cP)	1405.0 ± 7.07 ^c	1565.0 ± 14.14 ^{bc}	1599.0 ± 11.31 ^b	1575.5 ± 16.26 ^{bc}	1673.0 ± 11.31 ^a
Breakdown (cP)	198.0 ± 2.83 ^d	527.5 ± 4.95 ^b	436.00 ± 12.73 ^c	472.5 ± 17.68 ^{bc}	662.0 ± 7.07 ^a
Final viscosity (cP)	2807.0 ± 11.31 ^e	3288.0 ± 18.38 ^b	3055.0 ± 18.38 ^c	3017.5 ± 10.61 ^d	3652.0 ± 7.07 ^a
Setback (cP)	1557.0 ± 18.38 ^a	1499.5 ± 4.95 ^b	1339.5 ± 12.02 ^c	1013.5 ± 17.68 ^d	1004.0 ± 8.49 ^e

All values are means of six replicates ± standard deviation

^{a-e}Means with the same superscript letters within a row are not significantly different at $p < 0.05$ level

The ratios of Phitsanulok and red Jasmine rice flours were 100:00 (0RJ), 75:25 (25RJ), 50:50 (50RJ), 25:75 (75RJ), and 00:100 (100RJ)

Table 3 Color attributes, cooking properties, and sensory scores of the blended rice noodle

Noodle qualities	The blended rice noodle				
	0RJ	25RJ	50RJ	75RJ	100RJ
Color attributes					
L^*	83.38 ± 1.87^a	64.66 ± 0.02^b	60.64 ± 0.18^c	59.75 ± 0.45^c	52.89 ± 0.31^d
a^*	0.61 ± 0.11^d	10.18 ± 0.08^c	11.62 ± 0.08^b	11.97 ± 0.18^b	13.37 ± 0.01^a
b^*	10.47 ± 0.20^c	14.16 ± 0.06^b	15.14 ± 0.11^a	15.28 ± 0.16^a	15.07 ± 0.18^a
Cooking properties					
Cooking time (min)	4.40 ± 0.07^a	4.18 ± 0.04^b	4.19 ± 0.01^b	4.13 ± 0.04^{bc}	4.05 ± 0.01^c
Cooking loss (%)	2.31 ± 0.11^b	3.49 ± 0.09^a	3.88 ± 0.89^a	3.97 ± 0.10^a	3.28 ± 0.07^{ab}
Rehydration (%)	123.36 ± 0.50^c	153.83 ± 0.32^b	159.27 ± 0.90^{ab}	165.19 ± 0.81^a	173.18 ± 0.48^a
Sensory scores					
Color	6.69 ± 1.91	6.40 ± 1.80	5.88 ± 1.78	6.08 ± 1.80	5.80 ± 2.06
Flavor	5.88 ± 1.56	5.80 ± 1.78	5.63 ± 2.08	5.72 ± 2.11	5.96 ± 1.77
Taste	5.46 ± 2.16	5.52 ± 1.64	5.29 ± 2.01	5.68 ± 1.97	5.88 ± 1.83
Softness	4.35 ± 2.12^c	4.72 ± 1.84^{bc}	5.33 ± 1.88^{abc}	5.72 ± 1.99^{ab}	5.96 ± 2.19^a
Stickiness	4.15 ± 1.85^b	4.00 ± 1.71^{ab}	4.67 ± 1.66^{ab}	4.96 ± 1.88^{ab}	5.32 ± 2.44^a
Elasticity	3.69 ± 1.78^c	3.92 ± 1.78^{bc}	4.71 ± 1.99^{abc}	5.08 ± 1.96^{ab}	5.16 ± 2.41^a
Overall acceptability	5.05 ± 1.71^b	5.24 ± 1.72^{ab}	5.46 ± 1.61^{ab}	5.92 ± 1.93^{ab}	6.16 ± 1.80^a

Color attributes and cooking properties; all values are means of triplicates $\pm$ standard deviation

Sensory evaluation; the sensory evaluation carried out by a 9-point hedonic scale (where 9 = extremely like and 1 = extremely dislike) with thirty untrained panelists

^{a-d}Means with the same superscript letters within a row are not significantly different at $p < 0.05$ level

The ratios of Phitsanulok and red Jasmine rice flours were 100:00 (0RJ), 75:25 (25RJ), 50:50 (50RJ), 25:75 (75RJ), and 00:100 (100RJ)

negative effects on noodle texture, reducing the strength of noodle construction (Wang et al., 2016).

Color attributes of rice noodle

Noodle samples that were only prepared with pigmented rice flour (100RJ) had the highest a^* (13.37) and b^* values (15.07) (Table 3). Meanwhile, less pigment in PH provided the opposite results; the rice noodle sample 0RJ showed the lowest a^* (0.61) and b^* values (10.47); however, it had the highest L^* (83.38). These led a^* and b^* values in noodle samples increased (above 90% and 20%, respectively) when substituted PH with RJ at the ratio of 75:25 ($p < 0.05$). Meanwhile, L^* was reduced about 20% ($p < 0.05$) due to RJ pigments. Color attributes of rice flours and noodle samples are shown in Figs. 1 and 2, respectively. Higher a^* and b^* values in rice contribute to better antioxidant capacity, in which they inhibit free radical reactions, reduce oxidative stress, and delay cellular damage, which are significant contributors to health concerns such as cardiovascular disease (Pereira-Caro et al., 2013). Therefore, using RJ in rice noodles could be considered a net health benefit.

Fig. 1 Appearance of Phitsanulok (A) and red Jasmine rice flours (B)

Total phenolic content and antioxidant activities of rice noodle

The highest value of TPC (548.93 mg GAE/100 g DW sample) was found in noodle sample 100RJ (Table 1). This contributed to the highest value for antioxidant activities in that noodle, namely DPPH (189.15 μ M TE/100 g DW sample), FRAP (2.87 μ M Fe(II)/100 g DW sample), and ABTS (121.13 μ M TE/100 g DW sample). Higher amounts of RJ tended to deliver higher TPC and antioxidant activities ($p < 0.05$), thanks to the main pigment of RJ (proanthocyanidin) (Abdel-Aal et al., 2006). Pereira-Caro

Fig. 2 Color attributes of noodle prepared from the blended rice flour. The ratios of Phitsanulok (PH) and red Jasmine rice flours (RJ) were 100:00 (A), 75:25 (B), 50:50 (C), 25:75 (D), and 00:100 (E)

et al. (2013) reported that most phenolic compounds that are found in pigmented rice bring about better antioxidant activities thanks to great abilities to scavenge/stabilize free radicals.

Contrariwise, less pigment containing in PH led to the lowest TPC (394.88 mg GAE/100 g DW sample), DPPH (20.41 μM TE/100 g DW sample), FRAP (1.20 μM Fe(II)/100 g DW sample), and ABTS (10.45 μM TE/100 g DW sample) in the noodle 0RJ (Table 1). Phattayakorn et al. (2016) reported that TPC and antioxidant activities of white rice were lower than that of colored rice. Muntana and Prasong (2010) also found that TPC and antioxidant activities in white rice extract were lower than that of pigmented rice extracts. Thus, RJ could improve health benefits in rice noodle.

Cooking properties of rice noodle

Cooking time gradually declined (about 5%) when PH was replaced with RJ at the ratio of 75:25 ($p < 0.05$). This could be encouraged by lower amylose content, because amylose has low abilities for absorbing/holding water (Kerdsrilek and Garnjanagoonchorn, 2014). Conversely, amylopectin has greater ability to embrace water molecules due to its highly branched chains. Thus, the shortest cooking time was found in the rice noodle sample 100RJ (4.05 min) (Table 3). The longest value was found in the rice noodle sample 0RJ (4.40 min), considering as an undesirable property.

High cooking loss or high solid components leach out from noodle structure (Fig. 2) upon cooking is not required for noodle products because it increases stickiness of noodle structure and gives turbidity to noodle soups (Ahmed et al., 2015). Moreover, high cooking loss also refers to weak structure of rice noodle (Wang et al., 2016). Replacing PH with RJ in the ratio of 75:25 increased cooking loss by nearly 66%, because of lower amylose content in RJ ($p < 0.05$), contributing to less three-dimensional network formation (Kim et al., 2014). Besides, decreasing cooking time also contributes to high cooking loss because of the faster water absorption of starch granules, stimulating solid component leaching (Sompong et al., 2011). Consequently, PH gave rice noodles the lowest cooking loss (2.31%) (Table 3).

Almost 20% of rice noodle rehydration was increased by substituting PH with RJ at the ratio of 75:25 (Table 3) ($p < 0.05$). This could be caused by better water absorption of amylopectin RJ, requiring more amounts of water during cooking (Tong et al., 2015), indicating high stickiness of noodle texture (Ahmed et al., 2015). Oppositely, less water absorption ability and swelling power of high amylose rice flour result in less water needed during cooking (Cham and Suwannaporn, 2010). Thus, the lowest rehydration was found in noodles that are only made from PH (123.36%).

Texture properties of rice noodle

Mostly, low amylose rice flour (< 25%) is not considered appropriate for forming noodle because it produces poor

Fig. 3 Texture profile analysis of noodle prepared from the blended rice flour. ^{a-c} Means and standard deviation bars with different letters are significantly different at $p < 0.05$ ($n = 6$). The ratios of Phitsanulok and red Jasmine rice flours were 100:00 (0RJ), 75:25 (25RJ),

50:50 (50RJ), 25:75 (75RJ), and 00:100 (100RJ). Texture properties; tensile strength (A), extensibility (B), hardness (C), adhesiveness (D), cohesiveness (E), chewiness (F), and springiness (G)

qualities (Luo et al., 2015). Nonetheless, this study found that low amylose rice flour (RJ) (17.93%) increased tensile strength, extensibility, and cohesiveness of noodle samples ($p < 0.05$).

Improved tensile strength, elasticity, and cohesiveness by 18, 45, and 10% (Fig. 3) were found when PH and RJ were blended at the ratio of 75:25, respectively. This could be due to higher protein content in RJ ($p < 0.05$) because amino acids that are located in rice protein can form disulfide and covalent bonds that are stronger than hydrogen bonding during noodle processing (steaming), boosting up stronger network in food matrix (Cham and Suwannaporn, 2010). Increased tensile strength and extensibility could increase sturdiness and stability in rice noodle structure, that might also be supported by covalent bonding from amino acids of RJ protein (Kim et al., 2014). Furthermore, increasing cohesiveness ($p < 0.05$) also refers to greater strength of the internal bonds in the noodle structure, improving cooking tolerance (Purwandari et al., 2014).

Contrariwise, replacement PH by RJ at the ratio of 75:25 reduced noodle hardness around 32% (Fig. 3) thanks to lower amylose content in RJ. Ye and Sui (2016) reported that amylose enhances hardness in rice noodle as it provides a higher setback by three-dimensional network formation, giving rigid structure. Tong et al. (2015) also reported that low amylose content in rice flour contributes to softer texture in rice noodles because it has less ability to rearrange starch molecules, reducing stiffness.

At the same ratio, dropping hardness could decrease both gumminess and chewiness by about 24% in the noodle samples ($p < 0.05$) because of reducing energy required for breaking down rice noodle structure (Luo et al., 2015). However, no effect was found with respect to adhesiveness and springiness ($p > 0.05$), because of lacking of gliadin and glutenin in rice flour, in which the proteins principally boost values of these two texture properties (Pracham and Thaiudom, 2016).

Sensory evaluation of rice noodle

Sensory properties including softness, stickiness, elasticity, and overall acceptability were developed by RJ replacement ($p < 0.05$), however the replacing had no effect on sensory scores in terms of color, flavor, and also taste of rice noodles ($p > 0.05$). Using RJ provided the highest sensory scores in terms of softness (5.96), stickiness (5.32), elasticity (5.16), and overall acceptability (6.16) (Table 3) to rice noodle ($p < 0.05$). Actually, high amylose rice flour provides a respectable quality noodle (Cham and Suwannaporn, 2010). Nevertheless, this study found that the especially high amylose content in PH (30.05%) (Table 1) gave lower tensile strength and extensibility values to

noodle product ($p < 0.05$). Han et al. (2011) reported that very high amylose content (32.1%) of Milyang261 (rice variety) is a cause of poor cooking properties. Ye and Sui (2016) also confirmed that low tensile strength and extensibility in noodle decreased consumer acceptability. Thus, the lowest scores were found in the noodle sample ORJ ($p < 0.05$).

Replacing PH with RJ at the ratio of 75:25 improved the nutritional qualities of the blended rice flours. Furthermore, the effect of dropping amylose content due to RJ replacement also increased some values of rice flour pasting properties, including peak, trough, and breakdown viscosities. At the same ratio, TPC and antioxidant activities were developed due to RJ pigments. Increasing values of protein content and pasting properties in blended rice flours by RJ replacement improved some texture properties (e.g., tensile strength and extensibility) and sensory properties (e.g., softness and overall acceptability). Oppositely, decreasing amylose content reduced the noodle cooking time. Moreover, the noodle that was prepared from 100RJ had better values for most properties as compared to the rest of the rice noodle samples investigated in this study.

Therefore, RJ could be used for making rice noodle. It could be considered a very suitable substitution for PH in order to improve some quality attributes with higher health benefits. However, some disadvantages for using RJ remain such as increasing cooking loss and rehydration in the rice noodle. Therefore, those properties are needed to develop for further study.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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