Pasting Property of Jasmine Rice Flour, Quality and Sensory Evaluation of Gluten-Free Rice Penne as Affected by Protein and Hydrocolloid Addition

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Abstract. Jasmine rice flour (JMRF) is one of the most popularly consumed rice products in Thailand but applications to prepare gluten-free pasta are limited as JMRF amylose content is low. This research was carried out to develop JMRF suitable for gluten-free rice pasta (penne) (GFRP) by adding soy protein isolate (SPI, 5%), egg white protein powder (EW, 5%) and hydrocolloids (guar gum, GG and xanthan gum, XG, 1%). JMRF blended with proteins and hydrocolloids was investigated for pasting properties. JMRF blended with EW and SPI with GG showed the highest peak viscosity, whereas setback values observed in JMRF blended with EW and GG or XG were not significantly different. GFRP was prepared and determined for protein content, color and sensory evaluation. The protein content of GFRP with SPI blended with GG and XG ranged from 10.50 to 10.95% is higher than GFRP with EW and penne without SPI or EW (control). GFRP with SPI had higher yellowness than GFRP with EW. Adding SPI, EW and gums reduced cooking loss, while sensory evaluation showed a higher liking score for GFRP with SPI and GG than GFRP with EW. Results suggested that adding SPI and GG to JMRF improved pasting properties, protein content, color and acceptance. GFRP showed promise as a new alternative sustainable source to replace wheat in pasta products. However, characteristics, such as product chemical composition, texture analysis and nutritional benefits require further evaluation.

Keyword. Gluten-free pasta, penne, rice flour, hydrocolloid, protein

1. Introduction

Penne is a type of pasta that is widely consumed around the world, especially in European countries and North America. Penne is made from semolina or wheat flour (*Triticum durum* L.) mixed with water to form a dough. During kneading, a gluten network is developed that is necessary for pasta production [1]. The dough is extruded into cylinder-shaped pieces, with ends cut at an angle. However, pasta contains gluten, which causes allergies as a celiac disease [2]. Gluten-free pasta lacks the gluten network and shows poor sensory and cooking quality [3]. Rice is considered a gluten-free cereal grain and rice flour are used to produce gluten-free products, such as rice cookies [4], gluten-free rice spaghetti [5] and rice noodles [6]. Gluten-free rice spaghetti and rice noodles are produced from high amylose rice flour (> 22 %), which provides a satisfactory texture with low cooking loss and sensory acceptance [6, 7]. Jasmine rice (Khao Dawk Mali 105, *Oryza sativa*) is one of the most famous and popularly consumed rice varieties in Thailand. It has a unique fragrant smell and soft texture when cooked with low amylose content (< 20%). Jasmine rice is commonly consumed as whole grain or polished grain cooked rice. Broken Jasmine rice is a byproduct of the rice milling process and is generally sold as animal feed at a low price. Production of rice flour from broken rice can add value, reduce the production of waste and promote sustainable rice production. Jasmine rice flour has low amylose content and its application is limited to rice noodles and gluten-free pasta products. The amylose content in rice is related to the quality of rice noodles, and low amylose content produces rice noodles with low cooking quality. Previous studies have reported the development of gluten-free pasta using proteins and hydrocolloids as

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several gluten-free products using varieties of flour (e.g., rice, chickpea and maize) [4, 9]. Protein is a desirable food ingredient that promotes textural properties and nutrition enhancement. Gluten-free rice spaghetti incorporation with egg white protein improved textural properties [10]. The main protein in egg white is ovalbumin (54%), which has a free sulfhydryl (SH) group that enables gelation [11]. Detchewa and Naivikul [10] found that adding 5% egg white protein powder improved the texture, cooking quality and sensory evaluation of gluten-free rice spaghetti.

Soy protein is widely utilized in food products as a gelling agent. Detchewa *et al.* [5] improved the texture of gluten-free rice spaghetti by adding soy protein isolate (5%). Scanning electron microscopy showed that adding soy protein isolate to gluten-free rice spaghetti increased porosity at the surface and decreased cooking time. Rachman *et al*. [11] reported that the addition of egg white protein or soy protein improved the textural characteristics of banana pasta. Hydrocolloids are used in food products as thickeners, stabilizers, gelling agents and emulsifiers. Adding hydrocolloids improved the texture of gluten-free noodles. Silva *et al.* [12] found that adding 1% xanthan gum (XG) or 1% guar gum (GG) improved the strength of sweet potato starch noodles with 4% broccoli powder.

However, previous studies using protein and hydrocolloids to improve the quality of low amylose rice flour and preparation of GFRP using Jasmine rice are limited. This study investigated the effect of adding proteins, such as egg white (EW), soy protein isolate (SPI) and hydrocolloids including GG and XG on the pasting properties of Jasmine rice flour and the sensory evaluation of gluten-free rice penne.

2 Materials and Methods

2.1 Materials

Jasmine rice flour or Khao Dawk Mali 105 rice variety (*Oryza sativa* cv.) was purchased from Limited Partnership Charoenworrakit. Semolina or wheat flour (Divella S.p.A, Italy) was purchased from a local market. Soy protein isolate (SPI), egg white protein powder (EW), guar gum (GG) and xanthan gum (XG) were purchased from Krungthepchemi Co., Ltd., Bangkok, Thailand.

2.2 Proximate composition and amylose content

Moisture, protein (Nx6.25), fat and ash contents of the samples were analyzed according to the AOAC (2000) [13]. Protein contents of gluten-free rice penne samples were determined using the Kjeldahl method [13], while amylose contents of JMRF and semolina were determined according to the previous study by Juliano [14] using the iodine-based colorimetric method. Absorbance was measured at 620 nm wavelength (Biochem Libra S32, UK). Amylose content was estimated based on the standard curve of prepared potato amylose.

2.3 Pasting properties

Pasting properties of JMRF with proteins and hydrocolloids, and semolina were determined using a Rapid Visco Analyzer (model 4S, Newport Scientific, Australia) as pasting temperature, peak viscosity, hot paste viscosity, breakdown, final viscosity and setback [15].

2.4 Gluten-free rice penne production

Rice flour was blended with proteins and hydrocolloids following the mixture levels listed in Table 1.

The raw materials of each formula were well mixed before extrusion using a single-screw extruder (model CT, Chareon Tut, Thailand) to prepare pasta as penne type. Barrel temperatures were set at 50ºC, 90ºC and 90ºC for zones 1-3 and the die temperature was 80ºC. The screw speed was set at 220 rpm. The extruded GFRPP was dried at 50ºC using a tray dryer until moisture content was below 12% [16].

Table 1 Nomenclature of GFRP

Designated name	% Mixture				
	JMRF	EW	SPI	GG	XG
JMRF	100	-	-	-	-
JMRFEW5	95	5	-	-	-
JMRFSPI5	95	-	5	-	-
JMRFEW5GG1	94	5	-	1	-
JMRFEW5XG1	94	5	-	-	1
JMRFSPI5GG1	94	-	5	1	-
JMRFSPI5XG1	94	-	5	-	1

JMRF= Jasmine rice flour, JMRFEW5= Jasmine rice flour with egg white protein 5%, JMRFSPI5= Jasmine rice flour with soy protein isolate 5%, JMRFEW5GG1= Jasmine rice flour with egg white protein 5% and GG 1%, JMRFEW5XG1= Jasmine rice flour with egg white protein 5% and XG 1%, JMRFSPI5GG1= Jasmine rice flour soy protein isolate 5% and GG 1%, JMRFSPI5XG1= Jasmine rice flour soy protein isolate 5% and XG 1%

2.5 Color measurement

Cooked GFRP samples were measured for color using a Hunter Lab Color (Colex, USA). The color L* value indicates lightness, while a* and b* are redness and yellowness, respectively.

2.6 Cooking quality measurement

Cooking qualities of the GFRP samples and wheat penne were determined using the optimum cooking time, water absorption index and cooking loss according to the method of AACC [17] and Detchewa *et al*. [16].

2.7 Sensory evaluation

Gluten-free rice penne samples were evaluated after cooking by 30 untrained panelists for appearance, color, texture, flavor, taste and overall liking. The sensory evaluation was performed using a 9-point hedonic scale, where 9= like extremely, 5= neither like or dislike and 1= dislike extremely.

2.8 Statistical analysis

All experiments were conducted in triplicate. Results were analyzed by one-way analysis of variance (ANOVA) using SPSS version 22 (SPSS Inc, Chicago, USA). Duncan's multiple range test (DMRT) was used for multiple comparisons with statistical significance set at $p<0.05$.

3 Results and Discussion

3.1 Chemical compositions and amylose content

Chemical compositions of JMRF, semolina, EW and SPI are shown in Table 2. Moisture, protein, fat and ash contents of JMRF were 10.50%, 6.37%, 0.67% and 0.56%, respectively, while semolina contained 10.56% moisture, 12.92% protein, 0.97% fat and 0.80% ash content. Protein content in wheat flour was higher than JMRF. Sissons *et al.* [18] reported that protein content of semolina higher than 12-13% gave good pasta quality. SPI presented higher protein content (93.13%) than EW (82.20%). SPI has a minimum protein content of 90% dry weight basis, while egg white protein powder concentrate contains a minimum protein content of 65%. Amylose content was 14.10% in JMRF and 25.41% in semolina (Table 2). Bhattachary *et al.* [6] reported that noodles with high amylose content (> 22%) showed a positive correlation with hardness chewiness, gumminess and tensile strength.

Table 2 Chemical compositions of major raw materials

Raw material	Chemical composition (%)				
	Moisture	Protein	Fat	Ash	Amylose
JMRF	10.50 ±0.15^{a}	6.37 ±0.15^{d}	0.67± 0.12^{b}	0.56 ±0.10^{d}	14.10 ±0.26^{b}
Semolina	10.56 ±0.15^{a}	12.92 ±0.50^{c}	0.97± 0.08 ^{a}	0.80 ±0.10^{c}	25.41 ±0.11^{a}
EW	5.80 ±1.00^{b}	82.20 ±0.80^{b}	0.02 ±0.00^{c}	3.00± 0.20^{b}	-
SPI	4.70 ± 0.06^{c}	93.13 ±1.03^{a}	0.75± 0.09^{b}	3.80 ±0.14^{a}	-

Mean values with different small letter superscripts within the same column are significantly different at $p<0.05$.

3.2 Pasting properties

Pasting properties of JMRF and JMRF with proteins and hydrocolloids, and semolina are shown in Figure 1. Pasting temperature or gelatinized temperature of semolina, JMRF and JMRF with proteins and hydrocolloids are shown in Figure 1 (A). Wheat flour gelatinization temperature was higher than JMRF. The gelatinized temperature of JMRF added with egg white protein 5% (JMRFEW5) or soy protein isolate 5% (JMRFSPI5) was not significantly different from JMRF. Adding GG and XG as well as EW or SPI affected the gelatinization temperature. The gelatinized temperatures of JMRFEW5GG1, JMRFEW5XG1, JMRFSPI5GG1 and JMRFSPI5XG1 were lower than JMRF. This result concurred with Zhang *et al.* [19] who reported that the addition of hydrocolloids to high amylose starches showed initial onset of viscosity or gelatinization at low temperature.

Peak viscosity showed high viscosity of maximum starch swelling before disintegration. Peak viscosities of JMRFEW5 and JMRFSPI5 were lower than JMRF. Lower starch content and high protein content in this sample resulted in peak viscosity decreasing, as indicated in JMRF with egg white protein or SPI with XG 1%. Adding 1% XG gave a lower peak viscosity than JMRF, JMRFEW5 and JMRFSPI5. This result was similar to Weber *et al* [20]. The addition of XG to normal corn starch decreased peak viscosity at 95^{o}C. XG is highly hygroscopic and reduces water availability for starch swelling, resulting in decreased peak viscosity. Adding GG 1% to JMRF with EW or SPI showed higher peak viscosity. This result was similar to Chauban *et al.* [21] who reported that amaranth blended with 1% GG showed higher peak viscosity than 0.5% GG. GG interacted with the starch granules and the entanglement led to an increase in peak viscosity.

Breakdown viscosity reflects starch granule stability during the heating process with water. The low breakdown value indicated higher integrity of the starch granules or higher shear resistance of starch paste [22]. JMRF showed the highest breakdown while adding proteins and hydrocolloids decreased breakdown. Breakdown values of JMRFEW5GG1, JMRFEW5XG1, JMRFSPI5GG1 and JMRFSPI5XG1 were not significantly different from semolina. These results suggested that proteins and hydrocolloids improved the heat and shear resistance of starch.

Setback viscosity indicates the degree of starch retrogradation or recrystallization after the heating and cooling process [22]. Setback viscosities of JMRF and JMRFEW5 were higher than JMRF. Adding protein and gums (JMRFEW5GG1 and JMRFEW5XG1) showed the highest setback, while addition of SPI and GG or XG (JMRFSPI5GG1 and JMRFSPI5XG1) gave higher setback than JMRF only (control).

Proteins contain many hydrophilic groups, such as -NH_2, -OH-, -COOH- and -NH-, which form crosslinks with starch [23]. These crosslinks generated higher setback viscosity compared to JMRF only. High setback or high amylose retrogradation imparted good rice noodle quality through reinforcement of the amylose network [24, 25].

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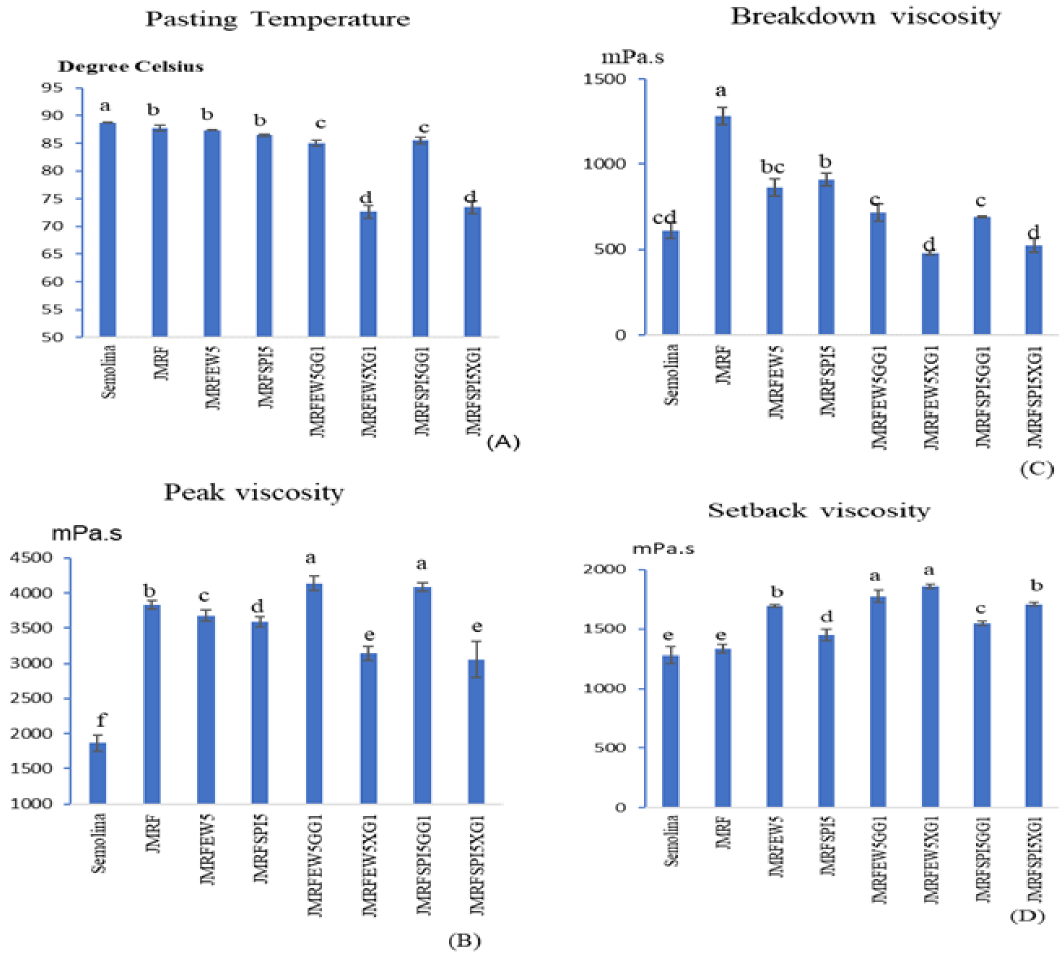

Figure 1. Pasting properties of JMRF, JMRF blended with protein and hydrocolloid, and semolina. Pasting temperature (A), peak viscosity (B), breakdown (C) and setback viscosity (D). JMRF= Jasmine rice flour, JMRFEW5= Jasmine rice flour with egg white protein 5%, JMRFSPI5= Jasmine rice flour with soy protein isolate 5%, JMRFEW5GG1= Jasmine rice flour with egg white protein 5% and GG 1%, JMRFEW5XG1= Jasmine rice flour with egg white protein 5% and XG 1%, JMRFSPI5GG1= Jasmine rice flour soy protein isolate 5% and GG 1%, JMRFSPI5XG1= Jasmine rice flour soy protein isolate 5% and XG 1%

3.3 Gluten-free rice penne

After the mixed rice flour was extruded to obtain GFRP, several quality aspects were evaluated. A photo of GFRP was compared with commercial wheat penne (Figure 2.)

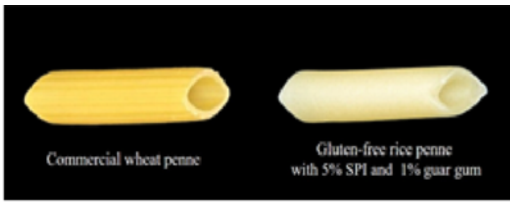

Figure 2 Commercial wheat penne and GFRP with 5% soy protein isolate and 1% GG

3.4 Color of gluten-free rice penne

The L*, a* and b* values of GFRP and wheat penne are shown in Table 3. The L* value of gluten-free rice penne varied from 67.21 to 70.33, while wheat penne was 62.56. The a* and b* values of GFRP ranged from 0.13 to 1.40 and from 11.87 to 17.41, respectively. GFRP added with egg white protein and gums (JMRFEW5, JMRFEW5GG1 and JMRFEW5XG) showed lower lightness (*L), redness(a*) and yellowness (b*) than GFRP made from JMRF only, while GFRP with soy protein isolate showed higher yellowness (b* value) with increasing SPI level than GFRP added with egg white protein and GFRP without egg white protein. Increasing SPI decreased the a* value. This result was similar to Detchewa *et al.* [5], who reported that increasing soy protein isolate content in gluten-free rice spaghetti resulted in increased yellowness (*b), while Akesowan [26] reported that adding soy protein isolate to ice cream increased the yellowness.

3.5 Protein content in penne

Protein contents of wheat penne and GFRP with proteins and hydrocolloids are shown in Figure 3. The protein content of wheat penne was 12.8%, significantly higher than the GFRP samples. Protein content higher than 12% gives good pasta quality, whereas flour with protein content below 10% is undesirable [27]. Protein content in GFRP with SPI (10.50-10.95%) was higher than GFRP with egg white protein (9.75-9.90 %). These results were similar to Rachman *et al.* [11] who reported that soy protein fortification in banana pasta gave higher protein content than banana pasta with egg white protein.

Table 3 Color of wheat penne and GFRP with proteins and hydrocolloids

Gluten-free rice penne	L*	a*	b*
Wheat penne	62.56±0.01^{h}	3.32±0.02^{a}	29.90±0.07^{a}
JMRF	70.33±0.26^{a}	1.40±0.03^{b}	11.87±0.02^{h}
JMRFEW5	67.87±0.12^{e}	0.13±0.02^{f}	14.02±0.02^{e}
JMRFSPI5	66.17±0.18^{g}	0.73±0.03^{c}	17.41±0.03^{b}
JMRFEW5GG1	69.90±0.17^{b}	0.17±0.06^{f}	12.57±0.03^{g}
JMRFEW5XG1	68.85±0.07^{c}	0.13±0.04^{f}	12.92±0.05^{f}
JMRFSPI5GG1	67.21±0.21^{f}	0.21±0.05^{e}	15.20±0.10^{d}
JMRFSPI5XG1	68.28±0.24^{d}	0.44±0.01^{d}	16.55±0.06^{c}

Mean values with different small letter superscripts within the same column are significantly different at $p<0.05$.

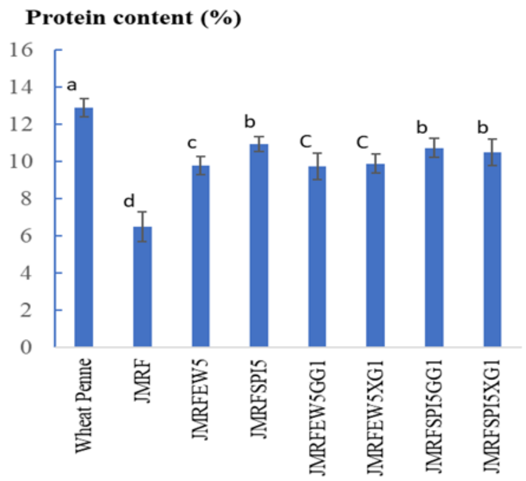

Figure 3 Protein content of wheat penne and GFRP with proteins and hydrocolloids

3.6 Cooking quality

The optimum cooking time, cooking loss and water absorption of GFRP and wheat penne samples are shown in Table 4. The optimum cooking time of GFRP was significantly higher (14.23-22.04 min) than wheat penne (10.02 min). Cooking loss in GFRP ranged from 22.05 to 34.39 %, higher than wheat penne (5.34%). When wheat penne was boiled in water, the gluten network entrapped the starch resulting in lower cooking loss [28]. Cooking losses of GFRP with 5% SPI and 1% GG (22.05%) were the lowest among the GFRP samples, while GFRP without protein and gum added showed the highest cooking loss (34.39%). Rachman *et al.* [11] reported similar results using SPI and egg white protein to decrease the cooking loss of banana pasta, while Chauhan *et al.* [21] found that 1% GG in gluten-free amaranth pasta gave the minimum cooking loss (8.5%) due to matrix formation between starch and gum. Water absorption expresses penne hydration after cooking and relates to the eating quality. Water absorption of wheat penne was 94.49%, whereas absorption of GFRP varied from 54.54 to 84.34%. Adding hydrocolloids increased water absorption due to their hydrophilic groups. GFRP with 5% SPI and 1% GG had higher water absorption than GFRP with 5% SPI and 1% XG. This result agreed with Chauhan *et al.* [20] who found that gluten amaranth pasta with 1% GG had higher water absorption (180.60%) than the control (144.78%). These results were also in agreement with Sutheeves *et al.* [29] who reported that the addition of GG in gluten-free instant noodles (297.26%) gave higher water absorption than XG (228.79%).

Table 4 Cooking quality of GFRP samples and wheat penne

Sample	Cooking time (min)	Cooking loss (%)	Water adsorption (%)
Wheat penne	10.2 ± 0.14^{g}	5.34 ± 0.48^{g}	94.49 ±0.32^{a}
JMRF	14.23 ± 0.16^{f}	34.39 ±0.55^{a}	54.54 ±0.05^{g}
JMRFEW5	15.08 ±0.03^{e}	32.40 ±0.57^{b}	56.44 ±0.12^{f}
JMRFSPI5	17.09 ±0.12^{d}	30.17 ±0.24^{c}	56.60 ±0.31^{f}
JMRFEW5GG1	19.27 ±0.38^{c}	22.25±0.07^{f}	60.66 ±0.38^{d}
JMRFEW5XG1	20.25 ±0.35^{b}	27.23 ±0.32^{d}	58.71 ±0.06^{e}
JMRFSPI5GG1	19.22 ±0.31^{c}	22.05 ± 0.35^{f}	88.23 ±0.59^{b}
JMRFSPI5XG1	22.04 ±0.06^{a}	25.20 ±0.28^{e}	74.34 ±0.48^{c}

Mean values with different small letter superscripts within the same column are significantly different at $p<0.05$.

3.7 Sensory evaluation

Sensory evaluation of GFRP with EW or SPI with hydrocolloids and wheat penne was evaluated by 30 untrained panelists who were familiar with penne consumption. The sensory evaluation reflects the quality of penne by consumer satisfaction through liking scores. GFRP was characterized by the mean scores of the sensory parameters including appearance, color, texture, flavor, taste and overall liking, as indicated in Table 4. GFRP with 5% SPI and 1% GG had the highest score for sensory attributes including appearance (8.0), color (7.6), texture (7.9), flavor (7.5), taste (7.3) and overall liking (7.8). The color of GFRP with SPI showed a higher score than GFRP with/without egg white protein because the color of soy protein was more yellow, as observed by the b* value in Table 3. The control GFRP received a high flavor score because it was made from Jasmine rice flour only, resulting in a more intense rice aroma than samples added with protein and gums. Daygon *et al.* [30] reported that Jasmine rice flour (Khao Dawk Mali 105) contained acetyl-1-pyrroline (2-ACPY), which has a fragrant or aromatic flavor and sweet aroma attribute.

Table 5 Sensory evaluation of wheat penne and gluten-free rice penne with proteins and hydrocolloids

Sample	Appearance	Color	Texture	Flavor	Taste	Over all liking
Wheat penne	8.4±0.6^{a}	8.7±0.4^{a}	8.2±0.5^{a}	8.0±0.7^{a}	7.6±0.8^{a}	8.5±0.5^{a}
JMRF	5.6±0.4^{e}	5.7±0.7^{e}	5.1±0.6^{f}	7.6±0.5^{b}	7.1±0.8^{b}	6.3±0.3^{e}
JMRFEW5	6.2±0.6^{d}	5.8±0.6^{e}	6.1±0.5^{e}	7.4±0.4^{b}	7.0±1.0^{b}	6.4±0.2^{e}
JMRFSPI5	7.5±0.5^{c}	8.1±0.4^{b}	6.5±0.6^{d}	7.8±0.7^{b}	7.0±0.9^{b}	7.2±0.4^{c}
JMRFEW5GG1	7.8±0.2^{bc}	7.3±0.6^{cd}	7.2±0.7^{c}	6.5±0.6^{c}	7.2±0.4^{ab}	7.5±0.1^{c}
JMRFEW5XG1	7.5±0.5^{c}	7.2±0.7^{d}	7.1±0.7^{c}	7.0±0.2^{d}	7.0±0.2^{b}	7.0±0.1^{d}
JMRFSPI5GG1	8.0±0.5^{b}	7.6±0.4^{c}	7.9±0.6^{b}	7.5±0.3^{b}	7.3±0.4^{ab}	7.8±0.2^{b}
JMRFSPI5XG1	7.7±0.4^{bc}	7.4±0.6^{cd}	7.8±0.6^{b}	7.1±0.1^{d}	7.2±0.4^{b}	7.1±0.1^{d}

Mean values with different small letter superscripts within the same column are significantly different at $p<0.05$.

Figure 2 shows the appearance of wheat penne and GFRP with 5% soy protein isolate and 1% GG. Both penne samples revealed a good appearance. Thus, overall liking showed that GFRP with 5% soy protein isolate and 1% GG gave the highest scores, while the commercial wheat penne gave the highest score for all sensory attributes.

4 Conclusions

This research focused on GFRP production based on Jasmine rice flour. The addition of SPI or EW with GG or XG into JMRF affected the pasting property of rice flour. Results suggested that the quality of GFRP including protein content of penne, color, cooking quality and sensory acceptance was improved using SPI or EW with GG or XG. The incorporation of 5% SPI and 1% GG were the most suitable percentages to obtain good quality and acceptable GFRP. However, further studies are required to investigate product chemical compositions, texture and nutritional quality.

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