Research Article

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Development of Rice Spaghetti Using Propylene Glycol Alginate and Soy Flour by Twin-Screw Extrusion

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Abstract
Propylene Glycol Alginate (PGA) and Soy Flour (SF) were used to enhance qualities of rice spaghetti. Rice spaghetti was extruded using high-shear extruder. Cooking qualities and textural properties of rice spaghetti were determined. The optimum formulation was determined when the level of SF was 20% to 30% in combined with 0.3% to 0.5% PGA, leading to the acceptable cooking loss (5.45–8.31%) and firmness (3.38–4.19 N) when compared with commercial gluten free spaghetti. Sensory evaluation showed that rice spaghetti with 20% SF and 0.3% PGA received the liking scores insignificantly different ($p > 0.05$) from commercial gluten free spaghetti on all attributes.

Keywords: Gluten free, Pasta, Extrusion, Rice, Alginate

1 Introduction

Demand of commercial gluten free product is sharply growing because of the increasing of celiac disease, wheat allergy, and gluten related disorder. The consumption of gluten free food is the treatment for those conditions [1], [2]. Many gluten free products use rice flour as the main ingredient because it has bland taste and white color. Since it naturally has no gluten, rice spaghetti has inferior quality such as high cooking loss, low firmness, and sticky surface when compared with traditional pasta made from semolina flour [3]. The addition of ingredients and/or additives is the main approach to improve the quality of rice spaghetti [4].

Thailand is one of the rice production leaders and has area suitable for growing rice. Ayutthaya 1 rice variety can grow in flood area with high percentage of yield and high in chalkiness [5]. As chalky rice grains are considered as defects in rice milling industry, this research aimed to utilize those grains to develop a value-added product.

The mixture of food additives from hydrocolloids and protein sources often uses to improve qualities of rice spaghetti [6], [7]. Propylene Glycol Alginate (PGA) is an approved food additive (E405). PGA is typically used as a gelling agent [8]. Combination of soy protein and PGA could produce high gel strength because this mixture seems to be crosslinked through covalent bonds [9]. The use of PGA in gluten free bread resulted in increasing specific volume and decreasing crumb's firmness [10].

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The aim of this study was to investigate the optimization levels of PGA and full fat soy flour to improve qualities of rice spaghetti from chalky rice flour produced by twin-screw extruder. The cooking quality, textural and sensorial properties were investigated. Contour plots using Response Surface Methodology (RSM) were determined.

2 Materials and Methods

2.1 *Materials*

Chalky rice paddy (Ayutthaya 1 variety) was obtained from Rice Department, Ministry of Agriculture and Cooperatives, Thailand. The paddy rice was stored at 10ºC before dehusking within 6 mo. Chalky Rice Flour (RF) was prepared by using pin mill to grind the dehusked and polished rice kernels into fine flour through the sieve size of 35 mesh. PGA was kindly provided by FMC Chemical Co., Ltd., Bangkok, Thailand. Full fat Soy Flour (SF) (BBI Co., Ltd., Bangkok, Thailand) was purchased from local market (Bangkok, Thailand).

2.2 *Spaghetti production using extrusion*

Rice spaghetti was prepared using a twin-screw extruder (Hermann Berstorff Laboratory Corotating Twin Screw Extruder ZE25x33D). Barrel temperatures were maintained at 30, 45, 55, 70, 80, 100, 80 and 70ºC for zone 1 to zone 7 and die plate, respectively. Constant screw speed was applied at 200 rpm. Pentagon rotatable design with 32 factors (the level of SF at 20, 30 and 40%; the level of PGA at 0.1, 0.3 and 0.5%) was employed for experimental design. The formulation of each sample was shown in Table 1. The mixture of SF and PGA at different levels in chalky rice flour base was added into the feed hopper and extruded using 2 mm die diameter. The feed rate of the mixture was kept at 1.5 kg h^{-1} and the moisture was adjusted to 40%. Spaghetti was cut into 25 cm length and subjected to dry in tray dryer at 45ºC until moisture content less than 13%. The rice spaghetti samples were stored in aluminum foil pouches at ambient temperature until analyzed.

2.3 *Moisture content and water activity*

Moisture content was determined according to the AOAC method [11]. Two grams of uncooked and cooked spaghetti samples were dried in a hot air oven at 105ºC until constant weight.

Water activity (a_w) was determined by using water activity meter (AquaLab, Series3TE, Pullman, USA).

Table 1: Formulation of rice spaghetti by pentagon rotatable design

Formulation	Ratio of RF : SF	PGA Level (%)
M0.5	70 : 30	0.5
H0.3	60 : 40	0.3
L0.3	80 : 20	0.3
H0.1	60 : 40	0.1
M0.1	70 : 30	0.1

Note: The capital letter in each formulation means amount of SF; H, high M, medium and L, low amount of SF at 40, 30 and 20, respectively. The number after each capital letter means levels of PGA at 0.1, 0.3 and 0.5%.

2.4 *Color measurement*

Color of uncooked and cooked rice spaghetti was measured using Minolta Colorimeter (CM-3500d, Minolta, Japan) at illuminant D_{65} and 2° of standard observer. L^* (lightness), a^* (redness) and b^* (yellowness) in CIE system was determined. Whiteness index was calculated following the below Equation (1).

$$\text{Whiteness index} = 100-[(100-L^*)^2 + (a^*)^2 + (b^*)^2]^{0.5} \quad (1)$$

2.5 *Cooking quality*

Cooking quality of rice spaghetti was determined according to the AACC Method 66-50 [12]. The uncooked rice spaghetti (25 g) was cut into 5 cm in length and boiled in distilled water. The ratio of cooking water to sample was 10 : 1. The optimum cooking time was determined every 15 s until the white core of rice spaghetti sample was disappeared when squeezing between two clear glass slides. Water absorption was obtained after washing cooked spaghetti with 50 mL distilled water and drained for 5 min following the Equation (2). Both cooked and washed water was collected in preweighed beakers and dried in the hot air oven at 105ºC to determine cooking loss as shown in the Equation (3).

$$\text{Water absorption (\%)} = [(\text{weight of cooked pasta} - \text{weight of uncooked pasta}) / (\text{weight of uncooked pasta})] \times 100 \quad (2)$$

Cooking loss (%) = [(weight of cooking water after drying)/ (weight of uncooked pasta)] ×100 (3)

2.6 *Textural properties*

Texture of cooked rice pasta was analyzed by Texture Analyzer TA.XT Plus (Stable Micro Systems Co., Ltd., Godalming, UK). Light knife blade (A/LKB-F) was used to determine firmness according to the approved AACC Method 66-50 [12]. Texture was determined in compression mode with the settings of pre-test speed of 1.00 mm/s, test-speed of 0.5 mm/s, post-test speed of 10.00 mm/s and 75% strain with load cell of 2000 g. The 25 g of rice spaghetti (5 cm long) was boiled in distilled water according to the optimum cooking time and five strands of cooked rice spaghetti were used to determine firmness.

2.7 *Sensory evaluation*

The optimum formulation of rice spaghetti selected from the contour plot results and commercial gluten free spaghetti (63% maize flour, 15% potato starch, 7% rice flour, 7% soy flour and monoglyceride) were evaluated for sensory properties. Extruded rice spaghetti was cooked using a ratio of spaghetti to water of 1 : 10 until optimum cooking time, whereas commercial gluten free spaghetti was cooked for 8 min following the instructions by the manufacturer. The two spaghetti samples were individually served to the panelists. Each panelist received 45 g of cooked spaghetti with a separate container of 25 g sauce. Temperature of serving condition was controlled at 60–71ºC to ensure that both spaghetti and sauce were warm when testing. Each sample was labeled with random three-digit code. Fifty untrained panelists, consisting of students and staffs at Department of Product Development, Kasetsart University, were asked to evaluate liking score based on 9-point hedonic scale for these attributes (color, appearance, flavor, texture and overall liking).

2.8 *Statistical analyses*

The means and standard deviation of the cooking qualities and firmness data were statistically analyzed by Analysis of Variances (ANOVA). Duncan Multiple Range Test was used for means comparison by SPSS 12.0 statistical software program (SPSS Inc., Chicago, IL, USA). The differences among means values were declared with significant level at 0.05. Contour plots were accomplished using the STATISTICA software version 7.0 (StatSoft, Inc., OK, USA). The independent sample t-test was applied to compare the difference of means from the developed rice spaghetti and the commercial gluten free spaghetti on sensory evaluation.

3 Results and Discussion

3.1 *Moisture content and water activity*

The moisture content of uncooked and cooked rice spaghetti and water activity of uncooked rice spaghetti were shown in Table 2. Moisture content of uncooked rice spaghetti from all formulations was below 12%. The use of 0.5% PGA could lower moisture content of the cooked rice spaghetti because it was related to water absorption. Increasing in moisture content of rice spaghetti was found when water absorption of rice spaghetti was increased. Water activity of all uncooked rice spaghetti samples ranged from 0.66 to 0.68.

Table 2: Moisture content of uncooked and cooked rice spaghetti and its a_w

Formulation	Moisture Content (%)		a_w^{ns}
	Uncooked	Cooked	
M0.5	9.89±0.01^d	62.54±0.24^c	0.66
H0.3	10.09±0.07^c	64.21±0.46^b	0.68
L0.3	10.71±0.11^b	64.02±0.26^b	0.66
H0.1	11.22±0.23^a	67.06±0.26^a	0.68
M0.1	9.82±0.14^d	66.66±0.30^a	0.67

Note: $^{a–d}$ Means with different letters within column were significantly different ($p \leq 0.05$).

^{ns} Means non-significant different within column ($p > 0.05$)

3.2 *Color*

Pasta color is one of the important qualities. The color of rice spaghetti in *L**, *a**, *b** and whiteness index values of uncooked rice spaghetti were indicated in Table 3. The high level of SF at 40% (H0.1 and H0.3) yielded higher *a** (5.09–5.44) and *b** (34.74–35.81) values than other formulations. *L** did not have the same trend. Feillet *et al*. [13], Sereewat *et al*. [14] reported that *L** of rice spaghetti enriched with defatted

Table 3: *L**, *a**, *b** and whiteness index of uncooked rice spaghetti

Formulation	*L**	*a**	*b**	Whiteness Index
M0.5	59.94±0.14^{a}	3.76±0.04^{b}	32.91±0.44^{c}	48.02±0.33^{b}
H0.3	57.83±0.33^{b}	5.23±0.14^{a}	35.41±0.40^{a}	44.69±0.36^{d}
L0.3	59.89±0.21^{a}	3.64±0.16^{b}	30.48±0.07^{c}	49.49±0.16^{a}
H0.1	57.32±0.13^{b}	5.34±0.10^{a}	35.18±0.44^{a}	44.43±0.39^{d}
M0.1	59.96±0.06^{a}	3.75±0.12^{b}	33.89±0.16^{b}	47.41±0.12^{c}

Note: $^{a–d}$ Means with different letters within column were significantly different ($p \leq 0.05$).

Table 4: *L**, *a**, *b** and whiteness index of cooked rice spaghetti

Formulation	*L**	*a**	*b**	Whiteness Index
M0.5	68.52±0.21^{c}	–0.01±0.30^{bc}	16.57±0.35^{c}	64.43±0.36^{c}
H0.3	69.86±0.20^{a}	0.31±0.18^{ab}	17.29±0.47^{b}	65.26±0.39^{b}
L0.3	69.80±0.26^{a}	–0.33±0.26^{c}	15.25±0.16^{d}	66.17±0.30^{a}
H0.1	69.85±0.26^{a}	0.46±0.09^{a}	17.50±0.25^{b}	65.14±0.31^{b}
M0.1	69.15±0.12^{b}	0.04±0.08^{bc}	19.13±0.26^{a}	63.70±0.19^{d}

Note: $^{a–d}$ Means with different letters within column were significantly different ($p \leq 0.05$).

soy flour decreased when protein and ash contents increased. Rice spaghetti from H0.1 and H0.3 has the lowest whiteness index since these formulations employed SF at high amount (40%). After cooking rice spaghetti, *a** was negative in M0.5 and L0.3, indicating greenness (Table 4).

3.3 *Cooking quality*

Optimum cooking time of rice spaghetti is shown in Table 5. The combination of PGA and SF could provide strong gel formation of protein crosslinks [9]. Therefore, using high amount of PGA at 0.5% yielded the highest cooking time (9.63–10.07 min). Cooking time of all rice spaghetti formulations ranged from 8.24 to 10.07 min. Phongthai *et al*. [7] reported that cooking time of gluten free pasta was between 4.00 and 6.50 min since it had looser structure, allowing for faster penetration rate of water into the pasta structure.

Table 5: Cooking time of rice spaghetti

Formulation	Cooking Time (min)
M0.5	9.85±0.22^{a}
H0.3	8.45±0.21^{c}
L0.3	8.65±0.10^{c}
H0.1	8.75±0.18^{c}
M0.1	9.00±0.00^{b}

Note: $^{a–c}$ Means with different letters within column were significantly different ($p \leq 0.05$).

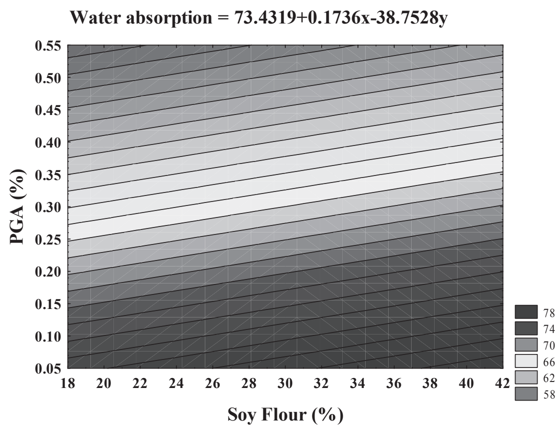

Figure 1: Contour plot on water absorption of cooked rice spaghetti.

Water absorption of rice spaghetti was presented in Figure 1. Using 0.1% PGA resulted in high water absorption (78%). As level of PGA increased, water absorption decreased because PGA could provide high gel strength through covalent bond [9]. Considering the influence between SF and PGA, using PGA had higher impact on water absorption than SF (58–78%). Applying 20 to 40% of SF provided water absorption approximately 58–62%. Similar to the study of Bouasla *et al*. [15], the addition of 30% yellow pea flour and 20–30% of chickpea flour to rice pasta significantly increased water absorption. Protein denaturation

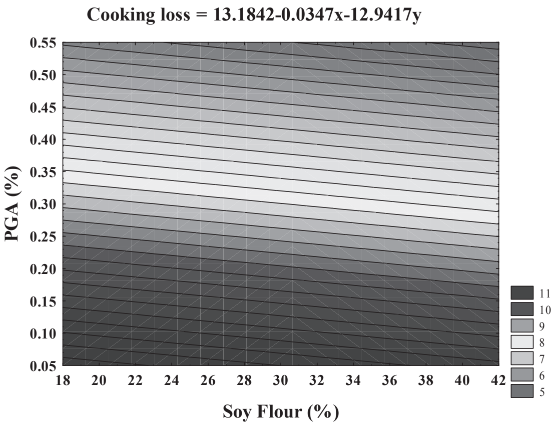

Figure 2: Contour plot on cooking loss of cooked rice spaghetti.

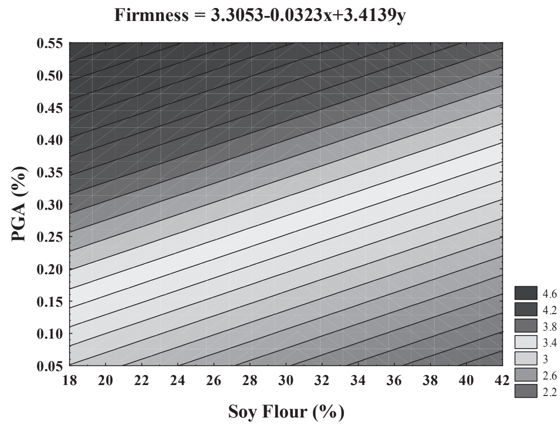

Figure 3: Contour plot on firmness of cooked rice spaghetti.

occurring during hot water hydration may provide higher accessibility for polar amino acid groups of protein, which lead to an increase of water affinity [16].

Cooking loss of cooked rice spaghetti was shown in Figure 2. PGA could decrease cooking loss as it functions as a gelling agent. At 0.5% of PGA, the cooking loss was about 5–6% in contrast to using 0.1% of PGA leading to high cooking loss (10–11%). Levels of SF (20 to 40%) maintained cooking loss less than 6%. Therefore, the combinations of SF and PGA that could effectively maintain cooking loss in the range of 5–8% were 20–40% of SF and PGA higher than 0.3%. During extrusion cooking, a compact and homogenous starch-protein matrix was found in rice pasta enriched with legume flours due to the combination of heat, pressure and mechanical shearing simultaneously being applied [15]. The integrity of pasta was hold by this matrix; therefore minimized cooking loss was obtained during hydration in hot water [15]. Cooking loss should be below the acceptable limit of 8% for durum wheat spaghetti [17].

3.4 *Textural properties*

Increasing PGA level from 0.1 to 0.5% increased firmness from 2.2 to 3.8 N (Figure 3). SF did not affect firmness (2.2–3 N). The addition of RF with PGA caused gel structure and firmer texture. Using SF could improve textural properties and provide desirable color appearance of spaghetti for consumers [14].

3.5 *Sensory evaluation*

Sensory evaluation of rice spaghetti and commercial gluten free spaghetti results were illustrated in Table 6. Rice spaghetti made from L0.3 (20% SF in combined with 0.3% PGA) received the liking scores on the following attributes (color, appearance, flavor, texture and overall liking) insignificantly different from the commercial gluten free spaghetti used in this study ($p > 0.05$).

Table 6: Sensory liking scores of rice spaghetti from L0.3 (20% SF combined with 0.3% PGA) and commercial gluten free spaghetti

Attributes	Rice Spaghetti (L0.3)	Commercial Gluten Free Spaghetti
Color ^{ns}	7.0±1.3	6.9±1.5
Appearance ^{ns}	6.3±1.6	6.8±1.9
Flavor ^{ns}	6.6±1.1	6.4±1.7
Texture ^{ns}	6.7±1.4	7.1±1.7
Overall liking ^{ns}	7.1±1.2	7.2±1.2

Note: ^{ns} indicates not significant difference ($p > 0.05$) using the independent sample t-test.

4 Conclusions

Using PGA more than 0.3% and SF provided acceptable levels of cooking loss and firmness. Sensory evaluation showed that the developed rice spaghetti had overall liking score similar to the commercial gluten free spaghetti. The rice spaghetti made of chalky rice flour enriched with SF and PGA was able to produce by extrusion process with desirable characteristics.

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