Research Article

Effect of Extrusion Conditions, Monoglyceride and Gum Arabic Addition on Physical and Cooking Properties of Extruded Instant Rice

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Abstract

Rice flour and tapioca starch 90/10% (w/w) were blended with monoglyceride at concentations of 0.5, 1.0 and 1.5% (w/w). Each moisture-adjusted (25 and 30% wet basis) blend was fed via hopper into a single screw extruder. Screw speed of 70 rpm and barrel temperature were varied at 100 and 120°C for full factorial experimental design. Extruded instant rice with monoglyceride at 1.0 and 1.5% (w/w) showed better appearance with less stickiness and increased hardness and whiteness after rehydration compared to the product without monoglyceride. Addition of gum arabic could improve the texture of the products and exhibited comparable overall acceptance compared to the commercial product.

Keywords: Cooking properties, Gum arabic, Extrusion, Instant rice, Monoglyceride, Physical properties

1 Introduction

Instant rice is becoming more and more popular in urban lifestyle nowadays because of its convenience, light weight and long shelf life. Instant rice is defined as the dehydrated rice that requires only 3–5 min for consumption by just pouring hot water before serving [1]. Many types of rice products such as ready-to-eat, chilled, frozen, canned, puffed and dried products were launched to serve for the consumer's demand [2]. The traditional process for producing instant rice is the long process involving soaking, cooking, drying and puffing while using extrusion for the production of instant rice would consume much less energy and exhibit higher production efficiency. Extrusion is the continuous process combining mixing, cooking and

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forming in the extruder. Extrusion conditions are important factors influencing the time required for rehydrating extruded instant rice and also the quality of the rehydrated product. Moisture content and temperature are considered as the most critical factors controlling the product properties in terms of texture, porous structure and rehydration time [3].

Generally, extruded rice products tend to have soft texture, stick together, and lose its shape after being cooked [2], [4]. Starch blends are frequently employed to impart desired physical and rheological properties of the product [5]. The rice-tapioca starch blend would have desirable and better pasting properties for developing rice starch based products than the use of rice starch alone [6]. In addition, the improvement in textural and physicochemical properties of instant rice product was obtained by using specified additives [7].

Food additives have also been widely used to improve the quality of extruded product [8]. The pre-gelatinised broken rice flour mixed with vital gluten and gum arabic was found to be suitable for the rice pasta product [9]. Emulsifiers (glycerol monostearate, soybean lecithin and sodium stearoyl lactylate), gums (xanthan gum, gum arabic and sodium alginate) and sticky rice were applied to improve the cooking property of extruded instant rice [2]. Glyceryl monostearate and monoglyceride were added to improve texture and reduce stickiness of the rehydrated extruded rice product [10].

In our previous study [4], monoglyceride was successfully used to improve the texture and appearance of the extruded rice vermicelli after rehydration by reducing the stickiness of the cooked products. Consequently, the objective of this research was to produce the extruded instant rice with acceptable physical and cooking qualities, indicating rehydration time not longer than the commercial product, 7 min. The effects of feed moisture content, extrusion temperature, monoglyceride and gum addition on appearance, textural properties and rehydration time of the extruded instant rice were investigated.

2 Materials and Methods

2.1 *Materials*

Rice (*Oryza sativa* L.) flour was purchased from Bangkok Inter Food Co., Ltd. (Bangkok, Thailand). Tapioca starch was purchased from E.T.C. Eaib Tong Chan Co., Ltd. (Bangkok, Thailand). Monomuls 90-35P, the monoglyceride based on palm oil (composed of fatty acid with chain length less than C12 max. 4%, C16 35–45%, C18 55–65% and more than C18 max. 2%) was supplied from Cognis Thai, Ltd. (Bangkok, Thailand). Gum arabic was purchased from Chemipan Corporation Co., Ltd. (Bangkok, Thailand).

2.2 *Chemical composition analysis*

Rice flour and tapioca starch were analyzed for moisture [11], protein, lipid and ash [12]. Amylose content was determined using the method of Juliano [13]. The sample, 0.1 g, was added with 1 mL of 95% ethanol and 9 mL of 1 N NaOH, and heated for 10 min. Distilled water was added into the sample and left at room temperature for 18 h before the addition of acetic acid and iodine solution. The absorbance of the solution at 620 nm was determined and the amylose content was calculated from the standard curve using pure amylose from potato (Sigma, St. Louis, MO USA) as standard. All determinations were carried out in triplicate.

2.3 *Extrusion process*

The extrusion was performed by using a single screw extruder (Brabender 19/20DN, Germany) equipped with a 19.1 mm screw diameter at a barrel length of 382 mm. The barrel consisted of 3 zones, entering zone (zone 1), mixing zone (zone 2) and at the ending die indicated as the third zone or zone 3. Extrusion parameters were as follows: screw speed of 70 rpm, feed rate of 175 g/min and die diameter of 1 mm. The effects of the barrel temperatures of zone 3 on instant rice properties were studied by adjusting temperature in zone 3 from 100°C to 120°C. For Zone 1 and 2, temperature was operated at 80 and 90°C, respectively. The rice flour and tapioca starch at the weight ratio of 90/10 (w/w) were mixed in a mixer (Kenwood KM230, England) at low speed (level 1) for 25 min [4]. To reduce the stickiness and improve the appearance of the rehydrated extruded instant rice, monoglyceride (Monomul 90-35P) was added to the flour blend at 0.5, 1.0 and 1.5% (w/w). Calculated amount of water was added to adjust the flour blend to two different moisture levels, 25 and 30%. The extruded instant rice were dried in a hot air drier for about 4 h at 45°C to obtain moisture content at around 10% and kept in polyethylene bags until further analysis.

Gum arabic was added to improve the texture of the extruded rice product. The flour blend prepared as described above with monoglyceride at 1.0% was added with gum arabic at 2.0, 4.0 and 6.0% (w/w), and moisture content at 30%. The instant rice was extruded using temperature in zones 1, 2 and 3 at 80, 90 and 120°C, respectively. The extrudates were dried, and kept in the plastic bag until the analysis for their cooking and physical properties. The extruded instant rice prepared from flour blend with 1.0% monoglyceride and 2.0% gum arabic was used for further sensory evaluation.

The normal cooked rice was prepared by using 200 g rice with 250 mL of water and cooked by using an electric cooker (Sharp, model KS-ZT18, Bangkok, Thailand) for 18 min and used for the comparison.

2.4 *Bulk density*

A 25 mL cylinder was filled with extruded instant rice and tapped on a table 5 times to allow a uniform packing of the extruded grains. Additional samples were filled to obtain a volume of 25 mL and total sample weight was recorded [14]. Bulk density was calculated as following equation (1).

$$Bulk\ density = \frac{weight\ of\ instant\ rice\ (g)}{volume\ of\ instant\ rice\ (mL)} \quad (1)$$

2.5 *Whiteness index*

A colorimeter (Hunter Lab Color Quest, USA) was used to measure the color of extruded instant rice in the CIE L* (lightness to darkness), a* (redness to greenness), b* (yellowness to blueness) system. The measurements were performed in six replications. Thereafter, whiteness index of instant rice was calculated using the following equation (2) [15].

$$Whitenes\ index = 100 - \left[(100 - L^*)^2 + a^{*2} + b^{*2}\right]^{0.5} \quad (2)$$

2.6 *Rehydration time and ratio*

Rehydration time was measured following the glass plate-white center method [16]. Boiling water was poured into 20 g of the extruded instant rice in a cup covered with a lid and 10 samples were removed every 30 s, the time when more than 80% of samples were translucent was used to determine the rehydration time. Rehydration ratio was determined by adding 100 mL boiling water into 10 g of extruded instant rice and held for pre-determined rehydration time, the excess water was drained for 5 min, and then weighed. The rehydration ratio was calculated from equation (3).

$$Rehydration\ ratio = \frac{weight\ of\ rehydrated\ rice\ (g)}{weight\ of\ instant\ rice\ (g)} \quad (3)$$

2.7 *Volume increase*

Volume increase was determined by measuring the volume of 20 g of instant rice using cylinders tapped 25 times to allow uniform packing of the samples [3]. The ratio was calculated as the volume of instant rice before and after rehydration. The instant rice was rehydrated by adding boiling water and holding for pre-determined rehydration time of each sample. The volume increase was calculated from equation (4).

$$Volume\ increase = \frac{volume\ of\ rehydrated\ rice\ (mL)}{volume\ of\ instant\ rice\ (mL)} \quad (4)$$

2.8 *Hardness and stickiness measurement*

The textural properties, hardness and stickiness, of rehydrated instant rice were determined by using a texture analyzer (Stable Micro System TA-XT2, Surrey, UK). Twelve grains of rehydrated extruded instant rice were selected and placed in 2 rows with 6 grains in each row. The samples were compressed to 80% deformation with a cylindrical probe of 25 mm diameters at pre-test speed of 1 mm/s and post-test speed of 10 mm/s [16]. Hardness was the peak force required to compress the grain samples whereas stickiness was the work for pulling the compressing plunger away from the sample.

2.9 *Microstructure and surface morphology study*

The microstructure of cross-sectional view of extruded instant rice and the surface appearance of rehydrated product were observed by using an optical stereomicroscope (Meiji Techno, Japan) at a magnification of 15×.

2.10 *Sensory evaluation*

Sensory evaluation was carried out using a nine-point hedonic scale test, varying from 1 (dislike extremely) to 9 (like extremely). The samples were evaluated for following attributes: appearance, colour, softness, stickiness, taste and overall preference. The instant rice products were cooked by pouring with boiling water at the predetermined rehydration time before they were served to the panelists. The sensory panel consisted of sixty untrained members who were students at the Department of Agro-Industrial, Food and Environmental Technology, King Mongkut's University of Technology North Bangkok. The normal cooked rice prepared by using an electric cooker was set as a control and commercial instant rice was also used for comparison.

2.11 *Statistical analysis*

The experimental data were subjected to the analysis of variance (ANOVA) using SPSS Version 22 software (IBM Corp., New York, USA) and presented as mean values with standard deviations. Duncan's multiple range tests were used to determine the significant differences between means at 95% confidence level.

3 Results

3.1 *Composition ofrice flour and tapioca starch*

The chemical compositions of rice flour and tapioca starch are given in Table 1. The contents of protein, lipid and amylose of rice flour are higher than those of tapioca starch.

Table 1: Chemical compositions of rice flour and tapioca starch

Component (% wet basis)	Rice Flour	Tapioca Starch
Moisture	11.46 ± 0.09[a]	11.87 ± 0.06[a]
Protein	6.59 ± 0.21[a]	0.10 ± 0.03[b]
Fat	0.63 ± 0.11[a]	0.12 ± 0.04[b]
Ash	0.24 ± 0.08[a]	0.20 ± 0.04[a]
Amylose	30.90 ± 0.60[a]	17.48 ± 0.55[b]

Values within a row with different letters are significantly different at $P< 0.05$ level.

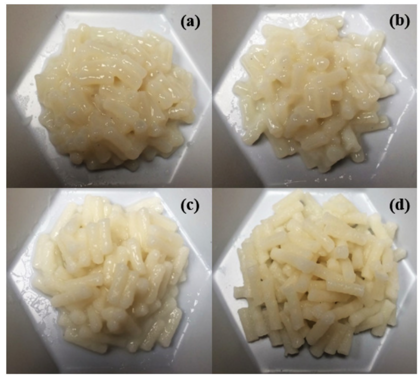

Figure 1: Appearance of rehydrated instant rice from the extrusion with monoglyceride addition at different level (w/w): (a) 0%, (b) 0.5%, (c) 1.0% and (d) 1.5%.

3.2 *Bulk density, whiteness, and volume increase*

Bulk density of extruded instant rice products varied between 0.49 ± 0.01 and 0.62 ± 0.01.The bulk density and whiteness index of the extruded product were not significantly affected by feed moisture content and barrel temperature ($P > 0.05$) as presented in the Table 2. The volume increase significantly declined with increasing monoglyceride content.

3.3 *Cooking properties*

The extruded instant rice exhibited rehydration time of 5.5–7.5 min and rehydration ratio of 1.80–2.09. The hardness of cooked extruded instant rice was observed as 18.98 to 28.25 N which was much lower than that of the normal cooked rice (49.23 N) as shown in Table 2. The rehydration of extruded instant rice without monoglyceride addition showed soft with high starch leaching on the product surface and sticked together while the cooked product became well shaped, not stick together when 1.0 and 1.5% (w/w) of monoglyceride was added in the blend before the extrusion (Figure 1).

Gum arabic added to improve the texture of the extruded instant rice could increase most of the texture attributes such as springiness, cohesiveness, gumminess and chewiness of the product (Table 3).

Sensory test showed that the product extruded from flour blend with 1.0% monoglyceride and 2.0% gum arabic exhibited comparable overall liking score compared to the commercial product, but lower than score of normal cooked rice (Table 4).

Table 2: Physical and cooking properties of extruded instant rice

Moisture Content (%)	Barrel Temp. (°C)	Mono-glyceride (%)	Extruded Instant Rice		Rehydrated Extruded Instant Rice				
			Density (g/mL)	Whiteness Index	Rehydration Time (min)	Rehydration Ratio	Volume Increase	Hardness (N)	Stickiness (N•s)
25	100	0	0.54 ± 0.01^{ab}	71.24 ± 0.08^{a}	6.0	1.96 ± 0.06^{bc}	1.38 ± 0.03^{cd}	20.67 ± 1.17^{a}	1.40 ± 0.10^{d}
		0.5	0.56 ± 0.02^{b}	71.63 ± 0.04^{b}	6.0	1.94 ± 0.02^{c}	1.36 ± 0.02^{c}	21.53 ± 0.90^{b}	1.24 ± 0.10^{cd}
		1.0	0.59 ± 0.02^{bc}	72.89 ± 0.05^{c}	7.0	1.88 ± 0.03^{b}	1.32 ± 0.05^{abc}	24.26 ± 0.99^{bc}	0.95 ± 0.12^{b}
		1.5	0.61 ± 0.01^{c}	73.47 ± 0.02^{c}	7.0	1.82 ± 0.04^{a}	1.26 ± 0.02^{ab}	26.62 ± 0.80^{d}	0.62 ± 0.06^{a}
	120	0	0.49 ± 0.01^{a}	71.63 ± 0.11^{ab}	5.5	2.09 ± 0.02^{d}	1.51 ± 0.04^{e}	18.98 ± 0.43^{a}	1.35 ± 0.11^{d}
		0.5	0.52 ± 0.03^{ab}	71.82 ± 0.03^{b}	6.0	2.01 ± 0.05^{cd}	1.44 ± 0.03^{de}	20.44 ± 1.00^{a}	1.16 ± 0.10^{cd}
		1.0	0.55 ± 0.01^{b}	72.93 ± 0.03^{c}	7.0	1.92 ± 0.02^{b}	1.42 ± 0.01^{d}	23.37 ± 0.66^{b}	0.70 ± 0.04^{a}
		1.5	0.56 ± 0.01^{b}	73.96 ± 0.10^{cd}	7.0	1.85 ± 0.03^{a}	1.38 ± 0.01^{c}	26.50 ± 1.01^{d}	0.56 ± 0.10^{a}
30	100	0	0.55 ± 0.02^{ab}	71.17 ± 0.24^{a}	6.0	1.92 ± 0.02^{b}	1.27 ± 0.04^{ab}	21.62 ± 0.50^{b}	1.44 ± 0.08^{d}
		0.5	0.57 ± 0.03^{bc}	71.34 ± 0.09^{a}	6.5	1.88 ± 0.04^{ab}	1.25 ± 0.03^{ab}	22.21 ± 0.87^{b}	1.25 ± 0.10^{cd}
		1.0	0.59 ± 0.01^{c}	72.49 ± 0.14^{bc}	7.0	1.84 ± 0.03^{a}	1.24 ± 0.04^{ab}	27.77 ± 1.10^{d}	0.92 ± 0.07^{b}
		1.5	0.62 ± 0.01^{c}	73.72 ± 0.10^{cd}	7.5	1.80 ± 0.01^{a}	1.22 ± 0.02^{a}	28.25 ± 1.00^{d}	0.67 ± 0.05^{a}
	120	0	0.53 ± 0.03^{ab}	71.37 ± 0.13^{ab}	5.5	1.93 ± 0.03^{bc}	1.36 ± 0.03^{bc}	22.51 ± 0.85^{b}	1.36 ± 0.10^{d}
		0.5	0.56 ± 0.01^{b}	71.55 ± 0.06^{b}	6.0	1.90 ± 0.03^{b}	1.35 ± 0.04^{bc}	23.38 ± 0.74^{bc}	1.13 ± 0.07^{c}
		1.0	0.58 ± 0.02^{bc}	73.04 ± 0.03^{c}	7.0	1.86 ± 0.04^{ab}	1.34 ± 0.03^{bc}	27.30 ± 0.48d	0.68 ± 0.09^{a}
		1.5	0.60 ± 0.03^{bc}	73.80 ± 0.07^{cd}	7.0	1.80 ± 0.03^{a}	1.27 ± 0.02^{ab}	27.57 ± 0.35^{d}	0.62 ± 0.10^{a}
Normal cooked rice			-	73.04 ± 0.15^{c}	-	-	-	49.23 ± 0.49^{e}	0.87 ± 0.10^{b}

Values within a column with different letters are significantly different at *P*< 0.05 level.

Table 3: Textural properties of instant rice extruded from flour blend mixed with gum arabic at various levels

Gum Arabic (%)	Hardness (N)	Stickiness (N•s)	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N)	Rehydration Time (min)
0	27.30 ± 0.48^{a}	0.68 ± 0.09^{bc}	0.33 ± 0.10^{a}	0.34 ± 0.11^{ab}	6.69 ± 1.61^{a}	2.03 ± 0.52^{a}	7.00
2.0	27.75 ± 1.10^{a}	0.74 ± 0.03^{c}	0.44 ± 0.06^{b}	0.46 ± 0.02^{b}	14.15 ± 0.65^{b}	8.74 ± 0.72^{b}	7.00
4.0	28.36 ± 0.79^{a}	0.83 ± 0.04^{d}	0.63 ± 0.10^{bcd}	0.54 ± 0.02^{c}	21.20 ± 1.02^{c}	13.53 ± 1.28^{b}	8.00
6.0	28.60 ± 0.47^{a}	0.92 ± 0.03^{d}	0.71 ± 0.02^{d}	0.65 ± 0.04^{d}	27.99 ± 0.88^{d}	19.11 ± 1.08^{c}	8.50
Instant Rice (commercial)	70.45 ± 1.04^{c}	0.34 ± 0.01^{a}	0.62 ± 0.03^{c}	0.42 ± 0.02^{b}	29.59 ± 1.86^{d}	18.34 ± 2.10^{c}	7.00
Normal Cooked Rice	49.23 ± 0.49^{b}	0.87 ± 0.10^{cd}	0.72 ± 0.12^{cd}	0.64 ± 0.04^{d}	32.13 ± 2.34^{d}	23.12 ± 5.82^{cd}	-

Values within a column with different letters are significantly different at *P*< 0.05 level.

Table 4: Sensory evaluation of extruded instant rice obtained from the experiment compared to commercial brand and normal cooked rice

Sample	Appearance	Colour	Softness	Stickiness	Taste	Overall Preference
Extruded Instant Rice	5.91 ± 0.37^{bc}	5.98 ± 0.26^{b}	5.76 ± 0.19^{b}	6.42 ± 0.30^{ab}	6.34 ± 0.36^{b}	6.30 ± 0.33^{b}
Commercial Brand	6.62 ± 0.34^{b}	6.20 ± 0.34^{b}	5.23 ± 0.26^{c}	5.77 ± 0.33^{b}	6.28 ± 0.40^{b}	6.31 ± 0.30^{b}
Normal Cooked Rice	8.05 ± 0.30^{a}	7.31 ± 0.21^{a}	7.36 ± 0.32^{a}	7.01 ± 0.29^{a}	7.54 ± 0.35^{a}	7.61 ± 0.28^{a}

Values with the same letter in the same column are not significantly different at *P*< 0.05 level.

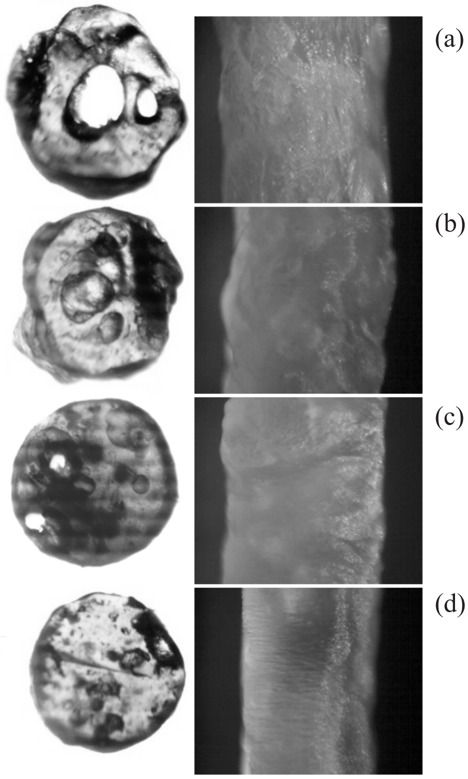

Figure 2: Cross section and surface appearance of extruded instant rice with the addition of monoglyceride at different levels (w/w) observed by optical stereomicroscope 15×: (a) 0%, (b) 0.5%, (c) 1.0%, (d) 1.5%.

3.4 *Microstructure and surface morphology*

Figure 2 shows the cross section and surface appearance of the extruded instant rice with the addition of monoglyceride at different concentrations.

4 Discussion

4.1 *Effects on bulk density, whiteness, and volume increase*

The bulk density of extruded instant rice varied between 0.49–0.62. Elastic force and dough viscosity will be dominant during extrusion at low moisture content and temperature [17]. Generally, increased moisture content in the melt extruded samples would soften the amylopectin molecular structure and reduce its elastic characteristics resulting in decreased volume expansion [18]. In addition, the rice blend was also extruded in zone 1, 2 and 3 at the barrel temperatures of 80, 90 and 130°C, respectively. However, the extrudate obtained from 130°C showed very high expansion with a rapid shrinkage at the die exit (data not shown). The instant rice obtained after rehydration was too soft and could not retain the shape.

The addition of the monoglyceride tended to increase the bulk density of the samples. When gelatinization increased, the expansion volume of extrudate increased and bulk density decreased [2], [19]. The degree of gelatinization was observed to be decreased with more emulsifier addition in instant rice extrusion [2]. The onset delay of the pasting of suspension of wheat, rice and other cereal starches by the addition of long-alkyl-chain (14–18 carbon atoms) monoglyceride were reported earlier [2], [4], [20]. The decrease in gelatinization with emulsifier addition might be due to the presence of hydrophobic group and hydrophilic group in the starch blend during extrusion resulted in the decrease of starch degradation [2], [4]. This result is in accordance with the use of glycerol monostearate in extruded instant rice product reported by Wang *et al*. [2].

Furthermore, Thachil *et al*. [21] reported that lower expansion of the extrudate was observed when lipid was added to the raw material for extrusion. The formation of amylose-lipid helical inclusion complexincrease during extrusion process could reduce the pore structure and increased the wall thickness leading to a denser samples [22]. The volume of extruded instant rice significantly decreased with increased monoglyceride content.

White colour is one of the important visual appeal of rice product. There was no significant effect of feed moisture content and barrel temperature on whiteness of the extruded product. However, the mixing of monoglyceride at 1.0 and 1.5% (w/w) tended to increase the whiteness of the extruded product from 71.17–71.63 to 73.46–73.96 probably due to the whitecolor of the monoglyceride.

4.2 *Effects on cooking properties*

Generally, products with lower bulk density tended to have lower rehydration time and hardness of cooked product, and higher rehydration ratio and volume increase. The instant rice with low bulk density indicated higher porous structure assisting water to be penetrated into the product in a relatively shorter time [4]. Comparing to our previous study [16], the instant rice prepared by traditional method indicated bulk density of 0.33-0.41 g/mL with 4.0–5.5 min of rehydration time and hardness at 21.17–46.13 N.

The hardness of cooked extruded instant rice was lower than the normal cooked rice.Native rice starch is not resistant to high temperature and high shear during extrusion leading to the breakdown of the starch granules and formation of dextrins and short chain polymers during processing resulting in stickiness [4]. The ability of monoglyceride to form water-insoluble which might form complexes with amylose, prevents leaching of amylose during gelatinization, inhibits swelling of starch granules in hot water, and reduces the water-binding capacity of starch, resulting in reduced stickiness [2], [4], [23]. The effects of feed moisture content and barrel temperature on product cooking quality were not significant in this study.

Gum arabic (2.0%) resulted in increasing the texture attributes such as springiness, cohesiveness, gumminess and chewiness of the extruded instant rice. However, the use of gum arabic at 4.0 and 6.0% resulted in rehydration time of instant rice higher than 7 min.

The extruded instant rice blend with 1.0% monoglyceride and 2.0% gum arabic showed sensory score comparable overall liking compared to the commercial product which was produced by the long and non-continuous conventional method. Wang *et al*. [2] reported that use of emulsifiers and thickeners such as gum arabic, sodium alginate, and sticky rice could provide extruded products with acceptable appearance and texture quality. Raina *et al*. [9] reported that pre-gelatinized broken rice flour with 1.5% gum arabic was suitable for pasta preparation with high quality on the basis of instrumental and sensory textural characteristics.

4.3 *Effect on microstructure and surface morphology*

The air bubbles and sponge-like structure of extruded rice were created with variable pore size and number by the rapid release of pressure, causing flash evaporation and expansion after exiting the die [24]. Extruded sample without Monomul 90-35P addition showed larger pore size than the monoglyceride added samples which may be due to the decreased gelatinization resulting in less expansion [2], [4], [19], [20] as described above.

5 Conclusions

Instant rice was prepared from rice flour and tapioca starch by extrusion with a single screw extruder. The effects of feed moisture content, barrel temperature and monoglyceride on physical and cooking properties of the instant rice products were investigated. Non-significant effects were observed since the range of feed moisture content and barrel temperature selected might be narrow. The increase of monoglyceride concentration tended to reduce gelatinization during the extrusion resulted in the decrease of product expansion. The rehydration time of the product without monoglyceride addition was only 5.5–6.0 min and the cooked instant rice was stick together. The addition of monoglyceride at 1.0% and gum arabic at 2.0% (w/w) could successfully improve the appearance of the cooked product with less stickiness and increase hardness and whiteness index. The product prepared by extrusion exhibited comparable sensory overall acceptance, with the commercial product prepared by the conventional method.

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