

Interaction of moisture content and fat content on puffing properties of expanded-product from native rice starch

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Abstract

Starch-based snacks and ready-to-eat breakfast cereal are commonly made in the form of puffed products. Puffed products are appreciated mainly for their lightness and crispness. One of the factors responsible for the qualities of puffed products is moisture and shortening content. This research aims to investigate the effects of moisture content and shortening content on pellet microstructure and puffing qualities. The rice starch mixture with amylose content (AC) of 5.05% was prepared by mixing native waxy and non-waxy rice starches. Starch pastes were cooked and aged at 4°C for 24 h. The aged slabs were dried. Deep-frying was then used for puffing. The pellet with 15% moisture content provided the maximum expansion. There was the interaction between moisture content and fat content on the expansion ratio and overall characteristic of puffed product. From Scanning Electron Microscope, starch pellet had cavities separated by very thin wall. Cavity size of expanded puffed product decreased as moisture and fat increased. From sensory evaluation of puffed product, increasing moisture and fat and their interaction caused in an acceptance of product crispness and puffiness.

Keywords: Puffed product, crispness, rice starch, moisture content, fat content

1. Introduction

Starch-based snacks and ready-to-eat breakfast cereal continue to increase in sales worldwide. Starch-based snacks are commonly made in the form of puffed products. Puffed products are appreciated mainly for their lightness and crispness. These qualities are related to the air cellular structure and degree of expansion. Puffed products can be made either by conventional method or extrusion. Puffed product can be made from starch sources having low or intermediate amylose content. In Thailand, rice is the most important cereal. Two varieties of Thai rice with different in amylose content will be used in this study. Crispness, the most important quality attribute of puffed product, relates directly to percentage (or ratio) of expansion (Siaw *et al.*, 1985; Kyaw *et al.*, 2001).

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It was reported that linear expansion was 300–400%, 120–190%, 100–115%, and 50–70% when waxy corn, cassava, wheat, and sago starches were used, respectively (Boischot *et al.*, 2003; Cheow *et al.*, 2004; Tongdang *et al.*, 2008; Saeleaw and Schleining, 2010). This indicated that linear expansion decreased as amylose content increased. For popular rice crackers in East Asia, such as yukwa, arare and okaki, waxy rice flour (<3% amylose content) is normally used to obtain linear expansion of 250–300 % (Lu and Lin, 2001; Cho *et al.*, 2003). However, rice flour of medium amylose content (15–18%) can be used (Villareal *et al.*, 1987; Chen and Yeh, 2001; Lu and Lin, 2001).

Effect of protein and lipid contents on puffed product properties is concerned when flour is used. Heating flour causes denaturation of protein and formation of protein-amylose, protein-protein, protein-lipid and lipid-protein-amylose complexes leading to an increase in the strength of micelle binding of starch, decrease in water hydrating and starch solubility, and inhibition of granule swelling (Ilo *et al.*, 2000; Hagenimana *et al.*, 2006; Ibanez *et al.*, 2007; Chaisiricharoenkul *et al.*, 2011; Saeleaw and Schleining, 2011). Anyhow, protein-amylose complex was also reported obstructing junction zone formation of amylose network affecting the gel firmness (Ibanez *et al.*, 2007). It was found that protein-protein network, forming during heating flour, was stronger than starch network (Suknark *et al.*, 1997). Therefore, the expansion ratio decreased as protein and lipid contents in the flour increased (Suknark *et al.*, 1997; Ibanez *et al.*, 2007). Waxy rice gives higher expansion ratio than normal rice (Villareal *et al.*, 1987; Lai and Cheng, 2004). For starch suspension (5 g of starches per 180 g water), starch granules were almost completely swollen after cooking at 120°C for 1 h (Noranizan *et al.*, 2010). A stable expanded structure of starch granules imparts crispiness to puffed products (Kyaw *et al.*, 2001). Gomez and Aquilera (1984) found that only fully gelatinized granules gave a stable expanded structure. Prior to puffing, starch gel will be dried yielding a stronger gel. The effects of water content on expansion can be related to the mechanical properties of gel. For pellets of rice flour, a maximum expansion ratio was obtained at a moisture content of 10% (Chen and Yeh, 2001; Ernoult *et al.*, 2002; Boischot *et al.*, 2003). At higher moisture content, the pellets were weak and soft resulting in low expansion ratio. While at lower moisture content, the pellets were brittle and hard, therefore, they were difficult to expand (van Soest *et al.*, 1996; Chen and Yeh, 2001; Vanduputte *et al.*, 2003 a;b).

From the information reviewed above, most of the researches have been revolved about effects of ingredients and/or process parameters on puffed product characteristics. One of the factors responsible for the qualities of puffed products is moisture content of pellet and shortening. For this research, it is hypothesized that moisture content and shortening affect puffed product characteristics. Therefore, this research aims to investigate the effects of

moisture content and shortening on puffing qualities. The obtained information can be used for designing starch-based puffed products having specific texture.

2. Materials and Methods

2.1 Starch isolation

Native colored waxy rice and non-waxy rice (Royal Umbrella Branding, Ayutthaya, Thailand) were washed twice and wet milled with a stone mill (Jiamjariyatam *et al.*, 2015). Starch mixtures were made by mixing waxy and non-waxy starch in ratios with non-waxy and waxy starch of 50:50. The starch was sieved through a 200-mesh screen, packed in aluminum foil bags and stored at $4\pm1^{\circ}\text{C}$.

2.2 Amylose content determination

Amylose content was determined using iodimetrically by amperometric titration (Jiamjariyatam *et al.*, 2015). The mixture of rice starch was determined to obtain amylose content of 5.05%.

2.3 Pellet preparation

Starch paste was prepared by pouring the starch solution in the hot water ($95\pm2^{\circ}\text{C}$) to obtain a starch concentration of 30% (w/w db) and cooked at $110\pm1^{\circ}\text{C}$ for 20 min in the closed system equipped with hand mixer (BUO-153263, Buono, Germany) for continuous stirring (Jiamjariyatam *et al.*, 2015). The 5 levels of shortening (fat) of 10, 20, 30, 40, and 50% by weight were added in the starch paste. The temperature of starch paste was determined and found to be $40\pm3^{\circ}\text{C}$ after spreading. Then, starch paste was cooled to 4°C and aged at 4°C for 24 h. The moisture content of starch paste was determined. The starch paste was dried by hot air oven at 60°C for 9, 12, 15, and 18 h to obtain 4 levels of moisture content of starch pellet; 25, 20, 15, and 10%. The experimental design of 5×4 factorials in CRD was used. The effect of two factors (fat and moisture content) on puffing properties were investigated by varying the 5 levels of fat (10–50%) and 4 levels of moisture content (10–25%).

2.4 Pellet properties determination

The starch pellet microstructure was studied using a scanning electron microscope (SEM). Prior to SEM study, starch pellet was cut to size 10×10 mm, and kept in a dessicator until further use.

2.5 Puffing

The starch pellets were fried in hot ($210\pm1^{\circ}\text{C}$) palm oil for 50 s to obtain puffed product.

2.6 Puffing properties determination

The thickness of puffed product before and after frying was determined by a vernia caliper in ten replicates, and expansion ratio was calculated (Jiamjariyatam *et al.*, 2015). The puffing qualities in term of expansion ratio and air cell structure will be determined.

2.7 Sensory properties of puffed products

Sensory analysis was conducted by 50 panelists. The terms of sensory attributes (crispness and puffiness) was scored by using the 7-point hedonic scale.

2.8 Statistical analysis

Experimental design in this research was a Completely Randomized Design (CRD). The main effect was moisture content of pellet and quantity of shortening. In this study, five levels of moisture content and four levels of shortening were used. All treatments were duplicates. Data was statistically analyzed using the analysis of variance (ANOVA) test and sample difference was analyzed by Duncan's Multiple Range Test at 95% confidence level. Response Surface Methodology (RSM) was used to illustrate effects and interactions among factors on puffing qualities.

3. Results and Discussion

3.1 Effect of moisture content and shortening on pellet microstructure

Rice starch pellet made of different levels of moisture and shortening content. The characteristic of dried starch pellet from Scanning Electron Microscope (SEM) were illustrated in Figure 1. All samples had no differences in pore size and shape of air cell and starch network denseness. There was the interaction between moisture content and shortening content. The samples that contained 10% fat content had a coarse structure with large cell size distribution. The shape of the cells was very irregular and the cell walls were thick. Moreover, pellet samples containing more than 30% fat content had more compactness of air cell that seemed to be no porosity and not difference in air cell/porosity of starch pellet. This research thus concluded that starch pellet with upper 30% fat content were not significant difference in appearance characteristic. However, the puffed product characteristic could relate to the starch structure especially in expansion or puffiness of final product.

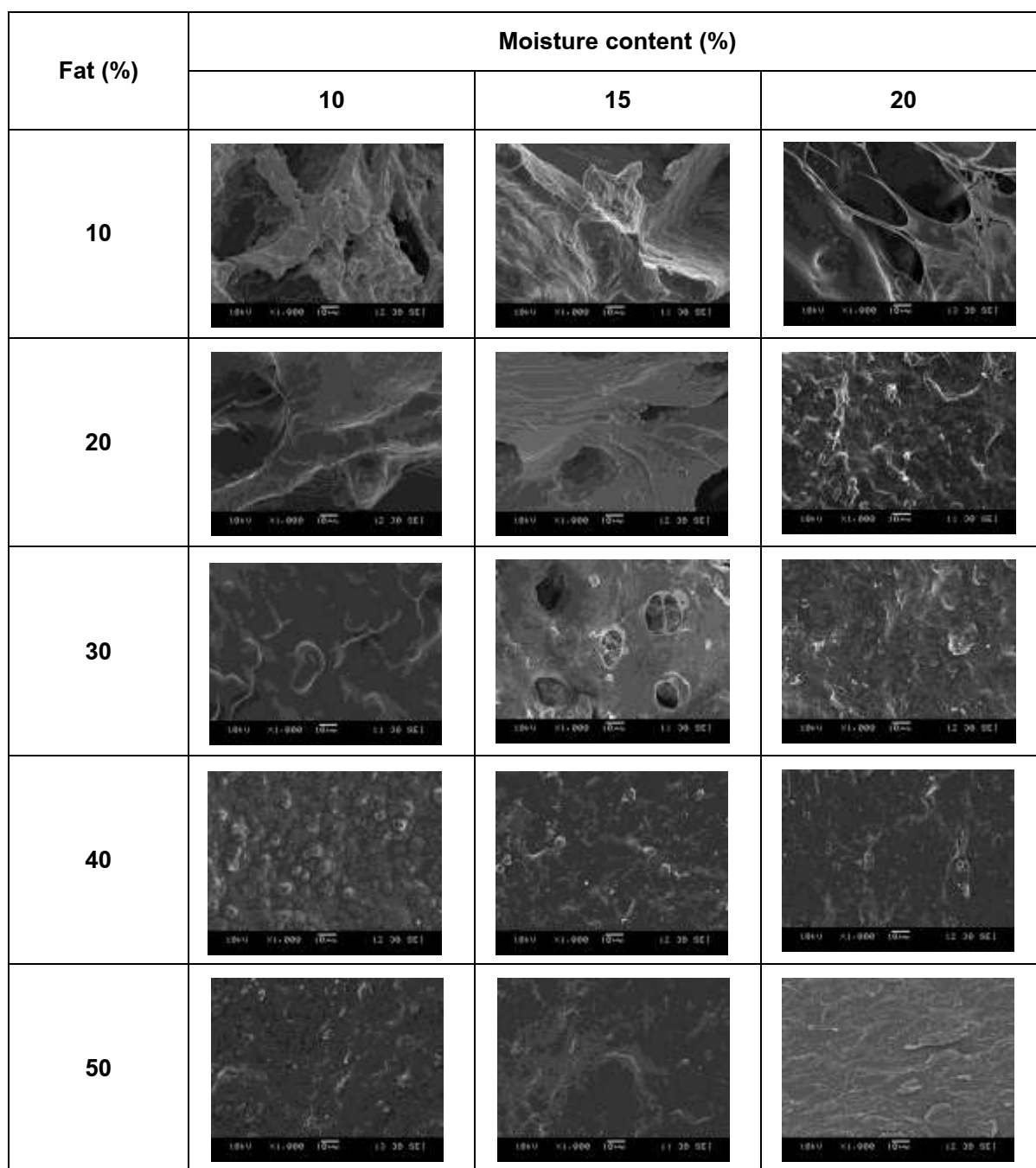


Figure 1 Comparative microscopy cellular structure from Scanning Electron Microscope (SEM) of starch pellet obtained from different moisture content and fat

3.2 Effect of different moisture content and shortening on puffed product properties

Moisture content plays a critical role in cereal expansion due to its ability to generate the driving force during the flash off process and also through its impact on the extensional viscosity and phase transitions of the food polymer matrix (Ernoult *et al.*, 2002). Higher degree of expansion was observed for the pellets with higher moisture content (Figure 2). The effect of moisture on expansion can be related to the mechanical properties of the matrix.

A pellet expands easier if its mechanical resistance is low, which is the case at high moisture content (Ernoul *et al.*, 2002). The expansion of pellets with high moisture content resulted in expanded products with a coarse structure, small number of big cells, and thick cell walls. For all samples, a much finer structure was obtained in the expanded pellets. These structural details can be observed by light microscope (40x) in Figure 2. The porosity and characteristic of all expanded-product was not different except the samples that used fat content at 50% and contained moisture content of 15%. The denseness of air cell/starch was observed in samples that used fat content at 50% and contained moisture content of 15%. This may affect the expanded-product used 15% moisture content provided the highest expansion. According to figure 3, there was a maximum expansion at a moisture content of 15%. The expansion ratio decreased dramatically when the moisture was raised from 15 to 25%. This was due to the starch pellets were too weak and soft with low elongation as the moisture increased. In other words, the pellets were not completely elastic but acted more like stiff gel-like materials (Chen and Yeh, 2001). It was difficult to expand, which resulted in low expansion ratio. The expansion ratio did not drop too much when the moisture content was further increased from 15 to 25%. On the other hand, the pellets became brittle and hard to expand as the moisture content was reduced from 15 to 10% (Chen and Yeh, 2001).

Similar patterns of expansion and moisture loss were observed for the amylopectin pellets that contained solid fat. The increased moisture release in the pellets that contained solid fat contributed to enhanced expansion. The addition of 10–40% fat resulted in a maximum expansion ratio. At 50% fat, expansion was lower than at every level due to the collapse of the expanded structure (Ernoul *et al.*, 2002). Fat also influenced the structure of the expanded products. The significant increase in expansion due to the addition of fat can be seen in Figure 2 and 3. At 15% moisture content, the addition of 10% fat resulted in a maximum expansion ratio. At 50% fat, expansion was lower than at 40% fat due to the collapse of the expanded structure. These results were confirmed by microscopic analysis of the samples. Figure 1 and 2 show microstructures of expanded samples obtained from pellets with different initial moisture content and fat content. This results was different from the previous studies. The pellets of rice flour with 10% moisture content gave a maximum expansion ratio (Chen and Yeh, 2001; Ernoul *et al.*, 2002; Boischot *et al.*, 2003). The response surface was illustrate the interaction between moisture content and fat content for the expansion ratio in Figure 3. The maximum expansion ratio was obtained from pellet that used fat content at 10–50% and contained moisture content of 13–17%. This fat and moisture level gave the high expansion ratio about 2.96. In contrast, the use of high moisture content at

25% gave a low expansion ratio about 2.16. Therefore, the optimum of moisture content was about 13–17% combined with fat content at less than 50%.

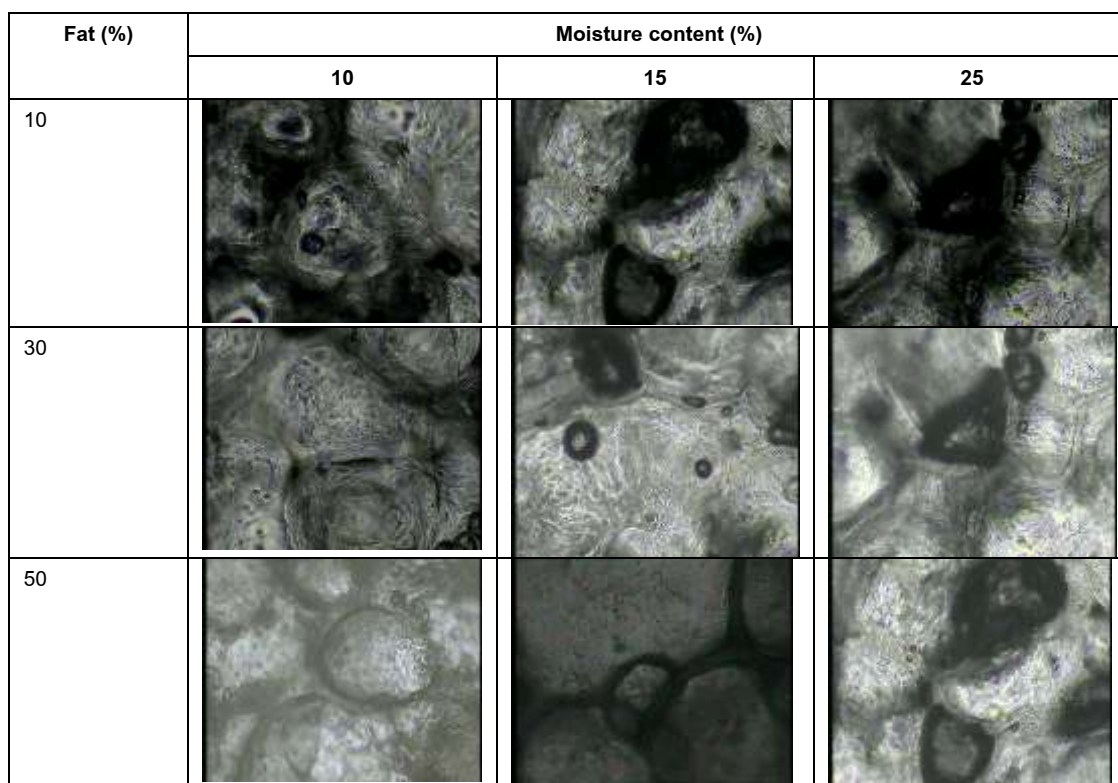


Figure 2 Comparative microscopy cellular structure from Light Microscope (40x) of puffed product obtained from different moisture content and fat

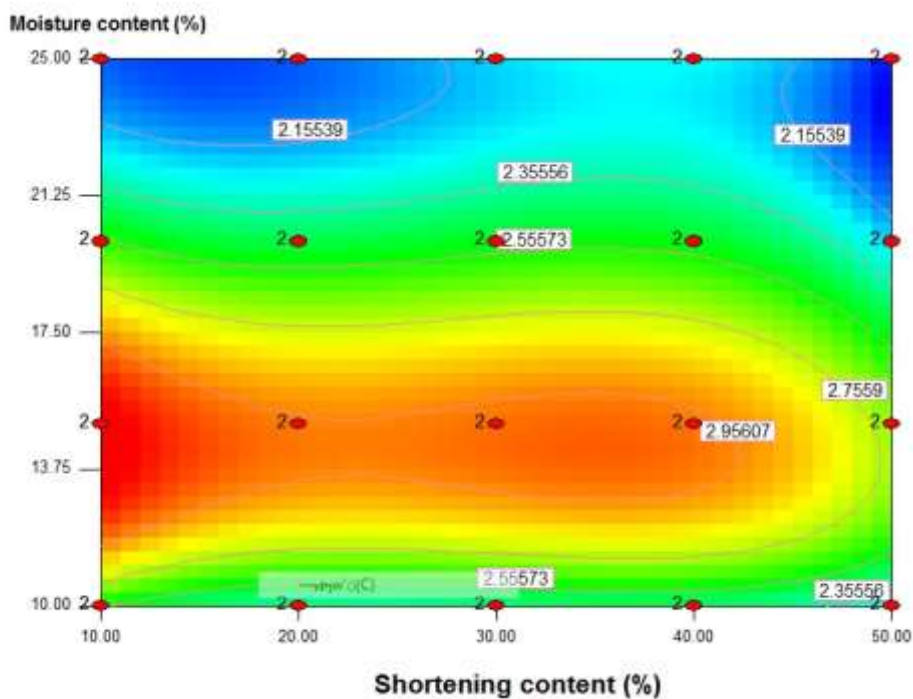


Figure 3 Expansion ratio of puffed product affected by different moisture content and fat

3.3 Effect of different moisture content and fat on acceptance

The sensory analysis resulted in the liking of crispness and puffiness puffed product samples. Puffed product likeness for the crispness attributes decreased significantly by increasing shortening. This was due to fat caused oiliness in mouth. Therefore, the perception of panelist detected the sample had low crispness. However, 20% of moisture content and 10–30% fat gave the highest liking score in a term of crispness of puffed product. For the liking score of puffiness, the highest score was found in samples obtained from 20% of moisture content and 10% fat. The lowest score found from sample with 10% moisture content and 50% shortening.

Table 2 Crispness liking score of puffed product

Shortening (%)	Crispness Liking Score			
	10% MC	15% MC	20% MC	25% MC
10	5.57 ±0.01 g	5.56 ±0.06 g	6.85 ±0.04 ab	6.66 ±0.13 bc
20	5.46 ±0.14 gh	6.58 ±0.09 cd	6.84 ±0.01 ab	6.89 ±0.01 ab
30	5.43 ±0.18 gh	6.21 ±0.02 ef	6.93 ±0.06 a	6.30± 0.19 ef
40	5.37 ±0.03 gh	6.07 ±0.003 f	6.79 ±0.15 abc	6.36 ±0.13 de
50	5.27 ±0.18 h	6.74 ±0.03 abc	6.28 ±0.16 ef	6.28 ±0.10 ef

Note: The different letter means significantly difference ($p \leq 0.05$)

Table 3 Puffiness liking score of puffed product

Shortening (%)	Puffiness Liking Score			
	10% MC	15% MC	20% MC	25% MC
10	5.33 ±0.15 e	5.35 ±0.01 e	6.99 ±0.33 a	5.30 ±0.25 e
20	6.34 ±0.32 abcd	5.56 ±1.41 cde	5.82 ±0.39 bcde	5.89 ±0.02 abcde
30	6.50 ±0.24 abc	6.38 ±0.08 abcd	6.44 ±0.15 abcd	5.54 ±0.31 de
40	6.61 ±0.37 ab	6.29± 0.37 abcd	6.60 ±0.23 ab	6.22 ±0.14 abcde
50	4.40 ±0.08 f	6.33 ±0.16 abcd	5.34 ±0.15 e	6.82 ±0.08 a

Note: The different letter means significantly difference ($p \leq 0.05$)

4. Conclusion

Moisture content and shortening content affected the pellet microstructure and puffing qualities. The expansion ratio of puffed product was highest in sample with 15% moisture content. However, the pore size of puffed product decreased as moisture and fat increased.

At 20% moisture content, the 30% shortening caused the highest score of crispness liking while the 10% shortening provided the highest score of puffiness liking.

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