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Development of gluten-free cream puff with the addition of carboxymethylcellulose and carrageenan

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Abstract

The consumption of gluten-free products is gaining attention since a growing number of people who suffer from celiac disease. However, many gluten-free products currently available in market are of low quality. The objective of this study was to evaluate the effect of the addition of carboxymethylcellulose and carrageenan on physical properties and sensory characteristics of cream puff made with 100% red brown jasmine rice flour. Cream puffs using 1% hydrocolloid at different concentrations of CMC mixed with carrageenan (0.25%+0.75%, 0.50%+0.50%, and 0.75%+0.25%) were developed and compared to a control sample prepared from wheat flour. The results showed that the use of rice flour reduced the effects of all physical properties and sensory characteristics. Compared to control, cream puff made with rice flour had a lower specific volume and darker. However, the incorporation of 0.50% CMC mixed with 0.50% carrageenan presented quality attributes similar to that of the control sample due to hydrocolloids act as polymeric substances that should mimic the viscoelastic of gluten. Therefore, it is feasible for gluten-free cream puff application.

1. Introduction

Among cereals, wheat has specific proteins that make it ideal for certain applications. The unique properties of wheat are generally ascribed to the visco-elastic properties of its gluten proteins. While monomeric gluten proteins (gliadin) show viscous behavior, polymeric gluten proteins (glutenin) are elastic (Veraverbeke and Delcour, 2002). Thus, wheat gliadins and glutenins, in the presence of water and mechanical work, form a continuous phase named gluten network. It is responsible for the extensible and cohesive properties of the dough while reducing its stickiness. Wheat dough is characterized for its tenacity, dough resistance to stretching and elasticity, dough ability to regain its original shape after being stretched. The unique elasticity of glutenin results to a large extent from its polymeric nature. Glutenin is a highly heterogeneous mixture of polymers consisting of a number of different high- and low-molecular-weight glutenin subunits linked by disulfide bonds (Veraverbeke and Delcour, 2002; Gómez and Sciarini, 2015). A variety of cereal foods are produced from wheat flour, such as bread, cake and pasta, all of which, contain gluten. However, many people suffer from gluten-related disorders. Celiac disease, also known as gluten intolerance to certain amino acid sequences found in the prolamin fraction of wheat (gliadin), rye (secalin) and barley (hordein) (Itthivadhanapong *et al*., 2016). Gluten replacement is one of the most challenging issues for food science and technology since finding high-quality gluten-free foods is a major issue for celiac disease sufferers (Turabi *et al.*, 2010; Itthivadhanapong *et al*., 2016). Among gluten-free raw materials that can be used for this purpose, the most important ones are cereal flours without gluten, as well as native starches. Rice flour is one of the most suitable raw materials due to its hypoallergenic properties, low sodium content, bland taste, and its easy availability in the market (Torbica *et al*., 2012). Nowadays, the consumption of pigmented rice such as brown, red, purple or black pericarp has gain attention in some Asian countries (Jeng *et al*., 2012). Pigmented rice is also known as a source of antioxidant compounds including flavonoid, anthocyanin, phytic acid, proanthocyanidin, tocopherols, tocotrienols, γ-oryzanol, and phenolic

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compounds (Butsat and Siriamornpun, 2010; Goufo and Trindade, 2014; Thitipramote *et al*., 2016). Thitipramote *et al*. (2016) reported that two native Thai pigmented rice (Brown red jasmine rice and Kam leumpua; black rice) compose of the higher phenolic compounds and greater antioxidant activities than Japanese brown rice. The greatest amount of these compounds and activities was found in red rice (Brown red jasmine rice). The phytochemical in pigmented rice, such as phenolics and anthocyanins are related with reducing the risk of developing chronic diseases, such as diabetes, obesity, cancer, and cardiovascular disease (Mau *et al*., 2017). Some bakery products have been studied on the use of rice flour as a replacement for wheat flour, such as rice flour cake containing lupin flour and whole buckwheat flour (Levent and Bilgiçli, 2011); chiffon cake prepared with black rice (Mau *et al*, 2017); yellow cake prepared from rice flour and peanut paste (Jaganathan, 2016), and white bread made from rice flour mixed with cornstarch and cassava starch (López *et al*., 2004). However, the use of rice flour to prepare cream puff has not been exploring yet. Thus, it would be beneficial to develop a novel formula for cream puff made from red jasmine rice. The replacement of gluten presents a major technological challenge, as it is an essential structure-building protein. To tackle this problem, hydrocolloids were incorporated in gluten-free flour to mimic the viscoelastic properties of gluten (Lazaridou *et al*., 2007; Pahwa *et al*., 2016). The addition of hydrocolloids in gluten-free formulation products is necessary in order for the hydrocolloids to act as polymeric substances that should mimic the viscoelastic properties of gluten and increase the dough's gas-retaining ability (Sabanis and Tzia, 2011). The hydrocolloid reduced the availability of water for granule swelling. The increased viscosity thereby increased the shear forces exerted on the swollen granules, thus increasing the breakdown viscosity. Associations between starch polymer molecules and hydrocolloid molecules could be responsible for the increase in the setback and final viscosity. Hydrocolloid molecules bound water reduced the mobility of the starch chains and thereby retard retrogradation (Satrapai and Suphantharika, 2007). Therefore, the purpose of this study was to develop gluten-free cream puff with the addition of hydrocolloids including carboxymethylcellulose and carrageenan.

2. Materials and methods

2.1 Materials

Commercial red brown jasmine rice was purchased from the local market in Phrae province, Thailand (Kaijae brand, Thailand). All-purpose wheat flour (Kite brand, UFM Food Center Co., Ltd, Thailand), cake flour (Red Lotus brand, UFM Food Center Co., Ltd, Thailand), butter (Allowri brand), margarine (Best Foods, Thailand) and fresh whole eggs (~50 g/piece) were used in this study, carboxymethylcellulose (CMC) and carrageenan were purchased from Union Science Co., Ltd. Thailand.

Red jasmine rice was ground using blender (Model HR 2115, Philips, Indonesia), and screened through a 150-mesh sieve five times. The rice powder was contained in an airtight box and then kept at room temperature (~25°C) before use.

2.2 Analysis of chemical composition of wheat flour and rice flour

Moisture content (oven at 105°C), Ash content (muffle furnace at 550-600°C), lipids (Soxhlet method), proteins (Kjeldahl method) and fiber were evaluated according to the official methods of the AOAC (2012). Total carbohydrates were calculated following equation (1).

$$\text{Total Carbohydrates} = 100 - [\text{weight in grams (moisture + ash + lipid + protein)}] \text{in 100 g of food} \quad (1)$$

2.3 Preparation of cream puff

The basic cream puff recipe was chosen according to our preliminary study. The control cream puff formulation contained the following ingredients: 120 g all-purpose wheat flour, 120 cake flour, 480 g water, 75 g butter, 75 g margarine and 350 g fresh whole egg. For red jasmine rice flour cream puff, 100% rice flour (240 g rice flour) was used to substitute wheat flour. CMC and carrageenan were added in 1% of flour basis. Cream puffs using 1% hydrocolloid at different concentrations of CMC mixed with carrageenan (0.25%+0.75%, 0.50% +0.50%, and 0.75%+0.25%). The cream puffs made from rice flour without hydrocolloid were also prepared. The cream puffs were manufactured using the following steps: flour was sieved through a 150-mesh sifter. Butter and margarine were then mixed in boiled water and stirred vigorously over low heat until mixture left the pan. The mixture was removed from heat and let it cool for 5 mins. Hydrocolloid was dissolved in cold water and blended with the mixture. Eggs were beaten with the mixture until smooth and velvety. The mixture was dropped onto a baking tray and baked in preheated oven 200°C for 20 mins. Cream puff was removed from the oven, cooled for 1 hr and kept in an airtight box and put in freezer at 8°C until analysis.

2.4 Physical characteristics of batters

The viscosity of batter was performed with a viscometer (RVT, Brookfield viscometer, USA). The 400 mL of cream puff batter was poured into a 500 mL beaker and its viscosity was measured. The specific gravity of batter was determined by dividing the weight of a standard container filled with batter by the same container filled with water (Lu *et al*., 2010). Each analysis was carried out in triplicates.

2.5 Physical characteristics of cream puffs

The physical characteristics of cream puff, including specific volume, color, weight loss and moisture content. The specific volume ($mL.g^{-1}$) of the cream puff batter was obtained by the ratio between the apparent volume (mL) and the cream puff mass (g) after baking. The mass was obtained by weighing the cream puff on a precision scale (Ohaus, Pioneer PA214, USA). The apparent volume of the cream puff was determined by the method of displacement of sesame seeds (Mau *et al*., 2017). The color of the cream puffs was measured using a colorimeter (Color Flex 500, Hunter Lab, USA). Results were expressed in CIE L* a* and b* values. The cream puffs were weighted before baking (W_0) and after baking and 1-hour cooling (W_1). The weight loss was calculated using equation (2) (Matos *et al*., 2014). Moisture content was measured according to the official methods of the AOAC (2012).

$$\text{Weight loss (\%)} = \frac{(W_0 - W_1) \times 100}{W_0} \quad (2)$$

2.6 Sensory evaluation

The degree of overall preference for baked cream puffs was determined by hedonic scale test (Mau *et al*., 2017). The untrained panelists were recruited from the students and staff at Maejo University-Phrae Campus. All untrained panelists were informed on how to evaluate cream puff. The 50 panelists received 5 samples and were asked to rate them based on the degree of preference on a 7-point hedonic scale (1 = dislike extremely, 4 = neither like nor dislike, and 7 = like extremely). Panelists evaluated the samples in a testing area and were instructed to rinse their mouths with water between samples to minimize any residual effect.

2.7 Statistical analysis

Data were subjected to Analysis of Variance (ANOVA) using SPSS for Window version 24. In case of any differences in mean, multiple comparisons were performed using Duncan's Multiple Range Test (DMRT) at 5 % level of significance ($P \leq 0.05$).

3. Results and discussion

3.1 Chemical composition of raw materials

The results for the chemical composition of the wheat flours and red jasmine rice flour are presented in Table 1. The composition of all-purpose flour on a wet basis was 11.73% moisture, 0.49% ash, 0.77% fat, 7.68% protein, and 79.34% carbohydrates. The similar composition was found in cake flour, but lower in protein content with 7.08% then resulting higher of carbohydrates. Meanwhile, the composition of rice flour was 10.49% moisture, 0.49% ash, 1.88% fat, 6.16% protein, and 80.98% carbohydrates.

The results indicated that rice flour had lower in protein content compared to wheat flour (all-purpose and cake flour) but higher in lipid and fiber. The results showed different composition with previous work carried out by Vallejos *et al.* (2015). They reported the chemical composition of the rice flour on a dry basis was 7.52% protein, 0.41% fat, 0.31% ash, and 91.76% carbohydrates. This may be related to this recent study reported on a wet basis.

3.2 Physical characteristics of batters

The foremost reason behind the ample use of hydrocolloids in food is their ability to modify the rheology of the food system, namely flow behavior (viscosity) (Saha and Bhattacharya, 2010). The effect of the addition of hydrocolloids on physical characteristics of the batters after complete substitution of the wheat flour by red jasmine rice flour is presented in Table 2.

Table 2. Physical characteristics of cream puff batter

Batter samples	Viscosity (cP)^{ns}	Specific gravity
Wheat flour	20,000±0	1.10±0.05^a
Rice flour (CMC: carrageenan)		
0:0	18,533±461	0.89±0.02^c
0.25:0.75	19,266±702	1.07±0.01^a
0.50:0.50	19,667±577	1.08±0.01^a
0.75:0.25	20,000±0	1.04±0.00^b

*Values followed by the different letter within the same column are significantly different from each other ($p \leq 0.05$).
** Values followed by ns within the same column are not significantly different from each other ($p > 0.05$).

Table 1. Chemical composition of wheat flour and rice flour

Samples	Chemical compositions (%)					
	Moisture ^{ns}	Ash ^{ns}	Lipid	Protein	Fiber	Carbohydrates
All-purpose flour	11.73±0.52	0.49±0.01	0.77±0.01^b	7.68±0.01^a	0.71±0.15^b	79.34±0.01^b
Cake flour	11.74±0.80	0.49±0.00	0.77±0.00^b	7.08±0.00^a	0.56±0.11^b	79.92±0.00^b
Rice flour	10.49±0.48	0.49±0.01	1.88±0.42^a	6.16±0.42^b	2.08±0.21^a	80.98±0.42^a

*Values followed by the different letter within the same column are significantly different from each other ($p \leq 0.05$).
** Values followed by ns within the same column are not significantly different from each other ($p > 0.05$).

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The specific gravity of batters estimates the air incorporated into a batter, a lower specific gravity indicates of a batter with more air and viscosity. All batter had a specific gravity higher than 0.75 indicating a stable emulsion (Lin *et al*., 1994; Singh, 2012). The viscosity of all cream puff batter did not differ significantly with replacing rice flour instead of wheat flour. The similar result was found by Mau *et al.* (2017) who used black rice flour as a replacement for wheat flour in chiffon cake. However, the viscosity of batter prepared from rice flour increased slightly with the addition of hydrocolloids, especially the increase of CMC ratio. Sidhu and Bawa (2000) reported that CMC involve its interaction with water. Carboxymethylcellulose interacts with protein molecules to provide suspension and solution stability. They found that the increase of CMC affected the increase of water absorption in bread batter. A decrease in the specific volume of batters was observed with the substitution of the wheat flour by red jasmine rice flour. This could be related the higher in lipid content as shown in Table 1 then resulting in lower specific gravity.

3.3 Physical characteristics of cream puffs

The effect of the addition of hydrocolloids on physical characteristics of cream puffs was investigated. The results are presented in Table 3.

From Table 3, the specific volume, weight loss, moisture and color of rice flour cream puff differed significantly compared to wheat flour cream puff. The cream puff prepared from wheat flour showed higher specific volume. This is related to higher weight loss then resulting in lower moisture content and resulting thin crust as shown in Figure 1. Cream puff structure setting must be timed so that the air bubble can properly be expanded by water vapor before it sets. Thus, the resulting puff structure is highly aerated and has a more defined structure. In this study, there was no difference among viscosity of all formula puff batter. However, the gluten of batter decreased when wheat flour was replaced with rice flour, and thus, the ability to retain air was poorer which produced the undesirable aerated structure with lower volume (Mau *et al*., 2017). Basically, the addition of hydrocolloids in gluten-free formulation products is necessary in order to act as polymeric substances that can mimic the viscoelastic properties of gluten and increase the dough's gas-retaining ability (Sabanis and Tzia, 2011). However, this recent study demonstrated that the addition of hydrocolloids did not increase the dough's gas-retaining ability but increase water absorption. It can be seen from higher moisture content in the final product. From Table 3, the result summarized that rice flour puff without the addition of hydrocolloid provided better physical characteristics than the addition of hydrocolloids. However, this study found that the rice puff's structure without the addition of hydrocolloid had weak crust structure during storage.

The Hunter, L*, a* and b*, values correspond to lightness, redness, and yellowness, respectively. The crust color of baked puff was greatly affected by replacing wheat flour with rice flour as shown in Table 3. The L* and b* values decrease but a* value increased, indicating that a darker, redder, and less yellow was obtained as a result of red jasmine rice replacement. The colors of pigmented rice as red jasmine rice attributes to anthocyanins and proanthocyanin which present the red or purple color (Min *et al*., 2011).

3.4 Sensory characteristics

Sensory characteristics were tested to evaluate acceptance by the consumer as shown in Table 4.

From Table 4, wheat flour cream puff demonstrated appearance, color, flavor, taste, texture and overall acceptance scores of 5.76, 6.10, 5.40, 4.68, 5.42 and 5.04, respectively. Meanwhile, rice flour cream puff showed appearance, color, flavor, taste, texture and overall acceptance scores in the range of 4.98-5.04, 5.24-5.46, 4.64-4.92, 4.00-4.36, 4.58-5.02 and 4.34-4.54, respectively. Although the substitution of wheat flour with red jasmine rice flour led to significantly decreased sensory characteristics the decrease of the score for all characteristics was less than 1 scale. In addition, all sensory characteristics of rice cream puff had scored higher than 4. This means that panelists accepted cream puff made from rice flour. When compared between baked rice flour cream puff, there was no difference among the appearance, color, flavor and overall acceptance score for all cream puff. However, the taste score of rice flour cream puff adding CMC: carrageenan with 0.50:0.50 did not differ significantly compared to wheat flour cream puff. Moreover, rice flour cream puff adding CMC: carrageenan with 0.50:0.50 had the highest score of color, flavor, taste and texture compared to other rice flour cream puff. In addition, it provided the highest specific volume as shown in Table 3. Therefore, the optimum red jasmine rice flour cream puff was the addition of CMC: carrageenan with 0.50:0.50.

4. Conclusion

The addition of hydrocolloids significantly affected some characteristics of rice flour cream puff. The ratio CMC: carrageenan with 0.50:0.50 increased cream puff's specific volume and had highest sensory score. The sensory qualities of each characteristic were 4.38-5.46 on a 7-point hedonic scale, indicated that the cream puff was moderately acceptable. Therefore, red jasmine rice

Table 3. Physical characteristics of baked cream puffs

Cream puff samples	Specific volume ($mL.g^{-1}$)	Weight loss (%)	Moisture (%)	Color		
				L*	a*	b*
Wheat flour	5.11±0.19^a	26.16±1.78^a	8.08±0.30^a	58.82±0.29^a	4.56±0.11^e	39.60±0.12^a
Rice flour (CMC: carrageenan)						
0:0	4.41±0.28^b	22.45±2.32^b	8.25±0.51^b	38.91±0.32^d	8.04±0.42^c	30.27±0.39^d
0.25:0.75	2.55±0.14^d	21.19±2.82^c	8.95±0.22^b	46.48±0.20^b	7.64±0.11^d	29.37±0.19^e
0.50:0.50	3.33±0.24^c	21.32±2.49^c	8.92±0.09^b	45.73±0.03^c	9.49±0.12^b	35.52±0.49^b
0.75:0.25	3.31±0.27^c	21.15±2.39^c	8.75±0.31^b	38.91±0.32^d	10.04±0.33^a	34.09±0.71^c

*Values followed by the different letter within the same column are significantly different from each other ($p \leq 0.05$).

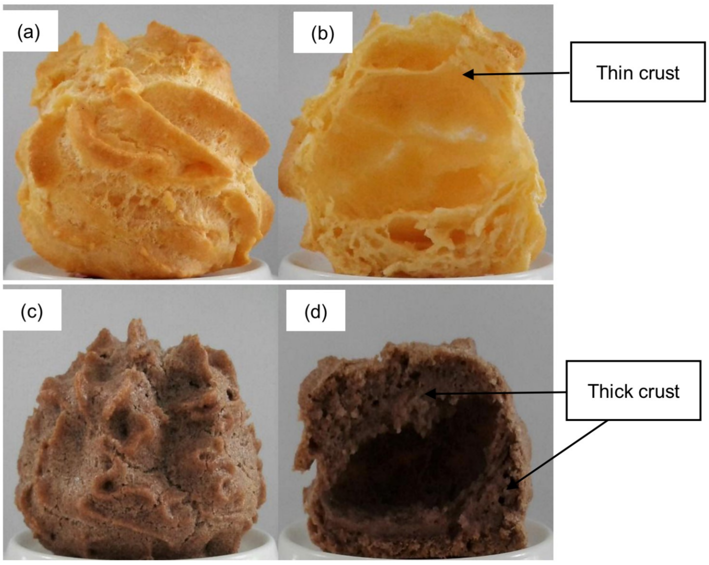

Figure 1. Photograph of cream puffs (a) wheat flour cream puff; (b) wheat flour cream puff crust; (c) rice flour cream puff without hydrocolloid; (d) rice flour cream puff crust without hydrocolloid

Table 4. Sensory characteristics of baked cream puff

Cream puff samples	Appearance	Color	Flavor	Taste	Texture	Overall Acceptance
Wheat flour	5.76±1.06^a	6.10±0.91^a	5.40±1.40^a	4.68±1.74^a	5.42±1.34^a	5.04±1.48^a
Rice flour (CMC: carrageenan)						
0:0	5.04±1.24^b	5.44±1.05^b	4.64±1.31^b	4.18±1.65^b	4.78±1.52^{bc}	4.34±1.65^b
0.25:0.75	4.98±1.27^b	5.38±1.03^b	4.84±1.53^b	4.28±1.77^b	4.80±1.54^{bc}	4.54±1.56^b
0.50:0.50	5.00±1.34^b	5.46±1.13^b	4.92±1.43^b	4.36±1.72^{ab}	5.02±1.44^b	4.38±1.52^b
0.75:0.25	5.04±1.24^b	5.24±1.09^b	4.76±1.36^b	4.00±1.55^b	4.58±1.54^c	4.52±1.40^b

*Values followed by the different letter within the same column are significantly different from each other ($p \leq 0.05$).

flour cream puff could be developed as an alternative bakery product for consumers who suffer from celiac disease and a novel functional food with antioxidant properties due to rich in bioactive compound.

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