Effect of Egg and Microwave Baking on Quality of Rice-Flour Bread

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Abstract

Bread has played an important role on Thai people's daily life due to the change in lifestyle. It is usually made of wheat flour that contained gluten and may cause an allergen. This research was to develop gluten free bread using Jasmine rice flour. Egg (17, 34 and 51 g/ 100 g rice flour) was added into the formula to determine its effect on quality of the gluten free bread. Rice-flour bread with egg had higher ($p \leq 0.05$) hardness, gumminess, a* and b* of crumb and crust but less ($p \leq 0.05$) specific volume, springiness, cohesiveness, L* of crumb and crust than the rice-flour bread without egg. From SEM, a fine structure was observed in the rice-flour bread with egg. With an increase in egg content, moisture content, gumminess, chewiness and springiness of bread were increased whereas hardness was decreased. The rice-flour bread with 34 g egg/ 100 g flour had the highest overall liking score and was selected for determination of baking condition. The rice-flour bread with addition of egg which was baked by the microwave baking (MW) and the combination of microwave and hot air baking (MW-HA) had higher ($p \leq 0.05$) specific volume, springiness, gumminess and chewiness than those baked by the hot air baking (HA). MW produced the rice-flour bread with high L*. By applying HA with MW could decrease the L* of crust resulting in brown crust. Therefore, addition of egg and MW-HA could develop the rice-flour bread with the highest overall liking score.

Keywords: gluten free, bread, rice flour, microwave, baking

1. Introduction

In the world population, people (around 1–2%) who suffer from Celiac disease cannot consume some of the most common products on the market, including breads made with wheat flour due to gluten allergy (Phimolsiripol *et al.*, 2012). Rice (*Oryza sativa* L.) which is one of the leading food crops in South East Asia has been proposed as alternative flour for making gluten free breads. This was because of its hypoallergenic proteins, soft taste, white color, low level of sodium and easily digestible carbohydrates (Lopez *et al.*, 2004). In rice, major storage protein was the glutelin (65–85%) while prolamin was the minor fraction. Nevertheless, rice flour protein could not develop a network with a similar property to gluten (Huebner *et al.*, 1990). Therefore, quality of the gluten free bread from rice flour may be deteriorated, compared with the wheat-flour bread. Some ingredients (ie. proteins and hydrocolloids) have been used to improve the quality of the gluten-free bread (Maghaydah *et al.*, 2013).

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Some proteins were added to the gluten-free bread to increase elastic modulus by cross linking (Elke and Fabio, 2008). The addition of protein could improve structure and texture and enhance Maillard browning reaction (Arendt and Bello, 2008). The most used protein in gluten-free baked products included skim milk powder, whey protein concentrate, soy protein isolate and egg (Demirkesen *et al.*, 2010). Egg could be used to improve color, enhance flavor and provide structure. In addition, egg contained easily digested proteins which were an ideal for recovering Celiac disease patients (Crockett *et al.*, 2011). Among the hydrocolloids, hydroxyproply methylcellulose (HPMC) was one of the most appropriate to improve volume and texture of the gluten free bread. It was recommended to use 3.5–5.3% flour based in the rice-flour bread formula (Gujral *et al.*, 2003).

For baking, microwave baking has been proposed to speed up baking process of bakery products, particularly bread (Patel *et al.*, 2005) and cake (Megahey *et al.,* 2005). The rapid heat transfers increased the internal pressure and enhance the mass transfer from the inner layer to the product surface. However, a microwave chamber was not hot resulting in condensation on the product surface. This slowed down formation of bread crust. Maillard browning reaction may not be completed. Thus, hot air baking should be combined with the microwave baking to complete crust color formation (Sumnu, 2001).

Therefore, this project aimed to determine effect of egg addition on quality of the gluten free bread from Jasmine rice flour. Moreover, quality of the gluten free bread baked by the convective baking was compared with those baked by the microwave baking and the microwave assisted hot air baking.

2. Materials and Methods

2.1 Preparation of gluten free bread from rice-flour

Jasmine rice-flour (Petchpantong, Thailand) and dry ingredients (listed in Table 1) were mixed with whole egg (0, 17, 34 and 51 g/100 g rice flour) and water in an electronic mixer (Kitchen Aid, Model 5K 566, USA.) at speed 1 for 2 min. Then butter was added and mixed at speed 2 for 3 min. The obtained dough was placed in mold and proved in a prover (Siam Incubator System, Thailand) at 35ºC and 95% relative humidity for 120 min. After that dough was baked in a baking oven (LG MP9489SRC, Thailand) with a convective heating mode at 195ºC for 30 min. Bread was brought to measure physical quality, chemical quality and sensory quality.

Table 1 Rice-flour bread formula

Ingredients	Trt 1* (control)	Trt 2	Trt 3	Trt 4
Rice-flour (g)	100	100	100	100
Yeast (g)	1.6	1.6	1.6	1.6
Sugar (g)	18	18	18	18
Salt (g)	1	1	1	1
HPMC (g)	4	4	4	4
Water** (g)	80	65	55	45
Butter (g)	20	20	20	20
Whole egg (g)	0	17	34	51

Note: * Adapted from Nishita *et al.*, (1976)

** Water in each formula was adjusted to form dough because the whole liquid egg contains about 75% water (Stanley and Linda, 2006).

2.2 Determination of bread quality

Physical, chemical and sensory quality of bread was evaluated. Specific volume was determined in triplicate using a rapeseed displacement method (AACC, 2000). Moisture content was determined by an oven method (AOAC, 2000). Color of bread crumb and crust in CIE system (L*, a* and b*) was measured by a spectrophotometer (Minolta Model CM-3500d, Japan). Texture profile analysis of bread crumb was investigated by a texture analyzer (TA-XT Plus, Stable Micro System, England). A probe (P/50) was used with 20 mm/min test speed. The deformation ratio was 9 mm. Structure of bread crumb was investigated by a scanning electron microscope (JSM-5600 LV, Japan) with an accelerating voltage of 10 kV. Magnification was adjusted to 1500X. For sensory quality (color, flavor, softness and overall liking), a 9-point hedonic scale was used to evaluate liking scores of the rice-flour bread using 50 untrained panelists. The formula that could produce bread with the desired quality and the highest liking score would be selected to study in section 2.3.

2.3 Determination of effect of baking on quality of rice-flour bread

Based on section 2.2, the rice-flour bread formula with and without egg were selected to prepare the dough for baking in 3 conditions including the hot air baking at 195ºC for 30 min (HA), the microwave baking at 600 watt for 12 min (MW) and the combination of the microwave baking at 600 watt and the hot air baking at 195ºC for 10 min (MW-HA). Quality of the bread was determined by the methods explained in section 2.2, in order to investigate the effect of baking condition on quality of the rice-flour bread.

2.4 Statistical analysis

All experiment was independently carried out twice. Analysis of variance was conducted at $p \leq 0.05$. Significant difference between means was evaluated using a Duncan's new multiple range tests (SPSS version 12.0.1 (SPSS Inc., Chicago, IL, USA)).

3. Results and Discussion

3.1 Effect of egg content on quality of the gluten free bread from rice-flour

Rice-flour bread had 62.29% moisture content and 0.95 cm^3/g specific volume. Addition of egg did not clearly affect the moisture content, but significantly ($p \leq 0.05$) decreased specific volume to 0.88–0.89 cm^3/g (Table 2). Some egg protein such as albumen could link with starch granules together (Arendt and Bello, 2008). This may restrict volume expansion.

Table 2 Specific volume and moisture content of the rice-flour bread

Egg (g/ 100 g flour)	Specific volume (cm^3/g)	Moisture content (% dry basis)
0 (Control)	0.95 ± 0.01^{a}	62.29 ± 0.53^{b}
17	0.88 ± 0.00^{b}	64.72 ± 0.94^{a}
34	0.89 ± 0.00^{b}	63.90 ± 1.00^{ab}
51	0.89 ± 0.02^{b}	63.00 ± 1.63^{ab}

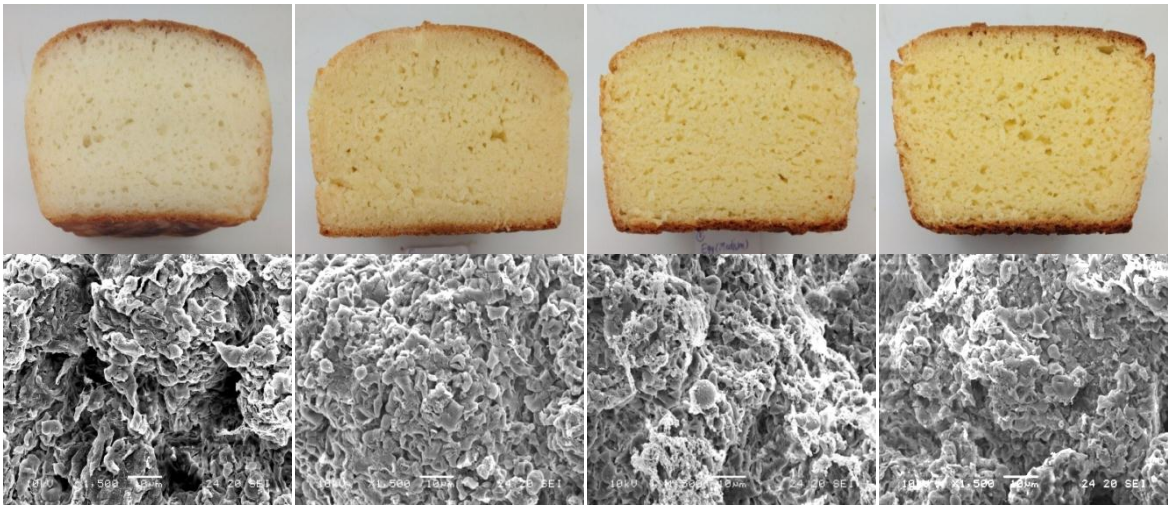
Note: a-b Means within the same column followed by different letters were significantly different ($p \leq 0.05$).

Texture of the bread without egg had low hardness and gumminess, but high springiness and cohesiveness (Table 3). This was possibly due to rough structure of the bread crumb (Figure 1). Gumminess of bread crumb with egg was significantly ($p \leq 0.05$) higher than that of the bread without egg. This coincided with the SEM of the bread crumb with egg showing a fine and packed structure. The increased egg content decreased hardness, but increased springiness and chewiness significantly ($p \leq 0.05$).

Table 3 Texture profile of the rice-flour bread crumb

Egg (g/ 100 g flour)	Hardness (N)	Springiness	Cohesiveness	Gumminess	Chewiness
0 (Control)	5.63±0.46^{d}	10.04±0.32^{a}	0.90±0.06^{a}	5.10±0.64^{c}	51.31±7.43^{b}
17	25.74±1.26^{a}	1.35±0.81^{d}	0.59±0.04^{c}	15.23±1.53^{a}	20.96±14.17^{c}
34	15.30±1.02^{b}	1.76±0.82^{c}	0.57±0.06^{c}	8.67±1.20^{b}	15.63±8.27^{cd}
51	11.99±2.27^{c}	8.77±1.13^{b}	0.68±0.13^{b}	8.13±1.92^{b}	72.17±21.65^{a}

Note: a-d Means within the same column followed by different letters were significantly different ($p \leq 0.05$)



(a) (b) (c) (d)

Figure 1 Appearance and SEM of crumb structure of the rice-flour bread (a) without egg, (b) with 17g/ 100 g flour, (c) with 34 g/ 100 g flour and (d) with 51 g/ 100 g flour at 1500x.

Regarding color, lightness (L* value) of the gluten free bread crust and crumb was significantly ($p \leq 0.05$) decreased when egg content was increased from 0 to 51 g/ 100 g flour (Figure 2). In contrast, a* and b* values were significantly ($p \leq 0.05$) increased with the increased egg content. This was because an increase in protein from addition of egg enhanced Maillard browning reaction (Stanley and Linda, 2006).

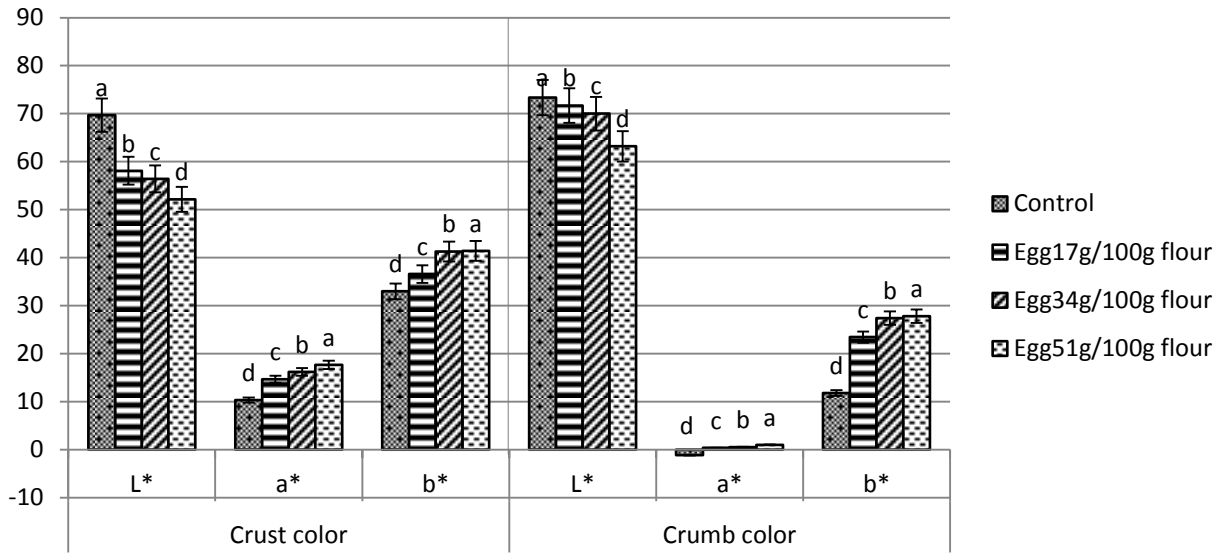


Figure 2 Crust and crumb color of the rice-flour bread

Note: a-d Means within the same column followed by different letters were significantly different ($p \leq 0.05$).

Although addition of egg caused a physical difference in texture and structure of bread crumb as shown in Table 3 and Figure 1, the liking score on softness of bread crumb was in a slightly like range, regardless of egg content (Table 4). Likewise, egg content did not significantly ($p \leq 0.05$) affect the liking score on flavor of the rice-flour dough. However, the increase in egg content from 0 to 34 g/100g flour could improve the liking score on color. Therefore, the rice-flour bread with 34 g egg/100 g flour had the highest overall liking score ($p \leq 0.05$). For a further study in baking condition, the formula with 34 g egg/100 g flour condition was then selected.

Table 4 Liking scores of the rice-flour bread

Liking scores	Egg content (g/ 100 g flour)			
	0 (Control)	17	34	51
Color	6.50±1.12^{b}	6.62±1.28^{b}	7.34±0.96^{a}	6.42±1.45^{b}
Flavor	5.96±1.57^{a}	5.66±1.56^{a}	5.50±1.72^{a}	5.76±1.67^{a}
Softness	6.10±1.04^{a}	5.92±1.73^{a}	6.18±1.5^{a}	6.12±1.68^{a}
Overall liking	6.40±1.63^{b}	6.24±1.45^{b}	6.92±1.08^{a}	6.20±1.58^{b}

Note: a-b Means within the same row followed by different letters were significantly different ($p \leq 0.05$).

3.2 Effect of baking condition on quality of the gluten free bread from rice-flour

Using the hot air baking, specific volume of the rice-flour bread was less than 1 cm^3/g, regardless of egg content. By applying microwave energy during baking, specific volume of all rice-flour bread was significantly ($p \leq 0.05$) increased and higher than 1 cm^3/g (Table 5). This was because the rapid heating generated high internal pressure during baking (Sumnu, 2001). As a result, volume expansion could be improved. However, the rapid heating from microwave possibly enhanced a rapid moisture transfer from the inner layer to the surface. Thus, moisture content of the bread was decreased significantly ($p \leq 0.05$). Nonetheless, addition of egg in the dough could reduce moisture loss during the microwave baking.

Table 5 Specific volume and moisture content of the rice-flour bread from various baking conditions

Condition	Baking condition	Specific volume (cm^3/g)	Moisture Content (%dry basis)
With egg	HA	0.89 ± 0.00^{e}	63.90 ± 1.01^{a}
	MW	1.31 ± 0.02^{c}	59.37 ± 0.24^{c}
	MW-HA	1.34 ± 0.00^{b}	55.66 ± 0.75^{d}
Without egg	HA	0.88 ± 0.01^{d}	62.29 ± 0.53^{b}
	MW	1.34 ± 0.00^{b}	49.05 ± 0.41^{e}
	MW-HA	1.50 ± 0.01^{a}	47.29 ± 0.47^{f}

Note: a-f Means within the same column followed by different letters were significantly different ($p \leq 0.05$).

The use of microwave during baking increased springiness of the bread with egg significantly ($p \leq 0.05$) without the significant effect on hardness. In contrast, in the case of bread without egg, hardness tended to increase particularly in the single microwave baking while springiness tended to decrease. However, the microwave baking and the combined baking (MW-HA) significantly ($p \leq 0.05$) increased chewiness of bread crumb, regardless of egg content (Table 6).

Table 6 Texture profile of the rice-flour bread from various baking conditions

Condition	Baking condition	Hardness (N)	Springiness	Cohesiveness	Gumminess	Chewiness
With egg	HA	15.30±1.02^{b}	1.76±0.82^{e}	0.57±0.06^{e}	8.67±1.20^{d}	15.63±8.27^{f}
	MW	15.50±1.70^{b}	8.46±1.93^{d}	0.61±0.06^{d}	9.41±1.59^{c}	80.62±27.64^{d}
	MW-HA	15.38±1.55^{b}	9.88±0.71^{c}	0.68±0.07^{c}	10.52±1.87^{b}	104.63±23.25^{b}
Without egg	HA	5.63±0.46^{d}	10.04±0.32^{a}	0.90±0.06^{a}	5.10±0.64^{f}	51.31±7.43^{e}
	MW	20.88±0.52^{a}	9.97±0.76^{b}	0.84±0.06^{b}	17.55±1.39^{a}	175.73±24.94^{a}
	MW-HA	10.23±0.68^{c}	9.96±0.71^{b}	0.83±0.15^{b}	8.57±1.81^{e}	85.98±22.18^{c}

Note: a-f Means within the same column followed by different letters were significantly different ($p \leq 0.05$).

Microwave baking produced the rice-flour bread with the highest L* values of crust. By applying it with the hot air baking, L* of crust was significantly ($p \leq 0.05$) decreased. However, it was still higher than those of the bread baked by the hot air condition. Moreover, a* and b* values of bread from the microwave baking and the combined baking were significantly ($p \leq 0.05$) lower than those from the hot air baking. That meant the microwave baked bread was pale. It is possible that condensation occurred on the bread surface during the microwave baking. Then the bread surface became moist and its temperature may not high enough to enhance browning reaction from both Maillard reaction and caramelization.

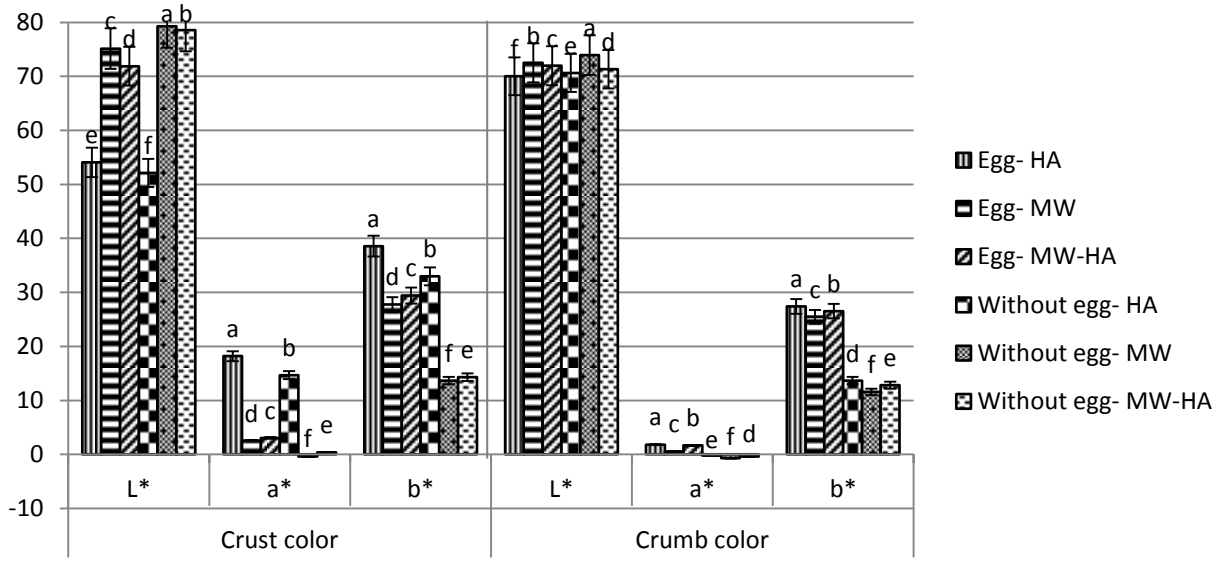


Figure 4 Crust and crumb color of the rice-flour bread from various baking conditions

Note: a-f Means within the same attribute followed by different letters were significantly different ($p \leq 0.05$).

Due to a short baking time with the improvement of volume, texture and color, the combined microwave with hot air baking was selected to bake bread for testing the liking scores of the gluten free bread from rice flour. By baking in the combined condition (MW-HA), the rice-flour bread with egg had higher liking scores on color and flavor, but lower liking score on softness than the one without egg. However, the bread with 34 g egg/100 g flour had the highest overall liking score (Table 7).

Table 7 Liking scores of the rice-flour bread from the combined baking condition

Liking scores	MW-HA	
	With egg	Without egg
Color	6.68±0.59[a]	5.17±1.09[b]
Flavor	6.30±0.67[a]	6.11±1.22[b]
Softness	5.23±1.49[b]	6.63±1.10[a]
Overall liking	6.37±0.39[a]	6.05±0.99[b]

Note: a-b Means within the same row followed by different letters were significantly different ($p \leq 0.05$).

4. Conclusion

Addition of egg into dough significantly increased ($p \leq 0.05$) gumminess and chewiness of the rice-flour bread. Moreover color and structure could be improved, compared with the rice-flour bread without egg. Microwave baking could significantly ($p \leq 0.05$) improve specific volume, but caused a pale bread crust. By applying it together with the hot air baking, brown crust was properly developed, resulting in the highest overall liking score. Therefore, addition of 34 g egg/100 g flour and the microwave assisted hot air baking should be used for development of the gluten free bread from Jasmine rice-flour.

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