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Effect of Wheat Flour Substitution with Brown Rice Flour on Sponge Cake's Qualities

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Abstract

The purpose of this research was to study the effect of wheat flour substitution with brown rice flour on sponge cake's physical, chemical and sensory characteristics. Five different levels of wheat flour substitutions at 10, 20, 30, 40 and 50% comparing to the control made from 100% wheat flour were studied. The substitutions of brown rice flour were found to affect the proximate composition, physical and sensory characteristics of sponge cake. The proximate analysis showed a slight increase in crude fiber content and a slight decrease in water, carbohydrate and energy contents with the increased levels of brown rice substitution. The substitution of brown rice flour caused an increase in specific gravity of sponge cake batter; resulting in a lower volume and a lower height of the sponge cake. Texture profile showed only a significant lower in springiness when the substitution of brown rice flour more than 20%. Compared to the control sponge cake with 100% wheat flour, the substitution of brown rice up to 30% showed no significant differences in sensory evaluation, protein, fat and crude fiber contents including specific gravity, loss rate, batter yield, hardness and cohesiveness. Inclusion of brown rice flour up to 40% and 50% of wheat flour showed a significant increase in crude fiber content ($p<0.05$) and a tendency of reduced energy content.

Introduction

Sponge cake is a popular bakery product consumed for its palatable taste. The main ingredients used in sponge cake production include wheat flour, sugar, eggs and fats. Among the different ingredients used in the production of cake, wheat flour constitutes a major component. Wheat flour is critical in baking products due to its gluten content. Gluten is the functional protein in wheat flour required for the quality characteristics of bakery products since the protein impacts on cell formation, crumb and crust structure, volume, porosity and other high quality attributes such as tenderness, shelf life and tolerance to stalling (Gomez et al., 2007).

Brown rice flour is produced from a non-polished rice which contains high nutrients, including vitamin B1, B3, B6, B12, folate, vitamin E, magnesium, phosphorus, potassium, manganese and gamma oryzanol, which is 6 times more powerful antioxidant than vitamin E. Brown rice contains more of insoluble fibers which helps prevent constipation (Charoenkul, 2013). Using brown rice flour may help to improve nutritional values of food products.

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However, the gluten content of brown rice is very low which may affect the characteristics of a product. Brown rice flour substitution in appropriate ratio can be accepted by the consumers. The study of germinated brown rice flour substitution in muffin found that the 50% substitution showed no significant differences in sensory evaluation ($p<0.05$) (Charoenkul, 2013). The substitution of 10% brown rice flour in steam bun has been accepted by consumers (Aussawasathein et al., 2004). The study of sinin rice flour substitution with commercial bread wheat flour showed that the substitution of sinin rice flour up to 30% showed no significant differences with commercial bread wheat flour (Phuphechr et al., 2009). The study of cheonnyuncho flour *(Opuntia humifusa)* substitution in sponge cake showed that 9% of cheonnyuncho flour was the best sensory properties (Jae et al., 2012).

The purpose of this research was to study the effect of wheat flour substitution with brown rice flour and to study the panelist acceptance of sponge cake. Physical properties, proximate composition and sensory evaluation were undertaken.

Materials and methods

1. Raw materials

Brown rice flour was prepared by dry milling method and passed through a 60-mesh sieve. The brown rice flour was contained in a polyethylene bag and kept at room temperature (Premprasopchok et al., 2014). The ingredients used in sponge cake formulas were composed of cake flour (United Flour Mills, Bangkok, Thailand), baking soda (United Flour Mills, Bangkok, Thailand), fresh eggs (Betagro, Bangkok, Thailand), sugar (Mitrphol, Suphan Buri, Thailand), salt (Prungthip, Nakorn Ratchasima, Thailand), butter (Orchids, Bangkok, Thailand) and milk (Friesland, Samut Prakan, Thailand).

2. Sponge cake preparation

Four sponge cake formulas (Jae et al., 2012; Jung et al., 2009; Manuel et al., 2012; Tsong et al., 2010) were tested and the formula that received the most acceptable by 30 panelists was selected for the experiment. Brown rice flour was substituted at 0, 10, 20, 30, 40 and 50% of wheat flour as shown in Table 1. Whole egg, sugar, fresh milk and salt were mixed in a mixer at medium-speed for 1 minute. The sifted wheat flour (cake flour) and baking soda were gradually added into the mixer on the low speed for 1 minute and then mixed on high-speed for 5 minutes and on low-speed for another 1 minute. After that, melted butter was added into the bowl and mixed on low-speed for 3 minutes. The cake batter, 360 grams, was immediately placed into 2-pound round cake pan and baked at 180°C for 20 minutes. The cakes were allowed to cool for 1 hour and then removed from the pan. The cakes were kept in polypropylene bags for physico-chemical and sensory analyses.

Table 1 Formulas of sponge cakes containing five different brown rice flour

Ingredients (Grams)	Brown rice flour substitution (%)					
	0	10	20	30	40	50
Cake flour	200	180	160	140	120	100
Brown rice flour	0	20	40	60	80	100
Baking soda	4	4	4	4	4	4
Eggs	360	360	360	360	360	360
Sugar	220	220	220	220	220	220
Salt	2	2	2	2	2	2
Butter	120	120	120	120	120	120
Milk	160	160	160	160	160	160

3. Proximate analysis of sponge cake

The proximate compositions of the sponge cakes, including moisture, crude protein, crude fat, and ash, were determined by AOAC methods (AOAC., 1990). The nitrogen content was estimated by the semi-micro Kjeldahl method, and the nitrogen conversion factor used for the crude protein calculation was 6.25. The carbohydrate content was calculated by subtracting the contents of crude protein, fat, ash, and moisture from 100 g of cake. Crude fiber was also determined by AOAC methods (AOAC., 1995). The energy values were obtained by the Atwater and Bryant method, using the factors of 4, 9, and 4 kcal/g for protein, fat, and carbohydrate, respectively (Atwater et al., 1899). The proximate compositions of the sponge cakes were analyzed in triplicate. The results were expressed on a wet basis.

4. Physical characteristics of sponge cake batter

The physical characteristics of the sponge cake batter, including specific gravity, baking loss rate, and batter yield, were measured in quadruplicate for the same sponge cake batter. The specific gravity of each type of sponge cake batter was determined by dividing the weight of the sponge cake batter by the weight of the water (Tietz, 1995). The baking loss rate and the batter yield of each type of sponge cake were expressed using the percentage of loss of cake weight after baking and the weight of the sponge cake batter.

$$\text{Specific gravity (mL/g)} = \frac{\text{Weight of cake batter}}{\text{Weight of water}}$$

$$\text{Baking loss rate (g/100g)} = \frac{\text{Weight of batter} - \text{Weight of cake}}{\text{Weight of cake}} \times 100$$

$$\text{Batter yield (g/100g)} = \frac{\text{Weight of cake}}{\text{Weight of batter}} \times 100$$

After cooling the cakes at room temperature for 1 hour, the center of each cake was cut lengthwise for measuring height and width of the cake. After cooling the cakes at room temperature for 3 hours, the cakes were cut from the center into pieces (3 × 3 × 3 cm each) for texture profile analysis (TPA) with a TA-XT2 Texture analyzer (hardness, cohesiveness and springiness). The Compression Platens Probe, size P/100, was pressed down on the sample at a test speed of 1 mm per second for a distance of 50% of its height. In addition, the probe was moved back to the speed of 5 mm per second and then stopped moving for 30 seconds, then pressed down on the sample again at the same speed (Premprasopchok et al., 2014).

5. Sensory evaluation

Sensory evaluation of sponge cakes was conducted with 30 trained taste panels selected from staff and students of the Faculty of Agricultural Technology, Lampang Rajabhat University, Lampang, Thailand who were regular cake eaters and between 18-45 years of age. A 9-point hedonic scale was used to evaluate the samples (3 × 3 × 3 cm) from the midsection of the cakes that had been held at room temperature. The samples were placed on white plates and were identified with random three-digit numbers. The panelists evaluated the samples in a testing area and were instructed to rinse their mouths with water between samples to minimize any residual effects.

6. Statistical analysis

A completely randomized design (CRD) was applied for the experiment of brown rice flour substitution for wheat flour. The sensory evaluation was undertaken under RCBD (Randomized Complete Block Design, RCBD). The differences among groups were evaluated by a One-way Analysis of Variance (ANOVA) and Duncan's multiple range tests for a statistical significance of $P<0.05$ by using SPSS software program version 17. All data are reported as means ± standard deviations (SD).

Results and discussion

1. Proximate composition of sponge cake

The results showed that there were no significant differences in ash, protein and fat contents. There were slight differences in moisture, carbohydrate and energy contents; they all tended to decrease as the amount of brown rice substitution for wheat flour increased. Crude fiber content increases significantly at 40% and 50% of wheat flour substitution with brown rice flour ($p<0.05$) (Table 2).

The decrease in moisture content may be due to structure of brown rice flour. Gluten content that impacts on cell formation in brown rice flour is lower than wheat flour. The weaker network formation by incorporating brown rice flour also resulted in deteriorating cooking quality of the product, which was determined based on water absorption or moisture content (Chung et al., 2012). As a result, the sponge cake containing more brown rice flour had reduced tendency to form a continuous network due to the reduced amount of gluten (Watanabe et al., 2004; Xu et al., 2012).

Table 2 Proximate composition of sponge cakes with different levels of brown rice flour

Properties	Brown rice flour substitution (%)					
	0	10	20	30	40	50
Moisture (g/100g)	39.99 ± 0.35^{a}	39.79 ± 0.46^{a}	37.59 ± 0.63^{ab}	37.69 ± 0.16^{ab}	36.63 ± 0.17^{ab}	31.93 ± 0.65^{b}
Ash^{ns} (g/100g)	1.47±0.48	1.40±0.20	1.42±0.07	1.62±0.10	1.77±0.08	1.52±0.17
$Protein^{ns}$ (g/100g)	8.80±1.10	8.56±0.91	8.13±0.49	8.11±0.14	8.29±0.36	8.64±0.31
Fat^{ns} (g/100g)	14.91±1.10	14.42±0.96	13.27±0.98	14.53±0.75	13.90±0.57	12.44±0.27
Crude Fiber (g/100g)	0.61 ± 0.29^{b}	0.72 ± 0.66^{b}	0.76 ± 0.34^{b}	0.78 ± 0.35^{b}	1.10 ± 0.23^{a}	1.38 ± 0.21^{a}
Carbohydrate (g/100g)	42.88 ± 0.75^{a}	39.11 ± 0.41^{ab}	38.36 ± 0.72^{ab}	38.04 ± 0.19^{ab}	37.43 ± 1.15^{b}	37.40 ± 0.89^{b}
Energy (kcal/100g)	336.54 ± 2.48^{a}	328.83 ± 2.87^{ab}	317.23 ± 1.67^{ab}	312.57 ± 1.92^{ab}	298.38 ± 1.11^{ab}	290.37 ± 1.55^{b}

Remark: Means with different superscripts along horizontal line are significantly different by Duncan's multiple range test at $p < 0.05$.
Mean with ns are not significantly different ($p \geq 0.05$)

2. Physical characteristics of sponge cake

The results showed that there were no significant differences in loss rate during baking and the batter yield. However a slight difference in specific gravity was noted; it tended to increase as the amount of brown rice substitution for wheat flour increased ($p<0.05$). In a cross-sectional observation, the height of the sponge cake was reduced when the substitution was increased.

The specific gravity of cake batter was a key factor to determine size, texture and volume of the sponge cake. Many air cells were incorporated into the cake batter when the specific gravity was low. So, when specific gravity increased, the lower volume of air cell was occurred (Jung et al., 2009). In addition, an increase of brown rice flour substitution diluted the protein and interferes with optimal gluten network formation during mixing. This dilution also changed the crumb structure and impair CO_2 retention, increasing the potential for the disruption of gluten network during baking and reducing the volume of bakery product (Tongtangwong & Suwansichon, 2010). The sponge cake reduced in volume and height as shown in Table 3 and Fig. 1.

The texture profile analysis showed that there were no significant differences in hardness and cohesiveness. The results showed a decrease in cake springiness with an increase of brown rice flour substitution ($p<0.05$).

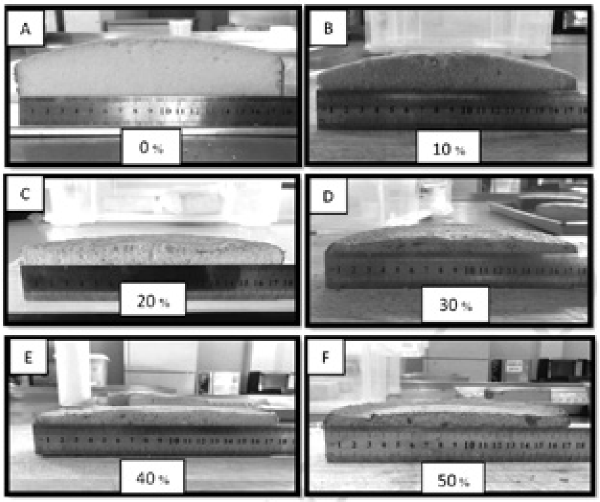

Fig. 1 Sponge cake with various levels of Brown Rice Flour (A)control (without added Brown Rice Flour), (B) addition of 10% of Brown Rice Flour, (C) addition of 20% of Brown Rice Flour, (D) addition of 30% of Brown Rice Flour, (E) addition of 40% of Brown Rice Flour and (F) addition of 50% of Brown Rice Flour

Springiness measures elasticity by determining the extent of recovery between the first and second compression (Sinchaipanit et al., 2017). A decrease in cake springiness resemble the findings of Watanabe et al. (2004) and Xu et al. (2012) that low gluten content in cake mixture reduces the ability to form a continuous network of cake texture.

Table 3 Specific gravity, baking loss, dough yield and cross-sectional observation of sponge cakes with varied levels of brown rice flour

Properties	Brown rice flour substitution (%)					
	0	10	20	30	40	50
Specific gravity (mL/g)	0.48±0.02^{a}	0.49±0.03^{ab}	0.51±0.06^{ab}	0.51±0.02^{ab}	0.53±0.00^{ab}	0.54±0.02^{b}
Loss rate^{ns} (g/100 g)	11.49±0.42	11.15±0.60	9.85±1.21	11.11±0.59	10.79±0.79	9.54±1.02
Batter yield^{ns} (g/100 g)	89.72±0.95	90.00±1.09	90.28±1.07	90.00±0.48	91.05±0.79	91.30±0.85
Cross-sectional observation						
- Height (cm)	5.33±0.47^{a}	4.90±0.46^{ab}	4.33±0.38^{bc}	4.07±0.35^{c}	3.93±0.06^{c}	3.90±0.17^{c}
- Length (cm)	17.80±0.20^{a}	17.63±0.06^{ab}	17.50±0.10^{b}	17.63±0.06^{ab}	17.47±0.15^{b}	17.40±0.10^{b}

Remark: Means with different superscripts along horizontal line are significantly different by Duncan's multiple range test at $p < 0.05$.
Mean with ns are not significantly different ($p \geq 0.05$)

Table 4 Textural properties of sponge cakes with varied levels of brown rice flour

Properties	Brown rice flour substitution (%)					
	0	10	20	30	40	50
Texture profile						
- Hardness^{ns} (g)	330.82 ±0.34	367.32±0.21	381.50±0.15	408.56±0.93	435.63±0.74	440.71±0.77
- Cohesiveness^{ns} (ratio)	0.74±0.01	0.74±0.01	0.75±0.02	0.75±0.01	0.75±0.01	0.76±0.01
- Springiness (mm/100 mm)	0.83±0.02^{a}	0.77±0.05^{ab}	0.74±0.05^{bc}	0.73±0.04^{bcd}	0.70±0.02^{cd}	0.66±0.02^{d}

Remark: Means with different superscripts along horizontal line are significantly different by Duncan's multiple range test at $p < 0.05$.
Mean with ns are not significantly different ($p \geq 0.05$)

Table 5 Sensory characteristics of sponge cakes with varied levels of brown rice flour

Sensory characteristics	Brown rice flour substitution (%)					
	0	10	20	30	40	50
Colour[ns]	7.27±1.12	7.31±0.93	7.15±1.14	7.35±1.14	7.35±0.85	7.19±1.20
Softness	7.38±1.10[a]	7.23±1.27[a]	7.62±1.36[a]	7.42±1.42[a]	6.81±1.27[b]	6.04±1.89[c]
Texture	7.62±1.44[a]	7.54±1.03[a]	7.35±1.50[a]	7.19±1.23[a]	6.50±1.30[b]	5.92±1.85[c]
Taste	7.46±1.10[a]	7.38±1.06[a]	7.27±1.31[a]	7.23±1.03[a]	6.88±1.21[b]	6.50±1.75[b]
Overall acceptability	7.69±1.19[a]	7.50±1.50[a]	7.31±1.52[a]	7.25±0.92[a]	6.76±1.22[b]	6.65±1.44[b]

Remark: Means with different superscripts along horizontal line are significantly different by Duncan's multiple range test at $p < 0.05$.
Mean with ns are not significantly different ($p \geq 0.05$)

The use of rice flour for preparing bakery products was found to cause some quality problems. The study of sinin rice flour substitution for wheat flour showed that water absorption, resistance to extension and extensibility of bread dough were decreased as the proportion of sinin rice flour increased (Phuphechr et al., 2009). The study of wheat flour substitution with sinin brown rice flour at 70-100% showed the effect on the decreased volume of black sesame carrot cake (Premprasopchok et al., 2014). Because of these quality problem, the study suggested the use of food additives such as hydrocolloids and vegetable protein to resolve the problems (Turabi et al., 2010).

3. Sensory evaluation

The sensory evaluation showed that there was no significant difference in color. There were also no significant difference in softness, texture, taste and overall acceptability when brown rice flour substitution at 0 - 30%. It was suggested that 30% of brown rice flour substitution was the highest substitution that showed no significant differences in sensory evaluation with 100% wheat flour sponge cake.

Conclusion

This study revealed that using brown rice flour as a wheat substitution at 10%, 20% and 30% to produce sponge cake showed no significant differences in sensory evaluation, protein, fat and crude fiber contents; including specific gravity, baking loss rate, batter yield, hardness and cohesiveness characteristics compared to 100% wheat flour sponge cake. A significant decrease in cake height and cake springiness were observed ($p<0.05$). Inclusion of brown rice flour up to 40% and 50% of wheat flour showed a significant increase in crude fiber content ($p<0.05$) and a tendency of reduced energy content. Although the sensory and some physical characteristics were significantly changed; calling for further research to improve the cake acceptability and properties. In order to offer value-added to rice product and to reduce gluten in sponge cake for health purpose, the present findings suggests brown rice flour could be acceptable for partial wheat substitution up to 30% to produce sponge cake.

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