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Effects of substitution of black glutinous rice flour for wheat flour on batter and cake properties

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Abstract

The effect of substitution of black glutinous rice flour for normal wheat flour on batter and cake properties was determined. Black glutinous rice flour was used to substitute 30, 50, 70 and 100% of wheat flour in a control cake formulation. Experimental data showed that pasting temperature, peak viscosity, final viscosity, breakdown and setback of all black glutinous rice and mixes flour samples were less than that of 100% wheat flour. Substitution of black waxy rice flour influenced the batter viscosity, resulting less viscous batters as the proportion of black rice flour increased. Moreover, the results also showed that the substitution of glutinous rice flour caused an increase in specific gravity and trended to decrease the specific volume of cake. The color of crust and crumb cake progressively became darker as the level of black glutinous rice substitution increased. According to texture profile analysis, the cake with black glutinous rice flours had greater firmness, gumminess and chewiness values compared to the control cake with no added black glutinious rice flour. Hedonic sensory tests revealed that the cake prepared with black waxy rice flour had similar (P>0.05) flavor, taste, texture, and overall acceptable scores to that of the control sample. Subsequently, the functional properties of black waxy rice may lead it to be a nutritionally and economicaly important to the bakery industry.

Introduction

Rice (*Oryza sativa* L.) is one of the leading food crops in South East Asia and the main cultivation regions included South Asia, China, Korea, Thailand and Japan. Rice can be classified as non-glutinous and glutinous rice (also called non-waxy and waxy or sweet rice, respectively) based on the amylose content of the rice grains (Belitz *et al.*, 2009). In addition, rice could be categorized by color into red, green, black and white (common) varieties, and this is determined by the composition of anthocyanin pigments that are ubiquitous throughout the plant kingdom (Chen *et al*., 2012). Colored rice has been consumed for a long time in many Asian countries. Among these varieties, black glutinous rice is the most famous one, generally used as an ingredient in snacks and desserts (Tananuwong and Tewaruth, 2010). The black rice has a number of nutritional advantages over common rice as it contains higher content of protein, dietary fiber, vitamins, minerals and natural anthocyanin compounds, such as cyanidin 3-glucoside and peonidin 3-glucoside, which possess anti-oxidative and anti-inflammatory activities (Hu *et al*., 2003). This biochemical composition had been reported to be highly effective in reducing cholesterol levels in human body (Lee *et al.*, 2008). The black rice has recently gained recognition in functional food category due to its health values (Suzuki *et al.,* 2004). In Thailand, black glutinous rice is known as Khao-Niao-Dam, large quantities are consumed as principle food commodity in daily meals in the north and northeastern parts of the country. The black glutinous rice can be used either as whole grains or as milled powder. In addition, many Thai use ground black rice powder in dessert products. In the bakery industry, cakes can be classified into two groups: (1) angel and sponge cakes and (2) layer and pound cakes. The first group is made up of sponge cakes, which usually contain cream or fruit fillings The second group includes homemade cakes and muffins. (Rosell and Gomez, 2014). Major quality parameters of homemade cakes and muffins are appearance, color, specific volume and integrity. Cake is one type of air-leavened product and the qualitiy characteristics of cakes depends on many factors such as the ingredients used for batter preparation, aeration of batters and the process. Wheat flour, fat, sugar and eggs are the important raw materials in the bakery industry. The use of other flour types as a substitution for wheat

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flour could be interesting because of nutritional and economic reasons, especially in those places where climate and soil conditions do not favor the wheat cultivation. Additionally, it opens new avenues for greater utilization of domestic flour products and economic benefits through saving the money to purchase wheat flour from foreign countries. Rice flour had only limited use for cake and baked products. Several studies were conducted on rice flour to improve quality of cake which was formulated with rice flour alone or in combination with other flours substitutes or novel ingredients (Bean *et al.*, 1983; Perez and Juliano, 1988; Mohamed and Hamid, 1998; Shobsngob Varavinit and, 2000; Jangchud *et al.*, 2004; Turabi *et al.*, 2008 and 2010; Sumnu *et al.*, 2010; Chueamchaitrakun *et al.*, 2011; Preichardt *et al.*, 2011; Gularte *et al.*, 2012; Kim and Shin, 2014; Matos *et al.*, 2014;). In general, flour from glutinous rice is under-utilized in the production of cake or similar products. Only limited amount of studies are currently available on using common glutinous rice as a raw material in cake production (Johnson, 1990; Chueamchaitrakun *et al.*, 2011; and Jongsutjarittam and Charoenrein, 2013). Previous study had revealed that the addition or substitution of white glutinous rice flour (5-25% of the total wheat flour) could lower the volume and dense texture of cake (Johnson, 1990). Unfortunately, according to our knowledge, no studies have been performed thus far to determine the effect of the use of black glutinous rice flours in cake products. Rice flour is free from gluten so it is not simply to substitute non-glutinous rice flour for regular wheat flour in cake product because gluten of wheat flour could significantly entrapped air during mixing resulted in softness and springiness of cake product. Compared with, non-glutinous rice cake became firm and stickiness after baking (Johnson, 1990). Therefore, the objectives of this study were to evaluate the effect of total or partial substitution of wheat flour by black glutinous rice flour on batter and cake characteristics and sensory properties. The results could bring valuable information to rice producers or food technologists to explore better utilization and consumption of black glutinous rice products and to promote consumer awareness of the health benefits of grains.

Materials and Methods

Proximate analysis of wheat flour and black glutinous rice flour

Moisture content of flour was determined by hot air oven drying (Binder FD 115, USA). Nitrogen content was determined by Kjedahl method. The conversion factors of total nitrogen to protein were equaled to 5.95 for black glutinous rice flour and 5.7 for wheat flour. Ash was determined by burning in a furnace at 550°C. Lipids contents were determined by the Soxhlet method and carbohydrate content was calculated as difference. All Proximate analysis methods were follows the methos of AOAC (2000). Amylose content was analysed by the method of Juliano (1971). Amylopectin was calculated by difference using following formula: (Amylopectin (%) = 100% - amylose (%).

Black glutinous rice flour substitution

Black glutinous rice flour (Double Bear Brand, Burapa Proster Co.,Ltd., Chonburi, Thailand) was purchased from local market. The black rice flour was used to replace commercial wheat flour (All Purpose Flour Brand, United Flour Mill Public Co., Ltd., Samutprakan, Thailand) at 0, 30,50, 70 and 100%, respectively.

Measurement of flour blend

Water absorption index (WAI) and water solubility index (WSI) of flour samples were determined following the method described by (Bryant *et al.*, 2001) with some modifications. Two and a half gram of dried flour sample was accurately weighed and suspended in 30 ml of distilled water and shaken in water bath at 30°C for 30 min. The content was centrifuged at 3,000 g for 10 min. The supernatant was carefully poured into an aluminum dish (of known weight) before drying till a constant weight at 105°C and weighing. The sediment was collected and weighed. The WAI and WSI were calculated from equations (1) and (2), respectively.

$$WAI = \frac{\text{weight of wet sediment}}{\text{Dry weight of flour}} \quad (1)$$

$$WSI\ (\%) = \frac{\text{weight of dried solids in supernatant} * 100}{\text{Dry weight of flour}} \quad (2)$$

The pasting characteristics of raw materials and flour blends were conducted by using RVA (RVA-4, Newport Scientific Pty. Ltd, Warriewood, NSW, Australia), controlled by Thermocline for Windows software. For all measurements, total solid concentrations were 10% suspension in de-ionized water (dry basis, w/v) from different wheat flour and black rice flour mixtures. The content was quickly stirred using a plastic paddle for 10 times before insertion into Rapid ViscoAnalyzer. The temperature profile consisted of equilibrating the flour suspension at 50°C for 1 min, then heated to 95°C within 3 min

42 s at 12.2°C/min and held at 95°C for 2 min 30 s. It was subsequently cooled to 50°C within 3 min 48 s at 11.8°C/min and held at 50°C for 2 min. The rotation speed was maintained at 160 rpm. The pasting characteristics: pasting temperature, peak time, peak viscosity, trough, breakdown, final viscosity and setback from trough were determined.

All ingredients of cake

(1) Each mixed flour by weight ratios of wheat flour and black rice flour was 275:0, 192.5:82.5, 137.5:137.5, 82.5:192.5 and 0:275, respectively. (2) A 300 g of Liquid whole fresh egg (Charoen Pokphand Foods PCL., Bangkok, Thailand) were prepared by blending 96 g yolks with 204 g white albumin according to the method of Edoura-Gaena *et al.* (2007). (3) 250 g of White sugar (Mitr Phol Co., Ltd., Kalasin, Thailand) (4) 100 g of butter (1.5% salt, United Dairy Food Co. Ltd., Bangkok, Thailand) (5) 75 g of margarine (Golden Jade Brand, Lam Soon, Co. Ltd., Bangkok, Thailand) (6) 30 g of evaporate milk (F&N, Co. Ltd., Bangkok, Thailand) (7) 10 g of vanillin flavor (Winner's Brand, Greathill Co. Ltd., Bangkok, Thailand) (8) 10 g of emulsifier (SP Brand, American Baker, Co., Ltd., Bangkok, Thailand) (9) 5 g of baking powder (double acting type, Unilever, PCL., Bangkok, Thailand) and (10) 1.5 g of Salt (Prungthip Brand, Thai Refined Salt Co., Ltd., Bangkok, Thailand)

Batter and cake preparation

Cakes were prepared using the following steps. The flour and baking powder was mixed together and sieved through a 100 mesh sifter before adding it into a bowl of mixer (KitchenAid, K 5 SS model, USA). Then eggs, evaporate milk, vanillin flavor, sugar, salt, margarine and SP (a type of emulsifier for baking products, commercial namely as Ryoto ester SP) were incorporated and continuously stirred at low speed for 30 s followed by high speed for 5 min and another stirring at low speed for 1 min. Next, melted butter was added and all mixture were stirred at low speed for 1 min. Finally, the batter was poured (~30 g) for each greased cake cup which was supported by stainless cup (6 and 3.5 cm radius at top and bottom, respectively, and 2.5 cm height). The cup trays containing batter were then steamed at 100°C for 20 min. To finish the process, the cakes were removed from the cup and allowed to cool for 1 h before they were packed in plastic bags and stored at room temperature (25 ± 2°C) for further testing.

Measurement of batter

Specific gravity of cake batter at (25 ± 2°C) was calculated by dividing the weight of a standard measure of the batter by the weight of an equal volume of water (Matos *et al.*, 2014). The viscosity of cake batter was determined using a Rapid ViscoAnalyser (RVA-4, Newport Scientific Pty. Ltd, Warriewood, NSW, Australia). A batter sample (25 g batter) was submitted to viscosity analysis over a 1-min period using a constant speed of 75 rpm and temperature of 25°C which was slightly modified from the method of Gularte *et al.* (2012).

Physical properties of cake

In order to measure specific volume, the cake was weighed upon 1 h cooling at room temperature (25 ± 2°C). Cake volume was measured by the sesame seed displacement method. The specific volume was also calculated as cake volume divided by cake weight. Color of the crust and cake crumb were determined by a Minolta CR-300 Chroma Meter (Minolta, Japan) in L^*, a^*, b^* color scale. All of color values were calculated in terms of the other color indicators as follows: hue angle = tan-1[b^*/a^*], chroma = $(a^{*2}+b^{*2})^{1/2}$ and color difference $(\Delta E)= ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$

Texture of cake was measured using a texture analyzer (Model TA.XT Plus, Stable Microsystem, Surrey, UK). The force required for 25% compression was recorded using the following conditions: crumb sample size 1 cm x 1cm x 1cm; load cell 2 kg. A standard double-cycle program (Texture profile analysis, TPA) was performed with a and plunger diameter 36 mm (p/36) and compression the samples at a speed of 1 mm/sec with 50% deformation of their original height at speed of 1 mm/s with waiting time 5 s before starting the second compression (Matos *et al.*, 2014). The parameters obtained from the curves were firmness (N), springiness (no unit), resilience (no unit), gumminess (N) and chewiness (N).

Sensory evaluation of cakes

Sensory analysis of cakes was conducted by 25 untrained panelists who were graduate students in the Department of Food Technology and Nutrition, Rajamangala University of Technology Krungtep. The sensory characteristics were carried out using a nine point hedonic rating scale for five attributes (color, odor, taste, texture and overall acceptance). All four sensory attributes were rated on a 1–9 intensity scale where 9 is like extremely and 1 is dislike extremely. Samples were presented with 3-coded digit number. Water was provided for rinsing between samples. Cakes were evaluated 4 h after cooling. Cakes were placed in plastic bags, sealed and stored at room temperature (25 ± 2°C) until subjected to sensory analysis.

Statistical analysis

Data were statistically analyzed by using ANOVA with six experimental groups appropriate to the completely randomized design with three replicates each. If the differences in mean existed, multiple comparisons were performed using the Duncan's Multiple Range Test (DMRT). All analysis was conducted using SPSS for Windows Version 11.0. Only significant differences are discussed in the text.

Results and Discussion

Flour blend properties

Proximate composition of wheat flour was 12.9% protein, 0.4% fat, 0.8% ash, 0.6% crude fiber and 85% carbohydrate by dry basis. While black glutinuous rice flour composed of 8.0% protein, 0.4% fat, 1.5% ash, 0.9% crude fiber and 89% carbohydrate by dry basis. The amylose content of wheat flour (24.2%) was greater than black glutinous rice flour (4.8%) and amylopectin contents of wheat and rice flour were 75.8% and 95.2% respectively. Starch paste behavior in aqueous systems depends on the physical and chemical characteristics of the starch granule, such as mean granule size, granule size distribution, amylose and amylopectin ratio and mineral content (Singh *et al*., 2003). According to previous studies, the amylose content of wheat starch could vary from 18 to 30% (Singh *et al*., 2003). A study by Sompong *et al*. (2011) indicated that Thai black glutinous rice varieties, Niaw Dam Pleuak Khao and Niaw Dam Pleuak Dam, had amylose content approximately 8.9 and 9.7%, respectively. Rice varieties were classified into five groups according to their amylose content: waxy rice (1–2%), very low amylose rice (2–9%), low amylose rice (10–20%), intermediate amylose rice (20–25%), and high amylose rice (25–33%) (Sompong *et al*., 2011). Therefore, the black glutinous rice flour was classified as a very low amylose rice.

WAI represents the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. It also indicates the maximum solubility of flour particle at a definite condition. Our results show that black glutinous rice flour had greater ($P<0.05$) WAI than wheat flour about 29% while WSI of black glutinous rice flour was approximately less than WSI of wheat flour 4 folds. Therefore, WAI and WSI of the flour mixtures were influenced by the levels of black glutinous rice flour substitution (Table 1). WAI was approximately increased from 2.0 to 2.7 with black glutinous rice flour substitution while WSI of mixed flour was decreased from 19.4 to 4.3%, with black glutinous rice flour subsitution from for 30 to 100%, respectively. This results may attribute to the different contents of amylose and crude fiber composition between two types of flour. Wheat flour had approximately 19.3% higher than amylose content ($P<0.05$) than black glutinous rice flour. The semi-crystalline structure of starch composed of amylose and amylopectin. As a result, the two different arrangements of starch molecule as amorphous and crystalline were appeared. The amorphous structure composed of amylose continue on amylopectin chain through hydrogen bonds resulting the difficult of water absorption compared to crystalline regions which contained only amylopectin (Belitz *et al*., 2009). While amylopectin had a higher branch structure so it's molecules were much more difficult to release water from their structure. The higher amylopectin to amylose ratio have could caused the less solubility of flour (Somto, 2004). Moreover, black glutinous rice flour had higher crude fiber content compare to wheat flour by approximately 0.3% by dry basis. Therefore, the higher total fiber present of black glutinous rice flour, might help to increase the water absorption and retard the solubility of flour.

The pasting characteristics of the flour and flour blends were shown in Table 2. Wheat flour exhibited the peak, trough and final viscosity as 2111 cP, 1444 cP and 2811 cP, respectively, at highest pasting temperature 86.3°C. Where as black glutinous rice flour showed, peak, trough and final viscosity, 1300 cP, 1120 cP and 1390 cP, respectively at the lowest pasting temperature 73.7°C. The setback from trough is related to amylose content and reflects retrogradation of starch. The setback of wheat flour was about 1096 cP more than black waxy rice flour, indicating that wheat flour had greater retrogradation than black glutinous rice flour. Wheat flour also had higher cooled paste viscosity as a result of the ability of amylose molecule to re-associate to cooling (Ragaee and Abdel-Aal, 2006). In addition to, the pasting temperature, peak time, peak viscosity, trough, final viscosity, breakdown and setback decreased directly with the increasing of black glutinous rice flour substitution ($p<0.05$). It is possible to explain that pasting properties of flour depended on the amylose content of flour mixtures. Consequently, amylose content of mixture rice flour was decreased as the black rice flour substitution. In the mixtures, the peak, trough and final viscosity including breakdown and setback values of the flour mixture pastes were decreased significantly ($p<0.05$)

Table 1. Amylose content, water absorption index and water solubility index of flour and flour mixtures

Black glutinous rice flour substitution (%)	Amylose (%)	Water absorption index (WAI)	Water solubility index (WSI) (%)
0	24.16 ± 0.10^{a}	1.89 ± 0.12^{c}	17.52 ± 0.31^{a}
30	9.51 ± 0.10^{b}	1.99 ± 0.16^{c}	19.41 ± 0.10^{b}
50	6.22 ± 0.21^{c}	2.02 ± 0.08^{c}	10.23 ± 0.21^{c}
70	5.69 ± 0.32^{d}	2.34 ± 0.09^{b}	5.71 ± 0.12^{d}
100	4.82 ± 0.15^{e}	2.66 ± 0.06^{a}	4.32 ± 0.11^{e}

Different superscripts in the same column mean that the values are significant differences ($p<0.05$, $n=3$)

Table 2. Viscosity behavior of wheat and black glutinous rice flour mixtures and properties of their batters

Sample	Black glutinous rice flour substitution (%)	Flour mixture							batters	
		Pasting temperature (°C)	Peak time (min.)	Peak viscosity (cP)	Trough (cP)	Final viscosity (cP)	Breakdown (cP)	Setback (cp)	Viscosity (cp)	Specific gravity
Flour mixtures	0	86.27 ± 0.89^{a}	6.30 ± 0.03^{a}	2111.00 ± 71.13^{a}	1444.33 ± 73.76^{a}	2811.00 ± 39.85^{a}	666.67 ± 4.16^{a}	1366.67 ± 10.82^{a}	8579.67 ± 75.26^{a}	0.83 ± 0.01^{d}
	30	83.65 ± 3.25^{b}	6.26 ± 0.01^{a}	1839.67 ± 36.95^{b}	1251.33 ± 27.54^{b}	2499.33 ± 78.42^{b}	588.34 ± 17.62^{b}	1248.33 ± 11.25^{b}	7351.33 ± 57.47^{b}	0.84 ± 0.01^{d}
	50	76.27 ± 1.21^{c}	6.23 ± 0.01^{ab}	1550.00 ± 72.13^{c}	1187.33 ± 89.87^{bc}	2192.67 ± 82.97^{c}	362.67 ± 19.40^{c}	1005.34 ± 18.77^{c}	6756.67 ± 58.45^{c}	0.92 ± 0.01^{c}
	70	75.22 ± 0.14^{c}	6.15 ± 0.04^{b}	1380.00 ± 25.24^{d}	1167.33 ± 34.65^{bc}	1923.67 ± 48.13^{d}	212.67 ± 10.26^{d}	756.34 ± 24.85^{d}	5382.67 ± 74.97^{d}	0.98 ± 0.01^{b}
	100	73.68 ± 0.06^{c}	4.13 ± 0.01^{c}	1300.33 ± 80.65^{d}	1119.67 ± 36.29^{c}	1390.33 ± 40.38^{e}	180.66 ± 15.37^{e}	270.66 ± 37.45^{e}	4436.00 ± 55.56^{e}	1.01 ± 0.01^{a}

Different superscripts in the same column mean that the values are significant differences ($p<0.05$, $n=3$)

with the increase of black glutinous rice flour from 1840 – 1380 cP, 1251-1167 cP, 2499-1924 cP, 588-213 cP and 1248-756 cP, respectively. In a study of Sompong *et al*. (2011), found that very low amylose (8.9-9.6%) black waxy rice varieties showed a low trough viscosity, low final viscosity and low setback value. Moreover, the pasting properties of the flour mixtures was in accord with the result of Blazek and Copeland (2008), which indicated that pasting properties in terms of peak viscosity, final viscosity, break down, setback of wheat flour correlated negatively with total amylose content of wheat flour. Therefore, the amylose content of flour was a good predictor of pasting properties. In contrast, there were no correlations between amylose content of starch and pasting property. These results indicated that protein, lipid and non-strach polysaccharide make important contributions to the viscosity of flour. Moreover, Debet and Gidley (2006) suggest that for high amylose starch, swelling behavior is dominated by the composition of carbohydrates and protein have a little effect.

Batter properties

Batters are obtained by aerating the liquid mixture via mechanical mixing to form the characteristics of the resulting cakes. Cake batter viscosity during baking is very important for final cake quality. Starch gelatinization and egg protein coagulation increase the viscosity of the batter tremendously (Mizukoshi *et al*., 1979). This imparts a solid character to the cake. The combined effect of the swollen starch granules and the continuous egg protein gel phase surrounding them, creates the firm structure of the cell wall material (Wilderjans *et al.*, 2010). Viscosity of batters were significantly decreased as black glutinous rice flour substitution from 8579 cP to 4436 cP for 0 to 100% of the substitution, respectively. ($p<0.05$, Table 2). The experiment of Kim and Walker (1992) indicated that an increase in batter viscosity could aid air incorporation so the less specific gravity of batter was detected. As a result, the maximum viscosity of wheat flour batter indicated the minimum specific gravity of the batter. Moreover, the specific gravity of batter was increased directly with the amount of black glutinous rice flour substitution from 0.8 to 1.0 for 0 to 100%, respectively. This might be due to the different types of protein presence in rice flour and wheat flour. Protein of rice flour include albumin, globulin, prolamin and glutelin in which glutelin was the major fraction, being about 80% of total protein. Whereas, wheat flour mainly contained gliadin and glutenin protein (Hoseney, 1994). Therefore, the wheat batter could entrap much more incorporated

Table 3. Color parameter of cake substituted with difference level of black glutinous rice flour

Black glutinous rice flour substitution (%)	Crust						Crumb					
	L*	a*	b*	hue angle	chroma	ΔE	L*	a*	b*	hue angle	Chroma	ΔE
0	74.83±0.79 ^{a}	5.65±0.10 ^{a}	37.24±1.17 ^{a}	81.37±1.36 ^{a}	37.67±1.17 ^{a}	-	77.77±0.53 ^{a}	3.14±0.23 ^{a}	38.14±0.83 ^{a}	85.29±0.88 ^{a}	37.67±1.42 ^{a}	-
30	45.28±1.41 ^{b}	3.40±0.16 ^{b}	11.69±0.13 ^{b}	73.78±037 ^{b}	12.17±0.36 ^{b}	39.13±1.53 ^{d}	48.81±1.59 ^{b}	1.69±0.17 ^{c}	13.83±021 ^{b}	83.03±043 ^{b}	12.1±1.83 ^{b}	37.84±2.13 ^{a}
50	40.90±0.56 ^{c}	3.38±0.15 ^{bc}	8.30±0.15 ^{c}	67.84±0.35 ^{c}	8.96±0.16 ^{c}	44.60±0.65 ^{c}	41.04±0.52 ^{c}	2.52±0.11 ^{b}	11.00±0.19 ^{c}	77.10±0.26 ^{c}	8.96±0.75 ^{c}	45.67±0.73 ^{b}
70	35.17±0.76 ^{d}	3.28±0.21 ^{bc}	5.14±0.29 ^{d}	51.46±0.61 ^{d}	6.10±0.62 ^{d}	51.08±0.76 ^{b}	35.97±0.97 ^{d}	3.10±0.07 ^{a}	8.88±0.16 ^{d}	70.76±0.33 ^{d}	6.10±0.98 ^{d}	51.02±1.06 ^{c}
100	31.99±0.38 ^{c}	3.09±0.12 ^{c}	3.37±0.09 ^{c}	47.48±0.14 ^{c}	4.57±0.16 ^{c}	54.67±0.36 ^{a}	32.08±0.34 ^{c}	3.02±0.37 ^{a}	6.46±0.93 ^{c}	64.94±1.09 ^{c}	4.57±1.09 ^{c}	55.60±1.24 ^{d}

Different superscripts in the same column mean that the values are significant differences (p<0.05, n=3)

Table 4. Physical properties of cakes

Black glutinous rice flour substitution (%)	Central height (cm)	Specific volume (cm^3g^{-1})	Density (g/cm^3)	Firmness (N)	Springiness ^{ns}	Resilience	Gumminess (N)	Chewiness (N)
0	3.46 ± 0.05 ^{a}	1.95 ± 0.07 ^{a}	1.33 ± 0.05 ^{c}	2.76 ± 0.60 ^{c}	0.80 ± 0.15	0.36 ± 0.04 ^{a}	2.19 ± 0.35 ^{c}	1.76 ± 0.52 ^{c}
30	3.34 ± 0.05 ^{b}	1.85 ± 0.08 ^{b}	1.41 ± 0.06 ^{bc}	4.18 ± 0.63 ^{b}	0.85 ± 0.09	0.30 ± 0.03 ^{b}	2.98 ± 0.37 ^{bc}	2.52 ± 0.23 ^{bc}
50	3.15 ± 0.05 ^{c}	1.78 ± 0.03 ^{b}	1.46 ± 0.03 ^{b}	4.58 ±1.06 ^{b}	0.86 ± 0.06	0.29 ± 0.06 ^{b}	3.17 ± 0.70 ^{b}	2.73 ± 0.73 ^{b}
70	3.11 ± 0.02 ^{c}	1.61 ± 0.10 ^{c}	1.62 ± 0.11 ^{a}	4.98 ± 1.20 ^{b}	0.87 ± 0.03	0.28 ± 0.17 ^{b}	3.50 ± 0.78 ^{b}	3.06 ± 0.75 ^{b}
100	2.78 ± 0.04 ^{d}	1.58 ± 0.05 ^{d}	1.65 ± 0.06 ^{a}	5.56 ± 0.82 ^{a}	0.88 ± 0.07	0.26 ± 0.33 ^{b}	3.94 ± 0.51 ^{a}	3.47 ± 0.57 ^{a}

Different superscripts in the same column mean that the values are significant differences (p<0.05, n=3)
ns within the same column are not significantly different (p≥0.05, n=3)

air during mechanical mixing. Consequently, the higher batter volume of wheat flour was obviously shown when compared with rice flour batter. This might have lead to the lower specific gravity of wheat batter.

Physical and sensory properties of cake

For all color parameters, the extent of color change in cake was dependent on the proportion of black glutinous rice flour and wheat flour. The L^*, a^*, b^* hue angle and chroma values of crust and crumb of cakes were significantly reduced as the levels of black glutinous rice flour substitution. (p<0.05, Table 3). The highest of L^* values a was found in cake prepared from 100% of wheat flour or 0% of black glutinous rice flour and L^* gradually decreased in cake substituted wheat flour with black glutinous rice flour from 30 g to 100%. As a result, crust and crumb of cakes became darker as the proximately decreasing lightness to maximum 57-59%, respectively, compared with wheat flour cake. The darkness of cake might have resulted from the pigments in black rice flour. It is known that, in rice, the black color arises mainly from ayanidin 3-glucoside and peonidin 3-glucoside, giving the kernels their dark purple shade (Sompong *et al*., 2011). The b^* values of crust and crumb of cake also decreased significantly with black glutinous rice flour substitution in cake formulation representing a decreased yellowness of cake. As an accordance with the result of hue angle, which indicated that colors of crust and crumb of cake were changed from yellow (Hue angle ≥ 80) to orange red (Hue angle ≥ 48). While, the chorma value of cake was significantly decreased as the black rice flour substitution (p <0.05) indicated the decreasing of color saturation. Moreover, the increasing of black rice flour substitution caused much more color difference from control cake (0% of black glutinous rice flour substitution) as the increased values. All color values were insisted with the appearance of the external and internal structure clearly revealed difference. It was observed that control cake had the yellow color while the cake produced with black glutinous rice flour, presented light brown to black color and satisfactory appearance in term of structure and shape.

Table 4 represents influence of black glutinous rice flour on the physical properties of the cakes. Substitution of wheat flour with glutinous rice flour significantly decreased the minimum specific

Table 5. Hedonic mean scores of sensory evaluation of cakes containing different amounts of black glutinous rice flour

Black glutinous rice flour substitution (%)	Color	Flavor[ns]	Taste[ns]	Texture [ns]	Overall acceptability [ns]
0	7.13 ± 1.54[a]	6.68 ± 1.46	6.93 ± 1.62	6.73 ± 1.69	7.00 ± 1.41
30	6.05 ± 1.85[b]	6.95 ± 1.28	6.88 ± 1.30	6.65 ± 1.59	6.85 ± 1.32
50	6.90 ± 1.28[a]	6.63 ± 1.31	6.83 ± 1.30	6.68 ± 1.33	6.60 ± 1.23
70	7.03 ± 1.03[a]	6.77 ± 1.31	7.13 ± 1.34	7.08 ± 1.16	7.10 ± 1.24
100	6.68 ± 1.93[a]	6.9 ± 1.49	7.05 ± 1.63	6.73 ± 1.60	7.08 ± 1.54

Different superscripts in the same column mean that the values are significant differences ($p<0.05$, n=3)
ns within the same column are not significantly different ($p\geq0.05$, n=3)

volume and central height of cake about 19% and 20%, respectively, compared with 100% of wheat flour cake. Varavinit and Shobsngob (2000) studied the characteristics of butter cakes prepared from rice flour and wheat flour, in which found that volume of wheat flour cake was higher than rice cake. The greater rising volume for the wheat flour cake over the mixed rice flour cake probably resulted from the higher ability of gluten to trap CO_2 gas liberated from baking powder. So far these properties of gluten have not been completely achieved in the rice flour mixtures. Moreover, Zhou and coworkers (2011) explained that cake volume was a measure as cake size and reflected the amount of air initially entrapped during mixing resulting the expansion of baking products. These gases may be dispersed in small cells throughout a fine crumb or in larger cells throughout a coarser crumb. Density of cake was significantly increased directly with black glutinous rice flour content substitution. The rice cake with 100% of black glutinous rice flour had the highest density about 1.7 g/cm^3, while the lowest density value (approximate 1.3 g/cm^3) was found in cake contained 100% of wheat flour. This fact could be explained by the increases in density caused by decrease in the air volume incorporated to the batter. These results were similar to the previous study by Varavinit and Shobsngob (2000) who found density values of cake samples added with rice flour were higher than those of wheat cake. Firmness of cake also increased with the increasing percentage of black waxy rice flour. As expected, the firmness of cakes was highly sensitive to the specific volume, with lower volume producing a denser crumb structure and a harder texture. Moreover, it can be observed that the gumminess and chewiness significantly increased when the percentage black glutinous rice flour increased, whereas the springiness appeared to a little affected ($P\geq0.05$). It may be explained that the change of pasting properties (Table 2) during heating and cooling with different mixing ratios of flour associated with cake texture. Particularly, peak viscosity was negatively correlated with firmness, gumminess and chewiness (correlation coefficient, r = -0.970, -0.966, and -0.971, respectively). This is also supported by the fact that gluten plays important role in producing internal texture of cakes. The batter viscosity decreased with lower gluten content. A higher batter viscosity prevented the loss of air and increased batter stability, thus, batter with high viscosity should have a lower firmness.

The sensory evaluation scores for color, aroma, softness, gumminess, taste and overall acceptability were are presented in Table 5. Color is an important quality factor directly related to the consumer acceptability of cake products. It was observed that 30% black waxy rice flour substitution gave the highest color score ($P<0.05$) and no significant scores ($P<0.05$) in the others formulations. No difference in flavor, taste, texture and overall acceptability scores were found between control cake and others formulations. According to texture profile analysis, the increase in substitution level of black glutinous rice flour resulted increased firmness, gumminess and chewiness, but did not affect with texture attribute from the sensory evaluation. Observing the overall acceptability scores, it can be stated that partial or overall substitution of black glutinous rice flour into wheat flour did not affect ($P>0.05$) acceptability of the products. So, black glutinous rice flour has a potential to be used as raw material for substitute 100% of regular wheat flour in cakes.

Conclusion

The substitution of black glutinous rice flour for wheat flour effected on the batter and cake functional properties without changing sensory qulity characteristics or consumer acceptance of the final product exhibiting similar or improved properties compared to the product made only using wheat floor. The black glutinous rice flour-substituted-cakes also had greater firmness, gumminess and chewiness values as compared to wheat cake. Therefore, glutinous back rice flour could be considered as a potential functional ingredient in bakery industry for adding value to the food product while providing health and economic benefits. Additionally, the future studies are recommended to determine the effect of hydrocolloids which may improve the quality characteristics of cakes.

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