International Food Research Journal 23(6): 2413-2418 (December 2016)

Journal homepage: *http://www.ifrj.upm.edu.my*

Effect of gluten free composite flour and egg replacer on physicochemical and sensory properties of cakes

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Article history

Received: 25 August 2015
Received in revised form: 2 February 2016
Accepted: 14 February 2016

Keywords

Gluten free
Composite flour
Egg replacer
Cake

Abstract

This study was aimed to find the formulation of composite flours from rice, cassava, and soybean flours, potato starch, and hydrocolloids, and also to find the egg replacer formulation from whey and soybean protein isolate. The composite flours and egg replacer then were used as wheat flour and egg alternatives in cake production, and some physicochemical and functional properties of the treated cake were compared with standard cake. The results showed that the different formulation gave the different effect on physicochemical and functional properties of composite flours. The composite flours from rice flour: cassava flour: potato starch: soybean flour: xanthan gum with the proportion of 30: 40: 15:14.5:0.5 had the pasting properties that comparable to those of wheat flour, although it still had the lower protein content than wheat flour. Egg replacer from the mixture of soy protein isolate, corn starch and xanthan gum had the functional properties that were comparable to those of whole egg flour. The gluten free of composite flour and egg replacer can be used as the raw material in gluten and egg free cakes with the acceptable sensory properties.

Introduction

Cake is a form of bread or bread-like food, typically a sweet baked dessert (Okaka, 2005). Cake popularity has encouraged the development of newer and more attractive products those are available in the market today. It is often a dessert of choice for meals at ceremonial occasions, particularly birthdays and wedding anniversaries.

Normally, cakes contain flour (usually from wheat), sugar, eggs, butter or oil with some varities also requiring liquid (milk or water) and leavening agents such as yeast or baking powder. Gluten is the main structural protein in wheat and it plays an important role in cake products since it provide the dough with its adequate viscoelastic properties. On the other hand several people encounter an adverse physiological reaction when they consume the food product that contains gluten or egg. This condition has prompted the rising demand for gluten and egg's free products. The gluten free diet can help in treatment of disorder such as celiac patient, autism, chronic fatigue, schizophrenia, attention deficit disorder, multiple sclerosis, migraine, and fertility problem. Gluten free and wheat free diets were also endorsed by celebrities as a weight loss regimen, and including them as part of their lifestyles (Packaged Facts, 2015).

Gluten free cakes can be produced by using composite flour which made by blending various gluten free flour, from cereals, legumes, tubers, and root crops in appropriate mixture (Olaoye *et al*., 2006). Xanthan gum is added to naturally gluten free flours to mimic the viscoelastic properties of gluten (Lazaridou *et al*., 2007), while soybean flour is used to improve the protein quality (Okoye *et al*., 2008).

Different egg replacers have been tried over the years to partially or completely replace egg. Some of these egg replacers include soy bean flour, wheat starch, gum, milk casein, rye, and blood plasma (Lynn, 1978; Johnson *et al*.,1979). There are reports based on studies to evaluate functionalities of egg replacer/egg alternatives in cake formulation (Johnson *et al*., 1979; Miller and Setser, 1983; Abdul Hussain and Al-Oulabi, 2009). These egg replacers have been tested to obtain comparable properties/qualities to those of conventional products.

The objective of this research was to evaluate the possibility of preparing an egg and gluten free cake by using composite flour and egg replacer with comparing some physical and chemical properties of the treated cake with standard cake.

Materials and Methods

Commmercial rice flour and wheat flour was

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procured from PT.Budi Makmur Perkasa Indonesia and PT.Indofood Sukses Makmur Tbk. Indonesia, respectively. Cassava tuber of Gunting Saga variety, and white tuber of sweet potato were processed into flour. Desiree variety of potato tuber was processed into starch, and Anjasmoro variety of soybean was processed into flour. All of these raw materials were sourced from local market in Medan, Indonesia. Maize starch, shortening, skimmed milk, sugar, vanilla, eggs, and baking powder were obtained from lokal market, Medan, Indonesia. Xanthan gum and guar gum (Sigma-Aldrich USA) were procured from PT.Elo Karsa Utama (Jakarta, Indonesia). Soy protein isolate was procured from Puritans Pride, USA.

Composite flour and egg replacer preparation

Cassava/sweet potato flour, potato/maize starch, soybean flour and xanthan gum were blended by using a mixer in different combination. "COM1" blends consisting rice flour, cassava flour, potato starch, soybean flour and xanthan gum in the ratio of 30:40:15:14.5:0.5. "COM2" blends consisting rice flour, sweet potato flour, maize starch, soybean flour and xanthan gum in ratio the of 30 : 40 : 15 : 14.5:0.5. "COM3" blends consisting rice flour, sweet potato flour, potato starch, soybean flour, and xanthan gum in the ratio of 30 : 40 : 15 : 14.5:0.5.

Four different egg replacers were also made through mixing the ingredients using a mixer. "A" blends contained soy protein isolate, maize starch, guar gum, and xanthan gum in the ratio of 70:29.5:0.5:0 and 70:29.5:0:0.5 and denoted as E_1 and E_2. "B" blends consisting whey protein isolate, maize starch, guar gum, and xanthan gum in the ratio of 70:29.5:0.5:0 and 70:29.5:0:0.5 and denoted as E_3 and E_4.

Each treatment of composite flour and egg replacer samples was analyzed for moisture, ash, crude fiber, protein (N *6.25), crude fat and carbohydrate (AOAC, 1995). The color of composite flours and egg replacer were determined by using a chromameter (Minolta Type CR-300, Japan) and considered the parameters L^*, a^* and b^*. The functional properties of composite flour such as water absorption index (WAI), oil absorption index (OAI) and swelling power were determined by standard methods. WAI and OAI were determined according to the methods of Niba *et al.* (2001). Rheological or pasting properties of composite flour were evaluated with Rapid Visco Analyzer (RVA, Model Tecmaster Newport Scientific, Australia). The following data were recorded: pasting temperature (Ptemp); peak viscosity (PV); breakdown viscosity (BD); final viscosity (FV) and setback viscosity (SB). The functional properties of egg replacer such as foam capacity and stability were measured using modified method of Barac, *et al.* (2010) and Balmaceda, *et al.* (1984), emulsion capacity and activity were measured using method of Yasumatsu, *et al*. (1972), and bulk density using method of Okaka and Potter (1977). Wheat flour (WF) and whole egg flour were used as control for composite flour and egg replacer respectively.

Sponge cake preparation

The gluten free cake was made by using composite flour which had the quality that closed to wheat flour, and egg free cake was made by using egg replacer wich had the quality resembling to whole egg flour. Cake batters were made according to Bennion and Pamford (1997) with some modifications. The formulation of gluten and egg free cake and control cake were shown in Table 1.

Flour, xanthan gum, and baking powder were mixed together; whole fresh egg or egg replacer, skimmed milk, shortening, and vanilla were whipped for 6 min using a mixer at high speed (for egg's free sample where egg was replaced by an egg replacer, more shortening was added to make whipped dough). Flour mixture was added gradually in the whipped milk-vanilla mixture, and beaten for 3 min using a mixer at low speed until a smooth batter formed. The batter then poured into stainless cake pan, placed in a preheated oven and baked at 180°C for 35 min. Cakes were allowed to cool for 30 min in the pans at room temperature.

Chemical, baking, and sensory properties of the cake samples were determined. Moisture content, protein, fat, ash, fiber, carbohydrate were analyzed according to AOAC (1995). The cake color was measured on crumb surface using a Chroma meter CR-200 (Konica Minolta Sensing, Japan). $L^*a^*b^*$ values were recorded and the results reported as browning index (BI), calculated according to Maskan (2001).

$$BI = \frac{[100.(x - 0.31)]}{0.17} \quad (1)$$

where x is defined as

$$x = \frac{a + 1.75L}{5.645L + a - 3.01b} \quad (2)$$

where a^* is redness, b^* is yellowness, and L^* is lightness. The average of three measurements was taken as the crumb color parameters.

Cake texture was measured as the resistance to shear force using Universal Testing Machine (UTM). Force required to attain a given deformation was measured as F max (in Newton). Sensory property was evaluated by 15 semi trained panelists for color, Tabel 1. Recipe used in dough formulation per loaf

Ingredient	Composition (g)			
	GFC	EFC	GEFC	CC
Cassava Flour (g)	30	0	30	0
Rice Flour (g)	40	0	40	0
Potato Starch (g)	15	0	15	0
Soybean Flour (g)	14.5	0	14.5	0
Wheat Flour (g)	0	100	0	100
Xanthan Gum (g)	0.5	0	0.5	0
Egg Replacer (g)*	0	18.2	18.2	0
Baking Powder (g)	3	3	3	3
Egg (g)	125	0	0	125
Sugar (g)	100	100	100	100
Skim Milk (g)	50	50	50	50
Shortening (g)	10	18	120	10
Vanilla flavoring (g)	2	2	2	2

GFC = gluten free cake, EFC = egg free cake, GEFC= gluten-egg free cake, CC = control cake (made from wheat flour and whole egg). Egg replacer = a mixture of soy protein isolate: maize starch: xanthan gum = 70:29.5:0.5

odor, taste and texture on a 5-point hedonic scale (5 = liked very much, 4 = liked, 3 = neither liked nor disliked, 2 = disliked, 1 = disliked very much).

Data analysis

Data using completely randomized design was analyzed using MINITAB Statistical software (Release 14, Minitab Inc. USA). The data reported in all tables are an average of triplicate observations subjected to one-way analysis of variance (ANOVA). Tukey's test was performed to compare differences among the mean values at a confidence level of 0.05.

Results and Discussion

Physicochemical and functional properties of composite flour and egg replacer

The results of physicochemical and functional properties of composite flours was shown in Table 2. Cassava, sweet potato and soybean flour had higher content of ash, fat and crude fiber which explains the higher content of these components in composite flour (Ansari *et al.*, 2013; Tharise *et al.*, 2014). However the wheat flour has the highest protein content compared with other samples.

Table 2 also shown that, in general the composite flours had the lower viscosity than thos of wheat flour. The composite flour with the composition of rice flour : cassava flour : potato starch : soybean flour : xanthan gum = 30 : 40 : 15 : 14.5 : 0.5 (COM1) had the similar pasting properties with those of wheat flour especially in PV, CPV, and SBV. Therefore this flour was used in making gluten free cake (GFC),

Table 2. Proximate composition of composite flour compared to wheat flour

Parameter	COM1	COM2	COM3	WF
Moisture (%)	9.37[c]	10.46[b]	10.52[b]	13.35[a]
Protein (%)	6.22[b]	5.69[c]	6.59[b]	7.52[a]
Fat (%)	4.91 [b]	7.60 [a]	4.79 [b]	2.12 [c]
Ash (%)	1.12 [b]	1.97[a]	1.91 [a]	0.75 [c]
Crude Fiber (%)	1.40 [b]	2.78 [a]	1.48 [b]	1.31 [c]
L* Value (Color)	95.88 [a]	91.79 [b]	91.85 [b]	95.02[a]
WAI (g/g)	2.36	2.25	2.17	2.12
OAI (g/g)	1.94	2.10	2.14	2.02
Baking expansion (ml/g)	0.68 [c]	0.81 [b]	0.81 [b]	0.87 [a]
Swelling Power (g/g)	4.27 [c]	7.25 [b]	11.35 [a]	11.70 [a]
Tg (°C)	72.07 [b]	74.8 [b]	73.68 [b]	83.97 [a]
PV (cP)	2312[b]	1089[c]	614 [d]	2472 [a]
CPV (cP)	2619[a]	1363[b]	408 [c]	2640 [a]
SBV (cP)	1305[b]	570 [c]	244 [d]	1329 [a]
BDV (cP)	998 [b]	296 [d]	283[c]	1161 [a]

The values are expressed as the mean of three replicate samples. Values with similar superscripts in a row do not differ significantly ($P<0.05$).
WF = Wheat Flour, COM = composite flour, WAI = water absorption index, OAI = oil absorption index. PV = peak viscosity, CPV = cold paste viscosity, SBV = setback viscosity, BDV = breakdown viscosity

whereas, the other composite flour (COM 2 and COM 3) had lower viscosity than those in wheat flour. These flour can be used in food product requiring lower gel strength such as sauce or cookies.

Physicochemical and functional properties of egg replacers compared to whole egg flour were shown in Table 3. The different protein used in egg replacers gave the significantly different in color (L^*, a^* and b^* value). Egg replacer from soy protein isolate had the lower lightness value (L^*), but had the higher a^* and b^* value than egg replacer from whey protein isolate. The L^* value of egg replacer were significantly higher ($P<0.05$) than those in whole egg flour. Table 3 shows that the different egg replacer had significant differences in chemical composition. Egg replacers had higher protein content but lower fat content than those of whole egg flour. There was no significant effect from the use of the different types of hydrocolloid on physicochemical and functional properties of egg replacer. Based on the foaming and emulsion characteristics, egg replacer with the similar characteristics of whole egg flour was E_2 (soy protein isolate, maize starch and xanthan gum), because it had the higher foaming stability. Therefore E_2 further was used as egg replacer in egg free cake.

Chemical composition of cake samples

The proximate composition of cake samples

Table 3. The physicochemical and functional properties of egg replacer compared with whole egg flour

Parameter	E_1	E_2	E_3	E_4	Whole egg flour
Color value :					
- L*	91.43^{b}	91.87^{b}	94.62^{a}	94.49^{a}	82.70^{c}
- a*	0.83^{b}	0.76^{a}	-0.31^{c}	-0.35^{c}	4.25^{a}
- b*	12.71^{b}	12.97^{b}	10.48^{c}	10.66^{c}	37.92^{a}
Density (g/ml)	0.66^{a}	0.65^{a}	0.59^{ba}	0.60^{b}	0.67^{a}
Moisture	8.44^{a}	8.51^{a}	8.32^{a}	8.40^{a}	8.60^{a}
Protein (%)	61.74^{a}	61.98^{a}	61.68^{a}	61.87^{a}	56.10^{b}
Fat (%)	1.32^{b}	1.09^{b}	0.37^{c}	0.38^{c}	25.34^{a}
Ash (%)	3.56^{a}	2.70^{b}	1.81^{c}	1.80^{c}	3.97^{a}
Foaming Capacity (%)	62^{b}	56^{b}	80^{a}	86^{a}	29^{c}
Foaming Stability (%)					
- 15min	98^{b}	98^{b}	57^{c}	57^{c}	99^{a}
- 30min	97^{a}	98^{a}	54^{c}	53^{c}	89^{b}
Emulsion activity (%)	44.1^{b}	44.2^{b}	41.2^{a}	41.3^{b}	54.0^{a}
Emulsion Capasity (%)	7.4^{b}	7.2^{b}	7.6^{b}	7.3^{b}	14.4^{a}

The values are expressed as the mean of three replicate samples. Values with similar superscripts in a row do not differ significantly (P<0.05).

Table 4. The chemical composition and baking quality of cake samples

Parameter	GFC	EFC	GEFC	CC
Moisture (% d.b.)	30.24± 0.83^{b}	22.39 ±0.84^{c}	30.24 ±0.83^{b}	33.29 ±0.69^{a}
Ash (% d.b.)	1.95± 0.07^{a}	1.72 ±0.09^{a}	1.02 ±0.22^{b}	1.68 ±0.03^{a}
Protein (% db)	5.07± 0.24^{bc}	18.83 ±0.33^{a}	4.84 ±0.52^{c}	5.66 ±0.07^{b}
Fat (% d.b.)	6.05± 0.12^{c}	15.06 ±0.52^{b}	24.21 ±1.42^{a}	4.70 ±0.12^{c}
Carbohydrate (% d.b.)	56.69± 0.69^{a}	42.00 ±0.60^{b}	39.69 ±2.52^{b}	54.67 ±0.82^{a}
Crude Fiber (% d.b.)	1.61± 0.08^{a}	1.46 ±0.33^{a}	2.85 ±0.96^{a}	0.77 ±0.23^{b}
Specific volume (ml/g)	1.57±0.33^{ab}	1.01±0.29^{b}	1.36±0.01^{ab}	1.96±0.25^{a}
Firmness (N)	6.62±0.47^{b}	11.40±1.^{18ab}	6.45±0.01^{b}	12.25±2.85^{a}
Browning Index	83.46±3.79^{b}	99.67±8.70^{a}	54.06±3.36^{c}	89.27±0.53^{b}

The values are expressed as the mean of three replicate sampels ± standard deviation. Values with similar superscripts in a row do not differ significantly (P<0.05). GFC = gluten free cake, EFC = Egg free cake, GEFC = gluten and egg free cake, CC = control cake (from wheat flour and whole egg). d.b. = dry basis

was shown in Table 4. Moisture content of cake was significantly (P<0.05) higher in control cake (CC) than the other cakes. EFC had the significantly lowest moisture content. Moistness is a favorable sensory attribute in baked products because it is synonymous with a soft, tender product. However, too much moisture promotes microbial growth (Nonaka, 1997). Table 4 shows that there was no significant difference among GFC, EFC and CC in ash content, but GEFC had significantly lowest ash content. The EFC significantly had the highest protein content, whereas it had no significant differences in protein content among GFC, EFC and CC. The higher crude fiber was found in GEFC, but it was insignificantly different from those in GFC and EFC. The significantly lowest crude fiber was found in the control cake. The fat content of cake was highest in GEFC, followed by EFC. This is due to the higher shortening addition in GEFC and EFC. There was no significant difference between GFC and CC in fat content.

Baking quality of cake samples

The baking quality of cake samples determined were specific volume, firmness, and browning index as shown in Table 4. The highest specific volume was found in control cake, but it did not different significantly from GFC and GEFC. High quality cakes should have a high specific volume. Fat or shortening aids in producing high volume cakes by incorporating and retaining air during the creaming stage (Penfield and Campbell, 1990). Therefore, although GEFC contains no eggs in its dough, but it had more shortening, so it had higher specific volume than those of EFC. Egg protein readily whips into foam of extremely fine air cells. When egg foam is subjected to heat, the air trapped within the bubbles will expand, thereby increasing the volume of the foam. As a result of the coagulation of the egg white, the egg foam will become rigid and will thus maintain its increased volume (Pyler, 1973). The addition of xanthan gum in GFC and GEFC may also increase foam stability (Mott, 1999). Pernell *et al*. (2002) found that the addition of xanthan gum in angel cake will increase its volume. Whereas, in EFC, the cake batter was probably not sufficiently viscous to minimize the coalescence of gas bubbles, which causes loss of leavening gases found during baking as large bubbles rises to the surface and escape (Penfield and Campbell, 1990).

Crumb firmness values for the cake samples are presented in Table 4. Significant differences (P<0.05) were found among the cake samples. GFC and GEFC were significantly softer (P<0.05) than CC, but were not different significantly (P>0.05) than EFC. No significant difference (P>0.05) between CC and EFC. The cake firmness was analyzed by using

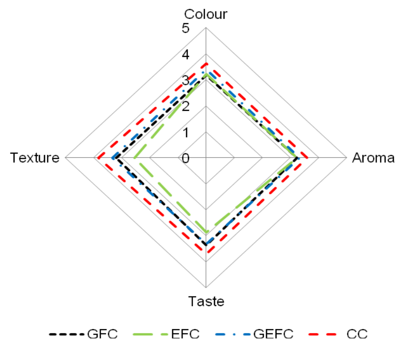

Figure 1. Hedonic sensory evaluation of cake samples (GFC = gluten free cake, EFC = egg free cake, GEFC = gluten and egg free cake, CC = control cake).

Universal Testing Machine which showed a crumb hardness of the cakes. It could be seen as softness or freshness of cake. The lower value of firmness crumb shows that the cake was softer and brittle. In the EFC, the higher firmness value shows that the crumb was elastic and rubbery (Heflich, 1996). The addition of soy protein isolate as egg replacer in EFC induced an increase in the higher value of crumb firmness

Significant differences ($P<0.05$) were observed in browning index among cake samples. The results of the crumb browning index indicated that EFC was significantly darker ($P<0.05$) than the other cakes, and GEFC sample had significantly less brown crumb. It is due to the higher content of protein in EFC, Mailard browning and caramelization, which are influenced by the water distribution and the reaction between sugars and amino acid (Kent and Evers, 1994).

Sensory quality of cakes

From Figure 1 shows averaged results of hedonic sensory evaluation of different cake samples. Although the acceptance of control cake by panelists was highest, but in color and aroma, there was no significant difference between CC and GEFC. In the taste attribute, there was no significant difference between CC and GFC. The hedonic score of GFC and GEFC were 3.18 – 3.40 (neutral to liked). As can be seen in Figure 1, EFC had the lowest score by panelists in all attributes of sensory quality.

Conclusion

The composite flour from rice flour, cassava flour, potato starch, soybean flour and xanthan gum with the proportion of 30%:40%:15%:14.5%:0.5% had the similar characteristics with those of wheat flour, and can be used as wheat replacer in gluten free cake. Egg replacer from a mixture of soy protein isolate, maize starch and xanthan gum with the proportion of 70:29.5:0.5 had a better foaming and emulsion characteristics and exhibited potential to produce an acceptable sponge cake. The sponge cake formulated with gluten free composite flour and egg replacer although still exhibited a brittle crumb and lower volume, but they had a comparable sensory quality than those of control cake.

Acknowledgement

We wish to thank to Directorate General of Higher Education, Ministry of National Education Republic of Indonesia for funding this research through "Hibah Strategis Nasional 2013-2014" project.

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