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Effect of Gluten-Free Flours on Physical Properties of Cakes

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Abstract: In this study, the effect of lupin flour (LF) and whole buckwheat flour (BF) on the physical properties of gluten-free cake was studied. LF up to 40% and BF flour up to 20% level were partially replaced with corn starch and rice flour mix in the gluten free cake recipe. Cake dough properties (specific gravity and pH), cake properties (weight, volume, symmetry and uniformity index, hardness), crust and crumb color values were investigated. High addition levels of LF decreased the pH values of the dough. Compared to control, volume index of the cakes improved with BF at 5% addition level or LF up to 20% level. While minimum level of the LF/BF gave softer cake texture, high substitution levels of LF (30%-40%) and BF (15%-20%) had detrimental effect on softness of the samples. All addition level of the LF increased the darkness and yellowness of the cake's crust and crumb, whereas BF above 5% level decreased lightness and yellowness of the samples. The high levels of LF (30%-40%) and BF (15%-20%) had reducing effect all physical properties of gluten-free cake samples.

Key words: Buckwheat flour, lupin flour, gluten-free, cake making.

1. Introduction

The most common disease caused by cereal protein ingestion is celiac disease. The main agents responsible for celiac disease are gluten proteins from wheat and similar proteins in other closely related cereals (barley, rye and oat) [1, 2]. The only life-long treatment is strict gluten-free diet which is difficult personally, since many foods contain gluten [2, 3]. Tandoruk [4] reported the prevalence of celiac disease in Europe, USA and Turkey as 1:200-1:350, 1:250-1:500 and 1:300-1:500 respectively. Rising demands for gluten-free products parallels the increase in the celiac disease [5].

Gluten-free foods are of low quality, more expensive, not widely available and lack variety with lower palatability [2, 6]. Most of the gluten-free products are on starch basis with the addition of different types of hydrocolloids. However, the gluten-free formulations containing gums as the gluten replacements lack in fibres and nutrients [7]. Therefore it is very important to develop gluten-free foodstuffs with high nutritional quality ingredients.

A large number of flours and starches (rice, corn, amaranth, cassava, soybean and peanut), gums and hydrocolloids, enzymes, soybean proteins, dairy products, egg white, prebiotics have been used to mimic viscoelastic properties of gluten in gluten-free cereal products in order to improve nutritional quality, structure, mouthfeel, acceptability and shelf life [8-10].

Lupin (*Lupinus albus* L.) is a species in the family Leguminosae. LF contains comparatively higher protein (about 40 % by weight) and dietary fibre (30%) contents (both soluble and insoluble) than wheat flour. The high lysine, low methionine content complements that of wheat flour proteins which are poor in lysine and relatively higher in the sulphur containing amino acids [11]. LF also found to provide a wide range of phytochemicals including antioxidants and

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phytosterols which are beneficial to health [12]. Considering its nutritional and functional properties, it has a high potential to be used in different foods such as fermented foods, pasta, crisps, bread, biscuits and cakes [13, 14]. LF is lower in cost compared with other similar legume flours such as soybean [15]. Therefore, with the substitution of LF, it can be produced products with improved nutritional and functional quality at a comparatively lower cost.

Buckwheat is safe for celiac disease patients because of their gluten-free characteristics [16]. Buckwheat grains are a rich source of proteins which have high biological value due to the favorable amino acid composition and vitamins [17, 18], fundamental polyunsaturated fatty acids [19], starch and dietary fiber [20], essential minerals [21] and trace elements [22]. Phenolic compounds are also found in abundance in buckwheat. In comparison to most frequently used cereals, buckwheat has been reported to posses higher antioxidant activity [23]. In order to increase the functionality of wheat based products, BF could have been incorporated into many formulations.

Cakes are popular bakery product which contains basically wheat flour, sugar, egg, shortening, dairy products, emulsifiers, leavening and flavoring agents [24]. In the literature, many studies have been performed in gluten free bread but studies on the other gluten-free bakery products such as cakes and muffins are limited. In our previous study, the effect of LF and BF on chemical properties of the gluten-free cake was researched [25]. Therefore the objective of this study was to investigate the effect of LF and BF on physical cake properties.

2. Materials and Methods

2.1 Materials

Buckwheat groats with 1.92% ash and 12.1% protein were purchased from Yar Gıda (Antalya, Turkey). Lupin seed (L. albus cv) was obtained as traditionally debittered from Doğanhisar, Konya, Turkey. Buckwheat and lupin seeds were ground in a hammer mill (Falling Number-3100 Laboratory Mill; Perten Instruments AB, Huddinge, Sweden) as whole flour. Other cake ingredients (fine granulating sucrose, all purpose shortening, skimmed milk powder, whole egg, salt, baking powder, ethyl vanillin) were obtained from Saray Bisküvi ve Gıda San. A.Ş. (Karaman, Turkey). All purpose shortening was a blend of palm, soybean and cotton seed oil including BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene) as an antioxidant. Corn starch and rice flour were supplied from local markets of Konya, Turkey. Guar gum and diacetyl tartaric acid esters of mono and diglycerides (DATEM, Rikevita, Malaysia) were also used in cake formulations.

2.2 Methods

2.2.1 Cake Preparation

Ingredients of control cake are given in Table 1. Firstly fat and sugar were whipped to a white cream in a Hobart mixer (Hobart N50, Canada Inc., North York, Ontario, Canada). Then egg was added and whipped for 5 min then the other ingredients were added and the batter was mixed for additional 1 minute. One hundred and thirty grams of cake batter were placed into baking pans with 7.5 × 6.6 × 12 cm dimensions and baked at

Table 1 Cake ingredients (gram).

	Control	Cake with LF*	Cake with BF**
Rice flour	100	90, 80, 70, 60	95, 90, 85, 80
Corn starch	100	90, 80, 70, 60	95, 90, 85, 80
Shortening	150	150	150
LF	0	20, 40, 60, 80	0
BF	0	0	10, 20, 30, 40
Sugar	150	150	150
Nonfat dry milk	10	10	10
Whole egg	150	150	150
Salt	1	1	1
Baking powder	9	9	9
Guar gum	4	4	4
DATEM***	1	1	1
Ethyl vanillin	0.2	0.2	0.2

* LF: Lupin flour, ** BF: Buckwheat flour, *** DATEM: diacetyl tartaric acid esters of mono and diglycerides.

160 °C for 50 min in an oven (Bosch HBT 112, Athens, Greece). In enriched cake formulations, rice flour and corn starch was substituted by LF and BF based on the following experimental design: LF substitution (10%, 20%, 30% and 40%) and BF substitution (5%, 10%, 15% and 20%). After baking, cakes were removed from the pan and left 30 min for cooling. After weighing, the cakes were packaged in polyethylene bags and sealed at room temperature (22 °C) until their test and analyses.

2.2.2 Properties of Cake Batter

Specific gravities of the cake dough were calculated with dividing of the weight of a certain volume of cake batter to the weight of the same volume of distilled water. The pH of the batter was measured by a pH meter after mixing 10 g of batter with 100 mL of distilled water.

2.2.3 Cake Properties

Volume index, symmetry index and uniformity index of the cakes were measured by using AACC template method 10-91 [26]. Firmness or softness of cakes was measured in Newton's per square centimeter by a texture analyzer using the procedure of Aydın and Öğüt [27].

2.2.4 Color Measurement

Color of the samples was evaluated by measuring the L (100 = white; 0 = black), a (+, red; -, green) and b (+, yellow; -, blue) values using a Hunter Lab Color QUEST II Minolta CR-400 (Minolta Camera, Co., Ltd., Osaka, Japan). Hue angle (H), which describes the hue or color of samples, was calculated (arctan [b^*/a^*]), as was the saturation index (SI) ($[a^{*2} + b^{*2}]^{1/2}$), which describes the brightness or vividness of color.

2.2.5 Statistical Analyses

Data were subjected to statistical analyses by one-way analysis of variance (ANOVA). The means which were statistically different from each other were compared using Duncan's multiple comparison test at 5% confidence interval. The TARIST (version 4.0, Izmir, Turkey) software was used to perform the statistical analyses.

3. Results and Discussion

3.1 Dough Properties

Specific gravity values of gluten-free cake doughs are given in Table 2. LF at 40% addition level gave the significantly ($P < 0.05$) higher dough specific gravity value than 5% BF addition level into dough formulation. Other addition levels of LF and BF showed similar specific gravity value compared to control. The amount of air incorporated into a batter can be determined by measuring the batter's specific gravity [28]. It has a direct relation to the volume, tenderness, and texture in finished cakes [29]. Low specific gravity is associated with good aeration of batter [30]. In the present study 40% LF addition into dough formulation increased specific gravity, but is not different statistically from control sample. pH of the cake doughs are summarized in Table 2. The crumb color of cake is often significantly affected by its dough pH. In the case of white cake with a given fineness of grain, lowering the pH by 0.2 unit will perceptibly improve crumb whiteness. As the pH of a cake increases, its grain tends to become coarse, with thicker cell walls, while its volume increases [29]. As seen in Table 2, pH of the doughs containing 30%-40% LF decreased significantly ($P < 0.05$) compared to control and other LF/BF addition levels.

3.2 Cake Properties

Some physical cake properties are given in Table 3. Only 5% BF addition level increased ($P < 0.05$) the weight of the gluten-free cakes compared to control. LF up to 20% level and BF at 5% level had a positive effect on gluten-free cake volume index. In contrast, Gȯmez et al. [31] reported that chickpea flour supplemented cakes presented lower gas retention and lower expansion. And also, the volume decreased with increasing amount of chickpea flours. Symmetry index which represents the contour of the cake [32], was decreased significantly ($P < 0.05$) by all addition levels of BF. Due to decreasing symmetry index values

Table 2 Some properties of gluten-free cake doughs and cakes.*

	Specific gravity (g/cm^3)	pH
Control	0.90 ± 0.01^{ab}	6.08 ± 0.01^{a}
10% LF**	0.91 ± 0.03^{ab}	6.07 ± 0.03^{a}
20% LF	0.92 ± 0.03^{ab}	6.02 ± 0.04^{a}
30% LF	0.94 ± 0.04^{ab}	5.85 ± 0.03^{b}
40% LF	0.96 ± 0.03^{a}	5.82 ± 0.03^{b}
5% BF***	0.88 ± 0.01^{b}	6.08 ± 0.01^{a}
10% BF	0.89 ± 0.04^{ab}	6.07 ± 0.03^{a}
15% BF	0.90 ± 0.03^{ab}	6.05 ± 0.03^{a}
20% BF	0.92 ± 0.01^{ab}	6.05 ± 0.01^{a}

* Means with same letter within column are not significantly different (P < 0.05), ** LF: Lupin flour, ***BF: Buckwheat flour.

Table 3 Some properties of gluten-free cake doughs and cakes.*

	Weight (g)	Volume index	Symmetry index	Uniformity index
Control	117.0 ± 0.71^{b}	130 ± 0.85^{c}	5.2 ± 0.28^{b}	1.1 ± 0.14^{b}
10% LF**	116.4 ± 0.57^{b}	135 ± 0.71^{a}	4.4 ± 0.28^{c}	1.2 ± 0.0 ^{b}
20% LF	116.6 ± 0.85^{b}	133 ± 0.85^{ab}	5.0 ± 0.28^{bc}	1.7 ± 0.28^{a}
30% LF	116.5 ± 0.71^{b}	130.0 ± 0.85^{c}	6.3 ± 0.14^{a}	1.9 ± 0.14^{a}
40% LF	116.8 ± 0.71^{b}	125 ± 0.42^{d}	3.70± 0.28^{d}	1.1 ± 0.14^{b}
5% BF***	119.7 ± 0.57^{a}	132 ± 0.42^{b}	2.1 ± 0.14^{f}	1.0 ± 0.14^{b}
10% BF	118.0± 0.71^{ab}	125 ± 0.71^{d}	2.2 ± 0.28^{f}	0.9 ± 0.14^{b}
15% BF	117.5 ± 0.71^{b}	120 ± 0.42^{e}	2.1 ± 0.14^{f}	0.1 ± 0.0^{c}
20% BF	117.7± 0.57^{ab}	116 ± 0.85^{f}	3.0 ± 0.14^{e}	0.1 ± 0.0^{c}

* Means with same letter within column are not significantly different (P < 0.05), ** LF: Lupin flour, ***BF: Buckwheat flour.

indicate that the cake has a flat surface [33, 34]. BF showed the improving effect on cake symmetry. Uniformity index values are also presented in Table 2. Bath et al. [33] and Mercan [34] reported that uniformity index could be nearest to zero for good cake quality. The highest level of BF (15% and 20%) improved the uniformity index of the cakes together with symmetry index, on the other hand decreased the softness of the cake crumb (Fig. 1). Like BF containing cakes, high levels (30%-40%) of LF adversely affected the softness of the cakes. Inversely, minimum usage levels of LF/BF gave softer texture compared to control. In a study by Dervas et al. [13], the volumes of breads decreased as the level of lupin flour increased, nevertheless, substitution at 5% or 10% concentrated lupin flour and defatted concentrated lupin flour gives parameter values at least as good as the control sample and produces acceptable bread in terms of weight, volume, texture and crumb structure.

3.3 Color Values of Gluten-Free Cakes

Crust and crumb colors of the gluten-free cakes are given in Tables 4 and 5. Crust and crumb lightness of the gluten-free cakes decreased with all levels of LF/LB addition except 5% BF compared to control. Low levels of LF (10%-20%) and the high level of BF (20%) gave the most reddish crust color. In LF containing cakes, high protein content of formulation could be caused acceleration of maillard reaction which is produced dark-brown substances. In BF containing cakes, high reducing sugars of BF could play an important role in browning reaction due to fact

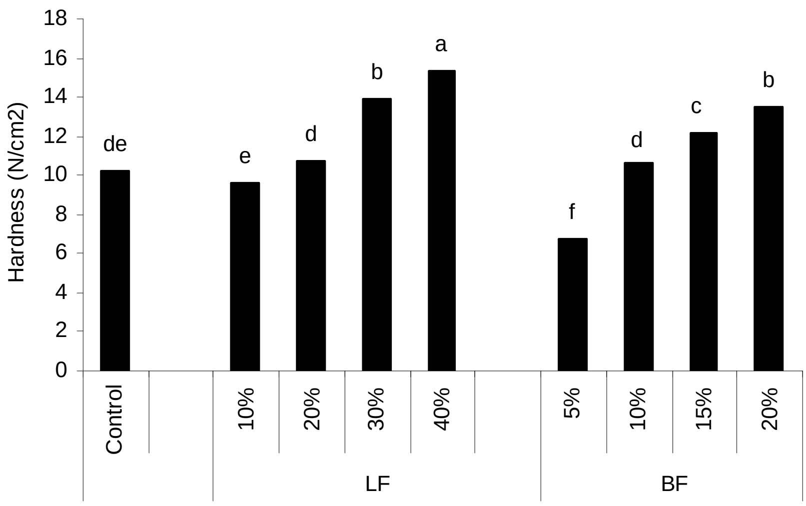

Fig. 1 The effect of LF/BF on hardness value of the gluten-free cake samples.

Table 4 Crust color of the cake samples.*

	L	a	b	SI	h
Control	61.84 ± 0.2[a]	9.45 ± 0.23[e]	28.56 ± 0.23[d]	30.08 ± 0.24[e]	71.69 ± 0.27[a]
10% LF**	59.07 ± 0.6[cd]	13.65 ± 0.24[a]	30.55 ± 0.21[b]	33.46 ± 0.16[b]	65.93 ± 0.24[d]
20% LF	59.73 ± 0.18[b]	13.3 ± 0.31[a]	30.41 ± 0.27[b]	33.19 ± 0.23[bc]	66.37 ± 0.34 [d]
30% LF	59.35 ± 0.14[bc]	12.29 ± 0.28[b]	30.33 ± 0.23[b]	32.72 ± 0.17[c]	67.95 ± 0.28[c]
40% LF	58.72 ± 0.14[d]	12.13 ± 0.3[b]	29.69 ± 0.25[c]	32.07 ± 0.17[d]	67.77 ± 0.33[c]
5% BF***	61.25 ± 0.21[a]	10.6 ± 0.21[d]	34.51 ± 0.2[a]	36.1 ± 0.21[a]	72.93 ± 0.35[a]
10% BF	59.81 ± 0.16[b]	11.32 ± 0.23[c]	30.08 ± 0.24[b]	32.81 ± 0.16[c]	69.82 ± 0.27[b]
15% BF	54.65 ± 0.21[e]	12.44 ± 0.3[b]	26.09 ± 0.27[e]	28.9 ± 0.2[f]	64.51 ± 0.28[e]
20% BF	53.49 ± 0.16[f]	13.27 ± 0.21[a]	24.49 ± 0.24[f]	27.86 ± 0.16[g]	61.55 ± 0.27[f]

* Means with same letter within column are not significantly different ($P < 0.05$). ** LF: Lupin flour, ***BF: Buckwheat flour.

Table 5 Crumb color of the cake samples.*

	L	a	b	SI	h
Control	73.97 ± 0.21[a]	-2.8 ± 0.17 [de]	24.15 ± 0.2[c]	24.31 ± 0.2[c]	-83.39 ± 0.34[c]
10% LF**	70.52 ± 0.18[c]	-1.8 ± 0.21 [bc]	25.73 ± 0.17[b]	25.79 ± 0.16[b]	-86.01 ± 0.31[e]
20% LF	70.88 ± 0.18[bc]	-3.15 ± 0.2[e]	26.07 ± 0.16[b]	26.26 ± 0.27[b]	-83.12 ± 0.28[c]
30% LF	70.51 ± 0.18[c]	-2.69 ± 0.16[d]	27.82 ± 0.18[a]	27.95 ± 0.21[a]	-84.47 ± 0,34[d]
40% LF	70.66 ± 0.16[c]	-2.09 ± 0.2[c]	28.53 ± 0.2[a]	28.61 ± 0.23[a]	-85.8 ± 0.3[e]
5% BF***	73.99 ± 0.2[a]	-1.78 ± 0.18[bc]	19.13 ± 0.23[d]	19.21 ± 0.18[d]	-84.68 ± 0.28[d]
10% BF	71.33 ± 0.18[b]	-1.41 ± 0.16[b]	18.64 ± 0.16[e]	18.69 ± 0.23[d]	-85.69 ± 0.28[e]
15% BF	66.97 ± 0.2[d]	0.52 ± 0.17[a]	17.94 ± 0.16[f]	17.95 ± 0.18[e]	88.38 ± 0.3[a]
20% BF	65.26 ± 0.18[e]	1.05 ± 0.2[a]	17.85 ± 0.18[f]	17.88 ± 0.25[e]	86.63 ± 0.31[b]

* Means with same letter within column are not significantly different ($P < 0.05$), ** LF: Lupin flour, ***BF: Buckwheat flour.

that buckwheat starch can be saccharified relatively easily, and thus cake containing BF could have higher reducing sugar content than control sample [35]. Hue angle values of the gluten-free cake crusts decreased with all levels of LF addition and BF over 5% addition level.

Cake crumb does not reach temperatures above 100 °C, so the Maillard or caramelization reactions by sugars fail to take place. Therefore crumb color must be the result of the raw materials colors and their interactions [31]. As expected, crumb yellowness of the cakes increased with LF addition due to the natural pigmentation of this flour. Adversely, BF has a decreasing effect of yellowness. In our previous studies this lowering effect of BF on yellowness were observed in different cereal products [36, 37]. Similarly yellowness values, LF addition increased saturation index value, but BF negatively affected this color parameter. Doxastakis et al. [38] reported that breads prepared with lupin have dark crust color and more yellowish crumb color. The yellow colors of the lupin flours have a considerable appeal and would be a value in many foods.

4. Conclusion

The effect of the LF and BF on physical properties of the gluten free cakes was investigated in this study. Volume index and softness of the cakes improved with BF at 5% addition level or LF up to 20% levels compared to control. While LF improved the crumb and crust yellowness, LF/BF generally had darkening effect on crust and crumb color. The highest levels of LF and BF had reducing effect all physical properties of gluten free cake samples. In our previous study [25], LF significantly ($P < 0.05$) increased the total protein, fat, Ca, Fe, Mn, P and Zn contents of the gluten free cakes, and BF especially enriched the ash, K and Mg contents of the samples. As a result, gluten free cakes could be prepared with LF/BF addition at low levels without any adverse affect on physical properties of the gluten free cakes.

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