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EFFECT OF WHEY PROTEIN CONCENTRATE AND BUTTERMILK POWDERS ON RHEOLOGICAL PROPERTIES OF DOUGH AND BREAD QUALITY

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ABSTRACT

Whey protein concentrate powder (WPC) and buttermilk powder (BP) were used in leavened and unleavened flat bread dough at different levels (0, 4 and 8%). The effects of WPC and BP on dough rheology were evaluated with farinogram and extensogram parameters. Some physical, chemical and sensory properties of breads were also studied. Generally, WPC and BP addition improved dough properties in terms of dough stability, resistance to extension and maximum resistance values. Protein content of the flat breads increased up to 14.6% with WPC usage. Significant ($P < 0.05$) increments were also observed in ash and mineral (Ca, K, Mg and P) contents of the leavened/unleavened flat bread with utilization of 8% WPC or BP. WPC at 8% level gave more yellowness (b^*) on leavened flat bread surface compared with other leavened/unleavened flat breads. As a result of sensory analysis, leavened/unleavened flat bread containing BP has achieved higher taste, odor and overall acceptability scores than control and WPC-containing breads.

PRACTICAL APPLICATIONS

Dairy by-products are used in the food industry to improve nutritional, functional and sensory properties of different products. WPC and BP as dairy by-products can be used for improvement of dough rheology. Usage of both dairy by-products can be recommended for enrichment of leavened/unleavened flat breads in terms of mineral and protein content. Sensory properties of breads can be improved with BP usage in flat bread formulation.

INTRODUCTION

Dairy by-products (DBP) have numerous functional and nutritional properties, and can be easily incorporated into bakery products to improve their nutritional and sensory quality (Erdoğdu-Arnoczky *et al.* 1996). DBP enhance protein quality, and also improve crust browning, crumb texture and flavor of breads (Jooyandeh 2009). DBP can be incorporated into bread dough in various forms such as milk powder, whey powder, whey protein concentrate powder (WPC) and buttermilk powder (BP; Bilgin *et al.* 2006).

Whey is a by-product of the cheese production (Ammar *et al.* 2011). The remaining milk serum during cheese production is named as whey. Whey includes most of the lactose, water-soluble vitamins and minerals of milk (Bilgin *et al.* 2006). Whey protein products such as WPC and whey protein isolate are the best source for the utilization of whey proteins (Jovanović *et al.* 2005). The most popular technique for production of WPC is ultrafiltration, as well as some different techniques as reverse osmosis, electrodialysis and microfiltration (Fox 2003). Protein content of WPC ranges from 30 to 80% (Huffman 1996; Secchi *et al.* 2011). It improves the nutritional value of bread by increasing the content of essential amino acids such as lysine, methionine and tryptophan (Vrignaud 1977; Warren *et al.* 1983). Besides nutritional superiority, WPC has some functional properties such as foaming, emulsifying, gelling, water binding and viscosity development (Kinsella and Whitehead 1989).

The buttermilk is the portion of milk remaining during the churning of cream in butter production. During the production of buttermilk, the butter and buttermilk constitute the fat phase and aqueous phase of emulsion, respectively (Pyler 1988). Besides all water-soluble components such as milk protein, lactose and minerals (Sodini *et al.* 2006), buttermilk contains some milk fat, which is not separated during production (Pyler 1988). The spray-dried form of buttermilk is known as BP (Wong and Kitts 2003). Buttermilk or BP is used in food formulation due to its emulsifying capacity and positive effect on flavor (Sodini *et al.* 2006).

Cereal-based foods have vital importance in human diet. Bread is a basic cereal food, which is an important source of carbohydrates, and as a consequence takes an important place in the recommended daily calorie intake (Doğan and Kücüköner 1998). Breads are categorized according to their specific volume. The flat breads are divided into two groups, as one (single) layered and two (double) layered. Two-layered flat breads are leavened with yeast; on the other hand, single-layered flat breads are produced in two ways, as leavened and unleavened (Qarooni 1996). There are so many flat breads all over the world known with different names such as barbari bread, battaw, bazlama, ciabatta, chapati, tortilla, hillalla, kalachi, tandoori, pita, baladi, taboon, lavash, yufka, etc (Qarooni 1996; Salehifar *et al.* 2010).

Widely produced flat breads in Turkey are bazlama, yufka, lavash and pide. Both bazlama and yufka are single-layered flat breads; on the other hand, bazlama is leavened and yufka is unleavened flat bread (UFB). Bazlama can be defined as circular flat bread with 3 cm thickness and 10–20 cm diameter and with creamy yellow color. Yufka has 1–2 mm thickness and 40–50 cm diameter with cream color surface (Tekeli 1970; Başman and Köksel 1999). Bazlama and yufka can be supplemented with different ingredients such as cereal, pseudo-cereal and legume flours or brans (Başman and Köksel 1999, 2001; Coşkuner and Karababa 2005; Levent and Bilgiçli 2012; Yıldız and Bilgiçli 2012). The effect of sorghum flour (Yousif *et al.* 2012), barley fiber-rich fraction (Izydorczyk *et al.* 2008), chickpea, barley, soy bean and fenugreek seeds (Indrani *et al.* 2011) on flat bread dough or flat bread properties has been studied by different researchers. The improving effect of precipitated whey protein on softness, yellowness (b^* value) and sensory quality of lavash bread has been reported by Jooyandeh (2009). The adverse effect of WPC (over 5% level) on the quality characteristics of parotta (UFB) has been found by Indrani *et al.* (2007).

In this study, the effects of some DBP on dough rheology and leavened flat bread (LFB) and UFB properties were researched.

MATERIAL AND METHODS

Materials

Wheat flour with 28.3% gluten, 95.4% gluten index, 39 mL Zeleny sedimentation and 338 s falling number values was used for preparation of flat breads. Wheat flour was obtained from Hekimoğlu A.Ş., Konya, Turkey. Compressed bakers' yeast and salt were purchased from local market of Konya, Turkey. WPC and BP were obtained from ENKA Milk Food Prod. San. and Tic. A.Ş. (Konya, Turkey).

METHODS

LFB and UFB Preparation

LFB (bazlama) and UFB (yufka) samples were prepared according to Akbaş (2000) and Başman and Köksel (2001). WPC and BP were used separately as 0, 4 and 8% levels replaced with wheat flour in both flat breads formulations. Control LFB formulation contains 200 g wheat flour, 5 g compressed yeast, 2 g sugar and 3 g salt, while control UFB is prepared with 200 g wheat flour and 3 g salt. Water content of dough adjusted according to farinogram water absorption value. All the ingredients were mixed in a Hobart mixer (Hobart N50, Canada Instruments, North York, Ontario, Canada) for optimum dough development. For LFB preparation, dough was fermented for 1 h at 30C and divided into two equal pieces. Then dough was rounded and rested for 6 min at room conditions. After that, doughs were sheeted to final thickness (10 mm) by using stainless steel circle (17 cm diameter). Baking was performed at 280 ± 5C on preheated sac (thin metal plate with a heating system consisting of electrical resistances) for 5 min (1,500 W). For UFB samples, after mixing, doughs were rested at 30C for half an hour and divided into four equal pieces, rounded into ball shape and sheeted by hand rolling to the final possible thickness. Baking was performed on preheated sac at 280 ± 5C for 1 min.

Physical Measurements

The diameter and thickness of LFB and UFB were determined after baking, and the spread ratio values of samples were calculated by dividing diameter to thickness. Surface color of bread samples was evaluated by measuring the L^* (light/dark), a^* (green/red) and b^* (blue/yellow) values using a Minolta CR-400 (Konica Minolta Sensing, Inc., Osaka, Japan) chromometer with illuminant D65 as reference. Color measurements were made on five different points of bread surface and the mean values were used for evaluation. The total color difference ΔE (taking the control LFB/UFB color as reference) was calculated as $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$.

Rheological Properties

Flour blends containing 0, 4 and 8% DBP were used for rheological measurements. Dough properties of these flour blends were determined with farinograph and extensograph. Farinograph measurement was carried out with Brabender Farinograph according to the AACC method 54-21 (AACC 1990). Water absorption, dough development time, dough stability, development time and softening degree were determined from the resulting farinogram. Extensograph tests were determined according to AACC method 54-10 (AACC 1990). Dough energy, resistance to extension, extensibility and maximum resistance were determined by a Brabender Extensograph.

Chemical Analyses

The samples were analyzed for their moisture (AACC 44-19), ash (AACC 08-01) and crude protein (AACC 46-12) using standard methods. Gluten and gluten index (AACC 38-12), Zeleny sedimentation (AACC 56-60) and falling number (AACC 56-81B) values of wheat flour were determined according to AACC (1990). The mineral (Ca, K, Mg, P and Zn) contents of the samples were determined by an inductively coupled plasma atomic emission spectrometer (ICP-AES; Vista series, Varian International AG, Zug, Switzerland) as given by Bubert and Hagenah (1987). Dry samples were digested using a closed vessel microwave digestion oven (MARS-5; CEM, Mathews, NC, USA) with concentrated acid, and the concentrations were determined by ICP-AES.

Sensory Analysis

Sensory properties of LFB and UFB were evaluated by 13 panelists. The samples were coded with letters and the order of sample presentation was completely randomized for serving to the panelists. All bread samples were served at the same time on the same day. The sensory quality characteristics of LFB (appearance, shape and symmetry, pore structure, chewiness, taste and odor, and overall acceptability) and UFB samples (appearance, elasticity, chewiness, taste and odor, and overall acceptability) were evaluated on a 1–5 scale, where 1 represented "dislike extremely" and 5 represented "like extremely".

Statistical Analysis

Statistical analysis was performed using statistical software (SPSS 15.0 for Windows, SPSS Inc., Chicago, IL). Means were compared using Tukey's HSD test at 5% confidence interval.

RESULTS AND DISCUSSION

Raw Material Properties

Some chemical properties and color values of the wheat flour and DBP samples are given in Table 1. WPC and BP had higher ash content than wheat flour due to its rich mineral content. Indrani *et al.* (2007) reported that ash content of wheat flour and WPC is 0.45 and 6.0%, respectively. As expected, protein amount of WPC and BP was found higher than that of wheat flour. Except Zn, mineral content of WPC and BP was found significantly ($P < 0.05$) higher compared with wheat flour. Similar mineral content for wheat flour, WPC and BP has been reported by Aktaş (2012). Color measurement showed that WPC has the lowest yellowness among the raw material.

Rheological Properties of Bread Dough

Farinogram and extensogram values of bread dough are shown in Tables 2 and 3. DBP decreased water absorption (from 61.3 to 53.3%) of dough; on the other hand, it improved the dough rheological properties in terms of increasing dough stability and development time. The highest dough stability values were obtained with 8% addition levels of DBP. Also 8% level of BP had the most prolonged effect on development time of dough. Softening degree of dough changed between 1.0 and 44 BU, and all DBP decreased softening degree of dough. These results could be attributed to the physicochemical properties of WPC and BP, which contain different protein source, milk fat and lactose (Bilgin *et al.* 2006). Indrani *et al.* (2007) studied the influence of WPC on the rheological characteristics of UFB (parotta) and they observed that dough stability increased with addition level of WPC from 0 to 15%.

Extensogram parameters were evaluated at three different resting times (45, 90 and 135 min). Compared with control dough, WPC addition increased dough energy in all resting times. A significant increase ($P < 0.05$) in dough energy was also obtained with 8% addition level of BP in 90 min resting time. Bilgin *et al.* (2006) reported an increase in dough energy due to the dough strengthening effect of the milk solids from WPC and BP. Resistance to extension of dough was positively affected by DBP usage and increased from 415 BU (control) up to 1,098 BU with 8% WPC (in 135 min resting time). Eight percent level of DBP had more improving effect on resistance to extension and maximum resistance than 4% addition levels of DBP. Generally, dough extensibility decreased with DBP addition in all resting times, and the lowest value (96 mm) obtained with 8% BP usage in dough formulation. Zadow (1981) reported that decrease in the extensibility values is the reason of

TABLE 1. SOME CHEMICAL PROPERTIES AND COLOR VALUES OF WHEAT FLOUR, WPC AND BP*

	Ash† (%)	Protein‡ (%)	Ca (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	P (mg/100 g)	Zn (mg/100 g)	*L**	*a**	*b**
Flour	0.52 ± 0.06^{b}	11.8 ± 0.28^{c}	20.0 ± 0.57^{c}	158 ± 1.41^{c}	43 ± 0.71^{c}	160 ± 1.13^{c}	0.65 ± 0.04^{a}	94.51 ± 0.58^{b}	-0.77 ± 0.11^{a}	9.59 ± 0.1^{b}
WPC	5.93 ± 0.38^{a}	32.7 ± 0.85^{a}	450.0 ± 0.85^{b}	$1{,}027 \pm 2.83^{b}$	92 ± 0.99^{b}	520 ± 1.56^{b}	0.33 ± 0.01^{c}	98.12 ± 0.68^{a}	-1.0 ± 0.13^{a}	8.36 ± 0.1^{c}
BP	6.81 ± 0.42^{a}	26.0 ± 0.57^{b}	540.0 ± 1.13^{a}	$1{,}350 \pm 4.24^{a}$	127 ± 1.13^{a}	670 ± 1.70^{a}	0.51 ± 0.03^{b}	96.03 ± 0.66^{ab}	-5.45 ± 0.3^{b}	19.65 ± 0.2^{a}

* Means ± standard error with same letter within column are not significantly different ($P < 0.05$).
† Ash, protein and mineral contents are dry weight basis.
‡ N × 6.25 for WPC and BP; N × 5.70 for wheat flour.
BP, buttermilk powder; WPC, whey protein concentrate powder.

interference of DBP sulfhydryl groups in the normal sulfhydryl/disulfide interchange reactions occurring during wheat flour dough development.

Physical Properties and Color Values of Flat Bread

Some physical properties and color values of flat breads are given in Table 4. UFB had lower thickness and weight but higher diameter and spread ratio than LFB due to its characteristic production techniques. Usage of BP at 8% level decreased the thickness of the LFB, and increased diameter and spread ratio of the UFB compared with control. Various studies in the literature showed that DBP decreased specific volume of breads (Gelinas *et al.* 1995; Kenny *et al.* 2000). Decrease in the specific volume of bread could be attributed to sulfhydryl groups of protein concentrate (Tadow *et al.* 1983). Madenci *et al.* (2012) reported a decrement in thickness of lavash and an increment in diameter/spread of lavash with usage of WPC and BP in formulation. Decrement in thickness of biscuit (Gallagher *et al.* 2005) and crackers (Sanchez *et al.* 1989) was also reported by WPC addition. Weight of the bread varied between 142.2 and 149.1 g in LFB and 57.47 and 60.78 g in UFB. DBP decreased the weight of bread significantly ($P < 0.05$) in all addition levels. Lightness (L^*) value of bread decreased with 8% WPC addition both in LFB and UFB. Generally, LFB had lower lightness and higher yellowness (b^*) than UFB due to longer baking time of LFB. BP at 8% level increased the lightness of LFB surface, while it adversely affected UFB surface lightness. Various studies expressed that surface lightness/darkness is related to Maillard reactions between proteins and reducing sugars (Gallagher *et al.* 2005; Bilgin *et al.* 2006; Jooyandeh 2009). The highest redness (a^*) values was obtained with WPC (4–8%) in LFB, and with BP (8%) in UFB. The total color difference (ΔE) is also given in Table 4. In LFB samples, 8% WPC addition gave the highest ΔE value. In UFB samples, 4% addition level of DBP gave lower ΔE value compared with 8% addition level.

Chemical Properties of Flat Breads

Some chemical properties and mineral content of the flat breads are given in Table 5. Eight percent addition levels of DBP decreased the moisture content of LFB. A significant increase was observed in ash and protein content of LFB/UFB with DBP usage, except 4% addition level of WPC for UFB. Rich ash and protein content of DBP (Table 1) affected the chemical composition of final product. It has been reported that increasing amount of DBP in bread (Kadharmestan *et al.* 1998), pasta (Murthy 1976), muffin and biscuit (Jisha and Padmaja 2011) formulation also increased the protein contents of final products.

TABLE 2. FARINOGRAM PROPERTIES OF FLOUR BLENDS*

	Water absorption (%)	Dough stability (min)	Development time (min)	Softening degree (BU)
Control	61.3 ± 0.14[a]	8.7 ± 0.14[d]	2.0 ± 0.14[d]	44 ± 1.41[a]
%4 WPC	56.1 ± 0.14[d]	14.1 ± 0.28[b]	7.8 ± 0.28[c]	9 ± 0.42[c]
%8 WPC	53.3 ± 0.28[e]	17.1 ± 0.28[a]	8.3 ± 0.000[bc]	6 ± 0.42[c]
%4 BP	59.1 ± 0.28[b]	12.9 ± 0.14[c]	8.9 ± 0.14[b]	16 ± 0.99[b]
%8 BP	58.2 ± 0.14[c]	16.3 ± 0.28[a]	10.2 ± 0.28[a]	1.0 ± 0[d]

* Means ± standard error with same letter within column are not significantly different ($P < 0.05$).
BP, buttermilk powder; BU, Brabender unit; WPC, whey protein concentrate powder.

Generally Ca, K, Mg and P content of the breads increased with DBP addition, and the richest mineral composition was obtained in LFB containing 8% BP. Especially enrichment ratio in Ca and K content of the flat breads with DBP utilization were found to be very remarkable. Bilgin *et al.* (2006) reported that mineral contents of bread samples were increased by addition of different levels of WPC and BP. They also emphasized that, particularly, Ca and K levels of bread samples were higher compared with the control samples. Madenci *et al.* (2012) found that mineral contents of lavash bread increased with addition of the WPC and BP.

TABLE 3. EXTENSOGRAM PROPERTIES OF FLOUR BLENDS*

Resting time (min)	Flour blends	Energy (cm^2)	Resistance to extension (BU)	Extensibility (mm)	Maximum resistance (BU)
	Control	116 ± 2.83[cd]	415 ± 5.66[e]	150 ± 2.83[ab]	588 ± 4.24[d]
	%4 WPC	127 ± 2.83[b]	486 ± 4.24[c]	142 ± 1.41[bc]	701 ± 2.83[c]
45	%8 WPC	152 ± 1.41[a]	544 ± 2.83[b]	155 ± 1.41[a]	755 ± 2.83[a]
	%4 BP	108 ± 1.41[d]	469 ± 2.83[d]	135 ± 2.83[c]	599 ± 4.24[d]
	%8 BP	118 ± 2.83[bc]	608 ± 2.83[a]	122 ± 0.00[d]	737 ± 2.83[b]
	Control	117 ± 2.83[c]	568 ± 5.66[e]	128 ± 1.41[a]	728 ± 2.83[e]
	%4 WPC	154 ± 4.24[a]	862 ± 4.24[c]	118 ± 2.83[b]	1,045 ± 4.24[c]
90	%8 WPC	166 ± 5.66[a]	932 ± 4.24[b]	122 ± 1.41[ab]	1,139 ± 2.83[a]
	%4 BP	122 ± 1.41[c]	702 ± 5.66[d]	115 ± 2.83[b]	869 ± 2.83[d]
	%8 BP	137 ± 2.83[b]	986 ± 4.24[a]	103 ± 1.41[c]	1,098 ± 4.24[b]
	Control	126 ± 2.83[c]	630 ± 4.24[d]	128 ± 2.83[a]	790 ± 2.83[e]
	%4 WPC	155 ± 5.66[b]	952 ± 5.66[b]	113 ± 1.41[b]	1,125 ± 2.83[b]
135	%8 WPC	181 ± 4.24[a]	1,098 ± 4.24[a]	116 ± 1.41[b]	1,317 ± 4.24[a]
	%4 BP	134 ± 2.83[c]	776 ± 5.66[c]	118 ± 2.83[b]	930 ± 2.83[d]
	%8 BP	136 ± 2.83[c]	965 ± 2.83[b]	96 ± 2.83[c]	1,072 ± 4.24[c]

* Means ± standard error with same letter within column are not significantly different ($P < 0.05$).
Means that are obtained in different resting time (45, 90 and 135 min) were compared separately according to resting time.
BP, buttermilk powder; WPC, whey protein concentrate powder.

TABLE 4. SOME PHYSICAL PROPERTIES AND COLOR VALUES OF FLAT BREADS*

Flat breads	Thickness (cm)	Diameter (cm)	Spread ratio	Weight (g)	L^*	a^*	b^*	ΔE
LFB (control)	1.51 ± 0.03[a]	16.4 ± 0.28[c]	10.86 ± 0.14[f]	149.1 ± 0.14[a]	75.76 ± 0.14[d]	–0.71 ± 0.11[d]	19.19 ± 0.17[e]	–
LFB (4% WPC)	1.50 ± 0.01[a]	15.8 ± 0.14[c]	10.53 ± 0.13[f]	144.8 ± 0.28[b]	72.37 ± 0.2[e]	0.97 ± 0.08[a]	24 ± 0.13[b]	6.12 ± 0.43[b]
LFB (8% WPC)	1.46 ± 0.03[ab]	15.7 ± 0.14[c]	10.75 ± 0.18[f]	142.2 ± 0.42[c]	70.82 ± 0.14[f]	0.74 ± 0.13[a]	25.46 ± 0.1[a]	8.11 ± 0.22[a]
LFB (4% BP)	1.44 ± 0.01[ab]	16.5 ± 0.28[c]	11.46 ± 0.17[f]	145.1 ± 0.42[b]	77.16 ± 0.21[c]	–0.61 ± 0.07[cd]	21.05 ± 0.1[d]	2.34 ± 0.15[d]
LFB (8% BP)	1.40 ± 0.03[b]	16.5 ± 0.14[c]	11.79 ± 0.14[f]	145.3 ± 0.14[b]	77.61 ± 0.13[c]	–1.69 ± 0.13[e]	21.96 ± 0.14[c]	3.48 ± 0.12[c]
UFB (control)	0.12 ± 0.01[c]	28.2 ± 0.28[b]	235.01 ± 1.41[e]	60.78 ± 0.25[d]	87.94 ± 0.2[a]	–0.32 ± 0.1[bc]	14.37 ± 0.23[h]	–
UFB (4% WPC)	0.10 ± 0.00[c]	27.7 ± 0.42[b]	277.00 ± 1.41[d]	58.81 ± 0.13[e]	87.82 ± 0.06[a]	0.04 ± 0.07[b]	14.56 ± 0.13[gh]	0.44 ± 0.02[e]
UFB (8% WPC)	0.09 ± 0.01[c]	28.6 ± 0.14[b]	317.78 ± 1.1[c]	57.63 ± 0.33[ef]	86.91 ± 0.16[b]	–0.02 ± 0.07[b]	15.72 ± 0.14[f]	1.73 ± 0.12[d]
UFB (4% BP)	0.09 ± 0.01[c]	30.1 ± 0.42[a]	334.44 ± 1.19[a]	58.53 ± 0.11[ef]	87.96 ± 0.13[a]	0.02 ± 0.08[b]	15.11 ± 0.17[g]	0.82 ± 0.05[e]
UFB (8% BP)	0.09 ± 0.03[c]	29.7 ± 0.14[a]	330.01 ± 1.27[b]	57.47 ± 0.59[f]	86.45 ± 0.31[b]	0.71 ± 0.1[a]	14.85 ± 0.18[gh]	1.88 ± 0.01[d]

* Means ± standard error with same letter within column are not significantly different ($P < 0.05$).
BP, buttermilk powder; LFB, leavened flat bread; UFB, unleavened flat bread; WPC, whey protein concentrate powder.

TABLE 5. SOME CHEMICAL PROPERTIES OF FLAT BREADS*

	Moisture (%)	Ash† (%)	Protein‡ (%)	Ca (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	P (mg/100 g)	Zn (mg/100 g)
LFB (control)	35.2 ± 0.14^{a}	2.00 ± 0.07^{de}	12.8 ± 0.28^{cd}	19.8 ± 0.42^{i}	190.8 ± 0.99^{f}	32.7 ± 0.57^{c}	165.4 ± 0.57^{e}	0.46 ± 0.03^{a}
LFB (4% WPC)	34.6 ± 0.28^{ab}	2.25 ± 0.07^{bc}	13.7 ± 0.14^{ab}	35.71 ± 0.69^{g}	224 ± 1.41^{d}	34.3 ± 0.28^{bc}	176.3 ± 1.13^{c}	0.45 ± 0.04^{a}
LFB (8% WPC)	31.8 ± 0.14^{c}	2.48 ± 0.03^{ab}	14.6 ± 0.28^{a}	54.21 ± 0.55^{c}	257 ± 1.13^{b}	35.8 ± 0.42^{ab}	187.3 ± 0.85^{b}	0.44 ± 0.01^{a}
LFB (4% BP)	33.7 ± 0.28^{b}	2.33 ± 0.03^{bc}	13.5 ± 0.14^{ab}	40.62 ± 0.47^{e}	240 ± 0.85^{c}	34.8 ± 0.71^{b}	180.3 ± 1.27^{c}	0.45 ± 0.04^{a}
LFB (8% BP)	32.7 ± 0.14^{c}	2.68 ± 0.03^{a}	14.1 ± 0.28^{ab}	60.12 ± 0.65^{a}	289 ± 1.98^{a}	36.9 ± 0.42^{a}	193 ± 1.13^{a}	0.44 ± 0.01^{a}
UFB (control)	11.5 ± 0.28^{d}	1.77 ± 0.01^{f}	12.2 ± 0.28^{d}	18.53 ± 0.75^{i}	173 ± 1.13^{g}	28.8 ± 0.42^{e}	152 ± 0.85^{f}	0.41 ± 0.03^{a}
UFB (4% WPC)	11.3 ± 0.14^{de}	1.92 ± 0.04^{ef}	13 ± 0.14^{bc}	33.13 ± 0.52^{h}	210 ± 0.85^{e}	29.8 ± 0.57^{e}	166 ± 1.27^{de}	0.39 ± 0.04^{a}
UFB (8% WPC)	11 ± 0.42^{de}	2.11 ± 0.06^{cd}	13.9 ± 0.42^{ab}	50.70 ± 0.71^{d}	244 ± 1.27^{c}	30.5 ± 0.28^{de}	179 ± 0.99^{c}	0.38 ± 0.03^{a}
UFB (4% BP)	11.5 ± 0.14^{d}	2.01 ± 0.11^{de}	13 ± 0.28^{bc}	38.13 ± 0.38^{f}	221 ± 0.99^{d}	30.6 ± 0.57^{de}	170 ± 0.85^{d}	0.43 ± 0.01^{a}
UFB (8% BP)	10.5 ± 0.28^{e}	2.25 ± 0.07^{bc}	13.7 ± 0.42^{ab}	57.51 ± 0.58^{b}	261 ± 0.85^{b}	32.3 ± 0.71^{cd}	188 ± 0.99^{b}	0.41 ± 0.01^{a}

* Means ± standard error with same letter within column are not significantly different ($P < 0.05$).
† Ash, protein and mineral contents are dry weight basis.
‡ $n \times 6.25$ for WPC and BP; $n \times 5.70$ for wheat flour.
BP, buttermilk powder; LFB, leavened flat bread; UFB, unleavened flat bread; WPC, whey protein concentrate powder.

Sensory Properties of Flat Bread

Sensory properties of flat breads are shown in Figs. 1 and 2. BP decreased the appearance and shape symmetry score of the LFB, while it positively affected pore structure, chewiness, taste and odor of the breads. DBP, especially BP, improved the overall acceptability scores of the LFB (Fig. 1). Compared with control, UFB, 4% WPC and 4–8% BP were liked by the panelists in terms of appearance and taste and odor. WPC in all addition levels negatively affected elasticity of the UFB. Also, 8% addition level of WPC decreased the chewiness of the bread. Especially, BP had an improving effect on overall acceptability (Fig. 2). Jooyandeh (2009) studied effects of whey protein on the physical and sensory properties of Iranian lavash flat bread and it was observed that whey protein increased acceptability and taste of breads. Bilgin *et al.* (2006) reported that supplementation of breads with WPC and BP increased the overall acceptability score.

CONCLUSION

In this study, the effect of WPC and BP on bread dough and LFB and UFB properties were studied. WPC and BP influenced positively the dough rheological properties. Especially, 8% BP improved dough rheology more remarkably among DBP. Besides ash and protein enrichment, a significant increase was also observed in Ca, K, P and Mg content of the bread with DBP usage. Generally, flat breads containing DBP gave similar or higher overall acceptability score compared with control bread. Both DBP can be used successfully in LFB and UFB for protein and mineral enrichment and also sensory improvement.

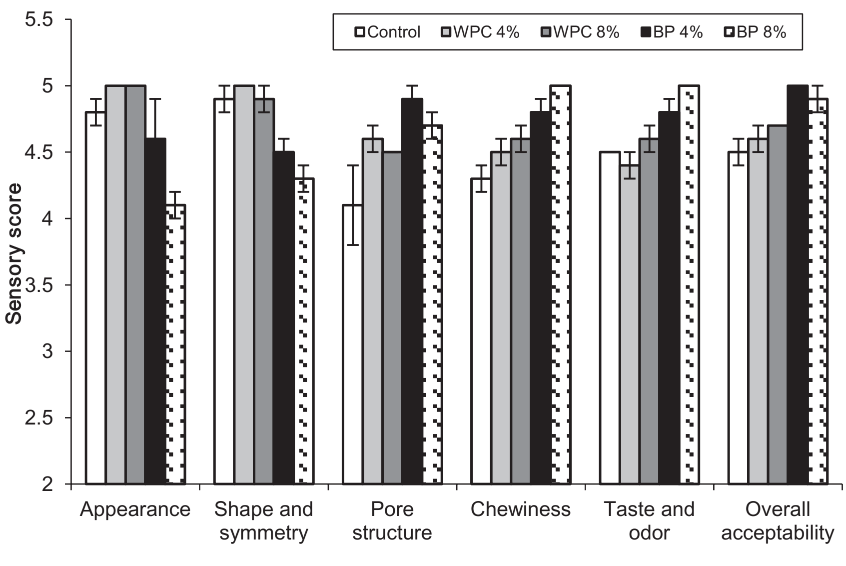

FIG. 1. SENSORY PROPERTIES OF THE LEAVENED FLAT BREAD
BP, buttermilk powder; WPC, whey protein concentrate powder.

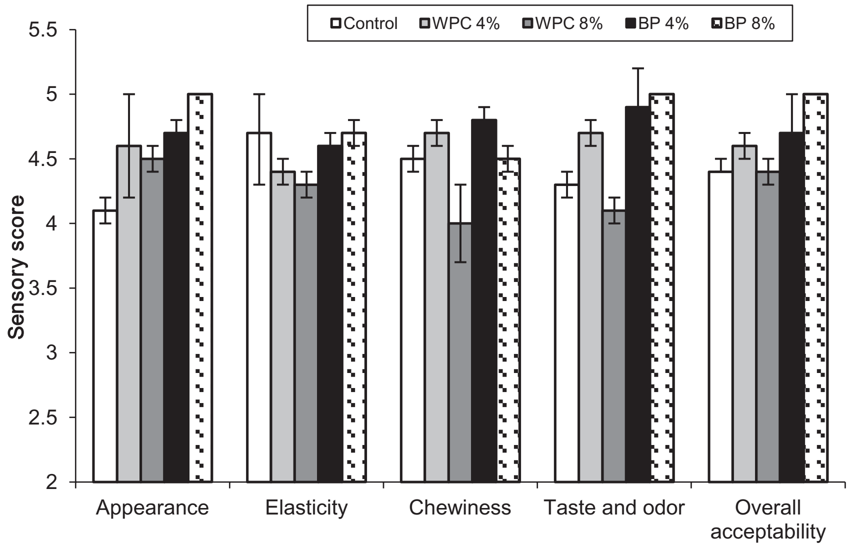

FIG. 2. SENSORY PROPERTIES OF THE UNLEAVENED FLAT BREAD
BP, buttermilk powder; WPC, whey protein concentrate powder.

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