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Utilisation of cereal-legume flour blends in commercial and traditional bread

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RESEARCH ARTICLE

Abstract

Commercial or traditional breads are commonly produced using refined wheat flour that contains limited amount of beneficial compounds such as minerals, dietary fibre, vitamins and phytochemicals which are mainly present in whole flours of cereals and legumes. In food formulations, cereals and legumes can be used together to complement their nutritional values e.g. to synergetically benefit from essential amino acids. In the present study, cereal-legume flour blend (CLFB) consisting of equal amount of cereal (rye, barley and oat) and legume (chickpea, soy and lupin) flours was obtained and then used at different ratios (0, 5, 10, 15, 20, 25 and 30%) in the production of commercial bread (CB) and traditional flat bread (TFB) to improve nutritional properties. The effect of CLFB on physical, chemical and sensory properties of breads was investigated. CB containing high ratios of CLFB (25-30%) has the highest yellowish and reddish colour in bread crumb. Increased ratio of CLFB in bread formulations lowered the volume in CB and enhanced the hardness of bread. Both CB and TFB revealed the highest chemical properties at the maximum percentage of CLFB (30%), with the most notable increases in protein, phytic acid, Ca, Fe, K, Mg and Mn contents. CB and TFB containing 5% CLFB demonstrated a better overall acceptability than control, and increased ratios of CLFB (10-15%) in CB showed similar overall acceptability scores to control bread. However, high ratios of CLFB decreased overall acceptability of CB and TFB samples. As a result, increasing amount of CLFB enriched the nutritional composition of breads, but high utilisation ratios of the CLFB (25-30%) resulted in some technological and sensory losses on breads. Those losses can be overcome with the help of specific additives.

Keywords: bread, flat bread, cereal, legume, phytic acid, mineral

1. Introduction

Bread is a basic food stuff in many societies and it can provide a significant portion of the daily energy requirement for the body. Bread containing whole flours of cereals such as rye, barley and oat, and legumes that are rich in protein, dietary fibre, B-complex vitamins, minerals and phytochemicals is a healthy alternative to white wheat bread (Slavin, 2004; Wilkes, 1996). Legumes need prolonged preparation time, including soaking and cooking due to their hard structure and hence may not be preferable by people who prepare practical and quick meals. In food formulations, cereals and legumes can be used together to complement their nutritional values especially in terms of protein and amino acid content (lysine and sulphur containing amino acids).

Cereals contain considerable amount of carbohydrate, beside vitamins such as vitamin E, B-complex, macro-micro elements such as calcium, potassium, magnesium, phosphorus, iron, zinc and copper, and phytochemicals. Moreover, oat, rye and barley are a great source of dietary fibres e.g. arabinoxylan, and β-glucan (Alais and Linden, 1991; Flander *et al.,* 2007; Lee and Inglett, 2006). High consumption of dietary fibres in the diet is associated with the reduced risk of several diseases such as cardiovascular and coronary heart disease and diabetes (Alminger and Eklund-Jonsson, 2008; FDA, 1997; Östman *et al.,* 2006).

Legumes like chickpea, soy and lupin are important sources of vegetable protein. On the other hand, legumes contain functional components, and consumption of those legumes in the diet helps prevent obesity, diabetes, blood cholesterol, heart disease, cancer, kidney disease and osteoporosis

(Belski, 2012; Henley *et al.*, 1993; Messina and Barnes, 1991). Chickpea is one of the most preferred legumes in preparation of regular or gluten-free cereal products. Lupin flour can be successfully incorporated into cereal products such as bread due to nutritional/functional composition, golden yellow colour, with high water/oil holding capacity and good emulsification properties (Dervas *et al.*, 1999). Soy and soy products are rich in protein, essential amino acids, lipids, minerals, vitamins and dietary fibres (Garcia *et al.,* 1997; Liu, 2004). Soy flour is commonly used in food formulation, especially for protein enrichment.

Most functional parts of the grains such as dietary fibres, essential fatty acids, vitamins and minerals are lost during milling of wheat grain to refined white flour. Therefore, in many studies have been attempted to enhance the nutritional quality of white bread with cereal, legume or composite flours e.g. the formulations of barley-wheat blend (Skendi *et al.,* 2010), barley-corn-wheat blend (Hussein *et al.,* 2013), oat-wheat blend (Ahmadkhani, 1992), rye-wheat blend (Buksa *et al.,* 2013), soy-wheat blend (Ivanovski *et al.,* 2012), chickpea-wheat blend (Mohammed *et al.,* 2012), lupin-wheat blend (Pollard *et al.,* 2002) have been created thus far. However, is a limited number of studies in the literature regarding the use of cereal-legume composite flour containing three or more different cereals or legumes for the production of commercial bread (CB) and traditional flat bread (TFB). To the best of our knowledge, this is one of the first reports that demonstrate new bread formulations using six different cereal-legume flours.

This study aimed to enrich CB and TFB with whole flours of cereal (rye, barley and oat) and legume (chickpea, soy and lupin) that have different nutritional and functional properties. This paper contains the first part of the whole study. In this part, the highest utilisation ratio of cereal-legume flour blend (CLFB) was tried to determine for optimum technological, sensory and nutritional properties of breads without any additive usage. In the second part (unpublished paper), different enzymes, emulsifiers, and oxidants have been tested in order to avoid the technological loss caused by the addition high level (25-30%) of CLFB. High amounts of phytic acid resulting from the addition of CLFB have been eliminated using different dephytinisation methods to improve mineral bioavailability. The utilisation possibilities of CLFB in breadmaking with and without additives were offered to consumer preference.

2. Materials and methods

Materials

Wheat flour (*Triticum aestivum* with 0.79% ash, 12.41% protein and 76% extraction rate; Selva, Konya, Turkey), salt (Salina, Konya, Turkey), baker's yeast (Pakmaya, Kocaeli, Turkey), defatted soy whole flour (Doğalsan, Ankara, Turkey) and chickpea (Saban, Mersin, Turkey) were obtained from a local market in Konya, Turkey. Hull-less barley, hull-less oat and rye were purchased from Sağlık Tarım (Konya, Turkey). Traditionally debittered lupin seeds were procured from Doğanhisar (Konya, Turkey). Rye, barley, oat, chickpea and lupin were milled (<500 μm) using a hammer mill (Perten 3100; Perten Instruments AB, Huddinge, Sweden) into whole grain flour with 100% extraction rate.

Methods

Preparation of cereal-legume flour blend

An equal amount of rye, barley, oat, chickpea, soy and lupin flours were mixed to prepare CLFB. Wheat flour was replaced with CLFB at 5, 10, 15, 20, 25 and 30% (w/w) ratios to produce CB and TFB.

Preparation of commercial bread and traditional flat bread

For the preparation of control CB (without CLFB), 100 g of wheat flour, 3 g of baker's yeast, 1.5 g of salt and water (adjusted according to farinograph water absorption value) were used as ingredients. All ingredients were kneaded with water until obtaining homogenous dough in the mixer (Kenwood KMX750RD, Hampshire, UK), and the dough was left to bulk fermentation (30+30 minutes (min), 30 °C and 80-90% relative humidity) and then rest for 60 min at 30 °C. At the end of this period, dough samples were baked at 240 °C for 15 min in an oven (Beko MF6, İstanbul, Turkey). Regarding other CB samples, wheat flour was replaced with CLFB at 5, 10, 15, 20, 25 and 30% ratios. The same breadmaking procedure was also applied to prepare control CB, as well as CB containing CLFB at the ratios of 5, 10, 15, 20, 25 and 30%.

TFB samples were prepared based on the method given by Akbaş (2000). 100 g of wheat flour, 2.5 g of baker's yeast, 1.5 g of salt, 1 g of sugar and water were used in control (without CLFB). The water content of dough was also adjusted according to farinograph water absorption value. All ingredients were kneaded with water thoroughly until obtaining a smooth and homogeneous dough. After the dough was allowed to ferment at 30 °C with 80-90% relative humidity for 60 min, it was rounded into a ball shape and stand for another 6 min at room conditions. The dough was flattened to final thickness of 10 mm using stainless steel circle of 17 cm diameter and then baked for 5 min on a sac (metal plate heated by electrical resistances, 1,500 W). CLFB used at 5, 10, 15, 20, 25 and 30% (w/w) ratios to produce TFB. The same breadmaking procedure was also applied to prepare control TFB, as well as TFB containing CLFB at the different ratios (5, 10, 15, 20, 25 and 30%).

Physical analyses

Bread samples were cooled at room temperature for 60 min, before weighing of CB. Bread volume was determined by rapeseed displacement as followed: a metallic container with a known volume was topped up with rapeseed. Bread sample was put into the metallic container. The volume of the rapeseed that was overflowed from the container was measured and bread volume was acquired. The volume of each CB sample was measured three times. Moreover, the specific volume of CB sample was calculated by dividing the volume value by the weight (Elgün *et al.,* 2001). Diameter and thickness values of TFB samples were measured with an ordinary ruler and a digital micrometre (0.001 mm; Mitutoyo, Tokyo, Japan), respectively. The spread ratio was obtained by dividing diameter values to thickness values. Colour parameters (L^*, a^* and b^*) of the raw materials and bread samples were measured with Minolta CR 400 (Konica Minolta Inc., Osaka, Japan). Saturation index (*SI*) was calculated by $(a^{*2}+b^{*2})^{1/2}$ formula. *Hue* angle (if $a^*>0$ and $b^*>0$, arctan $[b^*/a^*]$; if $a^*<0$ and $b^*>0$, arctan $[b^*/a^*] + 180°$) was calculated using a^* and b^* parameters. The colour values were determined as the mean of the measurements made at five different points of sample. Hardness values of bread were measured on a 25 mm thick slice using an aluminium 36 mm diameter cylindrical probe (P36/R) via a texture analyser (TA-XT.Plus Stable Micro System, Surrey, UK) after 24 and 72 hours of storage time according to the AACC 74-09 method (Anonymous, 2002).

Chemical analyses

The raw materials (wheat, rye, barley, oat, chickpea, soy and lupin flours, and CLFB) and bread samples were analysed with regard to the moisture (AACC Method 44-19), ash (AACC Method 08-01), protein (AACC Method 46-12) and fat (AACC Method 30-25) content (Anonymous, 1990).

The mineral content was determined by an inductively coupled plasma atomic emission spectrometer (ICP-AES) (Varian, Vista Model, Zug, Switzerland). Working conditions of ICP-AES: plasma gas flow ratio of 10.5-15 l/min (radial), 15 l/min (axial); auxiliary gas flow ratio of 1.5 l/min; viewing height of 5-12 mm; copy and reading time of 1-5 s (maximum of 60 s); and copy time of 3 s (maximum of 100 s) (Skujins, 1998).

The phytic acid content of the samples was measured by a colourimetric method as followed: the phytic acid in all the samples was extracted with solution of hydrochloric acid (0.2 N) and precipitated with a solution of ammonium iron (III) sulphate. 0.5 ml of extract was pipetted out into a test tube and 1 ml of solution of ammonium iron (III) sulphate was added. Test tubes were initially kept in a boiling water bath for 30 min and then kept in an ice bath for another 15 min. 2 ml of 2,2-bipyridine solution was added into the test tubes after they have reached to the room temperature. The absorbance (Abs) values were immediately recorded at 519 nm by a spectrophotometer (Biochrom – Libra S22, Cambridge, UK) and results were expressed as mg/100 g (Haug and Lantzsch, 1983).

Total phenolic content (TPC) was determined colourimetrically using Folin-Ciocalteu reagent. Powdered samples (0.5 g) were extracted for 2 h with 10 ml solvent (methanol:HCl:water, 8:1:1, v/v/v) at room temperature (25 °C). The extracts were separated by centrifuge at 3,000 rpm for 10 min (Beta *et al.,* 2005; Gao *et al.,* 2002). Supernatant sample (0.1 ml), diluted Folin-Ciocalteu reagent (0.5 ml) and saturated solution of sodium carbonate (1.5 ml) were added to test tube. The test tube was filled with water up to 10 ml. Test tubes were incubated for 2.5 h at room temperature, in a dark place. The Abs value was measured at 760 nm by a spectrophotometer (Biochrom – Libra S22). TPC was expressed as milligrams of gallic acid equivalents (GAE) per kilogram of dry weight. Antioxidant activity (AA) was measured using a free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Beta *et al.,* 2005; Gyamfi *et al.,* 1999). Powdered samples (1 g) were extracted with 10 ml methanol during 2 h and centrifuged at 3,000 rpm for 10 min. The supernatant (100 μl) reacted with freshly made DPPH solution (3.9 ml, 25 mg/l) in methanol. The Abs value was measured at 517 nm by a spectrophotometer (Biochrom – Libra S22). Percentage of inhibition was calculated as:

$$\text{Inhibition\%} = \frac{\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}}}{\text{Abs}_{\text{control}}} \times 100$$

Sensory analyses

The sensory evaluation of bread samples was performed by 25 panellists (aged from 22 to 48 years) from the Food Engineering Department of Necmettin Erbakan University. The bread samples were coded with numbers and the order of sample presentation was completely randomised for serving in a plastic plate to the panellists to prevent any prejudices. The panellists were given water to help cleanse their palates before proceeding the next sample. Each panellist received the bread samples in the same order. Sensory evaluation was performed in a room with appropriate temperature in the panel. All bread samples were served on the same day. Sensory properties (symmetry, pore structure, taste, odour, appearance and overall acceptability) were evaluated using the scale of 1-7 (1: dislike very much, and 7: like very much).

Statistical analyses

JMP (SAS Institute Inc., Cary, NC, USA) software was used to perform the statistical analyses. The averages of the obtained data were compared and summarised in tables. The analysis results were the average of triplicate measurements on the duplicate samples.

3. Results and discussion

Raw materials and CLFB properties

Table 1 presents the colour values and chemical properties of raw materials and CLFB. Rye and oat flours were more reddish than the other raw materials, whereas lupin flour remarkably yellowish. The moisture content of raw materials has varied in the range of 7.59 and 11.79%. Generally, legume flours have higher ash content compared to cereal flours. Soy flour exhibited 8.63 times more ash content compared to refined wheat flour due to the lower extraction rate of wheat flour during milling. It is well known that legumes are rich vegetable protein sources. In the present study, the protein content of legumes (chickpea, soy and lupin) has varied in the range of 21.61 and 53.38%. Lupin flour has demonstrated the highest fat content (11.86%) among all the raw materials. Here, it can be expected that the soy flour possess the highest fat content; however, its defatted form has been used in the current study. Refined wheat flour exhibited the lowest phytic acid content (370 mg/100 g), whereas soy flour was the richest in terms of phytic acid (2,520 mg/100 g). This was followed by oat, CLFB, chickpea and rye flours, respectively. Outer layers, bran, aleurone and germ of grains are the richest sources of phytic acid. Milling of the grains as whole flour including these parts resulted in high phytic acid content. AA and TPC of raw materials have varied in the range of 9.77 and 52.51%, 268 and 1,385 mg GAE/kg, respectively. CLFB displayed much more AA and TPC values than chickpea and lupin flours. Among all the raw materials investigated, barley flour has the highest AA and TPC value. As seen in Table 1, mineral contents of soy and chickpea flour were generally higher than those of cereals. Compared to wheat flour, soy flour showed 13.0, 12.6, 10.1, 9.3, 5.6 and 3.7 times much more Ca, Fe, K, Mg, P and Zn content, respectively. CLFB, as well displayed 7.0, 4.4, 3.8, 4.1, 2.3 and 2.4 times much more Ca, Fe, K, Mg, P and Zn content than wheat flour, respectively.

Colour values of CB and TFB

Table 2 displays the colour values of CB and TFB. Increased ratio of CLFB in CB and TFB formulation has accordingly increased the crust lightness (L^*). The CLFB ratio over 5% in CB and TFB decreased crust a^* value. 15-30% utilisation ratio of CLFB in CB formulation gave lower crust b^* values. Such an increase in CLFB content in CB formulation has

Table 1. Colour values and chemical properties of raw materials.[1,2]

Properties	Wheat flour	Rye flour	Barley flour	Oat flour	Chickpea flour	Soy flour	Lupin flour	CLFB
L^*	92.26±0.08^{a}	88.10±0.07^{d}	92.32±0.05^{a}	89.27±0.08^{c}	90.27±0.10^{b}	92.24±0.06^{a}	81.08±0.07^{e}	90.24±0.06^{b}
a^*	-0.40±0.03^{d}	0.67±0.03^{a}	0.22±0.01^{b}	0.58±0.06^{a}	-1.17±0.02^{e}	-1.52±0.03^{f}	-0.28±0.06^{cd}	-0.24±0.04^{c}
b^*	10.04±0.02^{e}	9.56±0.06^{f}	8.26±0.04^{g}	9.73±0.02^{f}	19.33±0.05^{b}	11.54±0.03^{d}	42.04±0.07^{a}	16.22±0.04^{c}
SI	10.05±0.02^{e}	9.59±0.06^{f}	8.26±0.04^{g}	9.75±0.02^{f}	19.37±0.05^{b}	11.64±0.04^{d}	42.04±0.06^{a}	16.68±0.04^{c}
Hue	92.28±0.16^{c}	85.97±0.18^{f}	88.47±0.09^{e}	86.59±0.34^{f}	93.45±0.06^{b}	97.52±0.14^{a}	90.38±0.08^{d}	90.51±0.03^{d}
Moisture (%)	11.79±0.10^{a}	8.57±0.07^{de}	8.02±0.09^{f}	9.46±0.02^{b}	8.37±0.07^{e}	7.59±0.05^{g}	8.94±0.01^{c}	8.67±0.06^{d}
Ash (%)	0.79±0.03^{f}	1.50±0.04^{e}	1.49±0.03^{e}	1.62±0.04^{d}	2.78±0.01^{b}	6.82±0.02^{a}	1.78±0.01^{c}	2.84±0.04^{b}
Protein (%)	12.41±0.06^{g}	11.81±0.06^{h}	13.12±0.13^{f}	15.99±0.10^{e}	21.61±0.05^{d}	53.38±0.08^{a}	37.41±0.06^{b}	26.32±0.03^{c}
Fat (%)	0.99±0.06^{e}	1.10±0.02^{e}	1.63±0.06^{d}	4.88±0.12^{b}	4.63±0.08^{b}	0.77±0.09^{e}	11.86±0.15^{a}	4.26±0.04^{c}
Phytic acid (mg/100 g)	370±7.1^{g}	959±5.7^{d}	504±2.8^{f}	1,251±4.2^{b}	964±5.7^{d}	2,520±7.1^{a}	587±2.8^{e}	1,185±7.1^{c}
AA (% inhibition)	28.15±0.09^{f}	39.01±0.16^{b}	52.51±0.05^{a}	30.19±0.05^{e}	17.53±0.03^{g}	38.37±0.03^{c}	9.77±0.02^{h}	32.58±0.06^{d}
TPC (mg GAE/kg)	397±3.4^{g}	1,361±5.4^{b}	1,385±5.4^{a}	1,315±2.0^{c}	268±4.3^{h}	818±4.4^{e}	791±6.0^{f}	1,048±7.1^{d}
Minerals (mg/100 g)								
Ca	23.50±0.06^{h}	66.14±0.08^{e}	30.69±0.05^{g}	49.65±0.19^{f}	117.25±0.39^{d}	307.04±0.31^{b}	330.20±0.27^{a}	164.13±0.03^{c}
Fe	1.65±0.04^{g}	6.59±0.05^{c}	3.95±0.04^{f}	4.13±0.03^{e}	5.37±0.02^{d}	20.85±0.07^{a}	4.21±0.05^{e}	7.34±0.03^{b}
K	185.14±0.16^{g}	478.57±0.35^{d}	386.27±0.11^{e}	335.55±0.19^{f}	1,026.24±1.75^{b}	1,871.71±2.42^{a}	55.00±0.21^{h}	710.00±1.41^{c}
Mg	35.41±0.12^{h}	101.66±0.08^{e}	99.85±0.06^{f}	124.62±0.04^{d}	149.31±0.10^{b}	331.30±0.15^{a}	92.97±0.23^{g}	145.12±0.04^{c}
Mn	0.88±0.01^{d}	2.28±0.04^{cd}	1.11±0.01^{d}	3.44±0.06^{c}	2.85±0.07^{c}	3.73±0.03^{c}	81.20±1.13^{a}	18.27±0.06^{b}
P	295.23±0.33^{h}	571.94±1.32^{d}	606.73±1.03^{c}	391.97±0.67^{g}	410.82±0.45^{f}	1,663.88±1.24^{a}	532.12±0.17^{e}	670.14±1.36^{b}
Zn	1.15±0.07^{f}	2.32±0.03^{e}	2.55±0.06^{d}	2.32±0.03^{e}	2.82±0.03^{c}	4.32±0.02^{a}	3.20±0.03^{b}	2.80±0.03^{c}

[1] Means followed by the same letter within a row are not significantly different ($P<0.05$). Values are the average of triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter.
[2] AA = antioxidant activity; CLFB = cereal-legume flour blend; TPC = total phenolic content.

Table 2. Colour values of commercial bread (CB) and traditional flat bread (TFB) samples.[1]

CLFB (%)[2]	*L**	*a**	*b**	*SI*	*Hue*
CB					
Crust					
0	61.98±0.04[f]	9.85±0.04[b]	30.54±0.06[a]	32.09±0.04[b]	72.12±0.10[e]
5	62.24±0.06[e]	10.12±0.02[a]	30.67±0.08[a]	32.29±0.08[a]	71.74±0.01[f]
10	63.93±0.06[d]	9.00±0.03[c]	30.48±0.06[a]	31.78±0.05[c]	73.56±0.09[d]
15	64.78±0.06[c]	8.36±0.05[d]	29.90±0.06[b]	31.05±0.04[d]	74.39±0.12[c]
20	65.25±0.03[b]	8.02±0.03[e]	29.52±0.03[c]	30.59±0.02[e]	74.80±0.07[b]
25	65.94±0.05[a]	7.79±0.04[f]	29.26±0.04[d]	30.28±0.05[f]	75.09±0.06[b]
30	65.92±0.07[a]	7.38±0.04[g]	28.91±0.06[e]	29.83±0.05[g]	75.68±0.11[a]
Crumb					
0	66.12±0.06[e]	0.68±0.01[f]	18.75±0.06[f]	18.76±0.06[f]	87.92±0.05[a]
5	66.87±0.04[c]	1.18±0.03[e]	19.02±0.03[e]	19.06±0.03[e]	86.46±0.08[b]
10	67.30±0.04[ab]	1.67±0.02[d]	19.32±0.06[d]	19.39±0.06[d]	85.07±0.05[c]
15	67.37±0.04[a]	1.83±0.04[c]	19.75±0.07[c]	19.83±0.07[c]	84.71±0.10[cd]
20	67.29±0.08[ab]	2.00±0.06[b]	20.20±0.06[b]	20.30±0.06[b]	84.35±0.15[de]
25	67.13±0.05[b]	2.12±0.06[b]	20.89±0.05[a]	20.99±0.04[a]	84.20±0.17[e]
30	66.50±0.07[d]	2.32±0.04[a]	21.02±0.06[a]	21.15±0.05[a]	83.70±0.13[f]
TFB					
Crust					
0	63.47±0.04[f]	10.55±0.05[a]	28.67±0.04[a]	28.87±0.02[a]	68.57±0.11[e]
5	65.04±0.06[e]	6.16±0.04[b]	26.25±0.04[bc]	26.96±0.05[b]	76.79±0.06[d]
10	66.78±0.03[d]	4.81±0.04[c]	25.97±0.03[e]	26.41±0.04[cd]	79.50±0.08[c]
15	67.64±0.06[c]	4.83±0.06[c]	26.37±0.05[b]	26.81±0.03[b]	79.63±0.15[c]
20	67.98±0.06[b]	4.30±0.06[d]	26.15±0.03[cd]	26.50±0.04[c]	80.66±0.11[b]
25	68.72±0.04[a]	3.93±0.04[e]	26.01±0.04[de]	26.31±0.05[d]	81.40±0.07[a]
30	68.65±0.03[a]	3.80±0.04[e]	25.31±0.04[f]	25.59±0.05[e]	81.46±0.08[a]

[1] Means followed by the same letter within a column are not significantly different ($P<0.05$). Values are the average of triplicate measurements on the duplicate samples.
[2] CLFB = cereal-legume flour blend.

resulted in higher crumb *a**, *b** and *SI* values. Our results agree with the literature. It should be noted that most of the existing studies have focused on the use of one-three type of cereal or legume in bread formulations only. Rizzello *et al.* (2017) reported lower *L** and *b** values in breads formulated with legume flour (30%) compared to control. In another study, higher *a** and *b** values in crumb were recorded with increased amount of rye flour in the bread formulations (Golzari, 2015).

Physical properties of commercial bread and traditional flat bread

Table 3 demonstrates the physical properties of CB and TFB. Weight values of CB varied in the range of 139 to 144 g. Volume and specific volume values of CB decreased with the increased ratios of CLFB. Dilution of gluten and deterioration of gluten network due to the replacement of CLFB with wheat flour resulted in a decrease of bread volume. Numerous studies have been reported that dilution of gluten content with non-wheat flour in bread dough formulation reduced bread volume (Pomeranz, 1988). This can be explained due to the visco-elastic properties of gluten proteins which are responsible for volume forming (Day *et al.*, 2006). Diameter, thickness and spread ratio values of TFB have varied in the range of 15.74 and 16.64 cm, 1.00 and 1.21 cm, 13.70 and 15.74, respectively. Utilisation of CLFB in TFB formulation increased the spread ratio values in comparison to control TFB containing only wheat flour (0% ratios of CLFB in CB and TFB named as control).

The highest hardness values of CB and TFB were obtained at 30% of CLFB ratio. As also reported in various studies in literature; Garcia-Mantrana *et al.* (2015), Nasar-Abbas and Jayasena (2012), Rieder *et al.* (2012), Sabanis and Tzia (2009). Crumb texture of control breads were softer compared to breads containing CLFB. This could be due to the lack of gluten which lowers the bread volume with

Table 3. Physical properties of commercial bread (CB) and traditional flat bread (TFB) samples.[1]

CLFB (%)[2]	Weight (g)	Volume (ml)	Specific volume (ml/g)	Hardness 24 h (F, g)	Hardness 72 h (F, g)
CB					
0	139±0.85^{b}	372±2.83^{a}	2.67±0.03^{a}	2,726±8.7^{g}	3,555±9.3^{g}
5	139±0.71^{b}	365±1.41^{b}	2.63±0.04^{a}	3,500±9.6^{f}	4,200±11.0^{f}
10	141±0.99^{ab}	335±1.41^{c}	2.37±0.03^{b}	3,850±11.7^{e}	4,522±10.6^{e}
15	142±0.14^{ab}	315±0.71^{d}	2.22±0.03^{c}	4,328±11.0^{d}	5,493±16.0^{d}
20	142±1.56^{ab}	290±0.71^{e}	2.04±0.05^{d}	4,932±9.3^{c}	5,682±12.8^{c}
25	143±0.85^{a}	255±1.41^{f}	1.78±0.05^{e}	5,321±8.3^{b}	5,975±10.5^{b}
30	144±0.14^{a}	204±1.08^{g}	1.42±0.01^{f}	6,040±13.9^{a}	6,979±9.1^{a}
TFB	**Diameter (cm)**	**Thickness (cm)**	**Spread ratio**	**Hardness 24 h (F, g)**	**Hardness 72 h (F, g)**
0	16.56±0.04^{a}	1.21±0.04^{a}	13.70±0.05^{e}	5,194±13.7^{g}	9,483±12.6^{f}
5	16.63±0.07^{a}	1.17±0.03^{ab}	14.20±0.03^{d}	5,268±10.8^{f}	1,0844±16.4^{e}
10	16.64±0.04^{a}	1.06±0.02^{ab}	15.65±0.04^{a}	5,795±10.9^{e}	1,1026±11.8^{d}
15	16.10±0.06^{b}	1.05±0.05^{ab}	15.29±0.06^{c}	6,572±14.1^{d}	1,2321±13.2^{c}
20	15.90±0.04^{bc}	1.05±0.06^{ab}	15.14±0.04^{c}	7,060±12.5^{c}	1,3251±10.5^{b}
25	15.77±0.07^{c}	1.02±0.06^{b}	15.46±0.03^{b}	7,223±13.4^{b}	1,4091±14.4^{a}
30	15.74±0.03^{c}	1.00±0.06^{b}	15.74±0.04^{a}	8,525±13.3^{a}	1,4135±9.6^{a}

[1] Means followed by the same letter within a column are not significantly different (P<0.05). Values are the average of triplicate measurements on the duplicate samples.
[2] CLFB = cereal-legume flour blend.

the addition of CLFB in formulations as explained above (Elgün and Ertugay, 1995).

Chemical properties of CB and TFB

Table 4 shows the chemical properties of CB and TFB. The moisture content of CB and TFB increased with the increasing ratio of CLFB. This is due to the high fibre content of whole flours of grains in CLFB which results in higher water absorption in the dough (Elgün and Ertugay, 1995).

Control breads had the lowest ash, protein and fat content among all type of breads, whereas CLFB usage at 30% ratio in both breads displayed the richest chemical composition. CLFB containing whole flours of grains with high ash content resulted in an increment in the ash content of the breads. On the other hand, the rich protein content of legume flours in CLFB increased the protein content of CB and TFB up to 16.75 and 16.99%, respectively. Hussein *et al.* (2013) reported that high level of whole barley flour in balady bread resulted in high moisture, protein, fat and ash values. Similar effects on chemical properties were observed upon utilising different ratios of barley flour (Ereifej *et al.,* 2006), chickpea flour (Goni and Valentin-Gamazo, 2003), soy flour (Tariqul Islam *et al.,* 2007), barley, oat and rye flours (Pourafshar *et al.,* 2015) in bread formulations.

As the CLFB ratio increased in CB and TFB formulation, the amount of phytic acid increased, also. Phytic acid content of control CB and TFB was found as 98 and 152 mg/100 g, respectively, while those values increased up to 365 and 455 mg/100 g with 30% CLFB usage. High extraction ratio of cereal and legume flours of CLFB may cause those increments in breads as also reported in literature Pozrl *et al.* (2009). Fermentation is an effective method for reducing phytic acid (Bilgiçli *et al.,* 2006). Higher fermentation time of CB resulted in lower phytic acid content from TFB.

As expected, the high AA and TPC of CLFB increased the AA and TPC in CB and TFB. Koletta *et al.* (2014) reported that bread prepared with 60% barley-oat-rye flour blend had higher TPC than that of control bread. Serpen *et al.* (2012) studied the effects of different flour (oat, rye, soy and corn) and wheat bran on AA of bread, and found that all of the flours and wheat bran increased the AA content compared to control.

Table 5 gives the mineral content of breads. Increasing amount of CLFB also increased the mineral content in both CB and TFB. Utilisation of 30% CLFB in CB increased the amounts of Ca, Fe, K, Mg, Mn, P and Zn 2.2, 2.1, 1.6, 2.2, 5.9, 1.35 and 1.34 times, respectively compared to control bread. The recommended dietary allowances (RDAs) for adult males are 800 mg of calcium, 10 mg of iron, 1.6-2.0 g

Table 4. Chemical properties of commercial bread (CB) and traditional flat bread (TFB) samples.[1]

CLFB (%)[2]	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Phytic acid (mg/100 g)	Antioxidant activity (% inhibition)	Total phenolic content (mg GAE/kg)
CB							
0	37.76±0.06^{d}	1.07±0.02^{f}	12.58±0.06^{g}	1.28±0.04^{f}	98±8.5^{g}	39.92±0.04^{g}	356±3.4^{f}
5	37.70±0.03^{de}	1.16±0.02^{ef}	13.06±0.04^{f}	1.45±0.03^{e}	128±5.7^{f}	40.29±0.03^{f}	379±2.5^{e}
10	37.56±0.03^{e}	1.23±0.03^{de}	13.75±0.06^{e}	1.63±0.04^{d}	170±8.5^{e}	40.53±0.07^{e}	394±5.0^{e}
15	38.69±0.04^{b}	1.28±0.03^{d}	14.52±0.06^{d}	1.84±0.03^{c}	229±6.6^{d}	40.97±0.03^{d}	418±5.5^{d}
20	38.42±0.04^{c}	1.38±0.02^{c}	15.60±0.04^{c}	1.94±0.04^{bc}	274±5.7^{c}	41.36±0.04^{c}	448±7.3^{c}
25	38.80±0.05^{b}	1.56±0.02^{b}	16.13±0.03^{b}	2.05±0.04^{ab}	321±5.7^{b}	41.75±0.04^{b}	469±5.8^{b}
30	39.57±0.06^{a}	1.65±0.01^{a}	16.75±0.04^{a}	2.11±0.04^{a}	365±7.1^{a}	42.29±0.07^{a}	496±5.0^{a}
TFB							
0	35.43±0.04^{g}	1.10±0.01^{f}	12.55±0.04^{g}	1.15±0.04^{e}	152±3.2^{g}	40.05±0.04^{g}	346±2.6^{g}
5	36.35±0.04^{f}	1.17±0.02^{ef}	12.93±0.04^{f}	1.32±0.06^{de}	221±2.6^{f}	40.56±0.04^{f}	366±1.8^{f}
10	36.63±0.06^{e}	1.24±0.02^{de}	13.71±0.04^{e}	1.41±0.03^{cd}	282±2.8^{e}	40.87±0.04^{e}	386±2.2^{e}
15	37.04±0.03^{d}	1.30±0.01^{d}	14.42±0.04^{d}	1.55±0.04^{bc}	335±4.2^{d}	41.34±0.04^{d}	410±2.6^{d}
20	37.37±0.03^{c}	1.38±0.01^{c}	15.50±0.04^{c}	1.68±0.04^{ab}	390±5.7^{c}	41.86±0.03^{c}	435±4.5^{c}
25	37.67±0.03^{b}	1.51±0.01^{b}	16.09±0.03^{b}	1.77±0.04^{a}	426±4.6^{b}	42.55±0.04^{b}	461±4.7^{b}
30	37.85±0.06^{a}	1.63±0.03^{a}	16.99±0.05^{a}	1.85±0.04^{a}	455±4.3^{a}	43.12±0.04^{a}	493±3.2^{a}

[1] Means followed by the same letter within a column are not significantly different ($P<0.05$). Values are the average of triplicate measurements on the duplicate samples. Results are based on dry matter.
[2] CLFB = cereal-legume flour blend; GAE = gallic acid equivalents.

Table 5. Mineral contents of commercial bread (CB) and traditional flat bread (TFB) samples (mg/100 g).[1]

CLFB (%)[2]	Ca	Fe	K	Mg	Mn	P	Zn
CB							
0	31.55±0.18^{g}	1.81±0.06^{g}	264.15±0.35^{g}	37.05±0.10^{g}	0.93±0.04^{g}	309.54±0.86^{g}	1.41±0.04^{f}
5	36.42±0.15^{f}	2.16±0.04^{f}	285.23±0.16^{f}	44.54±0.11^{f}	1.73±0.06^{f}	325.62±1.22^{f}	1.49±0.05^{ef}
10	43.19±0.27^{e}	2.45±0.04^{e}	321.14±0.20^{e}	53.21±0.14^{e}	2.44±0.03^{e}	345.26±0.82^{e}	1.57±0.01^{de}
15	50.56±0.31^{d}	2.89±0.05^{d}	344.86±0.42^{d}	60.84±0.07^{d}	3.21±0.04^{d}	362.48±1.07^{d}	1.66±0.03^{cd}
20	57.31±0.12^{c}	3.20±0.02^{c}	365.12±0.31^{c}	68.80±0.08^{c}	3.94±0.04^{c}	381.76±0.74^{c}	1.72±0.03^{bc}
25	64.23±0.25^{b}	3.54±0.03^{b}	395.74±0.06^{b}	75.64±0.07^{b}	4.78±0.04^{b}	397.21±1.26^{b}	1.82±0.04^{ab}
30	69.27±0.35^{a}	3.86±0.01^{a}	425.65±0.44^{a}	82.64±0.08^{a}	5.51±0.04^{a}	416.37±0.64^{a}	1.89±0.03^{a}
TFB							
0	30.41±0.14^{g}	1.70±0.05^{g}	257.45±0.20^{g}	36.45±0.08^{g}	0.87±0.04^{g}	302.12±0.23^{g}	1.33±0.03^{f}
5	35.77±0.08^{f}	2.01±0.04^{f}	282.45±0.16^{f}	43.18±0.15^{f}	1.62±0.06^{f}	318.65±0.20^{f}	1.43±0.04^{ef}
10	43.69±0.17^{e}	2.34±0.03^{e}	302.65±0.23^{e}	52.15±0.23^{e}	2.48±0.04^{e}	338.95±0.20^{e}	1.52±0.02^{de}
15	49.09±0.31^{d}	2.65±0.04^{d}	332.76±0.25^{d}	59.67±0.16^{d}	3.19±0.06^{d}	362.45±0.18^{d}	1.59±0.04^{cd}
20	55.50±0.32^{c}	3.06±0.04^{c}	355.23±0.31^{c}	68.13±0.20^{c}	4.02±0.04^{c}	379.32±0.18^{c}	1.69±0.04^{bc}
25	63.16±0.11^{b}	3.55±0.04^{b}	386.23±0.16^{b}	74.25±0.13^{b}	4.67±0.03^{b}	395.45±0.17^{b}	1.78±0.04^{ab}
30	69.12±0.28^{a}	3.80±0.04^{a}	419.65±0.24^{a}	80.88±0.13^{a}	5.42±0.04^{a}	413.86±0.24^{a}	1.85±0.04^{a}

[1] Means followed by the same letter within a column are not significantly different ($P<0.05$). Values are the average of triplicate measurements on the duplicate samples. Values are based on dry matter.
[2] CLFB = cereal-legume flour blend.

of potassium, 350 mg of magnesium, 800 mg of phosphorus and 15 mg of zinc (Demirci, 2007). When 100 g (dry matter) CB containing 30% CLFB were consumed, 8.7% of RDA for Ca, 38.6% of RDA for Fe, 23.6% of RDA for K, 23.6%

of RDA for Mg, 52.0% of RDA for P and 12.6% of RDA for Zn were taken by the human body. These RDA ratios were 3.9% of Ca, 18.1% of Fe, 14.6% of K, 10.5% of Mg, 38.6% of P and 9.4% of Zn in the control CB sample. It is estimated that legume flours (especially soy) had a dominant effect on mineral increment of breads because it has more mineral content than cereal flour. In literature, there are many studies on mineral enrichment of cereal products with the usage of whole flours of cereal and legumes in its formulation (Bilgiçli, 2013; Gupta *et al.,* 2009; Pawar *et al.,* 2015; Skrbic *et al.,* 2009).

Sensory properties of CB and TFB

Sensory properties of CB and TFB are presented in Figure 1 and 2. High usage levels of CLFB had an adverse effect on sensory quality, especially in terms of taste, odour, pore structure and appearance in CB and TFB. Beany taste of legume flours at high CLFB ratios was not preferable by the panellists. Low scores for pore structure and appearance of the breads may be resulted from dilution of gluten and deterioration of gluten network with CLFB at high ratios. The highest overall acceptability scores were obtained using 5% of CLFB in both breads. Increasing the CLFB ratio up to 10-15% in CB resulted in similar overall acceptability scores to control. High ratios of CLFB decreased overall acceptance of both breads.

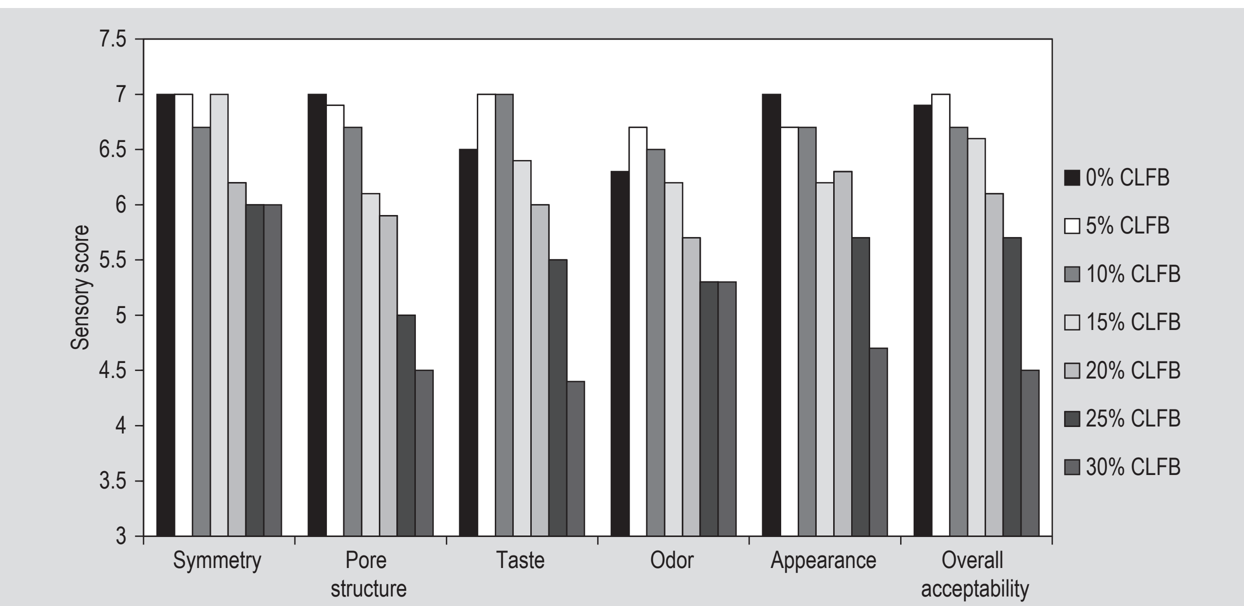

Figure 1. Sensory scores of commercial bread samples containing different ratios of cereal-legume flour blend (CLFB).

4. Conclusions

This study aimed at investigating the effect of CLFB (0-30%) on physical, chemical and sensory properties of CB and TFB. Although high percentage of CLFB resulted in maximum nutritional enrichment in both breads, it has lowered the technological quality of bread. For example, bread, e.g. crumb hardnes and loaf volume of CB. The most notable increases were observed in protein (1.04-1.33 times), phytic acid (1.31-3.72 times), calcium (1.15-2.20 times), iron (1.19-2.13 times), potassium (1.08-1.61 times), magnesium (1.20-2.23 times), and manganese (1.86-5.92 times) contents of CB formulated with 5-30% CLFB. Similar increases were also obtained for TFB using CLFB. CB containing low ratio of CLFB (5%) resulted in better overall acceptability score than control. High ratios of CLFB created noteworthy differences in the overall acceptability scores of both breads, compared to control. Taken technological and sensory qualities and chemical properties all together, it is recommended that CLFB can be used up to 15-20%. In the case of further increment in CLFB, specific additives should be used to improve the technological and sensory qualities of the breads. The results of specific additive trials on bread quality will be published separately.

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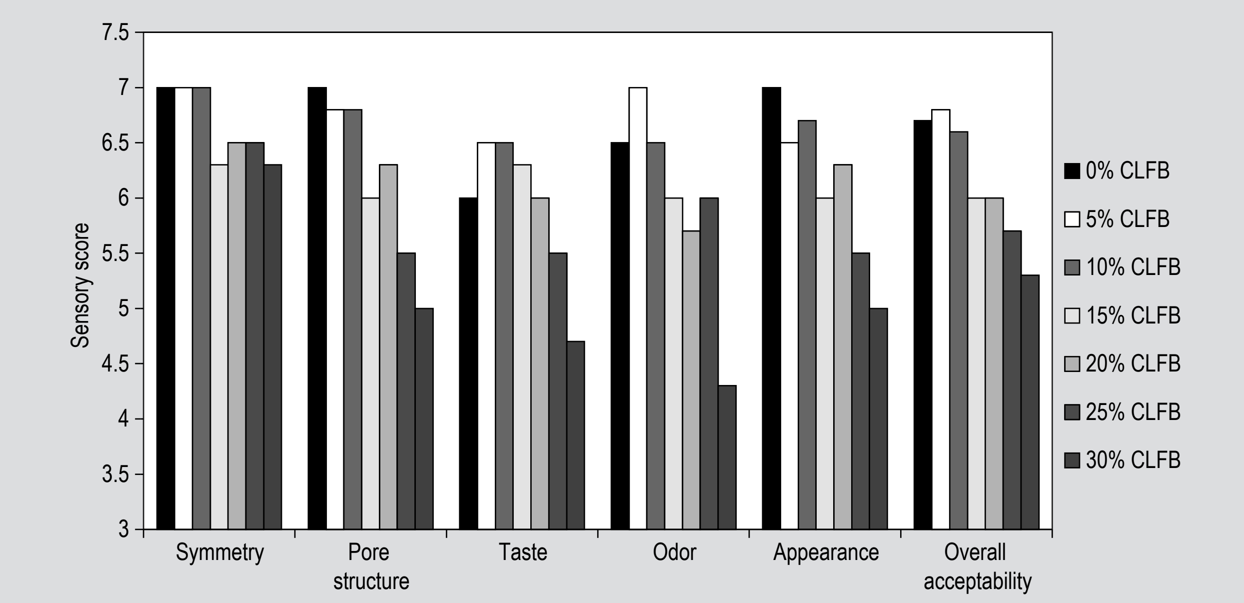

Figure 2. Sensory scores of traditional flat bread samples containing different ratios of cereal-legume flour blend (CLFB).

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