

Utilisation of buckwheat flour in leavened and unleavened Turkish flat breads

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Abstract

Whole buckwheat flour (WBF) was used in leavened flat bread (*bazlama*) and unleavened flat bread (*yufka*) formulations to improve the nutritional status of flat breads. WBF replaced wheat flour at 10, 15, 20, 25 and 30% levels in both flat breads. The effects of WBF on some rheological properties of dough and some physical, chemical and sensory properties of flat breads were studied. The effects of some additives (gluten and sodium stearoyl-2-lactylate; SSL) for improving dough rheology and bread properties were also investigated. For this purpose WBF replaced wheat flour at 20, 30 and 40% levels in flat bread formulation with the aid of additives. WBF increased water absorption and development time values of dough up to 93.3% and 14.4 min, respectively. While dough stability, energy and resistance values were adversely affected by an increasing level of WBF, usage of gluten and SSL improved those parameters significantly. Ash, protein and crude fibre content of both flat breads were found at the highest ratio in 30-40% level of WBF with additive combination. Phytic acid content ranged between 163.03 and 651.04 mg/100 g in *bazlama* and between 220.01 and 772.34 mg/100 g in *yufka* samples. Fe, K, Mg and P contents of both flat breads increased with an increasing amount of WBF in formulation. Mineral content of *bazlama* samples increased from 0.96 to 1.72 mg/100 g for Fe, 165.92 to 272.71 mg/100 g for K, 36.21 to 109.01 mg/100 g for Mg and 131.13 to 264.72 mg/100 g for P with 40% WBF usage. WBF content above 10% caused an increment in darkness, yellowness and redness of the flat bread samples. A sensory analysis revealed that the taste and odour score decreased above the 20% WBF level for *bazlama* and 30% WBF level for *yufka* compared to control *bazlama/yufka*.

Keywords: buckwheat, rheological properties, minerals, colour, sensory

1. Introduction

Buckwheat (BW) (*Fagopyrum esculentum* Moench), also known as common buckwheat, is a pseudo-cereal that belongs to the *Polygonaceae* family. It is usually classified as a cereal because of its similarity in terms of chemistry, structure, and use. BW originates from Asia and has become an important plant in many areas of the world (Ratan and Kothiyal, 2011; Wijngaard and Arendt, 2006). It has received increased interest worldwide due to its nutritional composition and the presence of biologically active compounds that provide health benefits such as reducing high blood pressure, lowering cholesterol, controlling blood sugar and preventing cancer risk (Dziedzic *et al.*, 2012; Li and Zhang, 2001; Mattila *et al.*, 2005; Metzger *et al.*, 2007). It is a good source of vitamins (B1, B2, B6 and E), minerals

(P, Fe, Zn, K and Mg), dietary fibre, starch, protein, and essential amino acids (Steadmen *et al.*, 2001; Wijngaard and Arendt, 2006). The amino acids in BW protein are well balanced and rich in lysine and arginine (Tomotake *et al.*, 2006). Furthermore, it contains no gluten and can therefore be eaten by people with Coeliac disease (Sedej *et al.*, 2011). It is high in resistant starch which is important for the preparation of low glycaemic index food (Skrabanja *et al.*, 2004). BW flour is generally used to make noodles in Asian and European countries, but can also be mixed with cereal flours to prepare a number of products, such as breads, biscuits, and cakes (Chillo *et al.*, 2008; Dvořáková *et al.*, 2012; Fessas *et al.*, 2008; Filipčev *et al.*, 2011; Kim *et al.*, 1999; Kreft *et al.*, 2006; Lin *et al.*, 2009; Sedej *et al.*, 2011; Wronkowska *et al.*, 2010).

Bread is widely consumed in the world in various types and forms depending on cultural habits (Cayot, 2007). *Bazlama* and *yufka* are flat breads which are the oldest and most popular product in Turkey. *Bazlama* can be defined as leavened bread with a creamy yellow colour. It has a circular shape with an average thickness of 3 cm and a diameter ranging from 10 to 20 cm (Başman and Köksel, 1999). *Yufka* is unleavened and very thin (1-2 mm thickness) flat bread with a circular, cream-colored and flexible appearance (Başman and Köksal, 2001). Wheat flour (WF) is extensively used for the production of these flat breads. However, breads prepared from WF are considered to be nutritionally poor (Sabanis and Tzia, 2009). Previous studies have reported that the partial replacement of WF with non-wheat cereal flours significantly improves the nutritional profile of breads (Alvarez-Jubette *et al.*, 2010; Chlopicka *et al.*, 2012; Dapčević-Hadnadev *et al.*, 2011; Lin *et al.*, 2009). BW flour has some limitations for bread-making in terms of colour and volume because of its natural dark colour and gluten-free composition (Pruska-Kedzior *et al.*, 2008; Yıldız and Bilgiçli, 2012). Additives are commonly used in the bread formulations to overcome the quality losses by influencing dough strength, tolerance, uniform crumb cell size, and improving gas retention and slicing characteristics (Azizi and Rao, 2005; Resurreccion, 2008). Gluten is a viscoelastic protein complex, which plays a key role in the rheological properties of dough and influences the structure and volume of the finished product (Day *et al.*, 2006). Sodium stearyl-2-lactylate (SSL) is an anionic emulsifier which is capable of enhancing gluten strength, improving mixing tolerance and CO₂ retention of the dough via its interaction with the hydrophobic side of gluten protein during dough mixing (Orthofer 2008; Ribitto *et al.*, 2004; Rosell and Gomez, 2006).

This study aims to determine the suitability of whole buckwheat flour (WBF) for the production of leavened (*bazlama*) and unleavened (*yufka*) flat breads through rheological, physical, chemical and sensory analysis. The effects of some additives (gluten and SSL) on flat bread quality have also been investigated.

2. Materials and methods

Materials

BW groats were purchased from Yar Gıda, Antalya, Turkey in order to get flour. The groats were milled using a hammer mill (Falling Number-3100 Laboratory Mill; Perten Instruments AB, Huddinge, Sweden) equipped with a 0.5 mm opening screen and WBF with 100% extraction ratio was obtained. Commercial WF, salt, fresh yeast and sugar were procured from a local market in Konya. Vital gluten (Meelunie B.V., Amsterdam, the Netherlands) and SSL (Palsgaard A/S, Juelsminde, Denmark) were used as additives for some bread formulations.

Bazlama and *yufka* preparation

Bazlama and *yufka* trials were conducted with and without additives (gluten and SSL). In the flat bread production (without additive), varying levels (10, 15, 20, 25 and 30%) of WBF replaced WF to produce *bazlama* (leavened) and *yufka* (unleavened) samples. In additive trials, gluten and SSL as a processing aid for improving dough rheology and bread properties were used in flat bread formulation. Vital gluten was added at 1.85, 2.78 and 3.71% levels (according to the diluted gluten content of flour blends) for 20, 30, and 40% level of WBF, respectively. SSL was also added in these three flour blends at a ratio of 0.5%.

Control *bazlama* samples were prepared according to the following formula: flour 200 g (14% moisture basis), salt 3 g, fresh yeast 5 g, sugar 2 g and water. The amount of water required was determined by the farinograph absorption. The ingredients were mixed in a Hobart mixer (Hobart N50; Canada Inc., North York, Ontario, Canada) for a period of 45 s at speed 3 (to obtain optimum dough consistency). The resultant dough samples were allowed to ferment at a temperature of 30 °C, and 85% relative humidity for 1 h and then the doughs were divided into two equal pieces. The dough pieces were dusted with flour of the same blend and rounded into ball shapes, sheeted, and left for 6 min at room temperature, and sheeted again to the final thickness of 1 cm and diameter of 17 cm. They were then baked on a hotplate (sac or sadj) (Otm, Konya, Turkey) for 5 min at a temperature of 280±5 °C (Akbaş, 2000).

Control *yufka* samples were made as well, according to Başman and Köksel (2001). For preparation of *yufka* samples, flour (200 g, 14% moisture basis), salt (1.5%) and water were mixed in a Hobart N50 mixer for a period of 45 s at the speed 3. After mixing, doughs were allowed to ferment at a temperature of 30 °C for 30 min. The doughs were scaled off into 4 pieces, and then were rounded into a ball shape and dusted with flour of the same blend to aid sheeting. The dough balls were rolled to the final thinnest thickness and then baked at a temperature of 280±5 °C on a *sac* for 1 min. Afterwards, baked flat breads were cooled to room temperature for 1 h, and then the physical, sensory and chemical characteristics of the samples were tested. For each type of bread, thickness was measured with a digital micrometer (0.001 mm; Mitutoyo, Tokyo, Japan), and the diameter was measured with an ordinary ruler.

Laboratory analysis

The chemical composition of flat breads, including moisture, protein and crude fibre was determined according to the methods of AACC 44-19, 46-12 and 32-10, respectively (AACC, 1990). Ash contents of the samples were determined by ICC method 104-1 (ICC, 2002). To determine the rheological behaviour of bread dough,

farinograph (Brabender GmbH and Co. KG, Duisburg, Germany) (AACC 54-21) and extensograph (Brabender GmbH and Co. KG) (AACC 54-10) properties were assessed according to methods described by AACC (1990). Phytic acid (PA) in the bread samples was extracted with 0.2 N HCl and precipitated with a solution of $\text{NH}_4\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ and measured according to the colorimetric method of Haug and Lantzsch (1983). The mineral contents of the samples were analysed using inductively coupled plasma-atomic emission spectrometer ICP-AES (Vista series, Varian International AG, Zug, Switzerland). About 0.5 g dried samples was put into a burning cup with 10 ml $\text{HNO}_3 + \text{H}_2\text{SO}_4$. The samples were incinerated by using closed vessel microwave digestion oven (Mars 5; CEM Corporation, Matthews, NC, USA) and solutions diluted to a specific volume (100 ml) with distilled deionised water (Skujins, 1998).

The colour measurements of flat breads were performed using a chromometer Minolta CR-400 (Minolta Camera, Co., Ltd., Osaka, Japan). Parameters L^* , a^* and b^* determine a three-dimensional colour space, in which L^* indicates lightness (100 = white; 0 = black), a^* values determine the redness (+) and greenness (-), and b^* values determine yellowness (+) and blueness (-). Three replicated measurements were performed on the external surface of the samples. Afterwards, according to the following equations, L^* , a^* and b^* values were used to calculate total colour differences (ΔE) and chroma (C) values (Kaur *et al.*, 2013).

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2}$$

Here, L_0^* , a_0^* and b_0^* are the colour parameters of control breads that were prepared from WF.

$$C = \sqrt{a^{*2} + b^{*2}}$$

Sensory analysis

Bazlama and *yufka* breads containing additives (gluten and SSL) were selected for sensory evaluation due to their superior physical and chemical properties compared to bread without additives. Sensory analysis was conducted by 10 panellists (age range of 30 to 60) from the Food Engineering Department of Selçuk University (Konya, Turkey). Crust colour, pore structure, chewiness and taste-odour of *bazlama* samples and crust colour, elasticity, chewiness and taste-odour of *yufka* samples were evaluated using a 5-point scale, 5 representing most desirable.

Statistical analysis

The results were analysed using the TARIST (version 4.0; Ege University, İzmir, Turkey) software program. Mean differences were tested for significance with a Duncan's multiple range test at a 5% level of significance.

3. Results and discussion

In our previous study, we presented the chemical composition and colour values of WF and WBF. WF and WBF had moisture, ash, protein and crude fibre contents of 10.7 and 11.1%, 0.47 and 1.73%, 11.6 and 12.1%, and 0.5 and 1.2%, respectively. For WBF the PA content was found to be 1,480 mg/100 g, which was 6.17 fold higher than WF (240 mg/100 g). Ca, Mg, P, Fe, K contents (mg/100 g) for WF were 21, 35, 127, 0.9 and 145, respectively; for WBF these contents were 22, 235, 455, 2.8 and 433, respectively. WBF had a lower L^* (77.96) and higher a^* (3.55) and b^* (17.19) value than WF ($L^* = 95.51$, $a^* = -0.77$ and $b^* = 9.89$) (Yıldız and Bilgiçli, 2012).

Rheological properties of dough

Some farinograph and extensograph (135 min) dough parameters are presented in Figure 1 and 2. Farinograph and extensograph curves of the flour blend with 40% WBF were not plotted.

A farinograph gives information about the mixing behaviour of dough when gluten develops (Arendt *et al.*, 2002). As the WBF level in flour blends increased, water absorption and development time increased, while stability of the dough decreased compared with the WF dough. WBF at the level of 30% with additives had the highest water absorption value (93.3%). The obtained results might be attributed to much higher fibre content found in WBF than in WF (Yıldız and Bilgiçli, 2012; Wang *et al.*, 2002). In addition

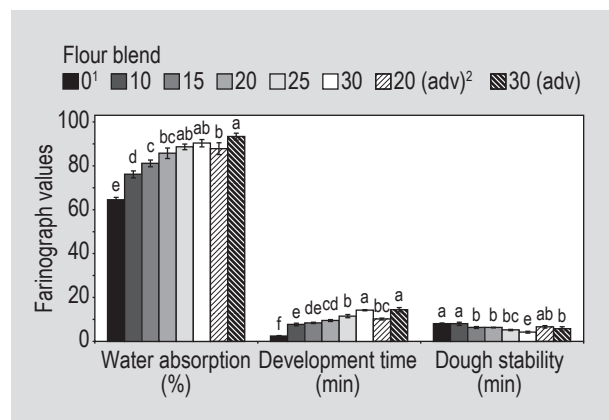


Figure 1. Farinograph values of bread dough. Bars with different letters are significantly different ($P < 0.05$). ¹WBF replacement ratio. ²WBF replacement ratio with additives.

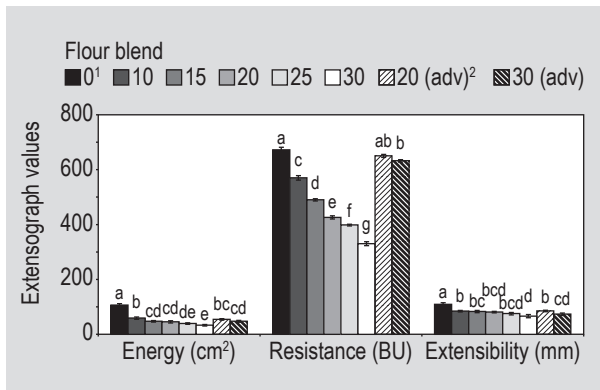


Figure 2. Extensograph values of bread dough. Bars with different letters are significantly different ($P < 0.05$). (¹WBF replacement ratio. ²WBF replacement ratio with additives.)

water binding capacity of BW starch is 109.9%, which is higher than that of wheat starch due to smaller particle size and bigger surface area of BW starch (Qian *et al.*, 1998). There was no significant ($P > 0.05$) difference between the water absorption of dough containing 30% WBF with and without additives.

Development time of the dough with 30% WBF (14.4 min) was found to be 6 times higher than that of the WF dough (2.4 min). Increased water absorption capacity with WBF addition extended the development time of dough. In addition, high crude fibre and pentosane contents of WBF (obtained with 100% extraction ratio) slowed down the water absorption of flour blends, hence increased the development time (Torbica *et al.*, 2010). An extended development time of dough with BW milling product addition was reported by a number of other studies (Bojnanska *et al.*, 2009; Kim *et al.*, 1996).

Dough stability, which is an index of dough strength, decreased with increasing levels of WBF from 8.0 min in the WF to 4.2 for WBF 30%. Gluten and SSL addition improved the dough stability significantly, compared to additive-free dough samples. Gluten content and quality are very important parameters for dough stability due to structure-forming ability and viscoelastic behaviour (Lazaridou *et al.*, 2007). However, BW flour proteins mainly consisted of non-gluten proteins (albumin and globulin) (Alvarez-Jubete *et al.*, 2010) and due to the lack of structure-forming ability of BW flour proteins, the replacement of WBF with WF decreased the stability of the dough.

An extensograph gives information about the viscoelastic behaviour of dough and measure some parameters as dough energy, extensibility and resistance to extension (Rosell *et al.*, 2001). Energy values of the WF-WBF blends dough with and without additives ranged from 33 to 59 cm², and 47 to 54 cm², respectively. Energy value of WF dough was determined as 106 cm². Increasing levels of WBF in flour

blends were affected the dough energy values negatively, just like farinograph stability, due to weakening of the protein network and reduction in the gas holding capacity of the dough. A number of researchers expressed that the decreasing energy values in extensogram were related to the diluted gluten amount of flour blends (Grobelnik-Mlakar *et al.*, 2009; Nikolic *et al.*, 2011). As expected, gluten and SSL additions increased the dough energy values descriptively, compared to those of the additive free flour blends.

Dough resistance decreased with the usage of WBF and showed a similar trend to the dough energy values. Gluten and SSL as additives increased the dough resistance significantly ($P < 0.05$). Bojnanska *et al.* (2009) and Atalay *et al.* (2013) reported the decreasing effect of BW milling products on dough resistance. Dough extensibility also decreased with the use of WBF in flour blends compared to that of WF alone. Some other studies also reported that BW milling products decrease the dough extensibility (Atalay *et al.*, 2013; Kim *et al.*, 2000).

Chemical properties

The chemical properties of *bazlama* and *yufka* are presented in Tables 1 and 2. Moisture content for *bazlama* and *yufka* changed between 31.64 to 40.14% and 6.61 to 9.38%, respectively. As the bread thickness (*bazlama* > *yufka*) decreased, and the diameter (*bazlama* < *yufka*) increased, the bread surface area for water evaporation during baking increased as well. Moisture content of bread samples increased with increasing levels of WBF in flour blends due to the higher water absorption capacity of WBF (Figure 1). Ash contents of *bazlama* and *yufka* changed from 1.24 to 1.79 and 1.20 to 1.75 g/100 g, respectively. The higher ash content of WBF compared to that of WF results in an increase in ash content of breads. Similar results were obtained by Bojnanska *et al.* (2009), Atalay *et al.* (2013) and Yıldız and Bilgiçli (2012). In the case of both flat breads with higher levels of WBF, an increment of protein content was observed. Also vital gluten in *bazlama* and *yufka* formulations increased the protein contents to 15.6 and 15.3 g/100 g, respectively. There was a significant increase ($P < 0.05$) in the crude fibre of all the bread samples, except for WBF 10%, compared to control breads produced from WF. It can be concluded that higher crude fibre content of WBF than WF, like its ash content, directly affected the end product's crude fibre content.

Generally speaking, the chemical compositions of the leavened flat bread-*bazlama* were found to be richer than those of the unleavened flat bread-*yufka*. Fermentation loss (carbohydrate loss) during the leavening process resulted in proportional increases in the other constituents like ash, protein and crude fibre. Elgün and Ertugay (1995) reported that the fermentation losses in straight and sponge dough breads were 2.5% and 3.5%, respectively. In another

Table 1. Some chemical properties and mineral contents of *bazlama* breads.^{1,2}

Flour blend	Moisture (%)	Ash (g/100 g)	Protein ³ (g/100 g)	Crude fibre (g/100 g)	Pythich acid (mg/100 g)	Ca (mg/100 g)	Fe (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	P (mg/100 g)
0 ⁴	31.64±0.42 ^g	1.24±0.06 ^f	11.81±0.06 ^e	0.55±0.04 ^d	163.03±2.69 ⁱ	26.22±0.14 ^c	0.96±0.08 ^f	165.92±2.26 ⁱ	36.21±1.56 ^g	131.13±2.12 ^j
10	33.41±0.14 ^f	1.37±0.03 ^e	11.84±0.04 ^e	0.61±0.03 ^{cd}	250.11±1.84 ^h	26.41±0.02 ^c	1.16±0.06 ^e	194.63±1.56 ^h	55.62±1.70 ^f	154.83±1.13 ^h
15	35.17±0.35 ^e	1.42±0.04 ^{de}	11.91±0.06 ^e	0.64±0.04 ^{bc}	305.35±1.98 ^g	26.43±0.14 ^c	1.26±0.08 ^{de}	207.21±1.56 ^g	66.82±1.84 ^e	167.29±2.26 ^g
20	37.58±0.14 ^b	1.48±0.04 ^{de}	11.93±0.04 ^e	0.66±0.01 ^{abc}	345.12±3.54 ^f	26.49±0.48 ^c	1.34±0.08 ^{cde}	220.42±2.26 ^f	74.63±1.13 ^d	178.46±1.84 ^f
25	39.16±0.07 ^a	1.53±0.03 ^{bcd}	11.98±0.08 ^{de}	0.69±0.04 ^{abc}	412.21±3.54 ^d	26.68±0.28 ^c	1.46±0.07 ^{bc}	235.13±1.41 ^d	83.89±1.27 ^c	192.82±0.28 ^d
30	40.14±0.14 ^a	1.60±0.03 ^{bc}	12.16±0.04 ^d	0.72±0.01 ^{ab}	474.02±2.26 ^c	26.63±0.14 ^c	1.56±0.03 ^{ab}	248.48±1.13 ^c	92.82±1.13 ^b	220.42±1.70 ^c
20 (adv) ⁵	37.05±0.28 ^{bc}	1.50±0.07 ^{cd}	13.73±0.04 ^c	0.64±0.02 ^{bc}	372.07±3.39 ^e	29.14±0.57 ^b	1.36±0.07 ^{cd}	228.35±2.69 ^e	75.90±1.57 ^d	190.31±1.70 ^e
30 (adv)	36.06±0.64 ^d	1.64±0.04 ^{ab}	14.76±0.08 ^b	0.69±0.03 ^{abc}	512.13±2.97 ^b	30.83±0.42 ^a	1.59±0.11 ^{ab}	257.73±0.99 ^b	92.42±1.26 ^b	230.38±2.40 ^b
40 (adv)	36.47±0.21 ^{cd}	1.79±0.04 ^a	15.60±0.16 ^a	0.75±0.06 ^a	651.04±3.82 ^a	31.57±0.85 ^a	1.72±0.01 ^a	272.71±0.99 ^a	109.01±1.84 ^a	264.72±0.85 ^a

¹ Means followed by the same superscript letter within a column are not significantly different ($P<0.05$).
² Based on dry matter.
³ N × 5.70 for wheat flour; N × 6.25 for whole buckwheat flour.
⁴ Whole buckwheat flour replacement ratio.
⁵ Whole buckwheat flour replacement ratio with additives (adv).

Table 2. Some chemical properties and mineral contents of *yufka* breads.^{1,2}

Flour blend	Moisture (%)	Ash (g/100 g)	Protein ³ (g/100 g)	Crude fibre (g/100 g)	Pythich acid (mg/100 g)	Ca (mg/100 g)	Fe (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	P (mg/100 g)
0 ⁴	6.61±0.14 ^d	1.20±0.03 ^g	11.60±0.06 ^f	0.50±0.01 ^e	220.01±2.40 ⁱ	23.62±0.14 ^e	0.90±0.02 ^g	147.30±1.84 ^g	35.38±1.70 ^g	125.31±1.84 ⁱ
10	7.05±0.07 ^{bc}	1.32±0.01 ^f	11.71±0.01 ^{ef}	0.55±0.04 ^{de}	346.07±3.54 ^h	23.58±0.28 ^e	1.06±0.08 ^f	175.64±2.26 ^f	54.54±0.71 ^f	139.10±1.13 ^h
15	7.12±0.14 ^{bc}	1.35±0.04 ^{ef}	11.74±0.04 ^{de}	0.60±0.01 ^{cd}	400.12±2.12 ^g	23.72±0.28 ^{de}	1.21±0.04 ^{ef}	191.84±2.12 ^e	65.68±1.13 ^e	155.83±2.55 ^g
20	7.24±0.11 ^b	1.42±0.04 ^{def}	11.76±0.01 ^{de}	0.63±0.03 ^{bc}	460.43±3.54 ^f	24.21±0.28 ^{cde}	1.25±0.04 ^{de}	206.21±1.98 ^d	73.81±1.13 ^d	163.43±2.83 ^f
25	6.79±0.18 ^{cd}	1.49±0.04 ^{bcd}	11.79±0.04 ^{de}	0.66±0.01 ^{abc}	520.16±1.98 ^d	24.34±0.28 ^{bcd}	1.39±0.08 ^{bcd}	215.43±2.40 ^c	83.53±0.99 ^c	184.31±3.25 ^d
30	6.16±0.21 ^e	1.54±0.06 ^{bc}	11.82±0.03 ^d	0.71±0.03 ^{ab}	590.23±2.83 ^c	24.42±0.42 ^{bcd}	1.41±0.04 ^{bc}	231.24±1.41 ^b	92.32±0.42 ^b	208.92±3.11 ^c
20 (adv) ⁵	9.11±0.04 ^a	1.45±0.04 ^{cde}	13.54±0.04 ^c	0.61±0.04 ^{cd}	485.28±3.68 ^e	24.87±0.14 ^{abc}	1.26±0.06 ^{cde}	209.19±0.99 ^d	74.52±0.85 ^d	183.52±0.71 ^e
30 (adv)	9.35±0.07 ^a	1.60±0.06 ^{ab}	14.36±0.06 ^b	0.67±0.03 ^{abc}	625.05±3.39 ^b	25.11±0.42 ^{ab}	1.44±0.07 ^{ab}	236.61±1.13 ^b	86.60±0.65 ^c	220.37±0.71 ^b
40 (adv)	9.38±0.21 ^a	1.75±0.04 ^a	15.30±0.03 ^a	0.73±0.04 ^a	772.34±2.40 ^a	25.32±0.42 ^a	1.66±0.07 ^a	256.74±2.26 ^a	98.47±1.67 ^a	256.14±1.56 ^a

¹ Means followed by the same superscript letter within a column are not significantly different ($P<0.05$).
² Based on dry matter.
³ N × 5.70 for wheat flour; N × 6.25 for whole buckwheat flour.
⁴ Whole buckwheat flour replacement ratio.
⁵ Whole buckwheat flour replacement ratio with additives (adv).

study, a proportional increase in dry matter composition of fermented *tarhana* as well was reported by Bilgiçli (2009).

PA content of samples changed between 163.03 to 651.04 mg/100 g for *bazlama*; 220.01 to 772.34 mg/100 g for *yufka* breads. PA is considered to be an anti-nutrient due to its ability to bind minerals and proteins (Afinah *et al.*, 2010; Lasztity and Lasztity, 1990; Rickard and Thompson, 1997). In yeast fermented *bazlama* samples, the highest decrement of PA was observed. Fermentation is considered as one of the most effective processes known to reduce PA in bread (Bilgiçli, 2009; Lopez *et al.*, 2002). While the PA content of

bread decreased with fermentation, increasing the amount of WBF levels negatively affected the PA degradation due to its higher PA content. Furthermore, breads with additives had a significantly ($P<0.05$) higher PA content; this can be caused by the high PA content of vital gluten (Egli *et al.*, 2003; Hidvegi and Lasztity, 2002). Başman *et al.* (2005) reported that the PA loss in *bazlama* samples supplemented with different levels of barley flour and wheat bran ranged between 20.1-30.8% and 8.7-18.4%, respectively.

Ca, Fe, K, Mg and P contents of the breads were also shown in Table 1 and 2. In general, all the investigated mineral

contents were found to be higher in the leavened bread than in the unleavened. As mentioned before, this increment was due to the fermentation loss and proportional increase in dry matter. In all types of bread used in this study, as the level of WBF in formulation increased, Fe, K, Mg and P content of the breads increased significantly ($P < 0.05$). On the other hand, the Ca, K and P content of *bazlama* samples was affected significantly ($P < 0.05$) with gluten and SSL addition. Steadman *et al.* (2001) and Wijngaard and Arendt (2006) also reported that the levels of Mg, Zn, K, P and Cu in WBF were higher than WF.

Spread ratio and colour values

Spread ratio and colour parameters of *bazlama* and *yufka* samples are given in Table 3. Spread ratio of *bazlama* samples changed between 10.78 and 13.16, and results showed that WBF and additives had no significant effect ($P > 0.05$) in the spread ratio of breads compared to control bread. However, in *yufka* formulation replacement of WF with WBF result in a significant ($P < 0.05$) increase in the spread ratio (except WBF30 and 40% with additives), with a corresponding decrease in the thickness and increase in diameter of *yufka* breads containing WBF in comparison

with WF bread (data not shown), due to disruption of the gluten structure. Also there was no significant ($P > 0.05$) difference between the spread ratio of control and bread containing 30 and 40% WBF with additives. On the other hand, in these formulations, gluten and SSL additions decreased the spread ratio when compared to that of *yufka* without additives at 30 and 40% WBF level. This decrease might be caused by the dough strengthening effect of vital gluten. This result corresponds to previous findings showing a decrease in the spread ratio when high-protein ingredients were used (Indrani *et al.*, 2007; Singh *et al.*, 1996; Yıldız and Bilgiçli, 2012). In addition, Levent and Bilgiçli (2012) reported that 30% BW flour usage in *bazlama* formulations significantly increased spread ratios from 12.6 to 16.2 compared to control (with WF) breads. In contrast, we found that 30% BW flour usage in *yufka* resulted in a significant decrease in the spread ratio from 225.4 (control sample) to 179.5.

The colour measurement results for the *bazlama* samples were: L* value in the range of 75.89 to 86.92, a* value in the range of 0.78 to 4.01, b* value in the range of 14.49 to 17.20. The L*, a*, and b* values of *yufka* breads varied between 77.03-88.29, 0.08-3.62 and 14.29-15.78, respectively. In

Table 3. Spread ratio and colour values of *bazlama* and *yufka* breads.¹

Flour blend	Spread ratio	L*	a*	b*	C	ΔE
<i>Bazlama</i> breads						
0 ²	11.42±0.75 ^{ab}	86.92±0.13 ^a	0.78±0.11 ^f	14.49±0.17 ^c	14.51±0.18 ^e	–
10	11.28±0.56 ^{ab}	83.61±0.27 ^b	1.74±0.08 ^e	14.77±0.25 ^c	14.87±0.26 ^e	3.46±0.30 ^g
15	11.29±1.49 ^{ab}	82.16±0.23 ^c	2.07±0.04 ^e	15.18±0.21 ^b	15.32±0.22 ^d	4.98±0.26 ^f
20	11.96±0.90 ^{ab}	80.68±0.37 ^d	2.55±0.20 ^d	15.29±0.13 ^b	15.50±0.16 ^{cd}	6.54±0.42 ^e
25	12.87±0.11 ^a	79.91±0.37 ^e	2.92±0.14 ^{cd}	15.33±0.11 ^b	15.61±0.14 ^{cd}	7.38±0.40 ^d
30	13.16±1.15 ^a	78.77±0.17 ^f	3.25±0.18 ^{bc}	15.53±0.11 ^b	15.87±0.15 ^c	8.58±0.23 ^c
20 (adv) ³	10.78±0.45 ^b	80.64±0.27 ^d	2.71±0.13 ^d	15.24±0.06 ^b	15.48±0.08 ^{cd}	6.61±0.30 ^e
30 (adv)	11.03±0.88 ^b	77.54±0.13 ^g	3.54±0.11 ^{ab}	16.62±0.16 ^a	16.99±0.18 ^b	10.01±0.18 ^b
40 (adv)	11.63±0.77 ^{ab}	75.89±0.20 ^h	4.01±0.31 ^a	17.20±0.11 ^a	17.66±0.18 ^a	11.81±0.30 ^a
<i>Yufka</i> breads						
0 ²	206.7±5.00 ^d	88.29±0.24 ^a	0.08±0.10 ^f	14.29±0.24 ^f	14.29±0.24 ^g	–
10	227.4±6.92 ^b	83.00±0.30 ^b	1.73±0.08 ^e	14.45±0.07 ^{ef}	14.55±0.08 ^{fg}	5.55±0.26 ^f
15	229.5±3.67 ^{ab}	79.85±0.16 ^d	2.73±0.16 ^d	14.87±0.25 ^{cd}	15.12±0.28 ^{cd}	8.87±0.21 ^d
20	228.0±4.58 ^b	78.23±0.41 ^e	3.28±0.07 ^{ab}	15.10±0.13 ^{bc}	15.45±0.14 ^{bc}	10.59±0.42 ^b
25	232.1±2.02 ^{ab}	77.17±0.17 ^f	3.49±0.07 ^a	15.38±0.10 ^{ab}	15.77±0.11 ^b	11.68±0.19 ^a
30	240.3±4.13 ^a	77.03±0.01 ^f	3.62±0.16 ^a	15.78±0.08 ^a	16.19±0.12 ^a	11.90±0.07 ^a
20 (adv) ³	221.8±3.48 ^{bc}	80.92±0.27 ^c	2.60±0.01 ^d	14.45±0.10 ^{ef}	14.68±0.10 ^{ef}	7.79±0.26 ^e
30 (adv)	209.9±4.14 ^d	80.97±0.11 ^c	2.84±0.01 ^{cd}	14.59±0.08 ^{def}	14.86±0.09 ^{def}	7.83±0.11 ^e
40 (adv)	212.4±1.04 ^{cd}	79.31±0.20 ^d	3.07±0.20 ^{bc}	14.68±0.10 ^e	15.00±0.14 ^{de}	9.47±0.25 ^c

¹ Means followed by the same superscript letter within a column are not significantly different ($P < 0.05$).

² Whole buckwheat flour replacement ratio.

³ Whole buckwheat flour replacement ratio with additives (adv).

L* = indicates lightness (100 = white; 0 = black); a* = redness (+) and greenness (-); b* = yellowness (+) and blueness; C = chroma; ΔE = total colour differences.

the case of both breads, while the L^* value of the sample decreased, the a^* and b^* values of breads increased with increased levels of WBF compared to control breads. C value, which is also known as colour strength or saturation, is the quantitative component of the colour (Pathera *et al.*, 2013). Compared to control bread, C value of samples increased in above 10% WBF levels, mainly due to the higher b^* values of the bread containing WBF. The colour difference (ΔE) of *bazlama* and *yufka* breads ranged from 3.46 to 11.81 and 5.55 to 11.90, respectively. As a raw material of breads, WBF had lower L^* and higher a^* and b^* colour values than that of WF. As expected, colour values of raw material affected the colour values of the final product. Furthermore, Maillard reactions, which occur between proteins or amino acids and reduce sugars during heating, may also be responsible for the formation of brown compounds (Nguyen and Schwartz, 1999). It is well known that BW starch can be saccharified more easily than wheat starch (Marshall and Pomeranz, 1982).

Sensory properties

Sensory properties of the breads used in this study are presented in Figure 3 and 4. Sensory evaluations were carried out on the bread samples with additives due to physical and chemical superiority of these samples. Compared to the control sample, the crust colour parameters of bread samples showed a decrease, which is connected with the increasing levels of WBF resulting in lower L^* and higher a^* and b^* values (Table 3). Pore structure of *bazlama* deteriorated in the samples with over 20% replacement level of WBF ($P < 0.05$). Elasticity of *yufka* increased with 30-40% WBF usage. While the chewiness scores of *bazlama* samples were negatively affected ($P > 0.05$) with WBF, chewiness of *yufka* samples ($P > 0.05$) increased in WBF breads compared to control sample. It is important to note that BW has a slightly bitter taste often rejected by consumers (Filipčev *et al.*, 2011). However, the highest taste and odour scores were obtained for *bazlama* and *yufka* containing 20% WBF in formulations. The highest replacement level of WBF (40%) was awarded the lowest taste and odour scores by the panellist.

4. Conclusions

WBF usage in flat bread formulation affected dough and bread characteristics. The water absorption and development time increased with the increase of the WBF levels in the flour blends while stability, energy, resistance and extensibility values of dough decreased. It was possible to partially improve the rheological properties of flour blends with the addition of gluten and SSL. An increase in darkness, redness and yellowness of flat breads was observed as the level of WBF increased in the flour blends. WBF enriched *bazlama* and *yufka* samples in terms of ash,

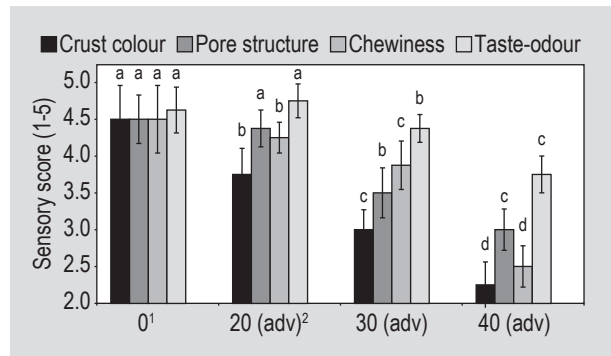


Figure 3. Sensory properties of *bazlama* breads. Bars with different letters are significantly different ($P < 0.05$). (¹WBF replacement ratio. ²WBF replacement ratio with additives.)

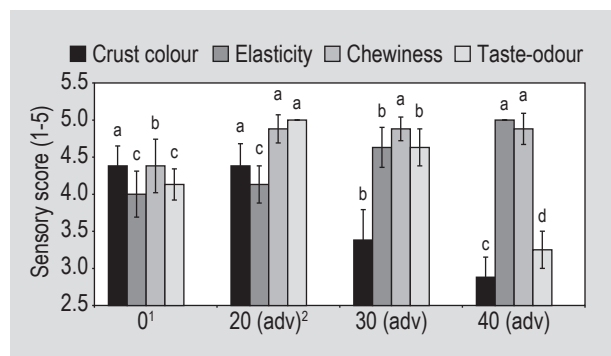


Figure 4. Sensory properties of *yufka* breads. Bars with different letters are significantly different ($P < 0.05$). (¹WBF replacement ratio. ²WBF replacement ratio with additives.)

crude fibre and mineral, especially Fe, K, Mg and P. This study indicated that WBF has the potential to be used as an ingredient in *bazlama* and *yufka* breads to develop the nutritional status of the products.

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