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# Effects of immature wheat on some properties of flour blends and rheological properties of dough

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**RESEARCH ARTICLE**

## Abstract

In this study, Bezostaya-1, Gerek-79 and Kızıltan-98 wheat cultivars were harvested at two different maturity stages. Flour of immature wheat were used for preparation of flour blends as whole wheat flour of immature wheat (WFIW) or refined white flour of immature wheat (RFIW). For flour blend preparation, WFIW replaced commercial whole-wheat flour at 0, 10, 20 and 30% and RFIW replaced commercial refined white flour at 0, 5, 10 and 15% ratios. These flour blends were used for preparation of leavened and unleavened bread. As well as some qualitative properties of wheat and flour blends, some physical properties of leavened bread (weight, volume, specific volume, hardness and crust colour) and unleavened bread (diameter, thickness, spread ratio and crust colour) were determined. Thousand kernel weight, test weight and gluten index values of wheat increased with the progress of the maturity stage. Immature wheat flour decreased water absorption, development time and dough stability in WFIW blends, and decreased only dough stability in RFIW blends. Leavened bread produced with flour blends of Bezostaya-1 were found superior in terms of physical bread properties. The adverse effect of WFIW flour on volume, specific volume, symmetry and hardness of bread was obtained at 30% replacement level. For unleavened bread, utilisation of WFIW or RFIW blends in dough formulation improved diameter and spread ratio of flat bread. Considering some of the physical properties of leavened and unleavened bread, it can be concluded that optimum usage ratio of WFIW and RFIW were 20 and 10%, respectively.

**Keywords:** immature wheat, flour blend, rheology, leavened bread, unleavened bread

## 1. Introduction

Wheat is one of the major cereal cultivated throughout the world. It is also raw material of many cereal based foods such as bread, pasta, noddle, biscuit, cake, cracker, bulgur, snack foods, etc. (Kızılaslan, 2004; Orth and Shellenberger, 1988). Wheat and wheat based foods provides 20% or more of dietary calorie needs of individuals in the world (Betschart, 1988). Moreover, wheat and wheat products are important sources of essential nutrients, carbohydrates and proteins as well as vitamins, minerals, dietary fibres and bioactive compounds (Betschart, 1988; Elgün and Ertugay, 1995; Yu, 2008). Cereal based foods, especially produced with whole-wheat flour are considered to be nutritious and healthy products and there is an increasing interest to these foods (Ragee *et al.,* 2011). Due to the dietary fibre and phytochemicals contents, consumption of whole grain products reduce the risks of obesity, cardiovascular disease, cancer, diabetes and other chronic diseases (Estruch *et al.,* 2009; Jacobs *et al.,* 1995, 1998; Polidori, 2003; Streppel *et al.,* 2008; Yu, 2008).

Some physical and chemical changes in composition of wheat occur during wheat growing process. Immature wheat has some additional nutritional advantages compared to physiologically mature wheat. As the wheat matured, ash content, diastase activity (Mangels and Stoa, 1928; Yang *et al.,* 2012), lysine, simple sugars and fructan content (Kim *et al.,* 2007; Nardi *et al.,* 2003; Pepe *et al.,* 2013), vitamin C and antioxidant compounds (Kim and Kim, 2016; Paradiso *et*

*al.,* 2006) decreased. At too early stage of maturity, moisture content of wheat is so high. Wheat containing high moisture amount is not suitable for threshing machines and the flour yield of this wheat is quite low. As the wheat matured, flour yield and technological properties increased. But considering nutritional characteristics and high amylase activity, immature wheat flour at early stage of maturity is a valuable food ingredient for various foods.

Bread has a unique, characteristic neutral taste and flavour which facilitates its consumption together with other food items. In Turkey, the consumption of leavened bread is common but there is a growing interest to traditional leavened or unleavened flat bread, such as bazlama, lavaş, yufka, etc. (Elgün and Türker, 2005). Yufka is unleavened and very thin (1-2 mm thickness) flat bread with a circular shape (Başman and Köksel, 2001).

Being the basic food in our diet, bread is an important vehicle for enrichment. In the literature, studies on the physical and chemical properties of bread prepared with immature wheat flour are limited. In general, studies on immature wheat have focused on nutritional quality of wheat (Levent and Bilgiçli, 2016). Besides there is no research examining the impact of immature wheat flour on unleavened bread quality. The present study aimed to determine the effects of whole-wheat flour of immature wheat (WFIW) and refined white flour of immature wheat (RFIW) replacement of commercial flour at different ratios on dough and leavened/unleavened bread quality.

## 2. Materials and methods

### Materials

Bezostaya-1 (*Triticum aestivum*) hard-red wheat, Gerek-79 (*T. aestivum)* soft-white wheat and Kızıltan-98 (*Triticum durum)* wheat cultivars were grown in Karaman, Turkey. Kızıltan-98 is durum wheat which has been selected due to high nutritional composition especially at immature form. All wheat cultivars were harvested at two different maturity stages according to moisture content of developing grains. The first (earliest) harvest of Bezostoya-1, Gerek-79 and Kızıltan-98 was made when grain reached the moisture content of 27.60, 30.15 and 30.64%, respectively. The second harvest (more matured) was made at moisture content of 18.89, 21.32 and 25.15%, respectively. Each wheat variety was harvested, tied as bunch and left in the field to air-dry at every stage of maturity. After passing through the threshing machines, samples were cleaned, stored until analysis and flour preparation. Commercial whole-wheat flour and commercial refined white flour were obtained from Konya Yıldızı Flour Mill, Konya, Turkey. Baker's yeast and refined salt used for bread making were supplied by local markets.

### Flour preparation

For obtaining WFIW (100% extraction rate), wheat samples were milled on a hammer mill (Perten LM3100; Perten Instruments AB, Huddinge, Sweden) and for RFIW (65±1% extraction rate), wheat samples were milled on a lab-roller flour mill (Chopin, Villeneuve La Garenne, France). For preparation of flour blends, WFIW replaced commercial whole-wheat flour at 0, 10, 20 and 30% ratio and RFIW replaced commercial refined white flour at 0, 5, 10 and 15% ratios. The factorial design for preparation of flour blend is given in Table 1. Leavened/unleavened bread were prepared with those flour blends.

**Table 1. Factorial design for preparation of flour blend.[1,2]**

| Wheat cultivar | Maturity stage[3] | WFIW ratio (%) | RFIW ratio (%) |
|---|---|---|---|
| Bezostaya-1 | I | 0 | 0 |
| | I | 10 | 5 |
| | I | 20 | 10 |
| | I | 30 | 15 |
| | II | 0 | 0 |
| | II | 10 | 5 |
| | II | 20 | 10 |
| | II | 30 | 15 |
| Gerek-79 | I | 0 | 0 |
| | I | 10 | 5 |
| | I | 20 | 10 |
| | I | 30 | 15 |
| | II | 0 | 0 |
| | II | 10 | 5 |
| | II | 20 | 10 |
| | II | 30 | 15 |
| Kızıltan-98 | I | 0 | 0 |
| | I | 10 | 5 |
| | I | 20 | 10 |
| | I | 30 | 15 |
| | II | 0 | 0 |
| | II | 10 | 5 |
| | II | 20 | 10 |
| | II | 30 | 15 |
| | | n=48[2] | n=48 |

[1] WFIW = whole-wheat flour of immature wheat; RFIW = refined white flour of immature wheat.
[2] Factorial design: (3 wheat cultivars × 2 maturation stage × 4 ratio) × 2 replication=48.
[3] I = first harvest of Bezostoya-1, Gerek-79 and Kızıltan-98 at 27.60, 30.15 and 30.64% grain moisture; II = second harvest at 18.89, 21.32 and 25.15% grain moisture content.

### Bread preparations

Control leavened bread formulation contained 100 g flour, 3 g baker's yeast, 1.5 g salt and water (based on 2 point over of farinogram water absorption value). All the ingredients were kneaded in a Hobart N50 mixer (Canada Inc., North York, ON, Canada) for optimum dough development. The homogeneous dough was subjected to bulk fermentation (80-90% relative humidity, 30 °C) for 30+30 min. At the end of this period dough was aerated and folded. After giving final shape to the bread dough, it was allowed to rest (proofing) for 50 min. Fermented dough was baked in an oven (Arçelik ARMD-580, Istanbul, Turkey) at 250 °C for 12 min.

Unleavened bread was prepared according to method given by Başman and Köksel (2001). Control unleavened bread formulation contained 200 g flour, 3 g salt and water (based on 2 point over of farinogram water absorption value). All the ingredients were kneaded in a Hobart N50 mixer. After mixing, dough was allowed to rest at 30 °C for 30 min and divided into four equal pieces, shaped like a ball, and sheeted by hand rolling to 1 mm thickness. After sheeting, it was baked on a preheated sac (thin metal plate with heating system consisting of electrical resistances) at 280±5 °C for 1 min.

### Physical and physicochemical properties of immature wheat and flour blends

Thousand kernel weight and test weight of wheat samples were made according to Elgün *et al.* (2001). American Association of Cereal Chemists (AACC) methods were used for determining wet gluten, gluten index (method 38-12) and falling number (method 56-81B) values of immature wheat and its flour blends (AACC, 1990). Zeleny sedimentation test was performed according to the International Association for Cereal Science and Technology (ICC) standard method 116/1 (ICC, 2002). Colour was determined by using a Minolta CR-400 (Konica Minolta Sensing, Inc., Osaka, Japan) chromometer in terms of L*(light/dark), a*(green/red), b*(blue/yellow) values. Chroma (C*) and hue angle (hue) values were calculated according to the following equations (Francis, 1998):

$$\text{Chroma } (C^*) = [a^{*2}+b^{*2}]^{1/2} \quad (1)$$

$$\text{Hue angle (hue)} = \arctan [b^*/a^*] \text{ (if } a>0 \text{ and } b>0) \quad (2)$$

$$\text{Hue angle (hue)} = (\arctan [b^*/a^*]+180^\circ) \text{ (if } a<0 \text{ and } b>0) \quad (3)$$

### Rheological properties of dough

WFIW and RFIW flour blends were used for rheological measurements. Farinograph measurement was carried out with a Brabender Farinograph according to the ICC standard method 115/1 (ICC, 2002). Water absorption, dough development time, dough stability and softening degree were determined from the resulting farinogram. Dough energy, resistance to extension, extensibility and maximum resistance were determined by a Brabender Extensograph according to ICC standard method 114/1 (ICC, 2002). Considering the bread making process, extensogram parameters at 135 min resting time were used.

### Physical properties of bread

For leavened bread: after cooling at room conditions for 45 min, leavened bread was weighed and loaf volumes were determined by means of a rape seed displacement method. Specific volume was calculated by dividing loaf volume to weight. Loaf symmetry and pore structure were determined according to Elgün *et al.* (2001). After 24 h storage, the crumb hardness of bread was measured as Newton/cm$^2$ on a texture analyser using the procedure of Aydın and Öğüt (1991).

For unleavened bread: the diameter and thickness of unleavened bread were determined after baking and the spread ratio values of samples were calculated by dividing diameter to thickness.

Colour values of leavened and unleavened bread were measured on five different points on the bread surface by a Minolta CR-400 chromometer as described above.

### Statistical analyses

The analyses of variance (ANOVA) were performed using the Statistical software JMP 8.0 (SAS Institute, Cary, NC, USA). The values are average of triplicate determinations on two replicate bread preparations. Wheat cultivars, maturation stage and WFIW or RFIW ratio were used as variance sources. Student's t test was used to determine significant differences among the samples. Significance was defined at the 5% level.

## 3. Results and discussion

### Raw material properties

Some physical, physicochemical, rheological properties and colour values of immature wheat are summarised in Table 2. Thousand kernel weight, test weight and gluten index values of immature wheat samples tended to increase with the progress of the maturity stage. Similar results for thousand kernel weight and test weight were found in previous studies (Özkaya *et al.,* 1999; Skarsaune *et al.,* 1970; Tipples, 1980). High falling number values indicate low amylolytic activity and the results show that more mature samples of Bezostaya-1 have lower amylolytic activity. According to the farinogram properties, water absorption, development

**Table 2. Some physical, physicochemical, rheological properties and colour values of immature wheat.[1,2]**

| Properties | Bezostaya-1 | | Gerek-79 | | Kızıltan-98 | |
|---|---|---|---|---|---|---|
| | Maturity stage I | Maturity stage II | Maturity stage I | Maturity stage II | Maturity stage I | Maturity stage II |
| Physical-physicochemical | | | | | | |
| 1000 kernel weight[3] (g) | 35.1±0.17$^{d}$ | 38.3±0.10$^{c}$ | 26.4±0.14$^{f}$ | 29.2±0.11$^{e}$ | 44.1±0.16$^{b}$ | 46.5±0.20$^{a}$ |
| Test weight (kg/hl) | 77.8±0.28$^{d}$ | 79.2±0.31$^{c}$ | 75.2±0.14$^{f}$ | 76.2±0.25$^{e}$ | 82.6±0.18$^{b}$ | 83.8±0.20$^{a}$ |
| Wet gluten (%) | 34.5±0.57$^{b}$ | 36.1±0.71$^{b}$ | 30.4±0.85$^{c}$ | 31.7±0.99$^{c}$ | 35.1±0.42$^{b}$ | 38.4±0.85$^{a}$ |
| Gluten index (%) | 89±1.41$^{b}$ | 92±0.85$^{a}$ | 56±0.71$^{d}$ | 63±0.57$^{c}$ | 51±0.85$^{e}$ | 57±1.41$^{d}$ |
| Zeleny sedimentation (ml) | 30±0.71$^{a}$ | 31±0.85$^{a}$ | 26±0.57$^{b}$ | 25±0.42$^{b}$ | 20±0.00$^{d}$ | 22±0.71$^{c}$ |
| Falling number (s) | 302±2.83$^{c}$ | 310±1.41$^{b}$ | 223±4.24$^{d}$ | 228±2.83$^{d}$ | 338±1.41$^{a}$ | 341±4.24$^{a}$ |
| Colour values | | | | | | |
| L* | 56.01±0.21$^{c}$ | 56.53±0.16$^{c}$ | 61.41±0.18$^{b}$ | 63.38±0.24$^{a}$ | 54.98±0.31$^{d}$ | 55.26±0.20$^{d}$ |
| a* | 6.90±0.04$^{a}$ | 6.96±0.10$^{a}$ | 6.02±0.08$^{c}$ | 5.38±0.09$^{d}$ | 5.73±0.04$^{c}$ | 5.67±0.07$^{c}$ |
| b* | 17.94±0.13$^{e}$ | 18.28±0.18$^{de}$ | 18.62±0.21$^{cd}$ | 18.97±0.17$^{c}$ | 23.15±0.10$^{b}$ | 24.01±0.24$^{a}$ |
| C* | 19.22±0.17$^{d}$ | 19.56±0.23$^{cd}$ | 19.57±0.18$^{cd}$ | 19.72±0.11$^{c}$ | 23.85±0.20$^{b}$ | 24.67±0.14$^{a}$ |
| hue | 68.96±0.51$^{d}$ | 69.16±0.29$^{d}$ | 72.08±0.34$^{c}$ | 74.17±0.46$^{b}$ | 76.10±0.55$^{a}$ | 76.71±0.37$^{a}$ |
| Farinogram properties | | | | | | |
| Water absorption (%) | 66.4±0.57$^{a}$ | 65.3±0.28$^{b}$ | 66.1±0.14$^{ab}$ | 65.4±0.42$^{b}$ | 66.2±0.57$^{ab}$ | 65.7±0.14$^{ab}$ |
| Development time (min) | 3.5±0.14$^{b}$ | 4.3±0.00$^{a}$ | 2.4±0.28$^{c}$ | 2.7±0.14$^{c}$ | 4.3±0.28$^{a}$ | 3.5±0.00$^{b}$ |
| Stability (min) | 3.9±0.28$^{b}$ | 6.1±0.14$^{a}$ | 1.9±0.00$^{c}$ | 2.2±0.28$^{c}$ | 3.7±0.00$^{b}$ | 3.5±0.14$^{b}$ |
| Softening degree (BU)[4] | 44±2.83$^{d}$ | 32±1.41$^{e}$ | 136±2.83$^{a}$ | 87±0.00$^{b}$ | 54±1.41$^{c}$ | 48±2.83$^{d}$ |
| Extensogram properties | | | | | | |
| Energy (cm$^{2}$) | 43±1.41$^{cd}$ | 55±4.24$^{ab}$ | 38±5.66$^{d}$ | 47±2.83$^{bcd}$ | 50±1.41$^{abc}$ | 58±5.66$^{a}$ |
| Resistance to extension (BU) | 332±2.83$^{bc}$ | 355±7.07$^{a}$ | 318±8.49$^{c}$ | 332±2.83$^{bc}$ | 346±5.66$^{ab}$ | 360±7.07$^{a}$ |
| Extensibility (mm) | 95±4.24$^{a}$ | 90±1.41$^{ab}$ | 92±2.83$^{ab}$ | 86±4.24$^{bc}$ | 90±2.83$^{ab}$ | 81±1.41$^{c}$ |
| Maximum resistance (BU) | 337±7.07$^{c}$ | 353±4.24$^{b}$ | 328±5.66$^{c}$ | 335±2.83$^{c}$ | 387±7.07$^{a}$ | 394±5.66$^{a}$ |

[1] The means with the same letter in row are not significantly different ($P$<0.05).

[2] Maturity stage I = first harvest of Bezostoya-1, Gerek-79 and Kızıltan-98 at 27.60, 30.15 and 30.64% grain moisture; maturity stage II = second harvest at 18.89, 21.32 and 25.15% grain moisture content.

[3] Results are dry-weight basis.

[4] BU = Brabender units.

time, stability and softening degree of dough prepared from immature wheat flour varied between 65.3-66.4%, 2.4-4.3 min, 1.9-6.1 min and 32-136 Brabender units (BU) (Table 2). Compared to maturity stage I of wheat samples, energy and resistance to extension values from extensogram generally improved at maturity stage II. Similarly, Tipples (1980), reported that dough energy values were improved with increasing maturity of wheat.

### Physicochemical properties and colour values of flour blends

Physicochemical properties and colour values of WFIW and RFIW blends are given in Table 3. Kızıltan-98 flour blend has the highest, Gerek-79 has the lowest wet gluten content in both WFIW and RFIW blends. The gluten index value of Bezostaya-1 flour blend was found higher than those found in Gerek-79 and Kızıltan-98 flour blends. As WFIW and RFIW ratio increased in flour blends, gluten index values decreased in both WFIW and RFIW blends as commercial whole-wheat flour and commercial refined white flour (used in preparation of all flour blends) were produced from strong wheat. The highest falling number value was found in Kızıltan-98 flour blend; this was followed by Bezostaya-1 and Gerek-79 flour blend (for WFIW and RFIW). Effects of 'Wheat cultivar × RFIW ratio' interaction on the falling number values of RFIW blends is presented in Figure 1. As the RFIW ratio increased in flour blends, falling number values decreased in all flour blends and the highest decrement was observed in Gerek-79 flour blend. Ercan *et al.* (1988) reported that red wheat cultivars generally have a high falling number value compared to white wheat cultivars. Falling number is an indicator of amylolitic activity and insufficient amounts of amylolitic enzymes causes inadequate bread quality with low volume (Ertugay, 2010a,b). Falling number values increased with maturity in both WFIW and RFIW blends. Similar results

**Table 3. Physicochemical properties and colour values of whole-wheat flour of immature wheat (WFIW) and refined white flour of immature wheat (RFIW) blends.[1]**

| | n | Wet gluten (%) | Gluten index (%) | Zeleny sedimentation (ml) | Falling number (s) | Colour values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | L* | a* | b* | C* | hue |
| WFIW blends | | | | | | | | | | |
| Wheat cultivars | | | | | | | | | | |
| Bezostaya-1 | 16 | 33.88$^{b}$ | 91.87$^{a}$ | 32.75$^{a}$ | 326.87$^{b}$ | 85.52$^{b}$ | 0.72$^{a}$ | 10.19$^{b}$ | 10.22$^{b}$ | 85.93$^{b}$ |
| Gerek-79 | 16 | 33.24$^{c}$ | 87.75$^{b}$ | 31.75$^{b}$ | 317.37$^{c}$ | 87.20$^{a}$ | 0.62$^{b}$ | 10.02$^{c}$ | 10.04$^{c}$ | 86.46$^{a}$ |
| Kızıltan-98 | 16 | 34.42$^{a}$ | 87.87$^{b}$ | 31.25$^{c}$ | 338.87$^{a}$ | 85.85$^{b}$ | 0.66$^{b}$ | 10.64$^{a}$ | 10.66$^{a}$ | 86.42$^{a}$ |
| Maturity stage | | | | | | | | | | |
| I | 24 | 33.73$^{a}$ | 88.91$^{a}$ | 32.00$^{a}$ | 325.25$^{b}$ | 86.10$^{a}$ | 0.69$^{a}$ | 10.24$^{a}$ | 10.26$^{a}$ | 86.13$^{b}$ |
| II | 24 | 33.96$^{a}$ | 89.41$^{a}$ | 31.83$^{a}$ | 328.16$^{a}$ | 86.28$^{a}$ | 0.65$^{a}$ | 10.33$^{a}$ | 10.35$^{a}$ | 86.40$^{a}$ |
| WFIW ratio (%) | | | | | | | | | | |
| 0 | 12 | 33.89$^{a}$ | 90.50$^{a}$ | 32.33$^{a}$ | 329.83$^{a}$ | 86.11$^{a}$ | 0.63$^{b}$ | 9.86$^{d}$ | 9.88$^{d}$ | 86.37$^{a}$ |
| 10 | 12 | 33.86$^{a}$ | 89.93$^{a}$ | 32.33$^{a}$ | 328.50$^{a}$ | 86.25$^{a}$ | 0.65$^{ab}$ | 10.19$^{c}$ | 10.22$^{c}$ | 86.30$^{a}$ |
| 20 | 12 | 33.82$^{a}$ | 88.33$^{b}$ | 31.83$^{b}$ | 325.50$^{b}$ | 86.22$^{a}$ | 0.70$^{a}$ | 10.44$^{b}$ | 10.46$^{b}$ | 86.13$^{a}$ |
| 30 | 12 | 33.81$^{a}$ | 88.00$^{b}$ | 31.16$^{c}$ | 323.00$^{c}$ | 86.18$^{a}$ | 0.69$^{a}$ | 10.65$^{a}$ | 10.68$^{a}$ | 86.28$^{a}$ |
| RFIW blends | | | | | | | | | | |
| Wheat cultivars | | | | | | | | | | |
| Bezostaya-1 | 16 | 32.42$^{b}$ | 98.12$^{a}$ | 34.00$^{a}$ | 365.87$^{b}$ | 95.51$^{a}$ | -0.72$^{a}$ | 8.32$^{b}$ | 8.35$^{b}$ | 94.95$^{b}$ |
| Gerek-79 | 16 | 31.74$^{c}$ | 96.12$^{b}$ | 33.62$^{b}$ | 355.25$^{c}$ | 95.81$^{a}$ | -0.96$^{b}$ | 8.27$^{b}$ | 8.33$^{b}$ | 96.66$^{a}$ |
| Kızıltan-98 | 16 | 33.09$^{a}$ | 95.62$^{b}$ | 33.37$^{b}$ | 371.50$^{a}$ | 95.70$^{a}$ | -1.01$^{b}$ | 8.86$^{a}$ | 8.92$^{a}$ | 96.53$^{a}$ |
| Maturity stage | | | | | | | | | | |
| I | 24 | 32.32$^{a}$ | 96.41$^{a}$ | 33.58$^{a}$ | 362.66$^{b}$ | 95.64$^{a}$ | -0.89$^{a}$ | 8.47$^{a}$ | 8.52$^{a}$ | 96.03$^{a}$ |
| II | 24 | 32.52$^{a}$ | 96.83$^{a}$ | 33.75$^{a}$ | 365.75$^{a}$ | 95.71$^{a}$ | -0.91$^{a}$ | 8.50$^{a}$ | 8.54$^{a}$ | 96.07$^{a}$ |
| RFIW ratio (%) | | | | | | | | | | |
| 0 | 12 | 32.43$^{a}$ | 97.66$^{a}$ | 34.00$^{a}$ | 371.00$^{a}$ | 95.91$^{a}$ | -0.75$^{a}$ | 8.45$^{a}$ | 8.48$^{a}$ | 95.13$^{b}$ |
| 5 | 12 | 32.43$^{a}$ | 96.83$^{b}$ | 33.83$^{ab}$ | 367.16$^{b}$ | 95.67$^{a}$ | -0.95$^{b}$ | 8.43$^{a}$ | 8.49$^{a}$ | 96.42$^{a}$ |
| 10 | 12 | 32.42$^{a}$ | 96.00$^{c}$ | 33.50$^{bc}$ | 361.66$^{c}$ | 95.60$^{a}$ | -0.92$^{b}$ | 8.52$^{a}$ | 8.57$^{a}$ | 96.19$^{a}$ |
| 15 | 12 | 32.38$^{a}$ | 96.00$^{c}$ | 33.33$^{c}$ | 357.00$^{d}$ | 95.53$^{a}$ | -0.96$^{b}$ | 8.53$^{a}$ | 8.58$^{a}$ | 96.45$^{a}$ |

[1] The means with the same letter in column are not significantly different ($P$<0.05).

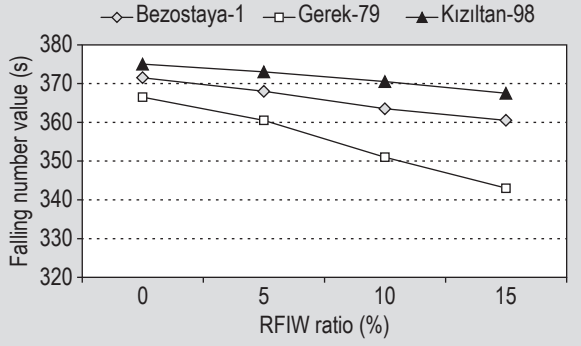


**Figure 1. Effects of 'wheat cultivar × refined white flour of immature wheat (RFIW) ratio' interaction on the falling number values RFIW blends.**

were reported by different researchers in the literature (Iametti *et al.,* 2006; Mangels and Stoa, 1928; Tipples, 1980). As WFIW and RFIW ratio increased, falling number value of flour blends decreased from 329.83 s and 371.00 s to 323.00 s and 357.00 s, respectively (Table 3).

L* values of Gerek-79 flour blends (for WFIW) were found higher than that of Bezostaya-1 and Kızıltan-98 flour blends. The colour of flour varied depending on the wheat cultivars and flour yield. Soft wheat gives more fine flour and as the fineness of flour also increased brightness according to light refraction principle (Elgün and Ertugay, 1995). a* values of Bezostaya-1 flour (for WFIW and RFIW blends) were found higher than that of Gerek-79 and Kızıltan-98 flour blends. In WFIW and RFIW blends, Kızıltan-98 gave the highest b* values among wheat cultivars. It is reported that the intensity of yellow colour is caused by carotenoid pigment content of endosperm (Elgün and Ertugay 1995).

According to the maturity stage, L*, a*, b* and C* values of WFIW and RFIW blends were not found statistically different ($P>0.05$) from each other. Lukow *et al.* (2011) indicated that during grain maturation, L* and b* values increased, a* values decreased in air-dried wheat. Dexter and Matsuo (1977) reported that yellow pigment contents of flour of durum wheat decreased rapidly during maturation.

### Rheologic properties of dough

Farinogram properties of WFIW and RFIW blends are given in Table 4. Flour blend of Gerek-79 (soft wheat) gave the lowest water absorption values among all flour blends. Flour of soft wheat has a lower water absorption value than flour of hard wheat (Elgün and Türker 2005). Water absorption value of both WFIW and RFIW blends decreased from 65.10 and 62.24% to 64.47 and 64.77% with the progressing of maturity stage, respectively. Tipples (1980) studied the effect of immaturity on the milling and baking quality of red spring wheat and found that damaged starch and farinograph absorption decreased with increasing maturity and most mature samples generally gave the lowest values. Effects of 'wheat cultivar × maturity stage' interaction on the water absorption values of dough prepared from WFIW blends are presented in Figure 2. The difference in water absorption values of dough prepared from Bezostaya-1 blends between maturity stage I and II is higher than that of other dough. Dough prepared from Kızıltan-98 flour blend gave a higher development time value than Bezostaya-1 and Gerek-79 dough (RFIW, $P<0.05$). Development time increased with increasing maturity in dough prepared from both WFIW and RFIW flour blends. As the WFIW ratio increased, development time values decreased in dough prepared from WFIW blends. Development time of dough prepared from commercial whole-wheat flour is higher than that of dough prepared from immature wheat flour (Table 2 and 4). Dough stability increased and softening degree decreased in dough of both WFIW and RFIW blends with increasing maturity. As the WFIW and RFIW ratio

**Table 4. Farinogram properties of whole-wheat flour of immature wheat (WFIW) and refined white flour of immature wheat (RFIW) blends.[1]**

| | n | Water absorption (%) | Development time (min) | Dough stability (min) | Softening degree (BU)[2] |
|---|---|---|---|---|---|
| WFIW blends | | | | | |
| Wheat cultivars | | | | | |
| Bezostaya-1 | 16 | 65.17$^{a}$ | 7.83$^{a}$ | 10.85$^{a}$ | 11.00$^{b}$ |
| Gerek-79 | 16 | 64.08$^{b}$ | 7.14$^{c}$ | 9.53$^{b}$ | 21.12$^{a}$ |
| Kızıltan-98 | 16 | 65.10$^{a}$ | 7.51$^{b}$ | 10.86$^{a}$ | 12.37$^{b}$ |
| Maturity stage | | | | | |
| I | 24 | 65.10$^{a}$ | 7.37$^{b}$ | 10.23$^{b}$ | 15.66$^{a}$ |
| II | 24 | 64.47$^{b}$ | 7.60$^{a}$ | 10.60$^{a}$ | 14.00$^{b}$ |
| WFIW ratio (%) | | | | | |
| 0 | 12 | 65.51$^{a}$ | 8.76$^{a}$ | 11.48$^{a}$ | 7.83$^{d}$ |
| 10 | 12 | 64.68$^{b}$ | 7.48$^{b}$ | 10.63$^{b}$ | 14.50$^{c}$ |
| 20 | 12 | 64.60$^{b}$ | 6.98$^{c}$ | 10.16$^{c}$ | 16.83$^{b}$ |
| 30 | 12 | 64.45$^{b}$ | 6.73$^{d}$ | 9.38$^{d}$ | 20.16$^{a}$ |
| RFIW blends | | | | | |
| Wheat cultivars | | | | | |
| Bezostaya-1 | 16 | 65.46$^{b}$ | 2.21$^{b}$ | 14.68$^{c}$ | 21.50$^{b}$ |
| Gerek-79 | 16 | 63.86$^{c}$ | 2.13$^{b}$ | 15.02$^{b}$ | 24.37$^{a}$ |
| Kızıltan-98 | 16 | 65.70$^{a}$ | 2.52$^{a}$ | 15.72$^{a}$ | 18.87$^{c}$ |
| Maturity stage | | | | | |
| I | 24 | 65.24$^{a}$ | 2.18$^{b}$ | 14.60$^{b}$ | 23.25$^{a}$ |
| II | 24 | 64.77$^{b}$ | 2.45$^{a}$ | 15.68$^{a}$ | 19.91$^{b}$ |
| RFIW ratio (%) | | | | | |
| 0 | 12 | 64.98$^{a}$ | 2.43$^{a}$ | 17.08$^{a}$ | 15.50$^{d}$ |
| 5 | 12 | 65.05$^{a}$ | 2.26$^{a}$ | 15.50$^{b}$ | 20.50$^{c}$ |
| 10 | 12 | 65.02$^{a}$ | 2.28$^{a}$ | 14.50$^{c}$ | 24.16$^{b}$ |
| 15 | 12 | 64.98$^{a}$ | 2.28$^{a}$ | 13.50$^{d}$ | 26.17$^{a}$ |

[1] The means with the same letter in column are not significantly different ($P<0.05$).

[2] BU = Brabender units.

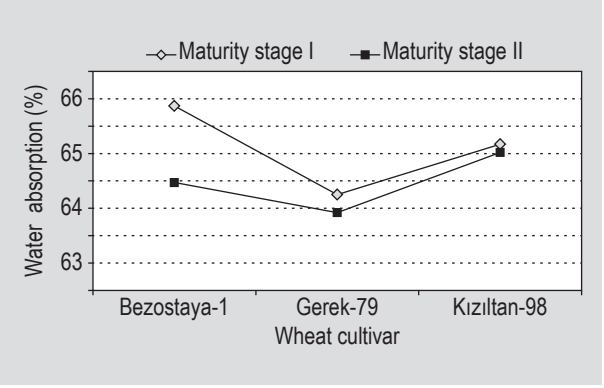


**Figure 2. Effects of 'wheat cultivar × maturity stage' interaction on the water absorption values of dough prepared with whole-wheat flour of immature wheat (WFIW) blends.**

increased, dough stability decreased and softening degree of dough increased (Table 4).

Extensogram properties of dough prepared from WFIW and RFIW blends are summarised in Table 5. Dough of Kızıltan-98 flour blends (RFIW) gave higher energy values than other dough. Energy values of dough prepared from RFIW blends increased from 115.00 $cm^2$ to 120.08 $cm^2$ with maturity. Tipples (1980) studied with different wheat cultivars for 4 different years and reported that extensogram area increased with increasing maturity and overall pattern was more erratic in the latter 2 year. The highest resistance to extension values was obtained from Kızıltan-98 dough and this was followed by Bezostoya-1 and Gerek-79 dough in both WFIW and RFIW blends. Resistance to extension value of dough prepared from WFIW and RFIW blends increased from 547.25 and 451.66 BU to 560.00 and 477.41 BU, respectively, with maturity. As the WFIW and RFIW ratio increased, resistance to extension and maximum resistance values decreased ($P$<0.05) (Table 5). Dough prepared from

**Table 5. Extensogram properties of whole-wheat flour of immature wheat (WFIW) and refined white flour of immature wheat (RFIW) blends.[1]**

| | n | Energy ($cm^2$) | Resistance to extension[2] (BU) | Extensibility (mm) | Maximum resistance (BU) |
|---|---|---|---|---|---|
| WFIW blends | | | | | |
| Wheat cultivars | | | | | |
| Bezostaya-1 | 16 | 62.62$^{ab}$ | 552.62$^{b}$ | 84.12$^{ab}$ | 577.00$^{b}$ |
| Gerek-79 | 16 | 59.63$^{b}$ | 511.50$^{c}$ | 85.50$^{a}$ | 517.50$^{c}$ |
| Kızıltan-98 | 16 | 63.87$^{a}$ | 596.75$^{a}$ | 82.37$^{b}$ | 592.00$^{a}$ |
| Maturity stage | | | | | |
| I | 24 | 61.33$^{a}$ | 547.25$^{b}$ | 83.16$^{a}$ | 547.66$^{b}$ |
| II | 24 | 62.75$^{a}$ | 560.00$^{a}$ | 84.83$^{a}$ | 576.67$^{a}$ |
| WFIW ratio (%) | | | | | |
| 0 | 12 | 64.50$^{a}$ | 579.33$^{a}$ | 81.50$^{c}$ | 582.83$^{a}$ |
| 10 | 12 | 63.33$^{ab}$ | 576.16$^{a}$ | 83.16$^{bc}$ | 580.50$^{a}$ |
| 20 | 12 | 60.16$^{b}$ | 530.17$^{b}$ | 85.00$^{ab}$ | 545.50$^{b}$ |
| 30 | 12 | 60.16$^{b}$ | 528.83$^{b}$ | 86.33$^{a}$ | 539.83$^{c}$ |
| RFIW blends | | | | | |
| Wheat cultivars | | | | | |
| Bezostaya-1 | 16 | 113.87$^{b}$ | 458.00$^{b}$ | 137.25$^{b}$ | 591.00$^{b}$ |
| Gerek-79 | 16 | 115.00$^{b}$ | 428.75$^{c}$ | 146.87$^{a}$ | 582.00$^{c}$ |
| Kızıltan-98 | 16 | 123.75$^{a}$ | 506.87$^{a}$ | 133.12$^{c}$ | 688.50$^{a}$ |
| Maturity stage | | | | | |
| I | 24 | 115.00$^{b}$ | 451.66$^{b}$ | 142.08$^{a}$ | 602.08$^{b}$ |
| II | 24 | 120.08$^{a}$ | 477.41$^{a}$ | 136.08$^{b}$ | 638.91$^{a}$ |
| RFIW ratio (%) | | | | | |
| 0 | 12 | 121.16$^{a}$ | 481.83$^{a}$ | 146.16$^{a}$ | 632.33$^{a}$ |
| 5 | 12 | 118.16$^{a}$ | 462.50$^{b}$ | 144.00$^{a}$ | 619.66$^{b}$ |
| 10 | 12 | 119.50$^{a}$ | 463.00$^{b}$ | 136.66$^{b}$ | 623.83$^{b}$ |
| 15 | 12 | 111.33$^{b}$ | 450.83$^{c}$ | 129.50$^{c}$ | 606.16$^{c}$ |

[1] The means with the same letter in column are not significantly different ($P$<0.05).
[2] BU = Brabender units.

Gerek-79 flour blends gave high extensibility values in both WFIW and RFIW blends (Figure 3 and Table 5). Extensibility values of dough prepared with RFIW blends decreased from 142.08 to 136.08 mm ($P$<0.05) with maturity (Table 5).

### Physical properties and colour values of bread

The highest leavened bread volume values were obtained with Bezostaya-1 flour blends in both WFIW and RFIW blends (Table 6). Bread volumes decreased with the use of more mature (maturity stage II) wheat in the flour blend and the lowest values were obtained at maximum WFIW and RFIW ratio. Mangels and Stoa (1928) and Lukow *et al.* (2011) found any significant changes in bread volume according to maturity stages but Preston *et al.* (1991) and Pepe *et al.* (2013) reported that preharvest of wheat negatively affected the bread volume. In the present study, flour blends prepared with wheat at maturity stage

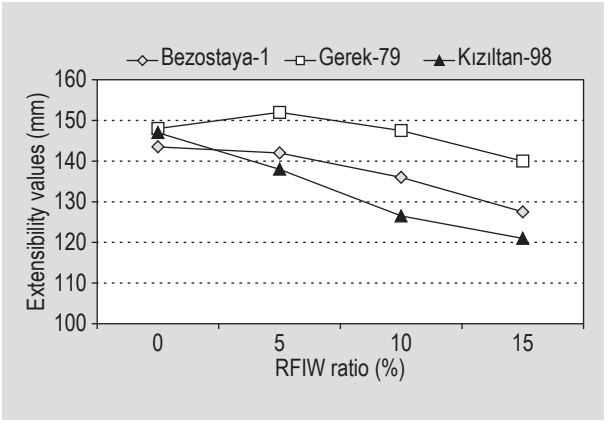


**Figure 3. Effects of 'wheat cultivar × refined white flour of immature wheat (RFIW) ratio' interaction on the extensibility of dough prepared from RFIW blends.**

**Table 6. Physical properties and colour values of leavened bread prepared from whole-wheat flour of immature wheat (WFIW) and refined white flour of immature wheat (RFIW) blends.[1]**

| | n | Weight (g) | Volume (ml) | Specific volume (ml/g) | Symmetry (1-9) | Pore structure (1-9) | Hardness (N/cm²) | Colour values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | L* | a* | b* | C* | hue |
| WFIW bread | | | | | | | | | | | | |
| Wheat cultivars | | | | | | | | | | | | |
| Bezostaya-1 | 16 | 155.09$^{b}$ | 289.71$^{a}$ | 1.86$^{a}$ | 8.12$^{a}$ | 7.05$^{a}$ | 0.37$^{c}$ | 58.60$^{c}$ | 9.53$^{a}$ | 20.23$^{b}$ | 22.37$^{b}$ | 64.77$^{c}$ |
| Gerek-79 | 16 | 155.24$^{ab}$ | 280.60$^{b}$ | 1.80$^{b}$ | 7.78$^{b}$ | 6.72$^{b}$ | 0.42$^{b}$ | 60.29$^{a}$ | 8.47$^{b}$ | 20.25$^{b}$ | 21.95$^{c}$ | 67.30$^{b}$ |
| Kızıltan-98 | 16 | 155.41$^{a}$ | 275.10$^{c}$ | 1.77$^{c}$ | 7.66$^{b}$ | 6.40$^{c}$ | 0.50$^{a}$ | 59.74$^{b}$ | 8.48$^{b}$ | 21.60$^{a}$ | 23.20$^{a}$ | 68.56$^{a}$ |
| Maturity stage | | | | | | | | | | | | |
| I | 24 | 155.08$^{b}$ | 294.69$^{a}$ | 1.89$^{a}$ | 7.84$^{a}$ | 6.81$^{a}$ | 0.42$^{b}$ | 59.42$^{a}$ | 8.83$^{a}$ | 20.64$^{a}$ | 22.46$^{a}$ | 66.80$^{a}$ |
| II | 24 | 155.41$^{a}$ | 268.92$^{b}$ | 1.73$^{b}$ | 7.87$^{a}$ | 6.63$^{b}$ | 0.45$^{a}$ | 59.67$^{a}$ | 8.81$^{a}$ | 20.75$^{a}$ | 22.55$^{a}$ | 66.95$^{a}$ |
| WFIW ratio (%) | | | | | | | | | | | | |
| 0 | 12 | 156.58$^{a}$ | 284.42$^{a}$ | 1.81$^{a}$ | 7.93$^{a}$ | 7.96$^{a}$ | 0.36$^{c}$ | 59.56$^{ab}$ | 8.64$^{c}$ | 20.70$^{a}$ | 22.43$^{a}$ | 67.34$^{a}$ |
| 10 | 12 | 155.51$^{b}$ | 284.65$^{a}$ | 1.83$^{a}$ | 8.08$^{a}$ | 6.43$^{b}$ | 0.42$^{b}$ | 59.86$^{a}$ | 8.82$^{b}$ | 20.65$^{a}$ | 22.47$^{a}$ | 66.86$^{b}$ |
| 20 | 12 | 154.57$^{c}$ | 284.80$^{a}$ | 1.84$^{a}$ | 7.91$^{a}$ | 6.31$^{bc}$ | 0.45$^{ab}$ | 59.59$^{a}$ | 8.88$^{ab}$ | 20.73$^{a}$ | 22.57$^{a}$ | 66.75$^{bc}$ |
| 30 | 12 | 154.31$^{c}$ | 273.35$^{b}$ | 1.77$^{b}$ | 7.50$^{b}$ | 6.18$^{c}$ | 0.49$^{a}$ | 59.15$^{b}$ | 8.94$^{a}$ | 20.68$^{a}$ | 22.55$^{a}$ | 66.55$^{c}$ |
| RFIW bread | | | | | | | | | | | | |
| Wheat cultivars | | | | | | | | | | | | |
| Bezostaya-1 | 16 | 144.09$^{b}$ | 623.57$^{a}$ | 4.32$^{a}$ | 8.27$^{a}$ | 8.07$^{a}$ | 0.07$^{b}$ | 63.38$^{c}$ | 9.36$^{a}$ | 29.23$^{b}$ | 30.71$^{b}$ | 72.24$^{c}$ |
| Gerek-79 | 16 | 141.72$^{c}$ | 613.59$^{b}$ | 4.32$^{a}$ | 8.00$^{b}$ | 7.81$^{b}$ | 0.08$^{ab}$ | 65.38$^{a}$ | 8.16$^{c}$ | 29.29$^{b}$ | 30.41$^{c}$ | 74.43$^{b}$ |
| Kızıltan-98 | 16 | 144.52$^{a}$ | 598.83$^{c}$ | 4.14$^{b}$ | 7.62$^{c}$ | 7.45$^{c}$ | 0.11$^{a}$ | 64.64$^{b}$ | 8.24$^{b}$ | 30.25$^{a}$ | 31.35$^{a}$ | 74.76$^{a}$ |
| Maturity stage | | | | | | | | | | | | |
| I | 24 | 143.78$^{a}$ | 614.52$^{a}$ | 4.27$^{a}$ | 8.17$^{a}$ | 7.92$^{a}$ | 0.06$^{b}$ | 64.26$^{b}$ | 8.60$^{a}$ | 29.60$^{a}$ | 30.82$^{a}$ | 73.79$^{a}$ |
| II | 24 | 143.10$^{b}$ | 609.48$^{b}$ | 4.26$^{a}$ | 7.75$^{b}$ | 7.63$^{b}$ | 0.10$^{a}$ | 64.67$^{a}$ | 8.57$^{a}$ | 29.58$^{a}$ | 30.81$^{a}$ | 73.84$^{a}$ |
| RFIW ratio (%) | | | | | | | | | | | | |
| 0 | 12 | 143.69$^{a}$ | 621.70$^{a}$ | 4.33$^{a}$ | 7.53$^{c}$ | 7.51$^{c}$ | 0.07$^{a}$ | 65.39$^{a}$ | 7.76$^{c}$ | 29.45$^{a}$ | 30.45$^{b}$ | 75.23$^{a}$ |
| 5 | 12 | 143.41$^{a}$ | 609.20$^{b}$ | 4.25$^{c}$ | 8.33$^{a}$ | 7.83$^{b}$ | 0.07$^{a}$ | 64.53$^{b}$ | 8.77$^{b}$ | 29.60$^{a}$ | 30.88$^{a}$ | 73.48$^{b}$ |
| 10 | 12 | 143.59$^{a}$ | 613.78$^{b}$ | 4.28$^{b}$ | 8.16$^{a}$ | 8.16$^{a}$ | 0.08$^{a}$ | 64.17$^{bc}$ | 8.89$^{a}$ | 29.61$^{a}$ | 30.92$^{a}$ | 73.28$^{b}$ |
| 15 | 12 | 143.08$^{b}$ | 603.31$^{c}$ | 4.22$^{d}$ | 7.73$^{b}$ | 7.60$^{c}$ | 0.10$^{a}$ | 63.78$^{c}$ | 8.92$^{a}$ | 29.71$^{a}$ | 31.04$^{a}$ | 73.26$^{b}$ |

[1] The means with the same letter in column are not significantly different ($P$<0.05).

I have adverse effects on bread making quality of flour blends in terms of farinograph, extensograph values and physicochemical analyses results. Despite these results, bread volume was positively affected by immature wheat (at maturity stage I) flour substitution compared to flour of wheat at maturity stage II. Two factors may have been effective on this result. Firstly, the high amylase activity (low falling number value) of immature wheat flour. Higher amylase activity provides more $CO_2$ formation, increased gas retention ability of dough, increased bread volume and smoother pore structure (Ertugay, 2010a,b). The second factor may be the stimulation of yeast by prebiotics (fructooligosaccharides) which are found in immature wheat in high content. Mitterdorfer *et al.* (2001) examined 17 strains of therapeutically relevant strains of *Saccharomyces cerevisia* for their capability of utilising selected carbohydrates of prebiotic importance and reported that among the prebiotic substrates the yeasts indicate a pronounced preference for metabolising the fructooligosaccharides. Similarly, Pepe *et al.* (2013) reported that the use of immature wheat flour with higher fructooligosaccharides concentrations in bread formulation stimulated the metabolism of lactic acid bacteria and yeasts. The high ratios of WFIW and all ratios of RFIW in flour blends, decreased bread volumes compared to control bread prepared with commercial whole or refined flour due to superior physicochemical and rheologic properties of this flour. In both WFIW and RFIW, bread prepared with Bezostaya-1 flour blend gave higher symmetry and pore structure score than other bread. The higher volume of bread prepared with Bezostaya-1 flour blends may positively affected the symmetry and pore structure score of bread. According to maturity stage variance source, crust colour values of WFIW bread did not change ($P>0.05$) significantly. L* values changed significantly ($P<0.05$) in RFIW bread.

Physical properties and colour values of unleavened bread prepared from WFIW and RFIW blends are summarised in Table 7. As expected, unleavened bread prepared with Kızıltan-98 flour blend gave a low diameter and spread

**Table 7. Physical properties and colour values of unleavened bread prepared from whole wheat flour of immature wheat (WFIW) and refined white flour of immature wheat (RFIW) blends.[1]**

| | n | Diameter (D, cm) | Thickness (T, cm) | Spread ratio (D/T) | Colour values | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | L* | a* | b* | C* | hue |
| WFIW bread | | | | | | | | | |
| Wheat cultivars | | | | | | | | | |
| Bezostaya-1 | 16 | 40.21$^{a}$ | 0.087$^{b}$ | 461.81$^{a}$ | 79.95$^{b}$ | 3.23$^{a}$ | 15.27$^{b}$ | 15.61$^{b}$ | 78.06$^{c}$ |
| Gerek-79 | 16 | 40.03$^{a}$ | 0.096$^{ab}$ | 418.10$^{b}$ | 81.36$^{a}$ | 2.94$^{b}$ | 15.44$^{b}$ | 15.72$^{b}$ | 79.20$^{b}$ |
| Kızıltan-98 | 16 | 39.55$^{b}$ | 0.110$^{a}$ | 360.52$^{c}$ | 80.17$^{b}$ | 2.90$^{c}$ | 15.78$^{a}$ | 16.04$^{a}$ | 79.55$^{a}$ |
| Maturity stage | | | | | | | | | |
| I | 24 | 40.05$^{a}$ | 0.097$^{a}$ | 415.46$^{a}$ | 80.31$^{b}$ | 3.06$^{a}$ | 15.49$^{a}$ | 15.80$^{a}$ | 78.79$^{b}$ |
| II | 24 | 39.81$^{a}$ | 0.098$^{a}$ | 411.49$^{b}$ | 80.68$^{a}$ | 2.99$^{b}$ | 15.50$^{a}$ | 15.79$^{a}$ | 79.08$^{a}$ |
| WFIW ratio (%) | | | | | | | | | |
| 0 | 12 | 39.34$^{c}$ | 0.100$^{a}$ | 393.73$^{d}$ | 81.66$^{a}$ | 2.64$^{d}$ | 14.23$^{d}$ | 14.48$^{d}$ | 79.46$^{a}$ |
| 10 | 12 | 39.91$^{b}$ | 0.101$^{a}$ | 400.17$^{c}$ | 79.91$^{b}$ | 3.03$^{c}$ | 15.46$^{c}$ | 15.76$^{c}$ | 78.90$^{b}$ |
| 20 | 12 | 40.10$^{ab}$ | 0.096$^{a}$ | 422.11$^{b}$ | 80.24$^{b}$ | 3.15$^{b}$ | 15.86$^{b}$ | 16.17$^{b}$ | 78.72$^{b}$ |
| 30 | 12 | 40.37$^{a}$ | 0.093$^{a}$ | 437.90$^{a}$ | 80.17$^{b}$ | 3.28$^{a}$ | 16.44$^{a}$ | 16.77$^{a}$ | 78.67$^{b}$ |
| RFIW bread | | | | | | | | | |
| Wheat cultivars | | | | | | | | | |
| Bezostaya-1 | 16 | 39.64$^{a}$ | 0.082$^{a}$ | 486.19$^{a}$ | 87.20$^{b}$ | -0.74$^{a}$ | 15.37$^{b}$ | 15.38$^{b}$ | 92.77$^{b}$ |
| Gerek-79 | 16 | 39.31$^{a}$ | 0.080$^{a}$ | 487.86$^{a}$ | 88.27$^{a}$ | -0.81$^{b}$ | 15.06$^{c}$ | 15.08$^{c}$ | 93.09$^{a}$ |
| Kızıltan-98 | 16 | 38.76$^{b}$ | 0.093$^{a}$ | 415.39$^{b}$ | 87.36$^{b}$ | -0.83$^{b}$ | 16.08$^{a}$ | 16.10$^{a}$ | 92.95$^{ab}$ |
| Maturity stage | | | | | | | | | |
| I | 24 | 39.29$^{a}$ | 0.086$^{a}$ | 468.84$^{a}$ | 87.49$^{a}$ | -0.80$^{a}$ | 15.49$^{a}$ | 15.51$^{a}$ | 92.95$^{a}$ |
| II | 24 | 39.18$^{a}$ | 0.084$^{a}$ | 457.45$^{b}$ | 87.73$^{a}$ | -0.79$^{a}$ | 15.51$^{a}$ | 15.53$^{a}$ | 92.91$^{a}$ |
| RFIW ratio (%) | | | | | | | | | |
| 0 | 12 | 38.11$^{c}$ | 0.087$^{a}$ | 440.94$^{c}$ | 87.56$^{a}$ | -0.80$^{a}$ | 15.10$^{b}$ | 15.12$^{b}$ | 93.05$^{a}$ |
| 5 | 12 | 39.36$^{b}$ | 0.089$^{a}$ | 444.18$^{c}$ | 87.87$^{a}$ | -0.79$^{a}$ | 15.58$^{a}$ | 15.60$^{a}$ | 92.92$^{a}$ |
| 10 | 12 | 39.55$^{ab}$ | 0.083$^{a}$ | 475.71$^{b}$ | 87.46$^{a}$ | -0.80$^{a}$ | 15.69$^{a}$ | 15.71$^{a}$ | 92.94$^{a}$ |
| 15 | 12 | 39.94$^{a}$ | 0.081$^{a}$ | 491.75$^{a}$ | 87.55$^{a}$ | -0.77$^{a}$ | 15.63$^{a}$ | 15.65$^{a}$ | 92.83$^{a}$ |

[1] The means with the same letter in column are not significantly different ($P<0.05$).

ratio value in both WFIW and RFIW blends. Spread ratio of unleavened bread decreased with usage of more mature wheat (maturity stage II) in flour blends. As the WFIW and RFIW increased in flour blends, diameter and spread ratio of bread also increased. Gerek-79 flour blends gave higher crust L* values for both WFIW and RFIW bread.

## 4. Conclusions

In this study, immature wheat flour was used in preparation of flour blends and leavened/unleavened bread formulations. In conclusion, as the wheat becomes more matured, test weight, thousand kernel weight were increased. Bezostaya-1 flour blends gave superior bread compared to the other flour blends considering the physical properties of leavened bread. Flour blends prepared from wheat at maturity stage I gave a higher bread volume and pore structure score in leavened bread, and higher spread ratio in unleavened bread compared to flour blends prepared from wheat at maturity stage II. Due to high amylase activity and prebiotic content of immature wheat, it is beneficiary to use immature wheat at early stage for yeast activity in bread formulation. Bread volume, specific volume and symmetry of leavened bread decreased with use of >20% ratio of WFIW. Similarly, low quality bread with low volume and specific volume were obtained at 15% ratio of RFIW. From the results of this study, it can be concluded that optimum usage ratio of WFIW and RFIW are 20% and 10%, respectively.

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