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Effects of Loaf Weight and Storage Time on the Qualitative Properties of White and Traditional Vakfıkebir Breads

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Abstract: Vakfıkebir bread (VB), a special kind of bread, is produced in Turkey, especially in Trabzon, Black Sea region. The aim of this research was to introduce VB and compare the properties of traditionally baked VB with those of white bread (WB). It has been reported that sourdough VB had a thick and hard crust, large pores in crumb, longer processing time with high tolerance, rich aroma, good quality, high volume and weight, later staling and longer baking time at low temperature. In this research 2 different loaf weights (500 and 1500 g) for the both bread types were studied. It was observed that bread type had a significant effect on the moisture contents of crumb, under-crust and crust, crumb hydration capacity, and Texture Profile Analyzer (TPA) parameters except for springiness. VB had higher crumb moisture, crumb hydration capacity, firmness, cohesiveness, gumminess, and chewiness values, and the moisture content of under-crust and crust compared to white bread. In addition, 500 g loaves had lower crumb moisture, crumb hydration capacity, springiness, cohesiveness, and chewiness compared to 1500 g loaves. It is concluded that the causes of long life freshness of VB versus WB were the high moisture content and low starch retrogradation speed of its crumb in spite of its firmer and more elastic crumb texture.

Key Words: Vakfıkebir bread, sourdough, loaf weight, crumb hydration capacity, moisture, crumb texture, staling

Depolama Süresi ve Somun Ağırlığının, Beyaz ve Geleneksel Vakfıkebir Ekmeklerinin Bazı Kalitatif Özellikleri Üzerine Etkileri

Özet: Vakfıkebir ekmeği Türkiye'de özellikle de Trabzon'da üretilen bir ekmek çeşitidir. Bu araştırmanın amacı geleneksel olarak üretilen Vakfıkebir ekmeğini (VB) tanıtmak ve beyaz ekmek (WB) ile karşılaştırmaktır. Vakfıkebir ekmeğinin kalın ve sert kabuklu, içinin iri gözenekli, aromatik, kaliteli, hacimli, ağır, uzun sürede işlenip, pişirildiği, ve geç bayatladığı rapor edilmektedir. Bu araştırmada, her iki ekmek çeşidi iki faklı somun ağırlığında (500 ve 1500 g) çalışılmıştır. Ekmek içi, kabuk altı ve kabuk rutubeti, su tutma kapasitesi ve esneklik haricindeki Doku Profil Analizi (TPA) parametreleri üzerine ekmek çeşidinin önemli bir etkiye sahip olduğu gözlenmiştir. Vakfıkebir ekmeği beyaz ekmekten daha yüksek ekmek içi rutubeti, su tutma kapasitesi, sertlik, yapışkanlık, sakızımsı yapı ve çiğnenme değerlerine sahiptir. Bununla beraber, 500 gramlık ekmek 1500 gramlık ekmekten daha düşük ekmek içi nemine, su tutma kapasitesine, esneklik, yapışkanlık ve çiğnenme değerlerine sahiptir. Sonuç olarak, Vakfıkebir ekmeği, beyaz ekmekle karşılaştırıldığında, ekmek içinin elastik ve sertliğinin yüksek olmasına karşılık uzun süre tazeliğini koruyabilmesi, ekmek içi su miktarının yüksek ve nişasta retrogradasyon hızının düşük olması sonucuna bağlanmıştır.

Anahtar Sözcükler: Vakfıkebir ekmeği, ekşi hamur, somun ağırlığı, ekmek içi su tutma kapasitesi, nem, tekstür, bayatlama

Introduction

The staling of bread was described as a combination of physical, chemical, and sensory changes resulting in an undesirable product (Vodovotz et al., 2002); however, Fessas and Schiraldi (1998) stated that bread is a biochemically inactive colloidal system if only it was kept in sterile conditions. Therefore mechanism of bread staling is quite complex and not very well understood (Chen et al., 1997; Sidhu et al., 1997; Rasmussen and Hansen, 2001).

Traditional sourdough preparation, oldest and most original form of leavened bread for more than 5000 years, was explained as merely using a piece of dough from the previous batch (Hansen and Schieberle, 2005). It has been used widely in some parts of the world (Spicher and Stephan, 1999). In modern sourdough, main goal is also to improve aroma characteristic and to lengthen shelf life of breads. Retarding retrogradation of starch in making white bread (Corsetti et al., 2000) and getting high bread

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volume and gradually hardening of bread (Corsetti et al., 1998) was realized by sourdough.

VB has been produced with the sourdough method, an indirect dough method likes sponge dough in Black Sea region in Turkey. It has thick and hard crust, big crumb pores, and high volume and weight. It is more qualified and aromatic and also has a longer processing and baking times with high toleration and late staling compared to regular breads (Kotancılar et al., 1998). It was reported that hard crust texture covering the crumb of bread yields fresher and moist crumb and thus it has long storage life (Pyler, 1988; Kotancılar et al., 2006).

Therefore, it was aimed to introduce VB by providing its advantageous properties over white bread.

Materials and Methods

Materials

Wheat flour (15.1% water, 12.1% protein, 0.54% ash, 28.5% gluten, and 60.2% water absorption), fresh baker's yeast and salt were obtained from the local market.

Production Method of VB

The production of VB was schematized in Figure 1a. Three kilograms dough from the first batch was incubated

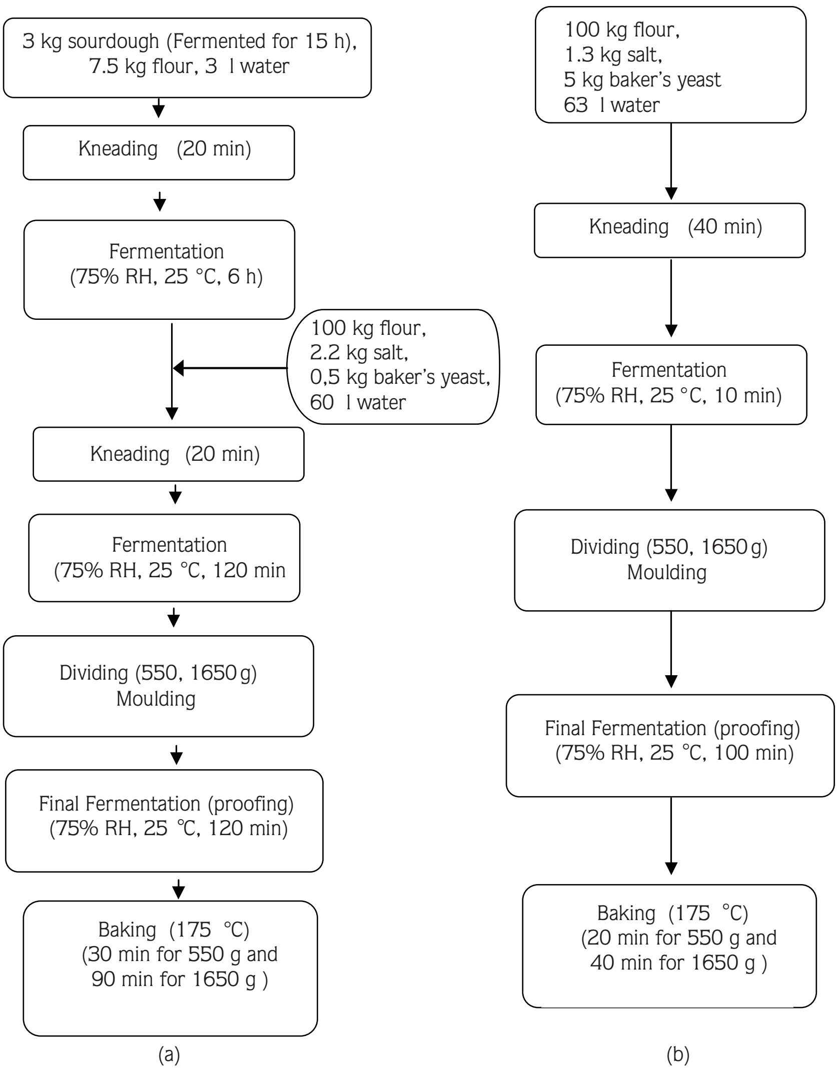

Figure 1. Production diagrams of (a) Vakfıkebir bread and (b) white bread.

at 75% RH, at 25 °C for 15 h and used as first sourdough. Then it was multiplied by 2.5 fold flour with 45% water (based on the flour weight) and kneaded (20 min) for second sourdough. During main dough preparation; 10 kg of the second sourdough together with 100 kg flour, 2.2 kg salt, 60% water (based the flour weight), and 0.5 kg compressed baker's yeast was kneaded for 20 min. Main dough was fermented at 75% RH, at 25 °C for 120 min. Prepared main dough was divided to approximately 550 g and 1650 g pieces to obtain 500 g and 1500 g bread loaves and rounded by hand. Rounded bread dough was fermented at 75% RH, at 25 °C for 120 min in plastic bowls with covered with a cloth. After the final fermentation, 550 g and 1650 g dough pieces were traditionally decorated and baked at 175 ± 5 °C for 30 and 90 min, respectively.

Production Method of WB

100 kg flour, 63 l tap water, 1.3 kg salt, and 5 kg baker's yeast were mixed for 40 min then it was rested for bulk fermentation at 75% RH, at 25 °C for 10 min. Prepared dough was divided into 550 g and 1650 g for 500 g and 1500 g bread loaves and rounded by hand. Rounded bread dough was fermented at 75% RH, 25 °C for 100 min as final fermentation. After the final fermentation, 550 g and 1650 g dough pieces were baked at 175 ± 5 °C for 20 and 40 min, respectively (Figure 1b).

The produced breads were wrapped up into polyethylene bags and stored at room temperature (20 ± 1 °C) for 5 days. Day 0 analyses were performed 12 h after taking the bread out of the oven.

Moisture Content

Moisture content of crumb (center), crust (2 mm for WB, 5 mm for VB) and under-crust (5 mm for WB and VB) were determined by oven drying for 12 h at 105 °C (Leuschner et al., 1999; Karaoğlu, 2002). Location of under-crust layer was determined as described by Czuchajowska and Pomeranz (1989).

Water-Hydration Capacity of Bread Crumb

Hydration capacity of bread crumb was measured by slightly modified method of Martin et al. (1991).

Measurements of Texture Profile

The texture analysis of bread crumb was executed according to Carr and Tadini's method (2003) using the texture profile analyzer (TPA) (SMS model TA-XT2i, Stable Micro System, England) with a 35 mm probe. The application conditions of the TPA method were - pre-test speed: 2 mm s^{-1}, test speed: 5 mm s^{-1}, post-test speed: 5 mm s^{-1}, distance: 20 mm, trigger type: auto-20 g, and time: 5 sec. Calculation of the texture parameters were described as: Firmness - the peak force during the first bite, (*N*); cohesiveness - area 2/area 1, (*dimensionless*); springiness - the height that the bread recovers during the time that elapses between the end of the first bite and start of the second bite, (*mm*); chewiness - firmness cohesiveness springiness, (*mJ*); gumminess – firmness cohesiveness.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) with SPSS 10.0 software for Windows (SPSS for Windows Release 10.0 SPSS Inc, Chicago). Following, Duncan's multiple comparison test was used to compare significant means at alpha 0.01 and 0.05 levels. All data are presented as the mean ± standard error (mean ± SE).

Results

The effects of bread type, bread weight, and storage time on moisture content and water hydration capacity of bread are shown in Table 1.

Bread type and storage time had significant ($P < 0.01$) effects on crumb moisture, under-crust moisture, crust moisture, and water-hydration capacity of breads. VB had higher crumb moisture, under-crust moisture, crust moisture, and water hydration capacity value than compared WB ($P < 0.01$). Crumb moisture and water-hydration capacity decreased, but under crust and crust moisture increased as storage time increased. Bread weight had also a significant effect ($P < 0.01$) on crumb moisture and water-hydration capacity. 1500 g bread had higher crumb moisture and water-hydration capacity value than 500 g bread ($P < 0.01$).

The effects of bread type, weight, and storage time on textural properties of breads are presented in Table 2. Bread type had a significant effect on firmness ($P < 0.01$), cohesiveness ($P < 0.05$), gumminess ($P < 0.01$), and chewiness ($P < 0.01$). VB had higher firmness, cohesiveness, gumminess and chewiness value than WB. 500 g bread had a higher firmness value than 1500 g bread while 1500 g bread has higher cohesiveness, springiness, gumminess and chewiness value than 500 g bread. Storage time had a significant effect ($P < 0.01$) on

Table 1. The effects of bread type, loaf weight, and storage time on the crumb moisture content and water hydration capacity of bread (mean ± Standart Error)

Factor	n	Crumb Moisture	Under-crust Moisture	Crust Moisture	Crumb Water-hydration Capacity
Bread Type					
Vakfıkebir	24	46.64 ± 0.10 a	32.16 ± 0.49 a	28.24 ± 0.66 a	2.03 ± 0.05 a
White Bread	24	44.05 ± 0.61 b	23.74 ± 0.52 b	21.15 ± 0.83 b	1.93 ± 0.02 b
P		**	**	**	**
Loaf Weight (gram)					
500	24	44.32 ± 0.65 b	28.21 ± 1.23 a	24.84 ± 1.23 a	1.94 ± 0.02 b
1500	24	46.38 ± 0.14 a	27.68 ± 0.73 a	24.53 ± 0.84 a	2.03 ± 0.04 a
P		**	NS	NS	**
Storage Time (day)					
0	8	46.57 ± 0.20 a	25.31 ± 2.20 c	19.04 ± 2.31 c	2.23 ± 0.07 a
1	8	46.39 ± 0.19 a	27.85 ± 1.11 b	24.03 ± 1.37 b	2.05 ± 0.03 b
2	8	45.61 ± 0.65 b	27.77 ± 1.72 b	25.25 ± 1.35 b	1.96 ± 0.04 c
3	8	45.33 ± 0.73 b	28.97 ± 1.59 ab	25.57 ± 1.24 b	1.91 ± 0.04 d
4	8	44.14 ± 1.12 c	28.29 ± 1.56 b	25.97 ± 1.59 b	1.90 ± 0.04 d
5	8	44.01 ± 1.46 c	29.50 ± 2.17 a	28.01 ± 1.52 a	1.84 ± 0.04 e
P		**	**	**	**

a-e; Any 2 means in the same line having the same letters in the same sections are not significantly different at $P < 0.05$. P: Probability, ** $P < 0.01$.

firmness, cohesiveness, and springiness. During the first 3 days of storage, cohesiveness and springiness decreased while firmness increased as storage time increased. After 3 days of storage, the changes in springiness and firmness were not significant.

The effects of bread weight and storage time on the crumb moisture contents and water-hydration capacity of VB are presented in Table 3. Crumb moisture contents were similar for the both loaf weights of VB. However, it was determined that moisture losses from the crumbs were very low in VB due to their thicker and harder outer covering. Under-crust and crust moisture content of 500 g VB were generally higher compared to 1500 g VB and both of them increased as the storage time increased. The highest under-crust and crust moisture values were determined from both loaf weights of VB on day 5. Crumb water-hydration capacity of 1500 g VB was higher compared to the others. However, it decreased with the increased storage time in the both bread types. The lowest crumb water-hydration capacity value was observed on days 4 and 5 for 500 g VB, and on day 5 for 1500 g VB.

Table 4 shows the effects of bread weight and storage time on TPA parameters of VB. Cohesiveness and springiness values of both weights of VB decreased as storage time increased. However, springiness value of 1500 g bread slightly decreased. Cohesiveness values decreased by approximately 50% for both weights of VB. The lowest springiness value was determined from 500 g VB on day 5. Based on the fact that cohesiveness equals Area 2/Area 1, decreasing cohesiveness value directly connected with Area 2. The decrease in Area 2 value may be ascribed to the crumb structure becoming crumbly. The change in chewiness value was disorderly for both weights of VB. 1500 g VB on day 3 had the highest chewiness value; however 500 g VB on day 5 had the lowest chewiness value. The highest cohesiveness values of 500 g and 1500 g VB determined on day 0 and decreased during storage time.

The effect of storage time on firmness of VB is shown in Figure 2a. Firmness increased for both weights of VB during storage time. The lowest firmness value was with 500 g and 1500 g breads on day 0. Effects of bread

Table 2. The general effects of bread type, loaf weight, and storage time on Texture Profile Analyzer parameters of bread crumb (mean ± Standart Error).

Factor	n	Firmness (N)	Cohesiveness	Springiness (mm)	Gumminess	Chewiness (mj)
Bread Type						
Vakfıkebir	24	34.3 ± 1.96 a	0.55 ± 0.03 a	18.66 ± 0.30 a	17.63 ± 0.70 a	330.1 ± 14.8 a
White Bread	24	4.2 ± 0.28 b	0.52 ± 0.02 b	18.39 ± 0.17 a	2.04 ± 0.09 b	37.4 ± 1.7 b
P		**	*	NS	**	**
Loaf Weight (gram)						
500	24	20.5 ± 3.61 a	0.47 ± 0. 03 b	18.00 ± 0.29 b	9.43 ± 1.64 a	169.7 ± 30.2 b
1500	24	17.99 ± 3.24 b	0.59 ± 0.02 a	19.05 ± 0.12 a	10.23 ± 1.75 a	197.8 ± 34.0 a
P		**	**	**	NS	*
Storage Time (day)						
0	8	10.2 ± 3.00 c	0.74 ± 0.02 a	19.69 ± 0.06 a	8.05 ± 2.44 b	158.4 ± 48.1 a
1	8	17.2 ± 5.58 b	0.59 ± 0.02 b	19.04 ± 0.19 ab	10.22 ± 3.25 ab	197.7 ± 62.9 a
2	8	18.5 ± 5.78 b	0.53 ± 0.03 c	18.81 ± 0.16 b	10.11 ± 3.25 a	193.1 ± 62.5 a
3	8	22.9 ± 6.94 a	0.47 ± 0.03 d	18.11 ± 0.36 c	10.76 ± 3.46 a	199.1 ± 66.1 a
4	8	24.1 ± 7.00 a	0.42 ± 0.02 e	17.68 ± 0.49 c	10.76 ± 3.28 a	192.9 ± 60.5 a
5	8	22.6 ± 6.58 a	0.45 ± 0.03 de	17.77 ± 0.55 c	9.07 ± 2.49 ab	161.2 ± 45.7 a
P		**	**	**	NS	NS

a-e; Any two means in the same line having the same letters in the same sections are not significantly different at $P < 0.05$.
* $P < 0.05$, ** $P < 0.01$, NS = not significant.

Table 3. Effects of loaf weight and storage time on the crumb moisture content and water hydration capacity of VB (mean ± Standart Error)

Loaf Weight (g)	Storage Time (day)	n	Crumb Moisture	Under-crust Moisture	Crust Moisture	Crumb Water-hydration Capacity
500	0	2	46.71 ± 0.43 a	32.33 ± 0.15 cd	27.68 ± 1.24 abc	2.15 ± 0.02 bc
	1	2	46.87 ± 0.23 a	32.12 ± 0.89 cd	29.52 ± 0.22 abc	2.02 ± 0.01 d
	2	2	46.54 ± 0.04 a	34.49 ± 0.10 b	29.62 ± 0.19 abc	1.87 ± 0.04 ef
	3	2	46.42 ± 0.05 a	33.80 ± 0.35 bc	28.27 ± 5.06 abc	1.83 ± 0.01 fg
	4	2	45.21 ± 0.02 b	33.45 ± 0.04 bc	31.08 ± 0.44 ab	1.74 ± 0.02 g
	5	2	46.92 ± 0.06 a	37.02 ± 1.35 a	32.84 ± 0.67 a	1.74 ± 0.00 g
1500	0	2	46.96 ± 0.16 a	29.55 ± 1.09 e	21.60 ± 1.37 e	2.58 ± 0.08 a
	1	2	46.66 ± 0.00 a	28.74 ± 0.11 e	25.16 ± 0.77 cd	2.17 ± 0.03 b
	2	2	47.03 ± 0.17 a	29.24 ± 0.12 e	27.59 ± 0.12 abc	2.15 ± 0.04 bc
	3	2	46.84 ± 0.20 a	31.92 ± 0.53 cd	26.67 ± 0.50 bcd	2.09 ± 0.06 bcd
	4	2	46.56 ± 0.21 a	30.48 ± 0.32 de	29.04 ± 0.40 abc	2.03 ± 0.02 cd
	5	2	46.94 ± 0.10 a	32.76 ± 0.70 bc	29.77 ± 0.44 abc	1.98 ± 0.01 de
		P	**	**	*	**

a-g; Means with different letters in the same column are statistically different at $P < 0.05$ level.
P: Probability, * $P < 0.05$, ** $P < 0.01$.

Table 4. Effects of loaf weight and storage time on Texture Profile Analyzer parameters of VB crumb (mean ± Standard Error)

Loaf Weight (g)	Storage Time (day)	n	Cohesiveness	Springiness (mm)	Gumminess	Chewiness (mj)
500	0	2	0.77 ± 0.01 ab	19.53 ± 0.07 ab	14.94 ± 0.12 a	291.9 ± 3.4 bc
	1	2	0.55 ± 0.00 cde	19.22 ± 0.39 ab	20.38 ± 3.26 a	390.6 ± 54.8 ab
	2	2	0.52 ± 0.07 def	18.82 ± 0.16 ab	18.86 ± 1.89 a	355.4 ± 38.6 abc
	3	2	0.38 ± 0.04 hi	17.48 ± 1.14 bc	15.23 ± 0.18 a	266.1 ± 14.1 bc
	4	2	0.42 ± 0.04 ghi	16.55 ± 1.59 c	18.39 ± 0.39 a	305.2 ± 35.9 bc
	5	2	0.33 ± 0.03 i	15.59 ± 0.90 c	14.30 ± 3.13 a	227.6 ± 63.5 c
1500	0	2	0.84 ± 0.03 a	19.80 ± 0.00 a	14.07 ± 0.64 a	278.6 ± 12.7 bc
	1	2	0.66 ± 0.03 bc	19.72 ± 0.09 a	16.74 ± 0.67 a	330.1 ± 11.7 abc
	2	2	0.59 ± 0.06 cd	19.47 ± 0.01 ab	18.07 ± 3.52 a	352.0 ± 68.7 abc
	3	2	0.56 ± 0.01 cde	19.26 ± 0.04 ab	23.54 ± 1.95 a	453.5 ± 36.6 a
	4	2	0.49 ± 0.02 defg	19.21 ± 0.07 ab	20.41 ± 1.47 a	392.0 ± 26.7 ab
	5	2	0.45 ± 0.02 fghi	19.22 ± 0.25 ab	16.54 ± 0.79 a	318.2 ± 19.4 bc
	P	**	**	NS	*	

a-i; Means with different letters in the same column are statistically different at P < 0.05.
P: Probability, * P < 0.05, ** P < 0.01, NS = Not significant.

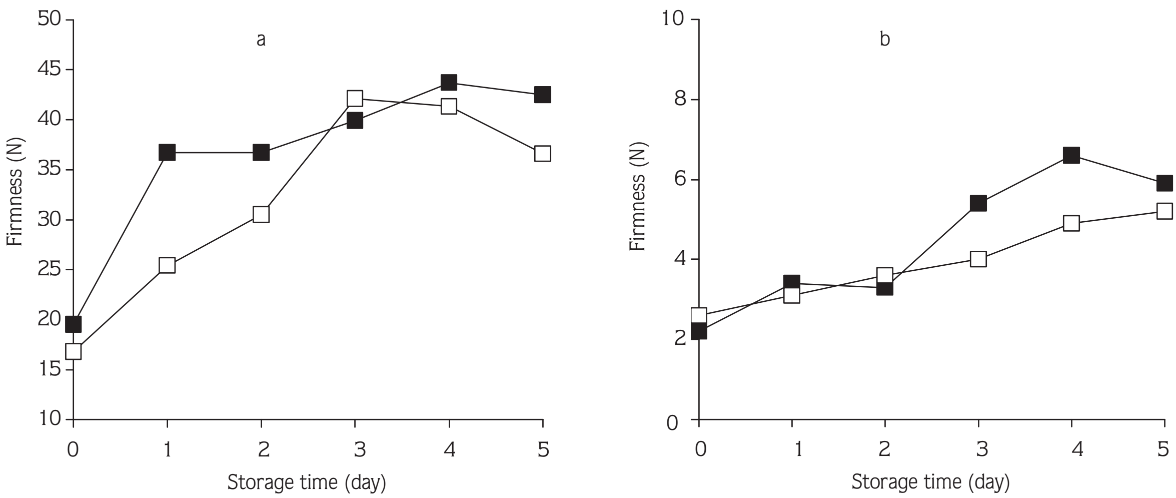

Figure 2. The effect of storage time on crumb firmness (a) Vakfıkebir bread, (b) white bread. (■ 500 g bread; ❏ 1500 g bread).

weight and storage time on the crumb moisture content, water-hydration capacity, and TPA parameters of WB are presented in Tables 5 and 6.

During storage, the loss of crumb moisture of 500 g WB was higher compared to 1500 g WB. The lowest crumb moisture value belonged to 500 g WB on days 4 and 5 (Table 5). When WB compared with VB, it was clearly seen that the loss of WB crumb moisture was higher compared to VB. The moisture content of under-crust and crust increased with increased storage time. Crumb water-hydration capacity values of WB decreased as storage time increased (Table 5). However the difference between 500 g and 1500 g WB was lower compared to VB.

The firmness values of 500 and 1500 g WB are presented in Figure 2b. Firmness increased as storage time increased for the both weights of WB. 500 g WB on day 4 had the highest firmness value while it had the lowest value at initial. As seen in Figure 2, after 4 days of storage, firmness decreased, which could be ascribed to the increase in crumbling. Other TPA parameters are given in Table 6.

Table 5. Effects of loaf weight and storage time on moisture content and water hydration capacity of white bread crumb (mean ± Standart Error)

Loaf Weight (g)	Storage Time (day)	n	Crumb Moisture	Under-crust Moisture	Crust Moisture	Crumb Water-hydration Capacity
500	0	2	45.77 ± 0.30 ab	19.23 ± 0.26 d	12.38 ± 0.13 e	2.17 ± 0.01 a
	1	2	45.57 ± 0.20 ab	24.92 ± 0.31 ab	20.04 ± 0.96 d	2.05 ± 0.00 b
	2	2	43.21 ± 1.76 cd	22.72 ± 0.08 bc	20.47 ± 0.03 cd	1.95 ± 0.00 cd
	3	2	42.01 ± 0.22 d	23.17 ± 0.67 bc	22.78 ± 0.56 bcd	1.88 ± 0.04 de
	4	2	39.07 ± 0.11 e	22.62 ± 0.66 bc	20.97 ± 0.04 cd	1.93 ± 0.05 cd
	5	2	37.48 ± 0.00 e	22.69 ± 0.13 bc	22.46 ± 0.11 bcd	1.90 ± 0.04 de
1500	0	2	46.85 ± 0.16 a	20.13 ± 1.98 cd	14.47 ± 0.23 e	2.01 ± 0.00 bc
	1	2	46.46 ± 0.00 ab	25.61 ± 1.27 ab	22.48 ± 1.33 bcd	1.94 ± 0.00 cd
	2	2	45.67 ± 0.52 ab	24.63 ± 0.56 ab	23.33 ± 0.76 bc	1.88 ± 0.02 de
	3	2	46.07 ± 0.27 ab	27.02 ± 0.74 a	24.55 ± 0.06 ab	1.83 ± 0.01 e
	4	2	45.73 ± 0.18 ab	26.61 ± 1.33 a	22.81 ± 0.41 bcd	1.89 ± 0.02 de
	5	2	44.71 ± 0.07 bc	25.54 ± 0.76 ab	26.96 ± 2.31 a	1.75 ± 0.00 f
		P	**	**	**	**

a-f ; Means with different letters in the same column are statistically different at $P < 0.05$.
P: Probability, ** $P < 0.01$.

Table 6. Effects of loaf weight and storage time on Texture Profile Analyzer parameters of white bread crumb (mean ± Standard Error)

Loaf Weight (g)	Storage Time (day)	n	Cohesiveness	Springiness (mm)	Gumminess	Chewiness (mj)
500	0	2	0.66 ± 0.02 a	19.82 ± 0.18 a	1.43 ± 0.01 e	28.3 ± 0.08 ef
	1	2	0.55 ± 0.02 c	18.62 ± 0.06 bc	1.90 ± 0.01 cd	35.4 ± 0.02 cd
	2	2	0.43 ± 0.02 e	18.38 ± 0.03 bc	1.45 ± 0.19 e	26.7 ± 3.64 f
	3	2	0.38 ± 0.01 f	17.36 ± 0.41 ef	2.08 ± 0.08 bcd	36.3 ± 2.17 bcd
	4	2	0.29 ± 0.02 g	16.94 ± 0.05 f	1.91 ± 0.19 cd	32.5 ± 3.26 def
	5	2	0.39 ± 0.00 f	17.63 ± 0.22 de	2.29 ± 0.15 b	40.5 ± 3.28 bc
1500	0	2	0.70 ± 0.00 a	19.63 ± 0.08 a	1.77 ± 0.11 d	34.8 ± 2.28 cde
	1	2	0.61 ± 0.01 b	18.59 ± 0.13 bc	1.86 ± 0.06 d	34.6 ± 1.27 cde
	2	2	0.58 ± 0.02 bc	18.59 ± 0.26 bc	2.07 ± 0.01 bcd	38.5 ± 0.39 bcd
	3	2	0.55 ± 0.00 c	18.35 ± 0.07 bc	2.20 ± 0.03 bc	40.4 ± 0.45 bc
	4	2	0.47 ± 0.01 d	18.04 ± 0.03 cd	2.34 ± 0.04 b	42.20 ± 0.78 b
	5	2	0.61 ± 0.00 b	18.66 ± 0.06 b	3.15 ± 0.01 a	58.8 ± 0.04 a
		P	**	**	**	**

a-g; Means with different letters in the same column are statistically different at $P < 0.05$.
P: Probability, ** $P < 0.01$.

Cohesiveness and springiness values of the both weights of WB decreased during storage, and the highest decrease is determined at 500 g WB. Springiness value of 500 g WB sharply, while that of 1500 g WB slightly, decreased during the storage. Gumminess and chewiness increased as storage time increased. The increase of firmness may cause an increase in the values of gumminess and chewiness during storage.

Discussion

Bread types differed significantly in terms of the parameters investigated in the present study. VB had more stable values especially in springiness and crumb moisture content and water-absorption capacity compared to WB during 5 days storage in spite of the firmer crumb structure of VB (Figure 2). Thus, it can be concluded that VB bread can be stored longer than WB.

Crumb moisture content of heavy breads was higher than that of light breads. Possible reason for increasing crumb moisture in heavy breads might be the increment in distance between crumb center and crust in heavy loaves.

VB had a thicker and harder crust than WB (Kotancılar et al., 1998). This property of VB intervented the water migration from crumb to crust and provided higher crumb, under-crust, and crust moisture contents than that of WB. Moreover, although 1500 g bread was baked longer than 500 g bread, its thick crust kept its crumb moisture more effectively. This might be the cause of high crumb water-hydration capacity (Table 1) due to the limited starch gelatinization and retro gradation in the crumb of VB with large loaves (Pyler, 1988). The other phenomenon is the high hygroscopic property of high residual sugars in the crumb of baked loaf of VB on this high moist crumb due to the prolonged baking at low temperature of VB with prolonged amylase activity (Ponte at al. 1963). It causes high residual sugar that had not been used by yeast, which might be an explanation for the differences between both bread making methods and also between both loaf weights.

As seen in Figure 2, the crumb firmness degree of VB is higher than that of WB. Firmness or softness of crumb is a texture property, which has attracted most attention in bakery product assessment because of its close association with human perception of freshness. Firmness of bread crumb is a very important indicator for the staling and Axford et al. (1968) reported that a high correlation (0.98) was found between firmness measured by uniaxial compression methods and sensorial assessments of staling rate.

The use of sourdough in VB production may provide more elastic gluten structure and crumbs with the porosity with thicker cell walls, so it causes to firm, stronger, and elastic bread crumb. This could explain the big difference between VB and WB in terms of firmness, gumminess, and chewiness values (Table 2).

Herein, the advantage of VB loaves versus WB is to keep the moisture involvement of crumb during prolonged baking at low temperature, which caused increments in the crumb moisture content and water-hydration capacity of VB loaves (Table 1). It was observed that when loaf weight increased, bread volume and the ratio of crumb/crust increase, too. In addition, moisture losses from the crumbs were very low in VB breads due to their thicker and harder outer covering. Here, in VB breads, there is a restricted water mobility due to thick crust (Elgün et al., 2002), and high residual sugar content with high hygroscopity as a result of prolonged amylase activity (Ponte, et al., 1963). Water migration from crumb to crust has been reported, which indicates that crumb moisture content decreases while crust moisture increases during storage (Elgün et al., 2002; Gray and Bemiller, 2003; Hug-Iten et al., 2003). Therefore, it was thought that the water mobility in bread during storage was one of the major factors of bread staling. Ruan et al. (1996) reported that there was a high correlation between water mobility and the firming process in starch-based systems. 1500 g VB had a higher crumb water-hydration capacity than 500 g VB. Therefore, 1500 g VB had a higher water-hydration capacity value than 500 g VB (Table 3). Karaoğlu (2002) reported that the increasing storage time reduced crumb water-hydration capacity of bread.

Based on the findings of the present study, it is concluded that the causes of longer freshness of VB, compared to WB, are the high moisture content of its crumb due to its hard and thick crust, high water hydration capacity due to its low starch gelatinization and retro gradation levels, and high residual sugar content as a result of the baking conditions at low temperature for long time, and the low water evaporation due to its high loaf weight and large volume, in spite of firmer crumb due to its bread making method with sourdough.

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