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Determination of Quality Characteristics of Sourdough Bread Produced by Isolated Lactic Acid Bacteria and Dephytinized Wheat Bran

Hümeyra Çetin-Babaoğlu[1*]
https://orcid.org/0000-0001-9115-6470

Nihat Akın[1]
https://orcid.org/0000-0002-0966-1126

Berrin Özkaya[2]
https://orcid.org/0000-0002-7326-7369

[1]Selçuk University, Agriculture Faculty, Department of Food Engineering, Konya, Türkiye; [2]Ankara University, Engineering Faculty, Department of Food Engineering, Ankara, Türkiye

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*Correspondence: humeyracetin@selcuk.edu.tr; Tel.: +90-332-2232892 (H.Ç.B.).

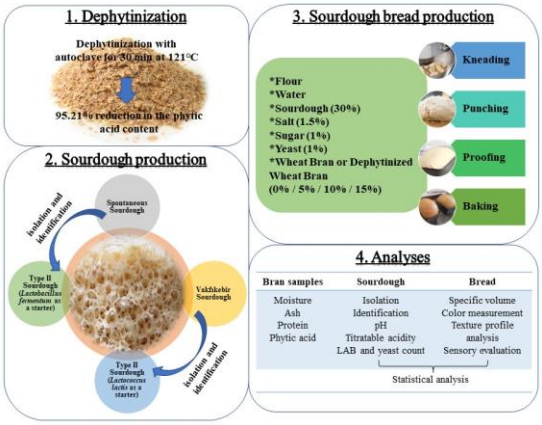
HIGHLIGHTS

- The dephytinized wheat bran reduced the specific volume of bread samples compared with wheat bran.
- The hardness and chewiness values of bread were increased, the springiness and cohesiveness values were decreased with raise in bran rate and storage.
- Sensory analysis revealed that the addition of dephytinized wheat bran or wheat bran up to 5% was acceptable.

Abstract: This study aimed to isolate sourdough starters and use them in the production of dephytinized wheat bran enriched bread. Four different sourdoughs, used separately in bread production, which were spontaneous sourdough (SS), Type II sourdough produced with *Lactobacillus fermentum*, isolated from SS, as a starter (LFS), local produced sourdough (Vakfıkebir, Trabzon, Türkiye) (VS), and Type II sourdough produced with *Lactococcus lactis*, isolated from VS, as a starter (LCS). The dephytinization process effectively reduced the phytic acid level of bran at the rate of 95.21 g/100 g. The highest specific volume was determined in the control bread produced with the local sourdough sample (3.27 mL/g). The lowest specific volume was determined in the sample of bread containing 15% dephytinized wheat bran produced with *Lactococcus lactis* fermented sourdough (1.82 mL/g). As expected, increasing bran level caused decreased *L** value of bread samples and increased *a** and *b** values. The high rates of bran had deleterious effects on the texture of bread. Additionally, the changes in texture profile were more intense in bread samples containing dephytinized wheat bran during storage. According to the sensory analysis results, it was determined that the scores of bread samples produced with *Lactobacillus fermentum* sourdough and including 5% wheat bran were higher.

Keywords: bread; dephytinization; isolation; lactic acid bacteria; sourdough.

GRAPHICAL ABSTRACT



INTRODUCTION

Wheat bran is a significant by-product obtained during conventional milling of wheat grains and formed from aleurone cells, along with the other bran layers and the embryo. In terms of health, studies showed that the consumption of bran has several benefits, such as reducing the risk of cancer, shortening the intestinal transit time, increasing the faecal mass, curing diverticulosis and irritable bowel syndrome, reducing the risk of obesity, the need for insulin or hypoglycemic substances [1].

The usage of bran as a dietary fiber source in flour, being a common application, affects the technological properties of flour and product quality. The addition of bran to flour can change the textural properties of the bread and reduce the bread volume. On the other hand, it can increase dough viscosity and stabilize gas cells [2,3]. The phytic acid content of bran limits the usage of it to produce fibre enriched products. Because of forming insoluble complex between phytic acid and mineral cations or proteins, bioavailability and solubility of these compounds decreases. Therefore, it will be better to use bran whose phytic acid has been degraded by an appropriate method [4].

Since bread is the most traditional food consumed globally, it is very important to make it healthier. Generally, three different leavening agents are used: chemicals, baker's yeast and sourdough. The sourdough method has recently become an important trend in bread production due to consumers' demands for good quality, chemical additives free and gluten free breads [5]. The advantages of sourdough usage can be summarized as improving viscoelastic properties of dough [6], reduction of phytate content due to increasing the endogenous phytase activity [7], delay in staling and molding, lower glycemic index, improving flavor and texture, enhancing organoleptic properties. The selection of the starter culture is important. Many microorganisms can be used in sourdough production, most of them are lactic acid bacteria strain [5].

There have been studies on the production and usage of dephytinized bran in the various food formulations [4, 8-11]. However, to our best knowledge, no single study related to the use of dephytinized wheat bran in sourdough bread production has been reported. In this study it was aimed to produce healthier breads with the use of dephytinized bran as a dietary fiber source in combination with sourdough method. *Lactobacillus fermentum* and *Lactococcus lactis*, which were isolated from spontaneous sourdough and a local sourdough (Vakfıkebir), respectively, were used as starter cultures to produce Type 2 sourdoughs. In order to determine the acceptability and quality of the breads, some physical, textural and sensory properties of the samples were investigated.

MATERIAL AND METHODS

Material

Wheat flour (moisture 12.17 g/100 g, ash 0.63 g/100 g, protein 13.99 g/100 g), wheat bran (moisture 11.39 g/100 g, ash 6.14 g/100 g, protein 15.53 g/100 g), sugar, salt and Baker's yeast were purchased from commercial companies in Konya, Türkiye. Vakfıkebir sourdough was obtained from a local bakery in Vakfıkebir, Trabzon, Türkiye. Wheat bran was passed through a laboratory type disc mill (Laboratory Mill 3303, Perten), and particle size was reduced to less than 300 µm. The chemicals used for molecular identification of lactic acid bacteria, primers and other chemicals were procured from Thermo Scientific, Sentebiolab (Sentebiolab Biotech, Ankara, Türkiye) and Merck (Dermasdat, Germany), respectively.

Dephytinization of wheat bran

Wheat bran was mixed with distilled water in a ratio of 1:15 (w/v), and the pH of bran slurry was adjusted to 4.0 with acetic acid (60.05 g/mol) and autoclaved for 30 minutes at 121°C. After cooling, the bran slurry was adjusted to the initial pH value of the bran and distilled water mixture by 6 N NaOH. Next, the slurry was strained in a sieve, rinsed five times with water and dried at 60°C in an oven to a maximum of 10% moisture content [9, 11]. Dephytinized wheat bran (moisture 5.77 g/100 g, ash 6.22 g/100 g, protein 14.60 g/100 g) was passed through a laboratory type disc mill (Laboratory Mill 3303, Perten), and particle size was reduced to less than 300 µm. The phytic acid contents of bran samples were calculated according to Haug and Lantzsch [12] by measuring the phytate phosphorus spectrophotometrically.

Sourdough fermentation, isolation and identification of lactic acid bacteria

For the production of spontaneous sourdough (Type I), the wheat flour and water were mixed at a ratio of 1:1 (w/v) as the dough yield (DY) was to be 200, and the mixture was left to fermentation at 30°C. Every 24 hours, 10% of the cross was taken, and back-slopping was performed by blending flour and water as the same DY. Fermentation of sourdough continued for 5 days until the pH of sourdough dropped to 3.6-3.8 and TA reached 0.72-0.90%.

In the production of Type II sourdough, lactic acid bacteria (LAB), which were dominant in spontaneous sourdough (SS) and Vakfıkebir sourdough (VS), were used as starter culture. Since *Lactobacillus fermentum* strain (Q1.3 LBS) was dominant in spontaneous sourdough, it was used as a starter culture to produce LFS sourdough. VS predominantly contained the same strain of *Lactococcus lactis* (MLG6-19). *Lactococcus lactis* was chosen as the starter culture because others were different strains of *Lactobacillus fermentum*. LCS sourdough was produced by using *Lactococcus lactis* strain (MLG6-19) as a starter culture. The DY was 200 as similar to SS production. The mixture was inoculated at least 10^6 cfu/g of LAB and left to fermentation at 30°C for 24 hours.

Isolation of LAB from spontaneous and VS was performed by spread-plate and streaking methods on Man Rogosa Sharpe Agar (MRS) containing 0.05 g/l of cycloheximide, LM17 medium supplemented with 0.5% (w/v) lactose and Rogosa agar. For this purpose, 25 g of sourdough sample was diluted in 225 ml of sterile 0.1% (w/v) peptone water and homogenised with a Stomacher (HG400V, Mayo International, Italy). Volumes of 0.1 ml from appropriate serial dilutions were plated on agar mediums. The plates were incubated at 37°C under facultative anaerobic conditions for MRS agar, at 30°C under aerobic conditions for LM17 and at 37°C under anaerobic conditions for Rogosa agar. After incubation, cultures, gathered randomly from plates, were streaked over surfaces of the medium having the same characteristics as that from which culture was taken and incubated under the same growth conditions. After repeating twice of this process, pure cultures were collected. The purity of cultures was checked with a microscope regularly. Finally, the pure cultures were transferred to the liquid medium, MRS broth for cultures grown on MRS agar and Rogosa agar, and M17 broth for cultures grown on LM17 agar to maintain their purity. Purified isolates in 20% (v/v) sterile glycerol solution were stored at -80°C and activated before use.

The strains, isolated from sourdough samples, were identified by 16S rRNA sequencing. For DNA extraction, activated stock cultures were incubated in MRS agar at 30°C for 24 h. After incubation, single colonies were suspended in sterile Eppendorf tubes containing 10 µl of PCR-grade water. Next, 1 µl of each suspension was transferred to Eppendorf tubes separately. Then 21.3 µl of PCR-grade water, 1.2 µl of MgCl2, 3 µl of PCR buffer, 1 µl of reverse primer, 1 µl of forwarding primer, 0.5 µl of Taq DNA polymerase and 1 µl of dNTP solutions were added respectively to complete the final volume of PCR mixture to 30 µl.

The PCR amplification was performed using a BioRAD thermal cycler (T100TM, Foster City, California, USA) and F27 (5´-AGAGTTTGATCCTGGCTCAG-3´) and R1492 (5´-GGTTACCTTGTTACGACTT-3´) universal primers, designed from an invariant region in the 16S rRNA sequences for LAB, were used. The PCR amplification procedure conditions were as follows: initial denaturation at 95°C for 5 min, 34 cycles of 95°C for 1 min, 58°C for 30 s, 72°C for 45 s and then final step at 72°C for 10 min. The PCR products were separated with electrophoresis at 80 V for 1 h to verify their purity. The sequencing of PCR products was executed by BM Labosis (Ankara, Türkiye), and obtained sequence results were compared with the DNA sequence database present at the National Centre for Biotechnology Information (NCBI) by using the BLAST algorithm (http://blast.ncbi.nlm.nih.gov/) to identify strains.

Sourdough bread production

For dough making, wheat flour was blended with wheat bran or dephytinized wheat bran at four different levels as 0, 5, 10, 15%. Then, 1 g sugar, 1.5 g salt, 1 g yeast, 30 g sourdough and water-based on water

absorption determined in farinograph (the amount of flour and water from sourdough were taken into account) were added to 100 g of the flour mixture and kneaded for 10 minutes in a kitchen-type dough kneader (KitchenAid, 5KSM45, ABD) at slow speed. The dough was fermented for 120:35 min (punching, proofing) at 30°C and 80±5% relative humidity. After proofing, doughs were baked at 225°C for 15 minutes.

Determination of pH and titratable acidity values (TA) of sourdough samples

The pH and titratable acidity values of sourdough samples were determined according to AOAC Standard Method No: 943.02 [13] and AACC Standard Method No: 02-31.01 [14], respectively.

Microbiological analyses of sourdough samples

For microbiological analyses, 10 g of sourdough or bread dough was weighed into a sterile stomacher bag and homogenised in 90 ml of 0.1% peptone water. After homogenisation, appropriate serial decimal dilutions, prepared with 0.1% peptone water, were used for inoculation by spread plate technique, and the results were expressed as log10 colony-forming units per gram sample (log10 CFU/g). Total LAB were cultured on MRS agar containing 0.05 g/l of cycloheximide to prevent yeast growth and incubated anaerobically at 30°C for 48 h. Yeast was counted on Potato-Dextrose Agar (PDA, Merck, Germany) acidified by sterile tartaric acid (1.4 g/l) after incubation at 27°C for 5 days.

Specific volume of sourdough bread

The volume of bread samples was determined by the rapeseed displacement method according to AACC Standard Method No: 10-05.01 [14], and the specific volume (ml/g) of bread were calculated by proportioning the volume to the weight of bread.

Color measurement of sourdough bread

Hunter L*, a* and b* colour values of bread crumb, wheat bran and dephytinized wheat bran samples were measured with Minolta CR300 (Minolta Inc., Tokyo, Japan). The total colour change (ΔE) was calculated according to the following formula (1) in which L_0, a_0 and b_0 values were belonged to control bread containing no bran.

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \quad (1)$$

Texture profile analysis of sourdough bread

Texture profile analysis (TPA) of bread samples was performed with texture analyser (TA-TX2i, Stable Micro System, Surrey, UK) using a 30-mm diameter cylindrical probe with a test speed of 1.7 mm/s. A 3-cm thick slice taken from the centre of the bread sample was compressed two times with a time interval of 10 s and a strain deformation of 50%. The force versus time curves was used to calculate hardness, springiness, cohesiveness and chewiness parameters. The bread samples were stored for 5 days, and measurements were taken on the 1st, 3rd and 5th days.

Sensory evaluation of sourdough bread

The sensorial parameters of bread samples, being crust appearance, crumb colour, texture, springiness, crumb grain, homogeneity, taste, odour and general acceptance, were determined by sensory analysis carried out by nine panelists using a 10-point hedonic scale (1: poor, 10: extremely good).

Statistical analysis

All data, expressed as the mean of at least triplicate measurements, were analysed with SPSS software (V.20, IBM, Armonk, NY, ABD) using one-way analysis of variance (ANOVA). The significant differences between the group means were verified with Tukey's test ($p<0.05$).

RESULTS AND DISCUSSION

Phytic acid contents of wheat bran and dephytinized wheat bran

The dephytinization process decreased the phytic acid content of wheat bran from 3043.55 mg/100 g to 145.64 mg/100 g. Thus, there was a rate of 95.21% reduction in the phytic acid content of wheat bran.

Although phytic acid is resistant to heat, its thermal stability deteriorates under high temperature and acidic conditions. Under these conditions, its solubility increases and a high rate of phytic acid loss may occur [10]. Servi and coauthors [11] determined a rate of 88.4-96.9% reduction in phytic acid contents of wheat bran samples by application of different dephytinization methods. It has been reported that the highest degradation rate was reached by the hydrothermal method.

Strains isolated from sourdough samples

Ten LAB from SS and four LAB from VS were identified using 16S rRNA sequencing (Table 1). Based on molecular identification, *Lactobacillus fermentum* SS1 (97.32%), *L. fermentum* SS2 (97.83%), *L. fermentum* SS3 (97.03%), *L. fermentum* SS4 (97.99%), *L. fermentum* SS5 (96.53%), *L. fermentum* SS6 (97.45%), *L. fermentum* SS7 (97.87%), *L. fermentum* SS8 (96.92%), *L. fermentum* SS9 (97.95%), *L. fermentum* SS10 (97.25%), *L. fermentum* VS1 (97.72%), *Lactococcus lactis* VS2 (97.20%), *L. lactis* VS3 (98.95%) and *L. lactis* VS4 (98.07%) were determined. Among the identified *Lactobacillus* strains from spontaneous sourdough, *L. fermentum* Q1.3 LBS was dominant, and it constituted 90% of the designated strains, of which 10% was *L. fermentum* 4793. Among the LAB isolated from VS, *L. lactis* MLG6-19 constituted 50% of the identified strains. 25% of the rest was *L. fermentum* Q1.3 LBS, and 25% was *L. fermentum* 7251. Considering these results, it was decided to use the *L. fermentum* Q1.3 LBS strain and the *L. lactis* MLG6-19 strain separately in sourdough production.

Table 1. LAB isolated from SS and VS and identified by 16S rRNA gene sequencing and their GenBank accession numbers adapted from NCBI-BLAST

Isolates	Closest known relative (strain No)	Identification (%)	GenBank Accession No
SS1	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.32	MT515774.1
SS2	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.83	MT515774.1
SS3	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.03	MT515774.1
SS4	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.99	MT515774.1
SS5	*Lactobacillus fermentum* strain (4793)	96.53	MT505566.1
SS6	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.45	MT515774.1
SS7	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.87	MT515774.1
SS8	*Lactobacillus fermentum* strain (Q1.3 LBS)	96.92	MT515774.1
SS9	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.95	MT515774.1
SS10	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.25	MT515774.1
VS1	*Lactobacillus fermentum* strain (Q1.3 LBS)	97.72	MT515774.1
VS2	*Lactococcus lactis* strain (MLG6-19)	97.20	MT473420.1
VS3	*Lactococcus lactis* strain (MLG6-19)	98.95	MT473420.1
VS4	*Lactobacillus fermentum* strain (7251)	98.07	MT516047.1

The dominant types of LAB found in sourdough vary according to the geographical region, and the number of dominant species found in the same product may be one or more [15]. *L. fermentum* is a key microorganism for sourdough technology due to its contribution to sourdough aroma and texture. There are many studies in which *L. fermentum* was isolated from sourdough and identified [15, 16]. *L. lactis*, which is a safe microorganism with a GRAS status, has been used as a starter for a long time like *L. fermentum* [17].

pH and TA values of sourdough samples

In the production of spontaneous sourdough, the time-dependent changes in pH and TA values were measured before each back-slopping. The pH and TA values of spontaneous sourdough, which were 6.16 and 0.14%, respectively, at the beginning of fermentation, decreased to 3.62 and increased to 0.99%, respectively, at the end of fermentation. The pH and TA values belonged to mature spontaneous sourdough, and belonged to other sourdoughs are given in Table 2.

The pH value of VS was higher, and the TA value was lower than the other sourdough samples ($p<0.05$). In previous studies, it has been reported that sourdough's pH and TA values ranged between 3.6-3.8 and 0.72-0.90% (lactic acid) respectively, in sourdough fermentation [18]. Torrieri and coauthors [6] determined that the pH and TA values of sourdough samples were ranged from 4.00-4.02 and 6.40-7.40 ml, respectively.

Table 2. The pH and TA values, LAB and yeast count of sourdough samples (mean ± std. error)

Sample	pH	TA (%) (lactic acid)	LAB count log_{10} cfu/g	Yeast count log_{10} cfu/g
SS	3.62 ± 0.00[b]	0.99 ± 0.01[b]	8.77 ± 0.01[a]	n.d.*
VS	4.97 ± 0.02[a]	0.23 ± 0.05[a]	5.48 ± 0.72[b]	4.92 ± 0.05
LFS	3.66 ± 0.01[b]	1.03 ± 0.01[b]	9.00 ± 0.08[a]	n.d.
LCS	3.63 ± 0.01[b]	1.01 ± 0.01[b]	8.96 ± 0.04[a]	n.d.

[1] Values followed by different superscript letters (series "a-b") within each column (indicating differences among average of sourdough sample) are significantly different at $p<0.05$.
[2] *n.d.: not detected

Total LAB and yeast count of sourdough samples

In SS production, no yeast growth was observed while the number of LAB increased by the fermentation progress. Therefore, it is considered that the number of yeast was below the limit that can be determined at the beginning of the fermentation period, and the process conditions negatively affected the yeast growth. The pH decrease occurred rapidly in the sourdough sample. The increase in the number of yeast did not occur due to the predominance of LAB in the following days and the effect of the acid formed. Gobbetti and Gänzle [18] stated that the number of LAB in sourdough varied from 7 to 9 log_{10} cfu/g.

When the LAB and yeast count of the sourdough samples are examined from Table 2, it is seen that the sample with the lowest LAB and highest yeast count was VS ($p<0.05$). Dertli and coauthors [19] determined that the LAB and yeast count of VS varied between 8.35-8.96 log_{10} cfu/g and 6.70-6.96 log_{10} cfu/g, respectively. It is thought that this difference is due to the bakery from which the sourdough is supplied and the production method. Torrieri and coauthors [6] found that the LAB numbers of sourdough samples produced with starter culture were 8.40-8.62 log_{10} cfu/g.

Specific volume of bread samples

The results belonged to the specific volume of bread samples are shown in Table 3. The specific volume of bread samples decreased with the addition of bran ($p<0.05$). The sourdough type was effective on the specific volume. It was determined that the samples containing sourdoughs produced with starter cultures had the lowest specific volume, and the highest values were obtained in samples containing SS or VS sourdoughs. It was seen that the dephytinized wheat bran reduced the specific volume of bread samples compared with wheat bran.

The stable gluten network is necessary to hold the gas forming in dough fermentation. The reduction in the gluten concentration with the bran utilisation leads to a decrease in the volume of bread. The increase in the amount of cellulose in the bran with the dephytinization process may be one of the reasons for the decrease in bread volume. Since the water absorption capacity of bran is considerably high and sourdough fermentation also increases it, more water remains in the bread. In this case, the bread weight increases, and the specific volume decreases [10]. The proteolytic activities of microorganisms used as a starter culture can also be effective on the specific volume. The high proteolytic activity damages the gluten network and reduces the CO_2 holding capacity.

Color values of bread samples

The results belonged to color values (L^*, a^*, b^*, ΔE) of bread samples are shown in Table 3. It is seen that the L^* values of crumbs decreased with the addition of bran ($p<0.05$). The sourdough type significantly affected the L^* values of the bread except for the control samples ($p<0.05$). The highest L^* values were determined in the samples produced with SS, and the lowest L^* values have belonged to samples produced with LCS. The addition of dephytinized wheat bran reduced L^* values of samples compared to wheat bran additive.

The bread crumb a^*, b^* and ΔE values increased with bran addition. The ΔE values of the samples containing dephytinized wheat bran were higher than the samples containing wheat bran. It has been reported that the color changes resulting from dephytinization may be due to the Maillard reaction occurring during the hydrothermal process and drying [20].

Textural properties of bread samples

The results of the textural profile analysis parameters measured on the 1st, 3rd and 5th days of the bread samples are presented in Table 4.

Table 3. The specific volume values, crumb hunter-lab color values and total color change (ΔE) of bread samples (mean ± std. error)

Sourdough Type	Bran Type	Addition Rate of Bran (%)	Specific volume (mL/g)	*L**	*a**	*b**	ΔE
SS	Wheat Bran	0	3.15 ± 0.01^{aA}	74.61 ± 1.30^{aA}	-1.52 ± 0.06^{cA}	14.23 ± 0.22^{cA}	---
		5	3.07 ± 0.00^{aAP}	70.32 ± 0.44^{abAP}	1.73 ± 0.16^{bAP}	16.38 ± 0.02^{bcAP}	5.80 ± 0.24^{cAR}
		10	2.85 ± 0.02^{bAP}	65.54 ± 1.30^{bcAP}	3.10 ± 0.34^{aAP}	18.03 ± 0.27^{abAP}	10.87 ± 1.32^{bAR}
		15	2.73 ± 0.05^{bAP}	60.92 ± 0.83^{cAP}	4.24 ± 0.12^{aAR}	18.80 ± 0.66^{aAP}	15.57 ± 0.49^{aAR}
	Dephytinized Wheat Bran	0	3.15 ± 0.01^{aA}	74.61 ± 1.30^{aA}	-1.52 ± 0.06^{dA}	14.23 ± 0.22^{bA}	---
		5	3.03 ± 0.03^{bAP}	65.71 ± 0.26^{bAR}	2.39 ± 0.01^{cAP}	16.33 ± 0.09^{aAP}	9.94 ± 0.22^{cAP}
		10	2.74 ± 0.01^{cAR}	58.43 ± 0.22^{cAR}	4.44 ± 0.24^{bAP}	16.63 ± 0.26^{aAP}	17.41 ± 0.15^{bAP}
		15	2.11 ± 0.00^{dAR}	54.62 ± 0.23^{cAR}	5.52 ± 0.03^{aAP}	17.10 ± 0.02^{aAP}	21.39 ± 0.22^{aAP}
VS	Wheat Bran	0	3.27 ± 0.02^{aA}	74.46 ± 0.11^{aA}	-1.59 ± 0.03^{cA}	14.10 ± 0.12^{cA}	---
		5	3.10 ± 0.03^{aAP}	68.33 ± 0.20^{bABP}	1.60 ± 0.07^{bAP}	15.78 ± 0.27^{bABP}	7.12 ± 0.27^{cAP}
		10	2.89 ± 0.01^{bAP}	63.80 ± 0.11^{cABP}	2.74 ± 0.60^{abAP}	17.40 ± 0.10^{aABP}	11.99 ± 0.09^{bAR}
		15	2.75 ± 0.05^{bAP}	60.24 ± 0.20^{dABP}	4.18 ± 0.38^{aAP}	17.95 ± 0.06^{aAP}	15.83 ± 0.34^{aAR}
	Dephytinized Wheat Bran	0	3.27 ± 0.02^{aA}	74.46 ±0.11^{aA}	-1.59 ± 0.03^{dA}	14.10 ± 0.12^{bA}	---
		5	3.06 ± 0.01^{bAP}	64.93 ± 0.91^{bAP}	2.26 ± 0.16^{cAP}	15.04 ± 0.20^{abAP}	10.33 ± 0.88^{cAP}
		10	2.80 ± 0.03^{cAP}	58.34 ± 0.43^{cAR}	4.38 ± 0.12^{bAP}	15.67 ± 0.41^{aAP}	17.27 ± 0.48^{bAP}
		15	2.14 ± 0.02^{dAR}	54.39 ± 0.26^{dABR}	5.36 ± 0.04^{aAP}	15.81 ± 0.16^{aBR}	21.31 ± 0.22^{aAP}
LFS	Wheat Bran	0	2.77 ± 0.02^{aB}	72.55 ± 0.10^{aA}	-1.89 ± 0.04^{dB}	13.98 ± 0.07^{dAB}	---
		5	2.65 ± 0.03^{abBP}	67.08 ± 0.16^{bBP}	0.73 ± 0.10^{cABP}	15.44 ± 0.06^{cBP}	6.24 ± 0.08^{cAR}
		10	2.51 ± 0.05^{bcBP}	63.34 ± 0.18^{cABP}	2.43 ± 0.09^{bAR}	16.62 ± 0.06^{bBP}	10.50 ± 0.21^{bAR}
		15	2.38 ± 0.03^{cBP}	60.13 ± 0.13^{dABP}	3.63 ± 0.09^{aAR}	17.80 ± 0.36^{aAP}	14.12 ± 0.24^{aAR}
	Dephytinized Wheat Bran	0	2.77 ± 0.02^{aB}	72.55 ± 0.10^{aA}	-1.89 ± 0.04^{cB}	13.98 ± 0.07^{aAB}	---
		5	2.61 ± 0.04^{abBP}	63.28 ± 0.20^{bAR}	2.19 ± 0.49^{bAP}	14.94 ± 1.05^{aAP}	10.23 ± 0.48^{cAP}
		10	2.44 ± 0.04^{bBP}	56.07 ± 0.09^{cBR}	4.21 ± 0.02^{aAP}	15.48 ± 0.49^{aAP}	17.65 ± 0.13^{bAP}
		15	1.87 ± 0.04^{cBR}	52.41 ± 0.27^{dBCR}	5.28 ± 0.10^{aAP}	15.63 ± 0.02^{aBR}	21.44 ± 0.29^{aAP}
LCS	Wheat Bran	0	2.71 ± 0.05^{aB}	72.47 ± 1.25^{aA}	-1.95 ± 0.01^{cB}	12.93 ± 0.27^{bB}	---
		5	2.60 ± 0.07^{aBP}	66.23 ± 0.57^{bBP}	0.52 ± 0.31^{bBR}	15.30 ± 0.07^{abBP}	7.12 ± 0.63^{cAR}
		10	2.50 ± 0.01^{abBP}	61.57 ± 0.21^{cBP}	2.08 ± 0.06^{aAR}	16.53 ± 0.28^{aBP}	12.17 ± 0.12^{bAR}
		15	2.30 ± 0.02^{bBP}	57.98 ± 0.16^{cBP}	3.47 ± 0.39^{aAP}	17.72 ± 1.02^{aAP}	16.23 ± 0.57^{aAR}
	Dephytinized Wheat Bran	0	2.71 ± 0.05^{aB}	72.47 ± 1.25^{aA}	-1.95 ± 0.01^{cB}	12.93 ± 0.27^{bB}	---
		5	2.45 ± 0.05^{abBP}	62.72 ± 0.46^{bAR}	2.14 ± 0.11^{bAP}	14.82 ± 0.09^{aAP}	10.75 ± 0.39^{cAP}
		10	2.23 ± 0.04^{bCR}	55.72 ± 0.19^{cBR}	4.17 ± 0.23^{aAP}	15.31 ± 0.04^{aAR}	18.00 ± 0.10^{bAP}
		15	1.82 ± 0.06^{cBR}	51.74 ± 0.60^{cCR}	4.80 ± 0.01^{aBP}	15.45 ± 0.21^{aBP}	21.95 ± 0.59^{aAP}

[1] Values followed by different superscript letters (series “a-d”) within each column (indicating differences among average of bread samples at same sourdough type with same bran type and with different addition rate), by different uppercase letters (series “A-D”) within each column (indicating differences among average of bread samples at different sourdough type with same bran type and with same addition rate), and by different letters (series “P-R”) within each column (indicating differences among average of bread samples at same sourdough type with different bran type and with same addition rate) are significantly different at $p<0.05$.

Table 4. The texture profile parameters of bread samples during storage (mean ± std. error) a) the hardness and springiness values, b) the cohesiveness and chewiness values

Sourdough Type	Bran Type	Addition Rate of Bran (%)	Hardness (g)			Springiness		
			1st Day	3rd Day	5th Day	1st Day	3rd Day	5th Day
SS	Wheat Bran	0	981.04 ± 2.35^{bCY}	2229.15 ± 175.07^{bBX}	2746.77 ± 58.50^{bBX}	0.97 ± 0.00^{aAX}	0.92 ± 0.02^{aAX}	0.90 ± 0.01^{aAX}
		5	1110.76 ± 80.29^{bCPY}	2401.23 ± 291.24^{bAPX}	3001.34 ± 4.20^{abAPX}	0.93 ± 0.01^{abAPX}	0.89 ± 0.01^{aAPX}	0.87 ± 0.01^{abAPX}
		10	1158.15 ± 21.18^{bCRZ}	2779.76 ± 48.54^{bAPY}	3345.70 ± 56.81^{abBRX}	0.90 ± 0.00^{bAPX}	0.87 ± 0.01^{abAPX}	0.84 ± 0.00^{bcAPY}
		15	1515.49 ± 5.47^{aBRY}	3312.43 ± 106.24^{aARX}	3696.42 ± 227.75^{aARX}	0.85 ± 0.01^{cAPX}	0.82 ± 0.01^{bAPX}	0.82 ± 0.00^{cAPX}
	Dephytinized Wheat Bran	0	981.04 ± 2.35^{dCY}	2229.15 ± 175.07^{bBX}	2746.77 ± 58.50^{cBX}	0.97 ± 0.00^{aAX}	0.92 ± 0.02^{aAX}	0.90 ± 0.01^{aAX}
		5	1170.23 ± 16.09^{cCPY}	2500.64 ± 150.36^{bBPX}	3650.04 ± 347.29^{bcAPX}	0.91 ± 0.00^{bAPX}	0.87 ± 0.00^{abAPY}	0.83 ± 0.00^{abAPZ}
		10	1542.66 ± 50.58^{bBPZ}	3394.87 ± 338.95^{bAPY}	4685.60 ± 139.13^{bAPX}	0.85 ± 0.01^{cARX}	0.83 ± 0.01^{bcAPX}	0.82 ± 0.01^{bAPX}
		15	2876.07 ± 6.30^{aAPZ}	4740.82 ± 219.92^{aAPY}	6119.09 ± 242.00^{aAPX}	0.80 ± 0.01^{dARX}	0.77 ± 0.02^{cAPX}	0.74 ± 0.02^{cARX}
VS	Wheat Bran	0	999.30 ± 83.47^{cCZ}	2337.04 ± 72.01^{bABY}	3279.85 ± 162.10^{aABX}	0.95 ± 0.01^{aABX}	0.92 ± 0.00^{aAX}	0.89 ± 0.01^{aAX}
		5	1120.75 ± 8.84^{cCRY}	2525.04 ± 5.54^{abAPXY}	3459.76 ± 429.42^{aAPX}	0.93 ± 0.00^{abAPX}	0.90 ± 0.01^{abAPXY}	0.86 ± 0.02^{aAPY}
		10	1604.11 ± 4.14^{bBPZ}	2864.43 ± 82.19^{abAPY}	4222.34 ± 179.21^{aAPX}	0.91 ± 0.00^{abAPX}	0.87 ± 0.01^{bAPY}	0.85 ± 0.00^{aAPZ}
		15	2329.73 ± 5.79^{aARX}	3484.86 ± 336.37^{aAPX}	4657.68 ± 833.39^{aAPX}	0.89 ± 0.01^{bAPX}	0.79 ± 0.01^{cAPY}	0.78 ± 0.01^{bAPY}
	Dephytinized Wheat Bran	0	999.30 ± 83.47^{cCZ}	2337.04 ± 72.01^{bABY}	3279.85 ± 162.10^{cABX}	0.95 ± 0.01^{aABX}	0.92 ± 0.00^{aAX}	0.89 ± 0.01^{aAX}
		5	1351.87 ± 11.20^{cCPZ}	2534.51 ± 100.13^{bBPY}	3839.88 ± 49.05^{cAPX}	0.92 ± 0.00^{aAPX}	0.88 ± 0.00^{aAPY}	0.84 ± 0.00^{abAPZ}
		10	1943.83 ± 90.15^{bABPY}	3565.58 ± 391.72^{abAPX}	4873.78 ± 122.97^{bAPX}	0.87 ± 0.01^{abARX}	0.82 ± 0.01^{bARX}	0.77 ± 0.04^{bcAPX}
		15	3064.51 ± 90.40^{aAPZ}	4753.29 ± 443.48^{aAPY}	6704.75 ± 65.14^{aAPX}	0.82 ± 0.03^{bAPX}	0.74 ± 0.02^{cAPX}	0.71 ± 0.01^{cARX}
LFS	Wheat Bran	0	1873.02 ± 55.09^{bAZ}	2600.42 ± 105.99^{bABY}	3764.49 ± 26.46^{bAX}	0.94 ± 0.00^{aABX}	0.87 ± 0.01^{aAY}	0.86 ± 0.00^{aAY}
		5	1908.33 ± 32.13^{bAPZ}	2866.40 ± 127.30^{bAPY}	4007.57 ± 120.81^{abAPX}	0.89 ± 0.00^{bBPX}	0.86 ± 0.01^{aAPX}	0.81 ± 0.01^{abAPY}
		10	2018.89 ± 89.38^{bAPZ}	3075.58 ± 24.49^{abAPY}	4379.48 ± 21.69^{abARX}	0.87 ± 0.01^{bcAPX}	0.83 ± 0.01^{aAPX}	0.78 ± 0.03^{abAPX}
		15	2533.75 ± 116.29^{aAPY}	3508.68 ± 14.44^{aAPY}	4881.35 ± 301.04^{aARX}	0.84 ± 0.00^{cAPX}	0.83 ± 0.00^{aAPX}	0.74 ± 0.00^{bAPY}
	Dephytinized Wheat Bran	0	1873.02 ± 55.09^{bAZ}	2600.42 ± 105.99^{bABY}	3764.49 ± 26.46^{cAX}	0.94 ± 0.00^{aABX}	0.87 ± 0.01^{aAY}	0.86 ± 0.00^{aAY}
		5	2028.12 ± 11.07^{bAPZ}	2974.22 ± 12.46^{bABPY}	4188.37 ± 79.08^{bcAPX}	0.86 ± 0.00^{bBRX}	0.86 ± 0.01^{aAPX}	0.80 ± 0.02^{bAPX}
		10	2322.79 ± 182.71^{bAPY}	3573.64 ± 440.74^{abAPXY}	4878.49 ± 103.51^{bAPX}	0.84 ± 0.01^{bAPX}	0.81 ± 0.01^{abAPX}	0.78 ± 0.01^{bcAPX}
		15	3279.47 ± 192.38^{aAPZ}	4874.36 ± 332.85^{aAPY}	6584.77 ± 255.87^{aAPX}	0.77 ± 0.01^{cARX}	0.74 ± 0.04^{bAPX}	0.73 ± 0.00^{cAPX}
LCS	Wheat Bran	0	1501.81 ± 30.09^{bBZ}	2908.58 ± 56.75^{aAY}	3938.23 ± 204.78^{aAX}	0.92 ± 0.00^{aBX}	0.88 ± 0.02^{aAX}	0.87 ± 0.01^{aAX}
		5	1636.01 ± 35.22^{bBPY}	3272.92 ± 307.59^{aAPX}	4075.96 ± 54.46^{aAPX}	0.91 ± 0.00^{aABPX}	0.85 ± 0.01^{aAPX}	0.85 ± 0.02^{aAPX}
		10	1667.09 ± 100.07^{bABPY}	3588.84 ± 387.37^{aAPX}	4490.14 ± 24.59^{aAPX}	0.90 ± 0.02^{aAPX}	0.84 ± 0.01^{aAPX}	0.83 ± 0.00^{aAPX}
		15	2356.88 ± 21.24^{aARY}	3899.10 ± 119.98^{aARXY}	4930.34 ± 601.82^{aAPX}	0.85 ± 0.02^{aAPX}	0.82 ± 0.03^{aAPX}	0.79 ± 0.03^{aAPX}
	Dephytinized Wheat Bran	0	1501.81 ± 30.09^{cBZ}	2908.58 ± 56.75^{dAY}	3938.23 ± 204.78^{bAX}	0.92 ± 0.00^{aBX}	0.88 ± 0.02^{aAX}	0.87 ± 0.01^{aAX}
		5	1782.70 ± 72.92^{bcBPZ}	3291.56 ± 34.86^{cAPY}	4277.66 ± 152.58^{bAPX}	0.91 ± 0.01^{aAPX}	0.85 ± 0.01^{aAPY}	0.83 ± 0.00^{abAPY}
		10	2181.31 ± 100.52^{bABPZ}	3641.16 ± 3.52^{bAPY}	5075.58 ± 389.27^{bAPX}	0.89 ± 0.01^{aAPX}	0.82 ± 0.01^{aAPXY}	0.77 ± 0.02^{bcAPY}
		15	3247.69 ± 137.00^{aAPZ}	5377.12 ± 75.51^{aAPY}	6588.52 ± 55.28^{aAPX}	0.82 ± 0.01^{bAPX}	0.77 ± 0.06^{aAPX}	0.74 ± 0.02^{cAPX}

[1] a) Values followed by different superscript letters (series “a-d”) within each column (indicating differences among average of bread samples at same sourdough type with same bran type and with different addition rate), by different uppercase letters (series “A-D”) within each column (indicating differences among average of bread samples at different sourdough type with same bran type and with same addition rate), by different letters (series “P-R”) within each column (indicating differences among average of bread samples at same sourdough type with different bran type and with same addition rate), and by different uppercase letters (series “X-Z”) within each column (indicating differences among average of bread samples at same sourdough type with same bran type and with same addition rate on different storage days) are significantly different at $p<0.05$.

Cont. Table 4

Sourdough Type	Bran Type	Addition Rate of Bran (%)	Cohesiveness			Chewiness (g)		
			1st Day	3rd Day	5th Day	1st Day	3rd Day	5th Day
SS	Wheat Bran	0	0.75 ± 0.01^{aAX}	0.56 ± 0.01^{aAY}	0.47 ± 0.01^{aAZ}	577.18 ± 17.48^{bBZ}	870.17 ± 25.10^{dAY}	1118.82 ± 8.29^{aAX}
		5	0.68 ± 0.00^{abAPX}	0.53 ± 0.01^{abAPY}	0.45 ± 0.01^{aAPZ}	632.07 ± 12.31^{bCRY}	1003.39 ± 21.08^{cBPX}	1204.39 ± 86.03^{aBPX}
		10	0.65 ± 0.02^{bAPX}	0.50 ± 0.01^{bcAPY}	0.44 ± 0.00^{aAPY}	658.73 ± 13.74^{bBRY}	1115.05 ± 19.44^{bARX}	1316.98 ± 118.98^{aAPX}
		15	0.63 ± 0.02^{bAPX}	0.48 ± 0.00^{cAPY}	0.43 ± 0.00^{aABPY}	788.92 ± 24.62^{aCRY}	1315.43 ± 2.53^{aARX}	1645.61 ± 151.90^{aBPX}
	Dephytinized Wheat Bran	0	0.75 ± 0.01^{aAX}	0.56 ± 0.01^{aAY}	0.47 ± 0.01^{aAZ}	577.18 ± 17.48^{cBZ}	870.17 ± 25.10^{cAY}	1118.82 ± 8.29^{bAX}
		5	0.67 ± 0.00^{bARX}	0.52 ± 0.01^{abAPY}	0.44 ± 0.01^{aAPZ}	700.57 ± 1.35^{bcBPY}	1107.11 ± 17.85^{bAPX}	1371.35 ± 113.02^{bAPX}
		10	0.65 ± 0.01^{bcAPX}	0.49 ± 0.01^{abAPY}	0.44 ± 0.01^{aAPZ}	841.38 ± 38.90^{bCPZ}	1280.44 ± 32.46^{bAPY}	1804.82 ± 0.60^{aAPX}
		15	0.61 ± 0.01^{cAPX}	0.47 ± 0.02^{bAPY}	0.43 ± 0.00^{aAPY}	1386.62 ± 62.01^{aAPY}	1790.71 ± 58.04^{aAPX}	2003.75 ± 60.47^{aAPX}
VS	Wheat Bran	0	0.69 ± 0.00^{aAX}	0.52 ± 0.00^{aABY}	0.46 ± 0.01^{aAZ}	637.44 ± 18.42^{bBZ}	1035.66 ± 3.65^{bAY}	1461.61 ± 92.70^{bAX}
		5	0.68 ± 0.03^{aAPX}	0.52 ± 0.01^{aAPY}	0.45 ± 0.02^{aAPY}	712.95 ± 10.60^{bCPZ}	1238.98 ± 52.71^{abABPY}	1653.34 ± 38.92^{bAPX}
		10	0.64 ± 0.01^{aAPX}	0.51 ± 0.05^{aAPXY}	0.45 ± 0.02^{aAPY}	922.21 ± 12.15^{aABPZ}	1312.02 ± 38.09^{aAPY}	1744.55 ± 7.68^{bARX}
		15	0.62 ± 0.01^{aAPX}	0.50 ± 0.00^{aAPY}	0.44 ± 0.00^{aAPZ}	1053.70 ± 57.67^{aBRZ}	1328.98 ± 55.06^{aARY}	2144.74 ± 6.86^{aAPX}
	Dephytinized Wheat Bran	0	0.69 ± 0.00^{aAX}	0.52 ± 0.00^{aABY}	0.46 ± 0.01^{aAZ}	637.44 ± 18.42^{dBZ}	1035.66 ± 3.65^{cAY}	1461.61 ± 92.70^{cAX}
		5	0.67 ± 0.01^{abAPX}	0.52 ± 0.01^{aAPY}	0.45 ± 0.00^{aAPZ}	738.16 ± 6.70^{cBPZ}	1272.64 ± 19.05^{bAPY}	1668.04 ± 24.23^{bcAPX}
		10	0.64 ± 0.01^{bABPX}	0.49 ± 0.00^{abAPY}	0.44 ± 0.01^{aAPZ}	1024.43 ± 22.87^{bBCPZ}	1386.16 ± 32.48^{bAPY}	2022.04 ± 46.04^{bAPX}
		15	0.59 ± 0.00^{cAPX}	0.48 ± 0.00^{bAPY}	0.43 ± 0.02^{aAPZ}	1604.99 ± 3.50^{aAPY}	1801.09 ± 34.02^{aAPX}	2554.20 ± 135.69^{aAPX}
LFS	Wheat Bran	0	0.71 ± 0.06^{aAX}	0.54 ± 0.00^{aABXY}	0.45 ± 0.01^{aAY}	1136.20 ± 68.90^{aAX}	1163.90 ± 99.45^{aAX}	1323.91 ± 89.79^{bAX}
		5	0.63 ± 0.02^{aAPX}	0.50 ± 0.01^{aAPY}	0.44 ± 0.00^{aAPY}	1224.17 ± 26.70^{aAPX}	1254.28 ± 81.30^{aABPX}	1416.22 ± 16.25^{abABPX}
		10	0.62 ± 0.00^{aAPX}	0.48 ± 0.03^{aAPY}	0.43 ± 0.01^{aAPY}	1226.49 ± 64.32^{aAPX}	1340.22 ± 53.41^{aAPX}	1588.19 ± 90.44^{abAPX}
		15	0.58 ± 0.00^{aAPX}	0.48 ± 0.00^{aAPY}	0.42 ± 0.00^{aBPZ}	1309.11 ± 0.30^{aAPY}	1358.87 ± 16.00^{aARY}	1765.91 ± 7.45^{aABPX}
	Dephytinized Wheat Bran	0	0.71 ± 0.06^{aAX}	0.54 ± 0.00^{aABXY}	0.45 ± 0.01^{aAY}	1136.20 ± 68.90^{bAX}	1163.90 ± 99.45^{bAX}	1323.91 ± 89.79^{bAX}
		5	0.62 ± 0.00^{aAPX}	0.50 ± 0.01^{abAPY}	0.44 ± 0.01^{aAPZ}	1224.78 ± 77.40^{abAPX}	1472.82 ± 146.01^{abAPX}	1609.00 ± 76.27^{bAPX}
		10	0.62 ± 0.00^{aBPX}	0.48 ± 0.00^{bAPY}	0.43 ± 0.01^{aAPZ}	1388.67 ± 74.48^{abAPX}	1494.30 ± 151.43^{abAPX}	1825.93 ± 13.32^{bAPX}
		15	0.57 ± 0.01^{aAPX}	0.47 ± 0.01^{bAPY}	0.41 ± 0.00^{aAPZ}	1816.40 ± 186.17^{aAPX}	1915.65 ± 116.51^{aAPX}	2449.52 ± 178.86^{aAPX}
LCS	Wheat Bran	0	0.68 ± 0.01^{aAX}	0.51 ± 0.00^{aBY}	0.46 ± 0.01^{aAY}	979.35 ± 14.35^{aAY}	1232.81 ± 73.18^{aAXY}	1421.22 ± 42.99^{cAX}
		5	0.64 ± 0.01^{abAPX}	0.50 ± 0.01^{aAPY}	0.46 ± 0.01^{aAPY}	1003.85 ± 60.06^{aBPY}	1377.60 ± 64.06^{aAPX}	1598.09 ± 24.17^{bcAPX}
		10	0.62 ± 0.01^{bAPX}	0.47 ± 0.00^{aAPY}	0.45 ± 0.00^{aAPY}	1044.59 ± 93.66^{aAPX}	1416.57 ± 214.06^{aAPX}	1620.92 ± 45.01^{bAPX}
		15	0.61 ± 0.01^{bAPX}	0.46 ± 0.03^{aAPY}	0.42 ± 0.00^{aABPY}	1098.08 ± 40.17^{aABRZ}	1443.37 ± 54.16^{aAPY}	1851.28 ± 13.25^{aABPX}
	Dephytinized Wheat Bran	0	0.68 ± 0.01^{aAX}	0.51 ± 0.00^{aBY}	0.46 ± 0.01^{aAY}	979.35 ± 14.35^{cAY}	1232.81 ±73.18^{bAXY}	1421.22 ± 42.99^{aAX}
		5	0.64 ± 0.02^{abAPX}	0.49 ± 0.00^{aAPY}	0.46 ± 0.01^{abAPY}	1045.83 ± 12.07^{cAPX}	1476.18 ± 21.35^{bAPX}	1657.62 ± 206.90^{aAPX}
		10	0.62 ± 0.00^{bBPX}	0.47 ± 0.00^{aAPY}	0.45 ± 0.01^{abAPY}	1300.05 ± 49.18^{bABPX}	1645.84 ± 13.48^{abAPX}	1923.53 ± 224.11^{aAPX}
		15	0.59 ± 0.01^{bAPX}	0.46 ± 0.02^{aAPY}	0.41 ± 0.00^{bAPY}	1729.34 ± 65.85^{aAPX}	2003.73 ± 124.81^{aAPX}	2513.29 ± 273.95^{aAPX}

[1] b) Values followed by different superscript letters (series “a-d”) within each column (indicating differences among average of bread samples at same sourdough type with same bran type and with different addition rate), by different uppercase letters (series “A-D”) within each column (indicating differences among average of bread samples at different sourdough type with same bran type and with same addition rate), by different letters (series “P-R”) within each column (indicating differences among average of bread samples at same sourdough type with different bran type and with same addition rate), and by different uppercase letters (series “X-Z”) within each column (indicating differences among average of bread samples at same sourdough type with same bran type and with same addition rate on different storage days) are significantly different at $p<0.05$.

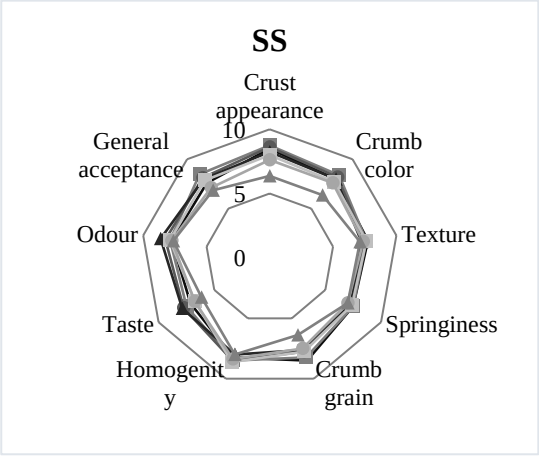
It is seen that while the hardness and chewiness values of bread were increased, the springiness and cohesiveness values were decreased with raise in bran rate. The effect of storage was similar to that of bran rate. The samples containing dephytinized wheat bran had higher hardness and chewiness values and lower springiness and cohesiveness values than samples with wheat bran. The lowest hardness and chewiness values and highest springiness and cohesiveness values belonged to the bread samples produced with SS.

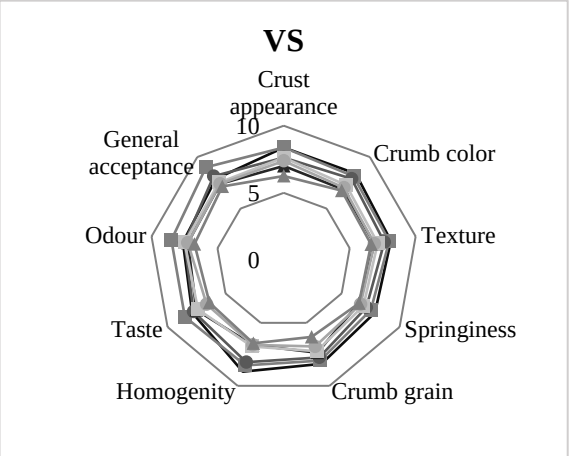
The moisture content of the bread affects starch retrogradation and staling. Since the amount of water released during baking is higher in bran added samples, starch gelatinisation increases. Thus, the volume of bread decreases and bread staling accelerates [21]. The metabolites generated by LAB can affect the rate of gelatinisation. Exopolysaccharides forming in sourdough fermentation reduce bread hardness [22]. Torrieri and coauthors [6] reported that metabolites formed during sourdough fermentation, biological acidification and proteolytic activities of LAB have positive effects on bread staling. The enzymes produced by LAB can affect starch molecules and change their retrogradation properties. Özkaya and coauthors [10] determined that the utilisation of concentrated bran increased the hardness of the breadcrumbs due to the high cellulose content. It was noted that the addition of bran hydrothermally dephytinized increased hardness values of bread samples while decreased cohesiveness and springiness values compared to standard wheat bran.

Sensorial properties of bread samples

The polar coordinate graphs of the sensory analysis results of the bread samples are given in Figure 1. It can be said that the samples produced with SS and LFS generally had higher scores, and the dephytinized wheat bran reduced the sensory properties scores compared to wheat bran. In addition, it was seen that 5% of bran rate increased the general acceptance scores for all sourdough types and both bran types, except for the dephytinized bran added samples produced with VS and LCS.

Ethanol, aroma components, organic acids such as lactic acid and acetic acid produced by heterofermentative and homofermentative LAB being in sourdough microflora, and sourdough method affect the sensory quality of the final product [23]. Rizzello and coauthors [24] reported that fermented wheat germ increased the acidic flavour and created a salty taste in bread samples. Also, the taste scores of the bread samples added with fermented wheat germ were higher than control samples or samples added with the typical germ. Majzoobi and coauthors [25] determined that sensory properties of cake samples were adversely affected when both standard wheat bran and dephytinized wheat bran rate was above 10%. It is thought that the differences between the results of the studies may be due to the product difference and the application of sourdough fermentation in this study.





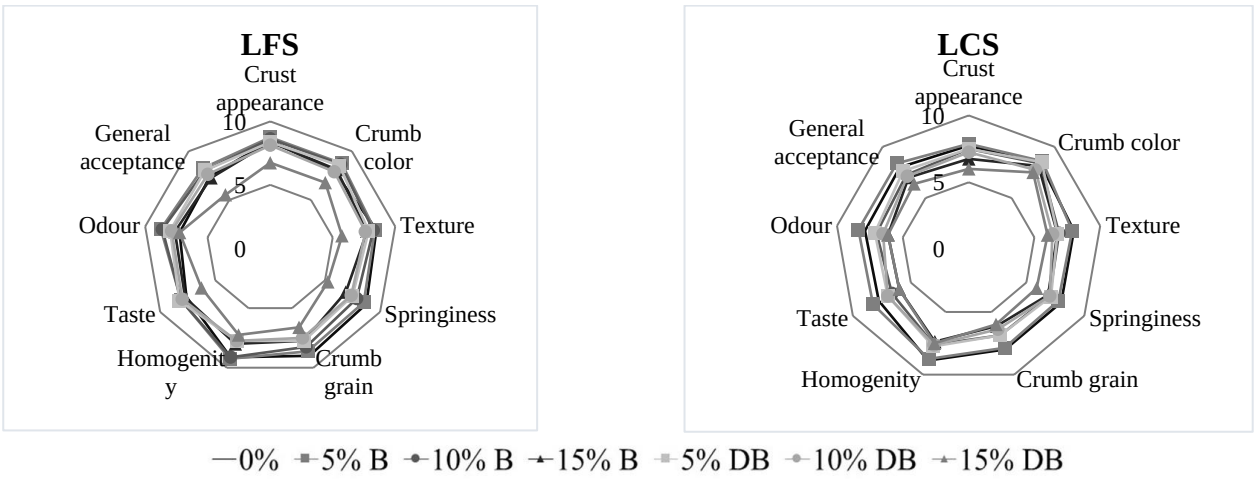


Figure 1. Polar coordinate graphs belonging to sensory analysis results of breads containing wheat bran (B) or dephytinized wheat bran (DB). SS: Spontaneous sourdough; VS: Vakfıkebir sourdough; LFS: Sourdough produced with using *Lactobacillus fermentum* as a starter; LCS: Sourdough produced with using *Lactococcus lactis* as a starter

CONCLUSION

The wheat bran is a by-product of milling, and it could be used to enrich food products with high-fibre sources. However, its high phytic acid content may cause nutritional problems. In this study, wheat bran was dephytinized to eliminate the adverse effects of phytic acid. The use of dephytinized bran caused intense changes in the colour values of bread samples compared to the use of wheat bran. Furthermore, the usage of dephytinized bran decreased the specific volume of bread due to the increase in the insoluble fibre fraction. Since dephytinized bran is more concentrated than wheat bran, its use in lesser amounts will be beneficial in eliminating the adverse effects on product properties. It was determined that SS positively affected the textural properties of the bread samples compared to other sourdoughs. Although the intense taste of bran was masked in bread samples with sourdough, high bran concentration decreased the sensorial parameter scores. Considering the results, it can be recommended to use SS and 5% bran in sourdough bread production.

The results obtained from this study will lead to studies on the use of LAB isolated from sourdough as s starter culture and dephytinized wheat bran as a dietary fibre source to enrich foods. Considering that dephytinized wheat bran contains more insoluble fibre fraction than wheat bran, its effect at lower concentrations than wheat bran on the quality properties of foods should be investigated. Due to the beneficial effects of sourdough fermentation on health and product quality, the studies encouraging its use in commercial products are very important today, where the demand for functional foods is high.

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