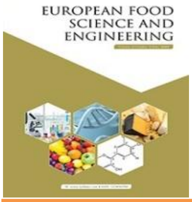

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Physicochemical, dough rheological and gluten aggregation properties of flours used in the production of flat breads in Eskişehir

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ABSTRACT

In this study, the physicochemical, gluten, and dough rheological properties of flat bread flours were evaluated. “Gözleme” flour had the highest solvent retention capacity (SRC) lactic acid, gluten performance index (GPI), and sedimentation values (118.11%, 0.648, and 65.0 ml, respectively). The dough stability of the “Gözleme” flour was also the highest at 4.15 min. The G' values of “Gözleme” and “Pide” flours were found to be higher (27200 Pa and 24525 Pa), and tanδ values of them were found to be lower (0.464 and 0.491). The “Bazlama” flour had the lowest protein content (9.84%), sedimentation (43.0 ml), and SRC lactic acid (84.13%). Bazlama” flour had low farinograph stability (1.30 min), GlutoPeak maximum tork (BEM) and energy values (36.3 BU and 26.0 J). The BEM value of “Lavash”, “Gözleme”, and “Pide” flours was higher than bread flour (around 45.0 BU). The “Lavash” and “Pide” flours had a short PMT value (around 50 s). The G' value of “Lavash” flour was the lowest (12215 Pa). “Lavash” and “Bazlama” flours had the highest Tanδ value (0.531 and 0.537). Generally, the dough and gluten-rheological properties of “Pide” flour were found to be higher, and those of Lavash” flour were more similar to “Bread” flour.

1. Introduction

Flat breads, such as “Pide”, “Lavash”, “Bazlama”, and “Yufka” (Yılmaz-Akçaözoğlu & Koday, 2019), are low-volume breads (Bulutdağ, 2021) that are consumed frequently every day in Turkey, either at home or out (Kurt & Dizlek, 2020). Flat bread can be categorized based on whether they're either single or double-layered, leavened as well as unleavened, and whether or not they are nailed (Çoşkuner & Karababa, 2021). Considering various consumption sectors such as restaurants, kebab shops, and raw meatball restaurants, flat breads are consumed pretty broadly and make up 5% of the entire amount of bread produced daily in our country (Satouf, 2022). Flatbreads are produced by baking them on a stove, pan, or hot stone, then rolled and filled with ingredients like cheese, meat, or other ingredients (Coşkuner et al., 1999; Coşkuner, 2003; Göçmen et al., 2009; Satouf, 2012; Parimala & Sudha, 2015; Pasqualone, 2018; Köten & Ünsal, 2020). The primary ingredients used to make flat breads are flour, water, salt, and yeast. Additives, oils, and seasonings can also be utilized (Al-Dmoor, 2012). The main component used to make flat breads is flour, which has low gluten quality (Pekmez, 2019). Flat breads are produced by the rolling and flattening process, so a soft dough with high extensibility is desired. The resistance to extensibility of the dough causes problems with the product properties of flat breads. The characteristics of flat breads are revealed by the dough properties, including its resilience to rolling and reopening, its ability to withstand cracks and crevices, inherent hardness, softness, and fragility (Çoşkuner & Karababa, 2021). Modest changes in the dough's viscoelastic characteristics may result in significant differences in the flat bread’s properties (Satouf, 2012).

In this study, the physicochemical, gluten aggregation, and dough rheological properties of commonly consumed flat bread flours were evaluated. Production is carried out in the bakeries where flat bread flour samples are supplied as follows: In the production of “Bazlama”, flour, water, salt, fresh yeast, sugar, and oil are mixed, and the dough is kneaded until it becomes a soft dough that sticks to the hand and left to ferment for 1 hour. The dough is cut in half and divided into pieces. The pieces are covered with the cloths and rested for 10 min. Then, the pieces are thinned to the desired thickness (approximately 1 cm) and baked in a heated pan by turning until the desired color. In “Gözleme” production, flour, water, salt, and oil are mixed, and the dough is kneaded until it

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becomes a soft dough that does not stick to the hand (about 10 min). The dough is divided into pieces. The pieces are covered with the cloths and rested for 10 min. The pieces are thinned to 2-3 mm. It is folded after the desired components are placed inside and baked on a lightly oiled sheet or in a pan with turning over. In the production of "Lavash", flour, water, salt, and oil are mixed, and the dough is kneaded until it becomes a soft dough that does not stick to the hand (about 10 min). The dough is divided into pieces and rolled. The pieces are thinned (about 2-3 mm). It is baked both front and back in an oil-free pan, then placed on top of each other and covered to prevent it from drying out. In "Pide" production, dry yeast, sugar, and warm water are mixed and waited for 10 min to rise. Oil, some of the flour, and salt are mixed. The remaining flour is added and kneaded to make a dough that does not stick to the hands (about 5 min). The dough is covered and fermented for 45 min. Fermented dough is cut into pieces. Then, the pieces are rolled by hand and thinned to approximately 3-4 mm. Desired components are placed on the dough, and the edges are folded, closed, and pressed to prevent opening while cooking. The product is baked in the oven at 200 °C for about 12 min (Çoşkuner & Karababa, 2021). In the study, the properties of the flour used in the production of flat breads were evaluated by comparing them with the flour used in the production of high-volume breads. The most crucial factors influencing the structural characteristics of flatbreads - such as their ability to shape, open without tearing, and keep intact - were carefully assessed concerning the flour and dough quality. The results provided information to the flour producers and flat bread bakeries to obtain standard-quality products**.**

2. Materials and Methods

2.1. Procurement of materials

The flours of flat breads were obtained from the production companies. A total of 4 flat bread flours (Gözleme, bazlama, pide and lavash) were used in the study. "Bread" flour was provided by a bakery producing bread using rapid production technique. The flours were stored in polyethylene bags and kept in a cold place (~ +10 °C) for further analysis.

2.2. Methods

Determination of proximate composition of flours

The moisture analyzer Pfeuffer HE-50-5 was used to determine the percentage of moisture. Using a measuring cup, approximately 10 g of the flour to be tested for moisture content was added to the gear chamber of the apparatus. With the aid of a latch, the threaded chamber lid was shut and sealed. The level of moisture was determined using the device's spinning mechanism to choose the product to measure. The ash content was determined according to AACCI Method No. 08.01 (AACC, 2010). A muffle oven (Thermnevo) was used to carry out the combustion process. After the sample was held at 500 °C for around 30 min, 5 g (0.1 mg precision) of it was weighed into the blazing crucibles. It was then brought to a consistent weight, cooled in a desiccator, and tared. The samples were put on top of the muffle furnace lid after it had been heated to 500 °C. After adding one to two milliliters of ethyl alcohol (Merck, absolute for analysis), they were pre-burned. The crucibles were put in the furnace and the fire process began following the pre-firing procedure. The ash was kept burning until it turned a light gray or white color. Following the firing procedure, the crucibles were placed on the asbestos plate and let to cool for one or two minutes. Water activity analysis was determined by WaterLab (Steroglass S.r.l., Perugia, Italy). The measurement was carried out at 25 ^{o}C. Protein content was determined by a Near Infrared Spectroscopy (NIR 6500, Foss, Hillerød, Denmark) device calibrated using the results of a nitrogen (N) analyzer (LECO FP628) operating with the Dumas combustion method AACC Method 46-30 (AACC, 2010).

Determination of technological quality properties of flours

The macro-SDS sedimentation (MSDS) value was determined in 3 g of flour samples in 100 mL standard test tubes. The flour sample was weighed and placed in a 100-mL measuring cylinder with a lid. 50 mL of bromphenol blue solution (10 ppm, w/v) was added, and the lid was closed. It was shaken horizontally 12 times in 5 s to ensure that the flour and solution were thoroughly mixed and shaken in the sedimentation shaking device for 5 min. At the end of 5 min, 50 mL of sodium dodecyl sulfate (Merck improve essential, 3%, w/w)-lactic acid solution (90%, Sigma-Aldrich®) was added and shaken in a mechanical shaker for another 5 min. After waiting for 5 min on a flat surface, the amount of precipitate that settled at the bottom was read from the measuring cylinder. Solvent retention capacity (SRC) analyses of lactic acid, water, sucrose, and sodium carbonate were performed by Guzman et al. (2015) and Karaduman (2020). The solvents that were used were pure water, lactic acid (Sigma-Aldrich, 5%, v/v), sodium carbonate (Merck anhydrous for analysis, 5%, w/v), and sucrose (Merck, 50%, w/v). Accordingly, into 2 mL centrifuge tubes, 0.3 g of flour was weighed and each solvent was added to it. After homogeneous mixing in the vortex, it was quickly placed in the thermomixer (Eppendorf™) and kept at 1400 rpm, 25 ^{o}C for 5 min. Then, the tube content was centrifuged at 400 g for 2 min. After pouring the solvent content, keeping it at room temperature for 10 min at a 45 degree angle, wiping the top of the tubes with a paper towel, the tube and the residue were weighed. The swelling index of glutenin (GSI) was done according to Wang & Kovacs (2002). For this purpose, 45 mL of the prepared 25% lactic acid (Sigma-Aldrich®) solution was taken and 50 mL of isopropanol (Sigma-Aldrich® -Propanol anhydrous, 99.5%) was added, and the volume was completed to 250 mL. 40 mg of flour was weighed into a 2 mL centrifuge tube, 0.8 mL of pure water was added and vortexed for 5 s. It was kept in the thermomixer at 1400 rpm, 25 ^{o}C for 10 min. 0.4 mL of isopropanol-lactic acid solution was added and vortexed again for 5 s. It was left in the thermomixer again at 1400 rpm, 25 ^{o}C for 10 min. It was centrifuged at 100 g for 5 min. Then, after pouring the solution and wiping the top of the tube with a paper towel, it was weighed. $L*$ (brightness), $a*$ (+red/-green), and $b*$ (+yellow/-blue) values of the flours were determined with Hunterlab MiniScan (XE Plus, USA). The wet gluten (extract) was determined using a gluten washing device (Perten Glutomatik 2100 system, Sweden). After wet gluten was obtained, it was placed on centrifuge sieves and centrifuged (at 6000 rpm) to calculate the gluten index value.

Gluten aggregation characteristics of flours

The Rapid Flour Control (RFC) method was used to measure the rheological properties of gluten using the GlutoPeak Device (Brabender GmbH and Co. KG, Duisburg, Germany). For analysis, 9.0 g of flour and 9.0 g of pure water were utilized. With a constant temperature of 36 °C and a constant stirring speed of 2750 rpm, the analysis was completed in 3 min. Peak maximum time (PMT), maximum torque (BEM), torque 15 s before the maximum torque (BM), torque 15 s after the maximum torque (BM), protein and gluten contents, energy value, and water absorption were determined (Wiertz, 2018; Karaduman et al., 2020).

Dough rheological properties of flours

Dough rheological properties were determined by using Farinograph AACC Method 54-21 (AACC, 2010). Firstly, flour water absorption was determined in the farinograph, and then the calculated water was given from the burette within 25 s. The drawing of the curve continued until 12 min after the curve started to fall. The elastic and viscous modulus values in the dough of the samples were measured by a rheometer (the Thermo Haake Mars IQ Air). In the preparation of the dough, water was given to the flour according to the water absorption determined by GlutoPeak. Kneading was done for 4 min, and the dough that stuck to the edges and the mixer arm was cleaned for the first minute. From the center of the prepared dough, 5.00±0.05 g of dough was weighed, folded inward by hand, and shaped before being used in the study. Measurements with the oscillation frequency sweep test were carried out using P35/Ti geometry at 2 mm compression, 0.1-10 Hz frequency ranges, and a 25 °C temperature. Frequency, storage-elastic modulus (G'), loss-plastic modulus (G''), and tanδ G''/G' were determined.

2.3. Statistical analyses

The JMP statistical software was used to assess the outcomes (SAS Institute, 1998). The flour properties were subjected to an analysis of variance (ANOVA) in a completely randomized design with three replications. A Tukey's HSD test was used to compare the means (P<0.05). The graphs were made using the chart part of the same statistics program, and the standard deviations were shown in the bar graphs.

3. Results and Discussion

3.3. The color and solvent retention capacity properties of flat bread flours

The L^* and b^* values, solvent retention capacity (water, sucrose, and sodium carbonate), and gluten performance index (GPI) values of the flat bread flours are given in Table 1. The color properties of flours are significantly effective in creating the unique color of flat breads demanded by consumers (Khattab et al., 2021). In the study, no significant difference was found between the L^* (brightness) values of the flours. The a^* values of the flour used in the production of “Bazlama” and “Lavash” bread were statistically in the same group as “Bread” flour. “Gözleme” and “Pide” flours were distinguished from other samples with lower a* values (Figure 1). The b^* value of “Gözleme” flour was lower than bread flour, while other flours were higher. The high amount of water absorbed by flour has a significant impact on gluten development, especially in kneading, product efficiency, and quality (Sapirstein et al., 2018). The composition of flours affects the retention of water and different solvents. Grain hardness and damaged starch (Mok & Dick, 1991), protein content (Preston et al., 2001), and pentosan and arobinoxylan content and properties (Courtin & Delcour, 1998) determine the amount of water retained by the flour. Wheat gluten can hold approximately 2.8 g of water per gram, starch 0.37 g, damaged starch 1.75 g, and arabinoxylans 10 g of water per gram (Kweon et al., 2011). Although “Bazlama” flour had lower solvent retention capacity (SRC) water values than bread flour (61.27%), no statistical difference was found between the flours. SRC sucrose is associated with pentosan and SRC sodium carbonate with damaged starch content (Gainess, 2000; Labuschagne et al., 2021). It was particularly noteworthy that “Gözleme” flour had the highest SRC value of these two compared to other flours. They were also high in “Lavash” and “Pide” flours. The “Bazlama” and “Bread” flours had lower values. Gluten is the main component that reveals the viscoelastic properties of the dough and determines its end-use properties (Shewry, 2023). SRC lactic acid and gluten performance index (GPI) values obtained by dividing the SRC lactic acid value by the sum of SRC water and sodium carbonate values are indicators of gluten strength (Guzman et al., 2015; Kweon et al., 2011, 2014).

Table 1. The color and solvent retention capacity (SRC) values of the flat bread flours.

Flours	L^*	b^*	SRC			GPI value
			Water (%)	Sucrose (%)	Sodium carbonate (%)	
1	88.29±1.86^a	11.38±0.10^a	6427±0.71^a	89.89±2.63^b	87.53±1.03^a	0.572±0.010^c
3	90.80±0.77^a	10.15±0.40^c	69.64±0.53^a	94.32±0.59^a	87.98±1.25^a	0.648±0.003^a
4	89.22±0.39^a	11.47±0.16^a	61.27±2.35^a	82.13±0.97^c	76.23±0.58^c	0.531±0.010^d
5	89.87±0.25^a	11.31±0.05^a	64.78±5.46^a	90.88±1.81^{ab}	85.38±0.92^b	0.591±0.015^{bc}
6	89.72±0.42^a	10.81±0.05^b	65.44±8.38^a	81.04±2.40^c	75.44±0.72^c	0.616±0.022^b
mean	89.58	11.02	65.08	87.65	82.51	0.592
$LSD_{0.05}$	n.s.	0.41**	n.s.	3.81**	1.86**	0.028**

[1]The solvent retention capacity test results have been corrected for the %14 moisture basis. The means of the parameters of flour types in the same column marked with different lowercase letters are statistically different from each other (P<0.05). The significance between flour properties at the 1% level is indicated by two asterisks (**); n.s.: not significant; 1: Lavash; 3: Gözleme; 4: Bazlama; 5: Pide; 6: Bread (Control); L^*: luminance; a*: +red/-green; b^*: +yellow/-blue color values; SRC: solvent retention capacity; GPI: Gluten performans index (SRC lactic acid / SRC sucrose + SRC sodium carbonate)

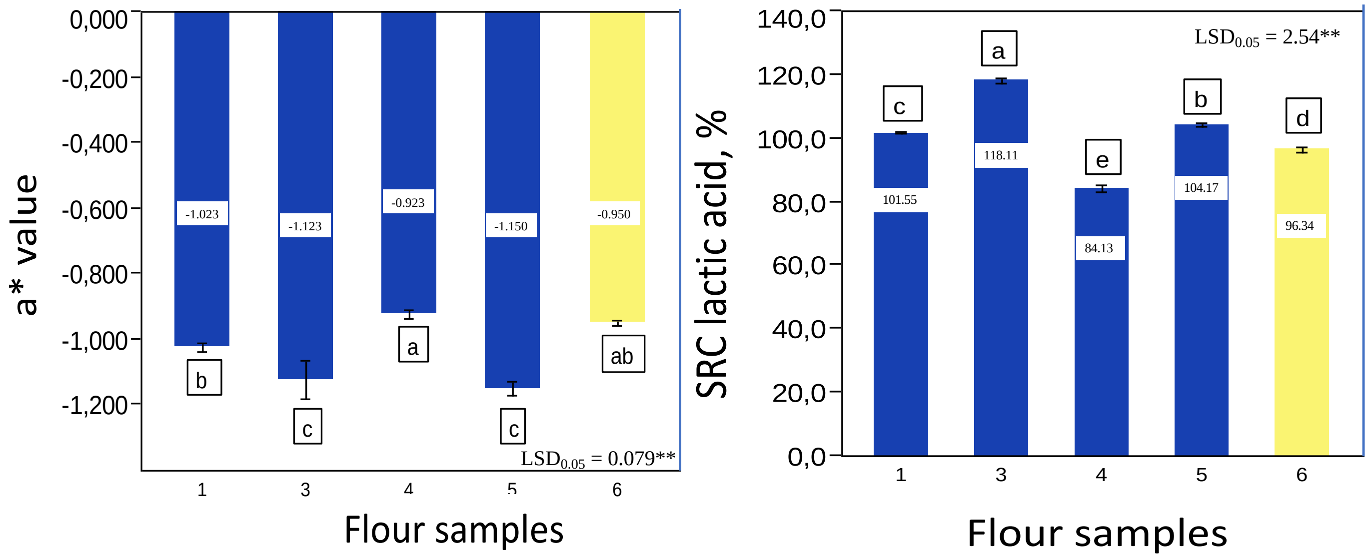

Figure 1. The *a** and SRC lactic acid values of the flat bread flours. (1: Lavash; 3: Gözleme; 4: Bazlama; 5:Pide; 6: Bread (control))

"Gözleme" flour was distinguished by the highest SRC lactic acid (Figure 1) and GPI value (118.1% and 0.648, respectively). Strong gluten was considered essential for allowing the "Gözleme" to be thinned to a low thickness, keeping its shape when cooked, and preventing the contents from leaking out. The "Lavash," "Pide", and "Bread" flours had closer SRC lactic acid values (around 100%). Thus, this showed that dough's viscoelastic properties must be softened for "Lavash" and "Pide" making. The "Bread" flour had moderate gluten quality (SRC lactic acid was 96.34% and the GPI value was 0.616). The bakery where the bread flour is supplied finds this level of flour quality sufficient as it produces bread with a short-term fermentation. The "Bazlama" flour had the lowest gluten strength (SRC lactic acid was 84.13% and the GPI value was 0.531). High gluten strength is not desired, as it causes shrinkage after the dough is thinned and a hard and firm texture in the "Bazlama".

3.2. Physicochemical and technological properties of flat bread flours

Some physicochemical and technological properties of flours are given in Table 2. The protein content ranged from 9.84 to 11.07%, the moisture content from 12.17 to 14.07%, the wet gluten from 22.83 to 27.87%, the gluten index from 86.65 to 99.62%, the sedimentation volume from 43.0 to 65.0 mL, the water activity from 0.478 to 0.559, and the ash content from 0.531 to 0.737%. A statistically significant difference was found between the flours in terms of these parameters, except for the swelling index of glutenin (SIG) value ($P < 0.01$). According to the Turkish Food Codex (TFC), flour must have a maximum moisture content of 14.5%. The moisture content of all flours was found to be in compliance with the legislation. In the TFC, it is also stated that the protein content of "Bread" flour should be at least 10.5% (d.m.). The protein content of the "Bread" flour was found to be 10.72%. The protein content of "Lavash" flour was close to that of the "Bread" flour (10.60%), while the protein content of "Pide" and "Gözleme" flour was higher (11.07% and 10.94%). The protein content of "Bazlama" flour was lower than other flours (9.84%), similar to its weak gluten strength (Figure 2). The wet gluten content of "Bazlama" flour was also the lowest (22.83%). Sedimentation value is related to the gluten quality of flours (Akman et al., 2021). The sedimentation value of "Gözleme" flour with high SRC lactic acid, GPI, and gluten index values was significantly above other flours (65.0 mL). Although the SRC lactic acid and GPI values of "Lavash" flour and "Pide" flour were close, the sedimentation value was clearly higher in "Lavash" flour (60.0 mL). In this case, it has been shown that the high gluten strength of the flour is more important for the production of "Lavash". Higher gluten strength is advantageous for making lavash because it helps thin the dough to the right thickness and gives the finished product an appropriate level of resistance to hold the food within. The sedimentation values of "Pide" and "Bread" flours were statistically similar, below those of "Gözleme" and "Lavash" flours (around 53.0 mL). "Bazlama" flour gave a sedimentation value below other flours (43.0 mL) (Figure 2). Gluten index (GI) is a criterion that defines the quality of gluten as poor (GI< 30%), normal (GI=30-80%) or strong (GI>80%) (Cubadda, 1992). Especially for high bread quality, gluten index values are required to be between 80 and 90% and not exceed 90%. Only the GI of "Bread" flour was <90% (86.65%), indicating a suitable gluten-viscoelastic balance for bread-making. Although the sedimentation value, SRC lactic acid, and GPI values of bread flour were at medium-good levels, its gluten balance was very suitable for bread-making and will contribute positively to the increase in bread volume. When the gluten index value of flat bread flours is >90%, gluten turns into a firm structure. High GI values showed that a significant increase in volume was not required as in normal bread and that gluten quality was more effective in the formation of the structure of flat breads. In general, the water activity value of flat bread flours is low, which limits the development of microbial activity (Syamaladevi et al., 2016). The ash content of bread flour was higher (0.737%) than that of flat bread flours, and it complies with the Turkish Food Codex. The ash content of flat bread flours varied between approximately 0.550-0.650. Lavash flour had the highest ash content (0.605%).

Table 2. The physicochemical and technological properties of flat bread flours.

Flours	Moisture content (%)	Wet gluten content (%)	Gluten index (%)	Swelling index of glutenin	Water activity (a_w)	Ash content[1] (%)
1	12.17±0.06[d]	27.87±0.59[a]	91.47±0.71[c]	3.17±0.47[a]	0.478±0.004[d]	0.605±0.014[c]
3	13.47±0.05[c]	26.37±0.21[b]	99.62±0.38[a]	3.53±0.31[a]	0.516±0.002[c]	0.531±0.018d
4	14.07±0.06[a]	22.83±0.25[d]	94.38±1.19[b]	3.84±0.03[a]	0.547±0.012[ab]	0.643±0.001[b]
5	13.83±0.05[b]	26.83±0.15[b]	95.26±0.74[b]	3.72±0.02[a]	0.559±0.006[a]	0.618±0.008[bc]
6	13.77±0.06[b]	25.63±0.35[c]	86.65±0.79[d]	3.38±0.03[a]	0.530±0.016[bc]	0.737±0.018[a]
mean	13.46	25.91	93.48	3.53	0.526	0.627
$LSD_{0.05}$	0.10**	0.54**	1.66**	n.s.	0.020**	0.035**

The means of the parameters of flour types in the same column marked with different lowercase letters are statistically different from each other (P<0.05). The significance between flour properties at the 1% level is indicated by two asterisks (**); n.s.: not significant; 1: Lavash; 3: Gözleme; 4: Bazlama; 5: Pide; 6: Bread (Control)

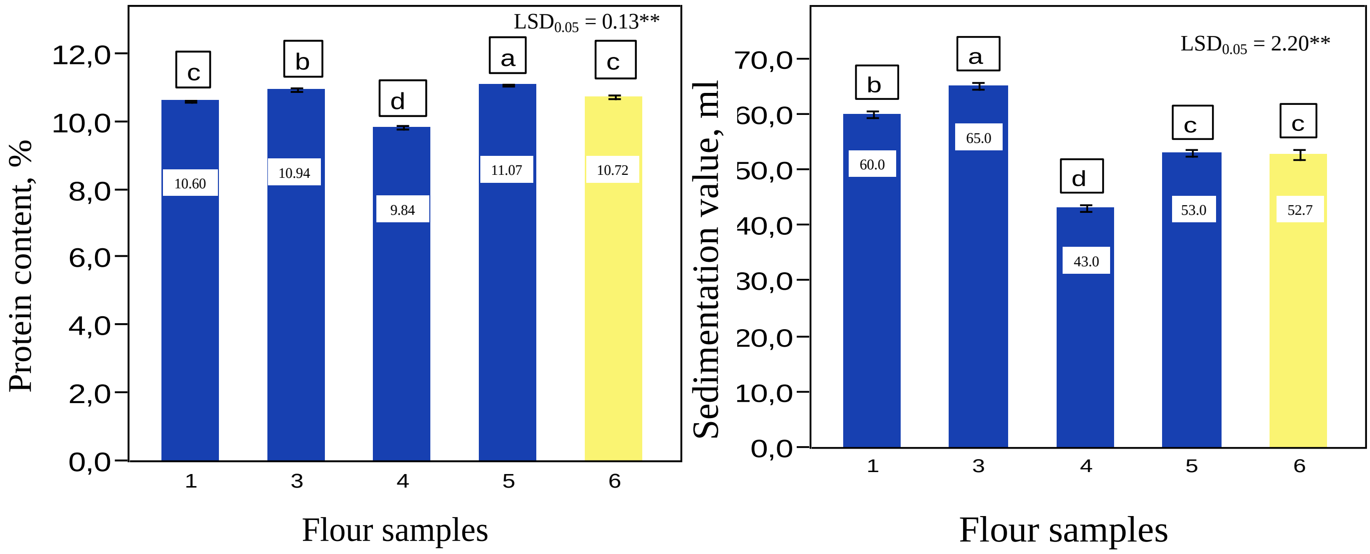

Figure 2. The protein content[1] and sedimentation value[2] of the flat bread flours (1: Lavash; 3: Gözleme; 4: Bazlama; 5: Pide; 6: Bread (Control); [1] The results have been corrected for dry matter; [2] The results have been corrected for %14 moisture).

3.3. Gluten agregation (GlutoPeak) properties of flat bread flours

The gluten aggregation (GlutoPeak) analysis results of the flours are given in Table 3. GlutoPeak PMT, BEM, W, and WA values of flours, which had statistically significant differences, are also shown graphically (Figure 3). The GlutoPeak device is a rapid test that has been used recently and has significant advantages in the cereal products industry. With the GlutoPeak device, gluten quality can be quickly distinguished (Karaduman et al., 2015, 2017, 2019, 2020). In this device, the high stirring force applied to the flour-water mixture is measured (Melnyk et al., 2011). In order to determine the quality of gluten by measuring its aggregation properties, gluten is first separated in the device, then the gluten network is formed, and with continued rapid mixing, the resulting gluten network is broken down. The time it takes to reach the maximum point, the peak height, and the decrease in the following peak are basic information in gluten quality evaluation. These properties can be determined even in whole wheat flour using 3-10 g of sample in a short time, which makes the test very valuable for the cereal industry. Among the parameters, the BEM value indicates maximum gluten resistance; the PMT value indicates the time it takes to reach BEM; the BM value represents the resistance 15 s before the BEM value; and the PM value expresses the resistance 15 s after the BEM (Chandi & Seetharaman, 2012). In the Rapid Flour Control (RFC) method, generally high BM, BEM, and PM values indicate high gluten strength and high bread-making quality. However, some weak flours can have a high maximum torque (BEM) with a tight gluten structure and a higher PM value with less decrease afterwards. As the gluten strength increases, the PMT value generally increases, and the bread-making ability increases. In the RFC, it can also be estimated by comparing protein content, gluten content, energy, and water absorption values. In the study, “Bread” flour had the longest PMT value with 102.0 s. The BM, BEM, PM, energy value, and water absorption of “Bazlama” flour, which had the lowest sedimentation, protein content, and weak gluten, were significantly lower than other flours (19.3 BU; 36.3 BU; 22.0 BU; 9.07%; 18.57%; 26.0 J; and 53.5%, respectively). However, the PMT value of “Bazlama” flour was close to “Bread” flour (96.3 s). The BEM value of “Lavash”, “Gözleme”, and “Pide” flour was above that of “Bread” flour (around 45.0 BU). Of these three flours, “Pide” and “Lavash” flours maintained their high BEM values after 15 s and gave high PM values (37.7 BU and 31.7 BU, respectively). Strong gluten provides the final product with the right level of resistance to hold the food in "Pide" and "Lavash." The “Bazlama” flour had the lowest PM value (22.0 BU). Especially in “Gözleme” flour, which had the highest sedimentation value, SRC lactic acid, and GPI values, all GlutoPeak values were the highest. “Pide” flour also had high gluten aggregation properties, close to “Gözleme” flour. These two flours had high energy and water absorption values in GlutoPeak (around 150.0 J and 60.0%).

Table 3. The gluten-rheological (GlutoPeak) properties of the flat bread flours.

Flours	BM value (BU)	PM value (BU)	Protein content (%)	Gluten content (%)
1	$28.3±9.3^{a}$	$31.7±4.51^{b}$	$10.23±0.32^{b}$	$22.00±0.95^{b}$
3	$32.0±3.5^{a}$	$40.3±1.53^{a}$	$10.80±0.10^{a}$	$23.57±0.25^{a}$
4	$19.3±1.2^{a}$	$22.0±0.00^{c}$	$9.07±0.06^{c}$	$18.57±0.15^{c}$
5	$25.3±11.0^{a}$	$37.7±0.58^{a}$	$10.63±0.06^{a}$	$23.20±0.20^{a}$
6	$21.3±4.0^{a}$	$30.3±4.16^{b}$	$9.97±0.25^{b}$	$21.17±0.81^{b}$
Mean	25.3	32.4	10.14	21.70
$LSD_{0.05}$	n.s.	5.40**	0.35**	1.05**

The means of the parameters of flour types in the same column marked with different lowercase letters are statistically different from each other (P<0.05). The significance between flour properties at the 1% level is indicated by two asterisks (**); n.s.: not significant; PM: torque after 15 s from BEM; BM: torque before 15 s before BEM; 1: Lavash; 3: Gözleme; 4: Bazlama; 5: Pide; 6: Bread (Control)

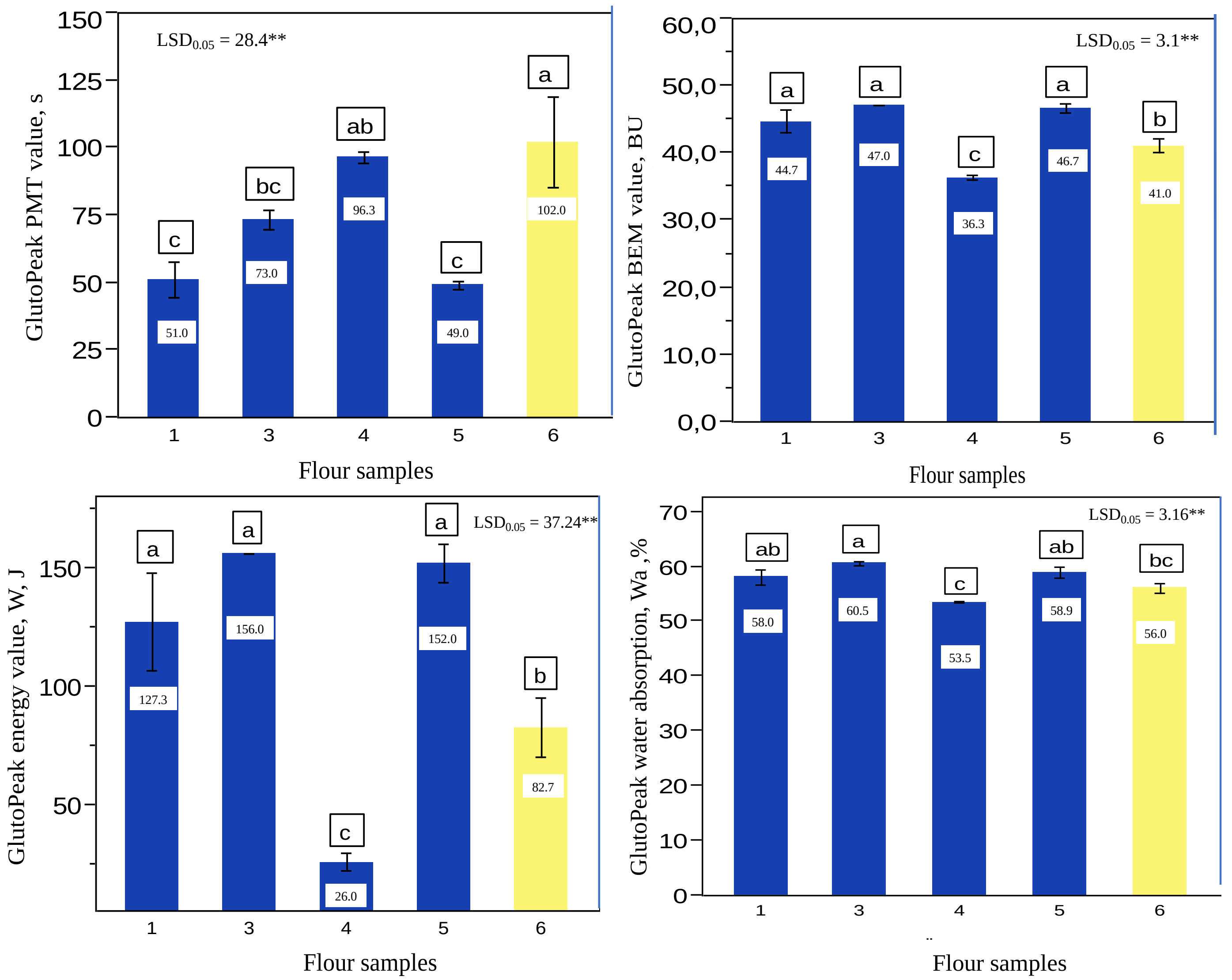

Figure 3. The gluten agregation (GlutoPeak) properties of the flat bread flours (1: Lavash; 3: Gözleme; 4: Bazlama; 5: Pide; 6: Bread (Control); PMT: peak maximum time; BEM: maximum torque; W: energy value; Wa: water absorption).

High dough gluten strength of “Gözleme" and “Pide” flours was necessary to be thinned to a low thickness, maintain its shape, and prevent the contents from spilling out. Although the gluten and protein content values of “Lavash” flour were similar to those of “Bread” flour, its energy and water absorption values were higher (127.3 J and 58.0%). The difference between “Lavash” and “Pide” flours was the short PMT values around 50 s. This showed that gluten development was rapid in these two flour doughs. However, “Lavash” flour had less continuous gluten strength (lower PM value).

3.4. The dough rheological (farinograph and rheometer) properties of flat bread flours

Dough rheological properties of bread wheat samples were determined using a farinograph and rheometer (Table 4). The farinograph stability, softening degree, and rheometer tanδ values of the flours are shown graphically (Figure 4). By kneading, all the flour components come together, and the elasticity, extensibility, and resistance of the dough are the most critical properties before obtaining the product. In bread dough, high gluten strength, tenacity, and medium-long extensibility are desired (Guzman et al., 2016). The rheological properties of dough are revealed using different devices. Doughs with high bread-making quality should have long stability, a high development time, and water absorption, and a low degree of softening (Aydoğan & Soylu, 2020). In the study, “Gözleme” flour, which had the highest gluten quality and rheological properties, was found to have the highest farinograph stability value (4.15 min) and the lowest softening degree (49.5 FU). Farinograph stability, development time and softening degree values were also good in “Pide” flour dough (3.05 min, 2.85 min, and 85.0 FU, respectively). The farinograph quality number (FQN) value of these two flours was also high (65.5 and 50.0). “Bazlama” flour had low stability, high softening, and low FQN values. The softening value was found to be the highest in “Bazlama” flour (243.5 FU). The farinograph properties of “Lavash” and “Bread” flour were similar to each other. The elastic modulus (G'), viscous modulus (G"), and tanδ G"/G' value of the dough are given in Table 4. The G′ values of all doughs were higher than the G″ values. The G′ values show the elasticity of the product and resistance to deformation (Brito et al., 2022).

Table 4. The dough rheological (GlutoPeak and Rheometer) properties of the flat bread flours.

Flours	Water absorption (%)	Development time (min)	Farinograph quality number (FQN)	Storage modulus G' (Pa)	Loss modulus G'' (Pa)
1	66.5 ± 4.1^{a}	1.55 ± 0.92^{a}	37.0 ± 1.4^{bc}	12215 ± 502.1^{c}	6433.5 ± 255.3^{c}
3	59.6 ± 0.2^{a}	3.45 ± 0.78^{a}	65.5 ± 6.36^{a}	27200 ± 1315.2^{a}	12620 ± 636.4^{a}
4	56.7 ± 2.7^{a}	1.45 ± 0.07^{a}	17.0 ± 5.66^{d}	18050 ± 1852.6^{b}	9685.5 ± 953.9^{b}
5	56.6 ± 4.0^{a}	2.85 ± 0.21^{a}	50.0 ± 4.24^{b}	24525 ± 2948.6^{a}	12035 ± 1393.0^{a}
6	60.1 ± 1.2^{a}	2.40 ± 0.14^{a}	28.0 ± 4.24^{cd}	16590 ± 56.6^{b}	8421 ± 135.8^{bc}
mean	59.9	2.34	39.5	19716	9839
$LSD_{0.05}$	n.s.	n.s.	14.5**	4318.5**	2100.6**

The means of the parameters of flour types in the same column marked with different lowercase letters are statistically different from each other (P<0.05). The significance between flour properties at the 1% level is indicated by two asterisks (**); n.s.: not significant; G': storage modulus; G":loss modulus, 1: Lavash; 3: Gözleme; 4: Bazlama; 5: Pide; 6: Bread (Control)

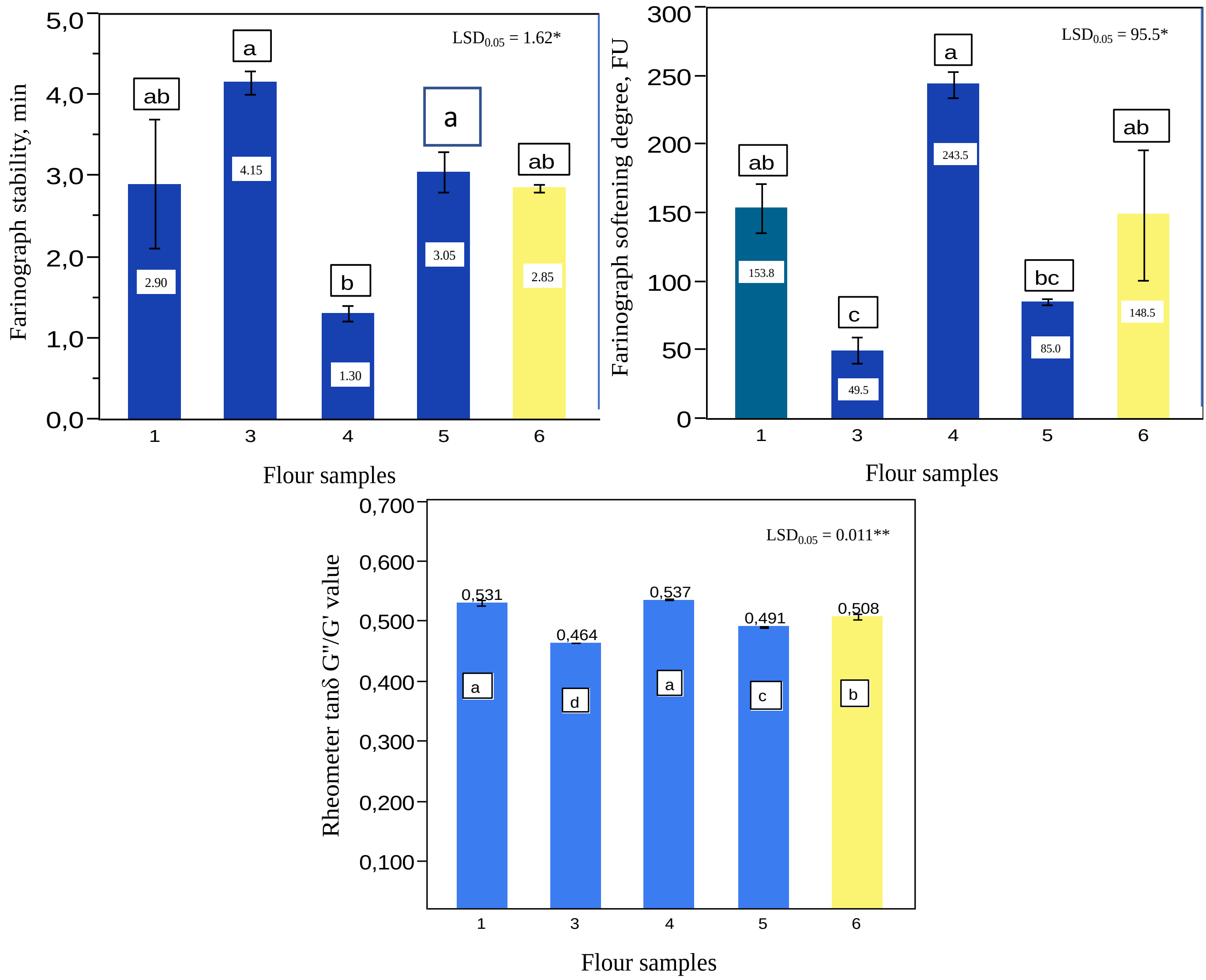

Figure 4. Dough rheological (Farinograph, Reometer) properties of the flat bread flours (1: Lavash; 3: Gözleme; 4: Bazlama; 5: Pide; 6: Bread (Control)).

The G' value of "Gözleme" and "Pide" flours, which had higher stability values in the farinograph, was found to be higher (27200 Pa and 24525 Pa). "Lavash flour" had the lowest G' value (12215 Pa). The G' values of "Bazlama" and "Bread" flour were similar (18050 Pa and 16590 Pa). A low G" value indicates that less stress is required for its extensibility (Di Mattia et al., 2015). "Gözleme" and "Pide" flours with higher storage resistance (G') had higher G" values (around 12000 Pa). "Lavash" flour had the lowest G"value (6433.5 Pa). The G" values of "Bazlama" and "Bread" flours were similar to each other. A higher tanδ value indicates the higher extensibility of the dough (Eroğlu & Orhan, 2024). "Gözleme" flour had the lowest Tanδ value (0.464). A higher tanδ value indicates the higher extensibility of the dough (Eroğlu & Orhan, 2024). "Gözleme" flour had the lowest Tanδ value (0.464). It was also low in "Pide" flour (0.491). The dough made with these flours was more elastic. The "Lavash" and "Bazlama" flours had the highest Tanδ values (0.531 and 0.537). As a result, lavash and bazlama flours have a weaker structure and are more extensible.

4. Conclusions

In the study, "Gözleme" flour was distinguished by having the highest gluten quality and dough rheological properties. The high gluten strength and dough viscoelastic properties are necessary to enable the "Gözleme" dough to be thinned and prevent the contents from spilling out. Generally, "Lavash", "Pide" and "Bread" flours had closer quality properties. Although "Lavash" and "Pide" doughs have less extensibility and gluten strength, it is necessary to change the process conditions (such as longer kneading time and adding more water), to optimize the gluten and dough viscoelastic properties. At the same time, the high dough strength helps the products have a more stable texture, extensibility without tearing, and resistance to hold the food within in the production of "Lavash" and "Pide". It was observed that "Bread" flour had moderate gluten quality and dough rheological properties. The bakery where the "Bread" flour is supplied finds this level of flour quality sufficient as it produces bread with a short-term fermentation. "Bazlama" flour had the lowest gluten strength. High dough strength is not desired, as it causes the "Bazlama" to be harder and shrinkage after the dough is thinned. This study aimed to reveal the quality characteristics of flat bread flour by comparing it with normal bread flour, whose properties are known. The results will be useful to flat bread producers to obtain standard-quality products and millers to make blends for these flours. In the study, a limited number of flat bread flours, which are consumed frequently in Eskişehir, were evaluated. Since the production techniques of flat breads may vary in different production places, new studies can be created by taking into account the process conditions. Also, it is considered an important necessity to determine in detail the nutritional contents of these flat bread flours and their properties, such as glycemic index and protein bioaccessibility, in future studies.

Ethics statements

The authors have read and followed the ethical requirements for publication and confirm that the current work does not involve human subjects, animal experiments, or any data collected from social media platforms.

Author' contributions

Yaşar Karaduman: Supervision, Collected the data, Investigation, Data curation, Formal analysis, Conceptualization, and Writing – original draft. **Onur Çiçek:** Collected the data, Investigation, Data curation, Formal analysis. **Nida Sarsılmazer:** Collected the data, Investigation, Data curation, Formal analysis. **Zeynep Sude Üstünkaya**: Collected the data, Investigation, Data curation, Formal analysis. **Eren Kaymak**: Collected the data, Investigation, Data curation, Formal analysis. **Merve Yüksel** Collected the data, Investigation, Data curation, Formal analysis.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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