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Journal of Agroalimentary Processes and Technologies 2026, 32 (1), 14-25

Journal of Agroalimentary Processes and Technologies

Study of the Effect of Mulberry Syrup on the Crumb of Bread made from Azamatlı-95 Wheat Flour

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Received 25 September, 2025; Revised 10 January, 2026, Published 15 January, 2026

Abstract

Enriching everyday food products, especially bread composition, is highly relevant. To enrich first-grade flour from Azamatli-95 wheat with proteins, vitamins, minerals, and biologically active substances, bread was prepared by adding mulberry syrup in proportions of 5%, 10%, and 15% to the wheat flour. Bread samples were evaluated based on their structural-mechanical properties, aroma, taste, crumb structure, and color. The research results showed that increasing the amount of mulberry syrup up to 5% added to Azamatli-95 wheat flour improved the organoleptically determined indicators characterizing the bread crumb. However, increasing the mulberry syrup content from 5% to 15% significantly reduced these indicators. Therefore, it is recommended to add up to 5% mulberry syrup to Azamatli-95 wheat flour when producing enriched bread.

Keywords: Azamatli-95 wheat, crumb, mulberry syrup, flour, bread.

1. Introduction

Global climate change negatively affects the health of all living organisms, including humans, as well as the quality, production, and yield of agricultural crops [1, 2]. One of the main factors affecting crop yield and product quality is drought. Drought is defined as a period of abnormally dry weather that causes a serious hydrological imbalance in a specific region [3]. Climate changes disrupt the process of photosynthesis. Theoretically, it is assumed that stimulation of photosynthesis at elevated CO_2 will be stronger at higher temperatures [4]. Plants lack sufficient synthesized nutrients. As a result, the quality and nutritional value of products (bakery products, etc.) decrease. The survival and well-being of humans and animals depend on plant production, which in turn heavily depends on the availability of minerals and other nutrients. That is why plants and animals (including humans) share several common nutrients [5-9]. Therefore, food security has become a global issue. Poor nutrition quality and nutrient deficiencies negatively affect human health, work capacity, and other factors [10-13]. This problem, of course, affects the quality of bread, which is a strategic food product. The formation of nutrients necessary for the human body, and the synthesis of organic and inorganic compounds in wheat, are reduced due to stress factors [14-16]. As a result, the amount of carbohydrates, especially starch, vitamins, biologically active substances, and mineral elements in wheat decreases. Therefore, to improve bread quality, it is desirable to use fruits. In recent decades, there has been a steady increase in rich sources of biochemical compounds, with growing popularity and research interest in all types of fruits [17]. According to literature and our research results, mulberry syrup is rich in nutrients, mainly proteins, vitamins, essential amino acids, fats, and other food components.

Citation: Omarov Y., Bayramov E., Nabiyev A., Study of the Effect of Mulberry Syrup on the Crumb of Bread made from Azamatlı-95 Wheat Flour, Journal of Agroalimentary Processes and Technologies 2026, 32 (1), 14-25
DOI: 10.59463/JAPT2026.1.2

Mulberry (Morus alba L), belonging to the Moraceae family, is widely distributed in Asia, Africa, Europe, South and North America [18].

Morus alba L. is widely cultivated in Asia, especially in China, Japan, and India, for rearing silkworms as well as for its edible fruits [19, 20]. Mulberry has been cultivated in Azerbaijan since ancient times as a valuable plant. Three types of mulberry grow in the country: white, black, and red. White and black mulberries are more common. White mulberry grows wild in tugai forests (small forested areas along rivers) in the Samur-Davachi zone. It is also widespread in the Kura-Araz and Alazani-Ayrichay lowlands. Additionally, mulberry grows in most parts of the country (Masalli, Ordubad, Ganja). Black mulberry can also bear fruit in plains and foothills. Black mulberry, also known as khartut, is widespread in Absheron. Among the mulberry species, khartut is considered the most valuable and beneficial. It contains 9% sugar, 2.3% organic acids, 2% protein, and 0.55% pectin [21].

The nutritional value of bread can be increased by adding a small amount of mulberry syrup to wheat flour during bread production. This may affect the structural-mechanical properties, porous structure, color and condition of the crumb, bread aroma, and taste qualities. Therefore, the aim of this work is to study the organoleptic indicators of bread crumb enriched with mulberry syrup based on sensory evaluations.

2. Materials and method

2.1. Raw materials

The object of the study was first-grade flour obtained from Azamatli-95 wheat. Azamatli-95 wheat was developed through selection at the Azerbaijan Scientific Research Institute of Crop Production. Mulberry syrup was used as the enriching agent. Mulberry syrup was added to the wheat flour in amounts of 5%, 10%, and 15% of the total flour mass.

The methods of the research: theoretical studies – comparative analysis of the literature resources, experimental studies – experiments based on the GOST standards.

Table 1 shows the preparation variants of bread samples.

Table 1. Variants for making bread

Variants	Flour from the variety wheat Azamatli-95	Mulberry syrup
Control	100	0
I	100	5
II	100	10
III	100	15

The research was carried out at the “Food Engineering and Expertise” department of the Azerbaijan Technological University, “Ganja-Deyirman”, Ganja “NEON” enterprises, and at the laboratories of the Georgian Research Institute and the ARİCH.

Mulberry syrup with 70% moisture content was purchased from the "Hyper Gold Amina" market in Ganja, along with dry yeast branded "Pakmaya" (Turkey) with 8% moisture content and iodized salt "Azeriduz" (Azerbaijan) with 3% moisture content.

2.2. Flour analysis

Flour analysis was conducted using well-established methods.

For wheat flour, the following parameters were determined: quantity and extensibility of raw gluten, gluten deformation index (GDI), flour moisture content, color, ash content, and falling number.

The content of wet gluten in first-grade wheat flour of the Azamatli-95 (A95) variety was determined according to GOST standards. Gluten extensibility was measured using a ruler, the gluten deformation index (GDI) was measured using the “GDI-1M” device, flour moisture content was measured using the “Pfeuffer HE-50” device (Germany), flour color was measured using the “P3-TBMS-M” device, and the falling number (FN) was measured using the “Hagberg-Perten” device (Switzerland).

2.2.1. Determination of wet gluten content

The wet gluten content in wheat flour was determined by manual washing, as described in detail in the literature [22]. Dough was prepared in a porcelain bowl by adding 14 ml of water to 25 g of flour. The water and flour were mixed until a completely homogeneous dough was obtained. The water temperature was 18°C (±2°C). Any particles sticking to the pestle, fingers, or mortar were cleaned off and added to the main dough mass. After kneading, the dough was hand-pressed, rolled

into a ball, placed in a bowl, covered with glass (to prevent drying), and left to rest for 20 minutes at 18°C (±2°C) to allow the flour to absorb the water evenly. After 20 minutes, the gluten was washed under a gentle stream of water over a fine sieve. Initially, washing was done carefully by kneading the dough with fingers to avoid tearing off pieces of dough or gluten along with the starch. Once most of the starch and bran were removed, washing was done more vigorously between both palms. Detached pieces of gluten were carefully collected from the sieve and added to the total gluten mass. Washing continued until the bran was almost completely removed and the water squeezed from the gluten was clear (without turbidity). The washed gluten was pressed between palms and wiped with a dry towel. During this process, the gluten was turned inside out several times and re-pressed until it began to slightly stick to the hands again.

The pressed gluten was weighed with an accuracy of two decimal places, then washed again for 5 minutes, re-pressed, and weighed again. Washing was considered complete when the difference between the two weighings did not exceed 0.1 g. The wet gluten content (in %) in the flour was calculated using a formula:

$$\%\ \text{gluten} = \frac{\text{the mass wet gluten} \times 100}{\text{the mass of flour sample}}$$

The result of the analysis was taken as the arithmetic mean of two determinations, provided the convergence requirement was met.

2.2.2. Determination of wet gluten quality

The quality of wet gluten was determined by its extensibility, as described in detail in the literature [23]. From the pressed gluten obtained by the manual washing method described in subsection 2.2.1, a 4 g sample was weighed using laboratory scales. The weighed piece of gluten was kneaded with fingers 3–4 times and shaped into a ball. The ball was placed in a dish with water at a temperature of 18–20°C for 15 minutes, after which extensibility was measured.

Extensibility of wet gluten refers to its ability to stretch in length. To determine extensibility, the gluten was held with three fingers of both hands and stretched evenly over a ruler with millimeter divisions until it broke, ensuring the stretching process lasted about 10 seconds. Twisting of the gluten during stretching was not allowed. At the moment of rupture, the length to which the gluten had stretched was recorded.

Based on extensibility, wet gluten was classified as follows:

- **Short**: extensibility up to 10 cm;
- **Medium**: extensibility from 10 to 20 cm;
- **Long**: extensibility over 20 cm.

2.2.3. Determining the wet gluten deformation index

The deformation index of wet gluten was determined using the IDK-1M device (Zelaz, Yekaterinburg, Russia) [24]. To assess the quality of wet gluten, a 4 g sample was taken from the fully washed, pressed, and weighed gluten. The sample was kneaded 3–4 times with fingers to form a smooth, spherical shape without surface tears. The manually formed gluten ball was placed in a dish with water at 18–20°C and then into a container with 2–3 dm^3 of water at the same temperature. The resting time for the gluten was 15 minutes. After resting, the gluten ball was removed from the dish and placed base-down in the center of the IDK-1M device table. When measuring compressive strain, the punch descends and compresses the gluten for 30 seconds. After the specified time, the punch movement automatically stops, and the reading is recorded on the instrument scale. After the punch automatically returns to its upper position, the gluten is removed from the instrument table. The arithmetic mean of two parallel determinations was taken as the gluten quality indicator. The results of gluten elastic property measurements were expressed in arbitrary instrument units, and based on these values, the gluten quality group was determined according to requirements.

The quality indicator of the gluten was taken as the arithmetic mean of two parallel measurements. The results of the elastic property measurements were expressed in arbitrary units of the device, and based on their values, the gluten was classified into the appropriate quality group according to the standards.

2.2.4. Determining of flour moisture content

The moisture content of the flour was determined using the “Pfeuffer HE-50” device

(Pfeuffer GmbH, Kitzingen, Germany). This device is a microprocessor-based electronic instrument that operates on the dielectric method of moisture measurement. The moisture meter passes an electric current through the flour and calculates the moisture content based on how quickly the current decays.

A flour sample was loaded into the lower part of the measuring cell and screwed in tightly. The measuring cell was then placed on the measuring unit, the selector was turned to the flour setting, and the measurement button was pressed. Within a few seconds, the temperature was automatically adjusted, and the measurement result was displayed.

2.2.5. Determining of flour color

Flour color was determined using the R3-TBMS-M device (EKAN, Sankt-Peterburg Russia). After thoroughly mixing the test flour, a portion weighing approximately 20 g was placed on a clean white sheet of paper. A measuring ring was mounted on the tester cylinder by carefully fitting it onto the circular ridge with the inner circular mark facing upward. The flour was gently poured from the paper onto the glass until it covered the circular mark inside the measuring ring. Using a plastic sampling spoon, the top layer of flour was lightly leveled, and a compactor was gently placed on top without applying pressure.

The flour whiteness value displayed on the indicator was recorded in arbitrary units. The used flour was then discarded. The measurement procedure was repeated, and the second reading was recorded. The whiteness of the tested flour, expressed in digital indicator readings, was determined as the arithmetic mean of the measurement results for two portions of flour isolated from the same sample, rounded to the nearest whole number. The permissible difference between the two portions of flour isolated from the same sample did not exceed one indicator reading, which corresponds to one arbitrary unit.

2.2.6. Determining the falling number of flour

The falling number of the flour was determined using the Hagberg-Perten device (PerkinElmer, Stockholm, Sweden).

Before starting the measurement, the water bath was filled to the limit level. The cooling system was turned on, and it was ensured that cold water flowed through the cooling lid. The falling number equipment was turned on, and the water was brought to a boil. The water bath was kept at a vigorous boil before and throughout the analysis.

A flour sample was placed into a clean, dry viscometer tube. Using an automatic pipette, 25 ± 0.2 cm³ of water at 22 ± 2°C was added. The viscometer tube was quickly sealed with a rubber stopper and shaken vigorously by hand up and down 20–30 times until a homogeneous suspension was formed. It was checked that no flour particles remained near the stopper at the top of the tube. Any particles stuck to the walls were returned to the suspension by slightly lifting the stopper and shaking the tube as needed.

The stopper was removed, and any remaining particles on its underside were returned to the tube. A viscometer stirrer was used to collect any remaining product from the tube walls. The stirrer was left inside the tube.

The viscometer tube with the stirrer was immediately placed into the boiling water bath through the lid opening. The tube was secured in place so that the device's photo sensor aligned with the stirrer. At this point, the timer automatically started. Five seconds after immersion, the stirrer began to mix the suspension automatically. After 60 seconds, the stirrer stopped in the upper position, and then began to fall freely. When it reached the bottom, the timer stopped automatically.

The falling number was determined from the timer — the time in seconds from the immersion of the tube into the water bath to the complete descent of the stirrer. The measurement was repeated twice.

The final falling number result was taken as the arithmetic mean of the two parallel determinations, with an allowable difference between them not exceeding 10% of their average value.

2.3.Preparation of flour, yeast suspension, and salt solution

During flour preparation for production, it was sifted and cleaned of impurities. Since the dry matter content in flour varies depending on its moisture, flour corresponding to 960 g of dry matter was used.

The mass of flour required for dough preparation was calculated using a specific formula:

$$\text{The mass of flour} = \frac{\text{The mass of the dry matter of flour} \times 100}{(100 - \text{Flour moisture})}$$

To ensure even distribution of yeast and salt in the flour, they were used in liquid form. Compressed yeast was finely chopped, dissolved in water at a ratio of 1:3, and used as a suspension. Salt was dissolved in water at a ratio of 1:4 and added to the wheat flour as a solution during dough mixing.

The mass of yeast suspension required for dough preparation was calculated using the formula:

$$\text{The mass of yeast suspension} = \frac{\text{The mass of flour} \times \text{mass of yeast} \times (1+3)}{100}$$

Where: 1 - mass of yeast, g; 3 - mass of water, ml.

The mass of salt solution required for dough preparation was calculated using the formula:

$$\text{The mass of the saline solution} = \frac{\text{The mass of flour} \times \text{mass of salt} \times 100}{1000 \times 26}$$

Where: 26 - is the mass of salt in 100 ml of solution, g; 1000 - is the conversion factor for flour.

The mass of syrup added to the wheat flour was also calculated using a specific formula:

$$\text{The mass of syrup} = \frac{\text{The mass of flour} \times \text{percentage of syrup added}}{100}$$

Baking was carried out under laboratory conditions [24].

2.4. Bread making

The dough was prepared using a single-phase method. The raw material consumption under production conditions was calculated using Microsoft Excel based on the corresponding formulas [25].

Table 2 shows the raw material consumption for preparing dough from wheat flour with 14% moisture content and 960 g of dry matter.

The technological parameters were adapted to production conditions:

•The dough temperature after kneading was required to be 32°C, and the temperature of the water used for kneading was not to exceed 45°C.

- During the experiment, the flour temperature was 24°C.
- Dough was prepared using a B20 spiral mixer (China) with a multi-speed drive.

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Table 2. Consumption of raw materials for the preparation of wheat flour dough with a moisture content of 14 % with a content of 960 g of dry matter

Raw materials and semi–finished products	Moisture content, %	Mass of raw material, g			
		Control	Dough preparation options		
			I	II	III
1– grade wheat flour	14.0	1116.3	1116.3	1116.3	1116.3
Yeast suspension	93.75	6.7	6.7	6.7	6.7
Salt solution	74.78	6.44	6.44	6.44	6.44
Mulberry syrup	70.0	–	55.81	111.63	167.44
Water for kneading	100.0	588.52	562.60	536.69	510.78
Dough	44.0	1717.9	1747.8	1777.7	1807.4

Dough was prepared using a B20 spiral mixer (China) with a multi-speed drive. To prepare the dough, the following ingredients were added to the mixing bowl: flour, water, salt solution, yeast suspension, and mulberry syrup. The mixture was kneaded for 10 minutes until a homogeneous mass was obtained:

- First 6 minutes at 100 rpm for mixing
- Then 4 minutes at 166 rpm for kneading

After kneading, the dough was weighed, its temperature measured, and then placed in a thermostat at (31±1)°C for 60 minutes of fermentation.

- The relative humidity in the thermostat was maintained at 80–85%.
- After 30 minutes of fermentation, the dough was kneaded again for 2 minutes at 100 rpm.

Fermentation was monitored by measuring the final acidity and observing the doubling of dough volume. The dough moisture content was 44%.

After fermentation, the dough was divided into three equal parts.

- Two dough pieces were shaped into baton-like forms;
- One piece was shaped into a ball.

The baton-shaped dough pieces were placed into metal molds pre-greased with vegetable oil. For baking hearth bread, the spherical dough was placed on a round metal tray.

The molds and tray with the dough were placed in a thermostat for final proofing at a temperature of 35–40°C and relative humidity of 75–85%. Since the proofing time depends on many factors, it was not fixed and could be adjusted. The end of proofing was determined organoleptically by the condition and appearance of the dough.

After proofing, one mold and the tray were placed into the oven first, followed by the second mold after 5 minutes. Bread samples were baked in an oven at 220–230°C after humidifying the baking chamber. The dough in molds was baked for 32 minutes, and the dough on the tray for 30 minutes.

After baking, the top crust of the bread samples was sprayed with water and weighed. Bread quality was evaluated after cooling for 8 hours post-baking. Moisture content was determined using drying method 930.15 [26], resulting in 43.8%, 43.8%, 44.0%, and 43.9% for the control, I, II, and III variants respectively.

2.5. Sensory analysis

Bread crumb samples were presented to a panel of 10 trained tasters (six men and four women aged 48 to 65) to assess sensory properties. Participants were selected based on their sensory skills and trained in sensory vocabulary and attribute identification. Each sample was placed on white plates and labeled with random three-digit numbers.

The crumb was evaluated for structural and mechanical properties, pore structure, color and appearance, aroma, and taste. Overall quality was rated on a 5-point scale. Below are the descriptors used for evaluating the organoleptic characteristics of the bread crumb samples.

2.5.1. Evaluation of structural and mechanical properties of crumb

A sliced bread sample was pressed with one or two fingers (at least 1 cm deep), and its recovery after deformation was observed.

- **5.0 points** – very soft, tender, and elastic;
- **4.0 points** – soft and elastic;
- **3.0 points** – moderately soft, slightly dense, and elastic;
- **2.0 points** – noticeably dense but elastic, or soft and heavily compressed;
- **1.0 point** – very squishy, moist to the touch, and sticky.

2.5.2. Evaluation of crumb porosity

Porosity was assessed by pore size (small, medium, large), distribution across the cut surface (uniform, fairly regular, irregular, uneven), and pore wall thickness (thin, medium, thick).

- **5.0 points** – small, thin-walled pores evenly distributed;
- **4.0 points** – small and medium or only medium pores, thin-walled, fairly evenly distributed;
- **3.0 points** – varied pore sizes, medium thickness, uneven distribution;
- **2.0 points** – very small or large thick-walled pores, few dense areas, noticeable crumb separation from crust;
- **1.0 point** – many dense areas, crumb fully separated from crust, unbaked spots, large gaps.

2.5.3. Evaluation of crumb color

Color was assessed in daylight. Bread was carefully sliced with a sharp knife and divided into two equal parts. Evaluated by base color (white, gray, dark, slightly dark), hue (yellowish, yellow, grayish, gray, etc.), and uniformity (even, uneven).

- **5.0 points** – very light;
- **4.0 points** – light;
- **3.0 points** – grayish or yellowish;
- **2.0 points** – gray or yellow;
- **1.0 point** – dark gray or yellow.

2.5.4. Evaluation of crumb aroma

The aroma (smell) of the bread was evaluated as follows:

- **5.0 points** – intensely expressed, typical bread aroma;
- **4.0 points** – well expressed, characteristic bread aroma;
- **3.0 points** – mildly expressed, characteristic bread aroma;

- **2.0 points** – weak, slightly off but acceptable;
- **1.0 point** – strongly sour, bitter, off-putting, unpleasant.

2.5.5. Evaluation of crumb taste

The taste of bread was evaluated as follows:

- **5.0 points** – intensely expressed, typical bread taste
- **4.0 points** – well expressed, characteristic bread taste
- **3.0 points** – mildly expressed, characteristic bread taste
- **2.0 points** – bland, slightly sour, doughy
- **1.0 point** – completely bland, sharply sour, salty, off-putting, unpleasant

2.6. Statistical analysis

The results were statistically processed using one-way analysis of variance (ANOVA). Correlation analysis between the variants was conducted using Microsoft Excel 2016 at a significance level of $p < 0.05$ [27].

3.Results and discussions

The flour analysis yielded the following results:

- Wet gluten content – 31.6%;
- Wet gluten extensibility – 9.5 cm;
- Gluten Deformation Index (GDI) – 77.8 units;
- Flour moisture content – 14%;
- Flour color – 52.5 units;
- Flour ash content – 0.6%;
- Falling Number (FN) – 265 seconds.

According to [28], the gluten content in Azamatli-95 wheat ranges between 30–32%. However, Hasanova et al. [29] found that Azamatli-95 wheat grown at the Terter Experimental Station had a gluten content of 34% and a GDI of 105.7 units. It was substantiated that gluten content in grain varies depending on cultivation conditions and environmental factors. This was further confirmed in a study of Azamatli-95 wheat grown at the Agstafa auxiliary experimental farm, where post-harvest storage duration was shown to affect gluten content. The average gluten content was 31.6%, with a GDI of 94.1 units [30].

In evaluating the crumb of bread samples, sensory attributes such as structural-mechanical properties, aroma, taste, porosity, and color were assessed. The sensory evaluation of bread crumb made with 5%, 10%, and 15% mulberry syrup added to flour from Azamatli-95 wheat is presented in Table 3. As shown in Table 3, the control bread received a score of 4.1 for crumb texture, as the crumb of samples without mulberry syrup was soft and elastic. Bread samples from variant I scored 4.8, as their crumb was very soft, tender, and elastic – 0.7 points higher than the control. Variant II samples scored 4.6, indicating a softer and more elastic crumb – 0.5 points higher than the control. Variant III samples scored 3.8, with a crumb that was soft, slightly dense, and elastic – 0.3 points lower than the control. This aligns with findings in [31], which reported that adding mulberry leaf powder increases crumb pore density and bread firmness.

Pore structure analysis of the control bread showed medium-sized, thin-walled, and fairly evenly distributed pores, scoring 4.3. Variant I scored 4.9 due to small, thin-walled pores that were more uniformly distributed – 0.6 points higher than the control. Variant II scored 4.4, with medium, thin-walled, evenly distributed pores – 0.1 points higher than the control. Variant III scored 4.1, with medium and fairly evenly distributed pores – 0.2 points lower than the control and variant I. This trend was also observed in [31], which found that mulberry leaf powder increases pore size in bread crumb.

Study [32] showed that bread with 10% mulberry filtrate had the highest overall acceptability. There was no significant difference in crumb texture, except that hardness increased with 30% filtrate addition.

Thus, it was established that adding up to 5% mulberry syrup to Azamatli-95 wheat flour improves crumb pore structure. However, increasing the syrup concentration from 5% to 15% gradually worsens pore structure. This agrees with [33], which showed that adding more than 15% sprouted legume flour reduces specific volume – lower than the control – despite improved porosity. When the level exceeded 20%, porosity declined.

As seen in Table 3, bread porosity in Variants I and II was better than the control, while Variant III was slightly lower. This supports findings in [31], which showed that mulberry leaf powder worsens crumb porosity. Study [34] also found that bayberry leaf addition reduces crumb pore size and bread height, attributed to decreased dough stability and

porosity during fermentation [35].
Study [36] showed that mulberry leaf extract has little effect on crumb texture, suggesting its potential for health-oriented products without compromising texture – an idea supported by [37].

Table 3. Evaluation of bread crumb from Azamatli-95 wheat flour with mulberry syrup addition

Variants	Crumb SMP	Pore structure	Color of crumb	Aroma (smell)	Taste	Average point
Control	4.1	4.3	4.8	4.2	4.4	4.4
I	4.8	4.9	4.7	4.8	4.8	4.8
II	4.6	4.4	3.7	4.5	4.6	4.4
III	3.8	4.1	3.4	4.4	4.3	4.0

Color analysis showed that up to 5% mulberry syrup slightly affected crumb color, while 5-10% had a more pronounced effect. The control bread had a very light crumb color and scored 4.8. Variant I had a slightly brighter crumb and scored 4.7. Variant II was slightly yellowish and scored 3.7. Variant III was more yellowish and scored 3.4-1.4 points lower than the control and 1.3 points lower than Variant I. This was also observed in [31], which found that mulberry leaf powder darkens crumb color. Study [36] confirmed that crumb color darkens with mulberry leaf extract. Similarly, [34] found that bayberry leaf addition darkens bread crumb color.
The analysis of bread samples prepared using all variants showed that mulberry syrup positively influences the aroma of bread crumb.

- The aroma of the control variant crumb was rated 4.2 points, as it had a typical wheat bread aroma.
- Variant I received 4.8 points for its crumb aroma, which was strongly expressed and distinctly bread-like.
- Variants II and III were rated 4.5 and 4.4 points, respectively, as their aroma was very pleasant compared to the control.

As the syrup concentration increased to 5%, the bread's aroma improved. However, with syrup concentrations from 5% to 15%, the bread's flavor profile changed and the mulberry aroma became more pronounced. Thus, tasters rated the aroma of Variants II and III lower than Variant I. Nevertheless, all syrup-enhanced variants scored higher in aroma than the control. This finding aligns with [31], which reported that mulberry leaf powder enhances bread aroma.
The analysis also showed that mulberry syrup positively affects the taste of bread crumb.
The control variant's taste was rated 4.2 points, reflecting a typical wheat bread flavour.
Variant I scored 4.8 points for its strongly expressed and characteristic bread taste. Variants II and III scored 4.5 and 4.4 points, respectively, with very pleasant flavors compared to the control.
As syrup concentration increased to 5%, the bread's taste improved. With concentrations from 5% to 15%, the taste gradually changed and the mulberry flavor became more pronounced. Therefore, tasters rated the taste of Variants II and III lower than Variant I. Interestingly, Variant III's taste was rated lower than the control, suggesting a threshold effect. This is consistent with [31], which found that bread with mulberry leaf powder has a unique flavor profile.
For visual representation, the average crumb scores of all bread samples are illustrated in Figures 1 and 2.
Tables 4 and 5 present the results of statistical processing of sensory evaluations for the organoleptic descriptors of bread crumb. As shown in Table 4, the F-value is less than the α threshold, confirming the acceptability of Variant I, which includes 5% mulberry syrup added to wheat flour.
A low P-value indicates the observed data is unlikely due to chance, suggesting the null hypothesis should be rejected. The *P-value* is less than the alpha level (p<0.05), that's whythe result is considered statistically significant ($P > \alpha$); *df* - degrees of freedom (total observations minus one); *SE* - standart error; the lowest SE was observed in variant I; Student's t-test used to determine whether differences between variants are statistically significant; confidence interval – indicates that 95% of mean values fall within two standard errors above and below the average. These results align with findings in [38].

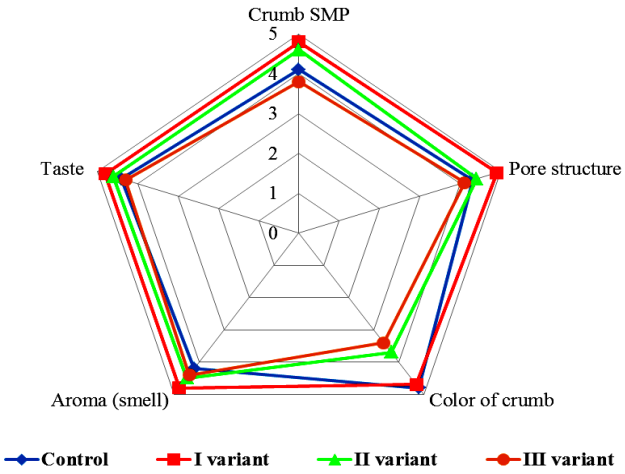

Figure 1. The results of tasting the crumb of all bread samples by average points

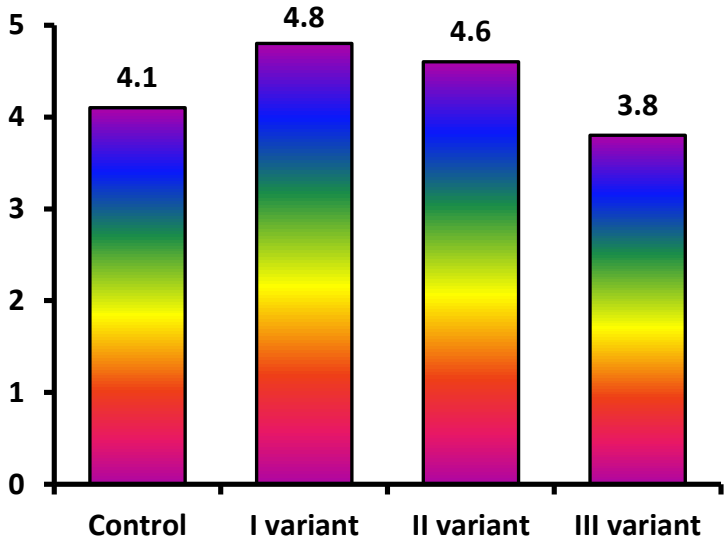

Figure 2. Tasting Results of Bread Crumb Samples by Average Scores

Table 4. Statistical processing of sensory evaluations of bread crumb organoleptic descriptors

Variants	*Count*	*Sum*	*Average*	*Variance*	*SE*	*t-test*	*α*	*confidence interval*
Control	5	21.8	4.4	0.073	0.121	2.31	0.05	0.21
I	5	24	4.8	0.005	0.032	2.31	0.05	0.07
II	5	21.8	4.4	0.143	0.169	2.31	0.05	0.30
III	5	20	4.0	0.165	0.182	2.31	0.05	0.33

Table 5. One-Way ANOVA of sensory evaluations for bread crumb organoleptic descriptors

Source of variation	*SS,*	*df*	*MS,*	*F*	*P-value*	*F crit*
Between variants	1.608	3	0.536	5.554	0.0083	3.24
Within variants	1.544	16	0.096			
Total	3.152	19				

MS - mean square; SS - sum of squares; F crit - critical F-value at the threshold α for rejecting the null hypothesis; P-value - statistical significance measure;

The results of the one-way ANOVA show that variant I is the most acceptable bread preparation method. Thus, sensory analysis confirms that Azamatli-95 wheat flour mixed with 5% mulberry syrup produces the best crumb quality – including structural and mechanical properties, porosity, color, aroma, and taste – compared to other variants.

As shown in Table 4 Control and Variant II scored 4.4;Variant I scored 4.8;Variant III scored 4.0.

According to overall crumb ratings: 1st place: Variant I; 2nd place: Control and variant II; 3rd place: Variant III.

4. Conclusions

The tasting results confirmed that the crumb quality of bread made with the addition of 5% mulberry syrup to first-grade flour from Azamatli-95 wheat surpassed all other variants. As the concentration of mulberry syrup increased to 5%, the sensory evaluation scores – reflecting crumb texture, aroma, taste, and appearance – also improved. However, when the syrup concentration increased from 5% to 15%**,** these scores declined significantly.

Therefore, for the production of fortified bread**,** it is recommended to add up to 5% mulberry syrup to flour made from Azamatli-95 wheat to achieve optimal crumb quality and sensory appeal.

Conflict of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

Acknowledgements

We express our gratitude to the Department of Food Engineering and Expertise of the Azerbaijan Technological University.

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