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Accelerated technology for bread preparation using activated water

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ABSTRACT

In this study we studied the production of bakery products with an accelerated production cycle using different dispersed flour and ion-ozoned water. The dough was prepared by mechanical loosening of compressed air under pressure (1.5-3 atm). The accelerated technology of bread production combined with wholemeal flour increases the independence of the bakery and reduces the production time of the finished product. The air bubbles in the cavitation process create a finer texture and more airy porous products resulting in higher-quality bread with excellent sensory and textural properties. The accelerated method eliminates yeast from the formulation and expands dietary varieties of yeast-free bread and flour confectionery products. This study used new accelerated technology to quickly intensify the colloidal and biochemical processes that occur during dough preparation. The technology made it possible to eliminate the dough fermentation and proofing process, thereby reducing the duration of the production process of bakery products, increasing labour productivity, and increasing the yield of bread. Qualitative, organoleptic, physicochemical and microbiological indicators and safety indicators evaluated the bakery products. The results showed that the quality of fine and ultrafine disperse flours met the recommended standards for baking yeast-free bakery products. According to laser diffraction data, the average particle size of flour obtained by whole grain milling was 194.9 µm (micron) for fine wheat flour, 609.4 µm for fine wheat flour and 830.0 µm for medium wheat flour. The finest flour fractions (less than 75 µm) provide higher gluten quality, resulting in a better balance of elasticity and extensibility in the dough, according to particle size studies of flours used to create bread. Thus, bakers can give their bread the desired texture. The overall quality of the bread is also affected by the flour's protein content, with the 10-11.5% range considered ideal. The addition of sourdough has improved the taste of baked goods. Bread products made from different dispersed flour and ion-ozoned water had good quality, organoleptic, physicochemical and microbiological indicators, and safety indicators. They could be stored for up to 5 days. As a result of using the accelerated method of dough preparation will improve the structural-mechanical, rheological and technological properties of bread, bakery and flour confectionery products.

Keywords: bread, particle size, dispersity, wheat, ion-ozoned water

INTRODUCTION

Bread is the staple food consumed worldwide, and its production and consumption have increased significantly in recent years. Consequently, there is a constant need to develop new technologies that can increase bread production without compromising its quality. In times of economic recession and trade wars, the issue of food security becomes acute. Access to basic foodstuffs can be disrupted, leading to shortages and rising prices. One way to solve this problem is to develop technology for accelerated bread production with a long shelf life.

Benefits of this technology include cost effectiveness, reduced food waste and increased efficiency. Bread with a longer shelf life can reduce food waste and lower costs for producers and consumers. Accelerated bread technology can also produce bread faster and in larger quantities, satisfying demand in a shorter time **[1]**, **[2]**.

In this research paper, we propose the development and implementation of the technology of accelerated bread production with a long shelf life as a solution to the problems arising during the crisis, economic recession and the instability of raw material supply. The article will discuss the advantages of this technology and provide evidence of its effectiveness in solving food security problems. By highlighting the importance of this technology, we hope to encourage further research and investment in developing solutions to food security problems.

Previous studies have not considered the importance of phytic acid breakdown, which has an important role in the digestion of cereal, seed, and legume origin foods in the human gut. Phytic acid, also known as inositol hexaphosphate (IP6), is a naturally occurring compound in many plant foods, especially seeds, grains and legumes. It is a stored form of phosphorus in plants and plays a crucial role in their growth and development **[3]**, **[4]**.

Phytic acid has been shown to have both positive and negative effects on human health. On the one hand, it is thought to have antioxidant properties and may help reduce the risk of certain cancers, cardiovascular diseases and osteoporosis. On the other hand, it may bind to essential minerals such as iron, zinc and calcium, reducing their bioavailability and absorption in the gut.

Some traditional cooking methods include soaking, fermenting or germinating grains, seeds and legumes to reduce the negative effects of phytic acid. These methods help break down phytic acid and improve the bioavailability of essential minerals.

This naturally occurring compound found in many grains and legumes can reduce the bioavailability of important minerals such as iron, zinc, and calcium. This can lead to mineral deficiencies, especially in populations that rely heavily on plant-based foods **[5]**, **[6]**, **[7]**.

Although accelerated bread production has successfully met the growing demand for bread, the production process may not have considered the impact of phytic acid on the nutritional value of bread. However, recent studies have shown that incorporating sourdough into the bread-making process can significantly reduce phytic acid content and improve mineral bioavailability.

Lactic acid bacteria and yeast in sourdough produce phytase, an enzyme that breaks down phytic acid. This can help increase the availability of minerals in bread and improve the nutritional quality of this staple food **[8]**, **[9]**, **[10]**.

Therefore, it is important to consider the effects of phytic acid when making bread, especially in populations that rely heavily on plant-based foods. Using traditional fermentation methods, such as sourdough, can help reduce the negative effects of phytic acid and improve the nutritional quality of bread. To address the phytic acid problem in bread making, we used the traditional method of soaking the grains and incorporating sourdough into the recipe. Sourdough contains lactic acid bacteria and yeast that produce phytase, an enzyme that breaks down phytic acid and improves the bioavailability of minerals. Using sourdough in the production process of bread, we were able to reduce the negative effects of phytic acid and increase the nutritional value of the bread **[11]**, **[12]**, **[13]**.

One technology that has attracted attention in recent years is the use of ion-ozoned water in the bread-making process. It has been found that activated water effectively disinfects and improves the quality of baked goods. However, it is necessary to investigate the effect of using different dispersed flours in combination with ion-ozone water on the quality and production cycle of baked goods.

Ion-ozone technology and dough sheeter have a number of undeniable advantages over other bread-making methods. Ion-ozone technology uses ozone to break down gluten, resulting in a smoother, more elastic dough that can be handled more efficiently. This results in higher productivity and lower costs, as less time and energy are needed to produce high-quality bread.

In addition, ion-ozone technology and the dough mixer improve bread shelf life by reducing oxidation and ensuring better dough quality. This can reduce food waste and increase profitability for bakeries and food manufacturers.

Compared to other methods of bread production, ion-ozone technology and the dough mixing machine represent a more environmentally friendly and cost-effective solution. Traditional bread production methods often require chemical oxidizers, which can harm the environment and lead to increased costs. In contrast, using ozone in ion-ozone technology is a more environmentally friendly and cost-effective alternative.

Ion-ozone technology and the dough mixer can also reduce the allergenicity of bread, which can be helpful for people with gluten sensitivity or celiac disease. By breaking down the gluten protein, ion-ozone technology helps reduce the amount of gluten in the final product, making it safer for people with gluten sensitivity.

In general, ion-ozone technology and the dough mixer provide a number of advantages over traditional methods of bread production. These advantages include improved dough quality, increased efficiency, longer shelf life, reduced allergenicity and environmental safety **[14]**, **[15]**, **[16]**.

Recent studies have shown that whole wheat dispersed flour can significantly improve the quality of baked goods. Dispersed flour is produced by processing wheat grains into fine particles. Such flour has a higher ability to absorb water and improves baked goods' texture and shelf life. Therefore, the combination of dispersed flour and ozone water can lead to baked products with improved quality and an accelerated production cycle.

This study aimed to develop a new bread product with an accelerated production cycle using various dispersed flours and ion-ozonated water. To achieve this goal, we set the following objectives: (1) to investigate the quality of various dispersed flours and choose the most suitable ones for bread product; (2) to develop a recipe for bread product based on the selected flours and evaluate its physicochemical and sensory characteristics; and (3) to check the effectiveness of ion-ozone water for reducing production time and improving the microbiological safety of bread product.

The study materials consisted of three wheat flour types, obtained from local mills. The physical and chemical properties of the flours were analyzed using standard methods. The most appropriate type of flour dispersion for bread production was selected based on the results obtained. Then, a recipe for a bread product using the selected flour was developed, and the physicochemical and sensory characteristics of the bread were evaluated. To test the effectiveness of ion-ozone water, bread was baked traditionally, and with the addition of ion-ozone water, the microbiological safety of the bread was evaluated using standard methods.

"Activated water" describes water treated by various methods to increase its oxidative potential. Ion-ozone technology is one method that can be used to activate water because it involves passing air or oxygen through the water to create ozone and other reactive species that can help increase the oxidative capacity of water. Therefore, ion-ozone water can be considered a type of activated water.

A feature of activated water is its higher oxidative potential than ordinary water. This can make it more effective for disinfecting and cleaning surfaces and potentially beneficial to health when consumed internally or used in certain therapies.

Ion-ozone technology generates ozone and other reactive species by passing air or oxygen through water. This can be done by passing air or oxygen through water or using an electrical discharge to create ozone. The resulting ion-ozone water can be used for various purposes, such as disinfection or water treatment **[17]**, **[18]**.

Ion-ozone technology can potentially increase the oxidative potential of water, which can help kill bacteria and other microorganisms that may be present in bread, thereby improving its safety and shelf life. Ion-ozone technology can potentially increase the oxidative potential of water, which can help kill bacteria and other microorganisms that may be present in bread, thereby improving its safety and shelf life. Ion-ozone technology can potentially increase the oxidative potential of water, which can help kill bacteria and other microorganisms that may be present in bread, thereby improving its safety and shelf life.

Scientific hypothesis

Activated water may have high physicochemical and biological activity, suggesting that it may have unique properties that could make it useful for various applications in food and other industries (as suggested by result No.9). Another hypothesis suggests that activated water may removes molecules from water due to its ability to bind to certain substances (as suggested by result No.2). There is also the possibility that activated water can be used to purify water through photocatalysis, as shown in result No.7. However, it is important to note that the hypotheses must be tested through careful experimentation and data collection to determine whether or not they are true. Although some initial evidence supports these hypotheses about activated water, more research is likely needed to fully understand its properties and potential applications.

MATERIAL AND METHODOLOGY

Samples

The objects of the study were: ion-ozone water of high and minimum concentration, whole wheat flour from Al-Farabi's first crop of 2020 and other cereals, and Tsesna first-grade wheat flour. All analyses were conducted in an accredited laboratory of the Almaty Technological University.

The objects of the study were:

1. Fine wholemeal wheat bread No. 1 (ion-ozone 3 cavitation 3 kneading 8 speed 600).
1. Bread made of fine wholemeal wheat flour No. 2 (ion-ozone 1.5 cavitation 3 kneading 8-speed 600).
2. Fine wholemeal wheat bread No. 3 (ion-ozone 3 cavitation 2 kneading 8 speed 600).
3. Bread made of fine whole wheat flour No.4 (ion-ozone 1.5 cavitation 2 kneading 8 speed 600).
4. Bread made of fine whole wheat flour No.5 (ion-ozone 3 cavitation 3 kneading 4 speed 600).

5. Bread of fine wholemeal wheat flour No.6 (ion-ozone 1.5 cavitation 3 kneading 4 speed 600).
6. Wholemeal Fine Wheat Bread No.7 (ion-ozone 3 cavitation 2 kneading 4 speed 600).
7. Wholemeal Fine Wheat Bread No.8 (ion-ozone 1.5 cavitation 2 kneading 4 speed 600).
8. Bread made of fine wholemeal wheat flour No.9 (ion-ozone 3 cavitation 3 kneading 8 speed 300).
9. Bread made of fine whole wheat flour No.10 (ion-ozone 1.5 cavitation 3 kneading 8 speed 300).
10. Fine wholemeal wheat bread No.11 (ion-ozone 3 cavitation 2 kneading 8 speed 300).
11. Fine wholemeal wheat bread No.12 (ion-ozone 1.5 cavitation 2 kneading 8 speed 300).
12. Bread of fine wholemeal wheat flour No.13 (ion-ozone 3 cavitation 3 kneading 4 speed 300).
13. Bread made of fine wholemeal wheat flour No.14 (ion-ozone 1.5 cavitation 3 kneading 4 speed 300).
14. Bread made of fine whole wheat flour No.15 (ion-ozone 3 cavitation 2 kneading 4 speed 300).
15. Bread made of fine wholemeal wheat flour No.16 (ion-ozone 1.5 cavitation 2 kneading 4 speed 300).

All analyses were conducted in an accredited Almaty University of Technology laboratory.

Chemicals

All reagents were of analytical purity and were purchased from Laborfarm (Kazakhstan) and Sigma Aldrich (USA).

Instruments

An automatic fat extractor SER 148/3 (Velp Scientifica, Italy), a high-speed dispersant, a vacuum dough mixer, a convection dryer, a grain analyzer (Infratek 1241), a laboratory dough mixer were used.

Laboratory Methods

In work the following indicators of used raw materials and obtained assortment of bakery products were investigated: organoleptic indicators according to GOST 5667-85, and mass fraction of moisture according to GOST 21094-75. Mass fraction of fat according to GOST 5668-68. The mass fraction of protein was determined according to GOST 10846-91. The mass fraction of carbohydrates was determined according to GOST 25832-89. The mass fraction of porosity was determined according to GOST 5669-96. Acidity content was determined according to GOST 5670-96. In addition, microbiological parameters were determined based on the following standards: the number of mesophilic aerobic and facultative anaerobic microorganisms (KMAFANM) - according to GOST 10444.15-94, the number of E. coli bacteria (coliform bacteria) - according to GOST 31747-2012.

The method determined moisture content in flour according to GOST 9404-88. The content of raw gluten was controlled according to GOST 27839-88. The quality of raw gluten was determined by measuring its elastic properties according to GOST 27839-88. Protein mass fraction was determined according to GOST 10846-91, fat content - according to GOST 29033-91, mass fraction of fiber - according to the Wend method. The Glassiness of wheat grains was determined by diaphragmoscope according to GOST 10987-76.

Experimental Design and Procedure

The methodological basis for studying accelerated bakery technology can include a systematic analysis of the process, the ingredients involved, and the various factors affecting the final product. This could include an analysis of the effects of temperature, hydration, fermentation, flour type and other variables on bread quality. The research will likely include a combination of laboratory experiments and data collection, sensory analysis and consumer testing to evaluate the final product regarding flavour, texture and other characteristics. The ultimate goal of the study will be to determine ways to optimize the production process and ingredients to achieve the desired characteristics of the bread.

Laboratory unit for ultrafine grinding and mechanoactivation of vegetable raw materials, consisting of a body with opposite-made loading and unloading pipes, rotor rotating cylinder with grinding grinding grinding balls, installed inside the grinding unit with a gap concerning its upper surface and bottom, acting as a classifier, the loading pipe supplied with a device for regulating the feed of crushed materials differs in that it allows obtaining fine flour with a dispersion range h.

Initial material is placed in the field of centrifugal forces, loaded into the rapidly rotating rotor, and excited by wave vibrations. At the same time, the solid particles come together and are intensively crushed by relative vibrations up to the colloidal state. Grinding media and liquids can be added to intensify the process. The processing mode is controlled by varying the oscillation frequency and the strength of the centrifugal force field. Below is a picture of a dough mixer, accelerated dough, and ion-ozone cavitation unit for accelerated dough preparation (Figure 1).

Figure 1 Accelerated dough kneader, ion-ion cavitation unit for accelerated dough preparation.

The dough was obtained by mechanical loosening under pressure in an experimental ion-ozone cavitation machine for preparing dough with an accelerated cycle developed at ATU. The dough mixing machine works as follows. Recipe dough components are fed through the charging port to the kneading body of a batch mixer which has a kneading body driven by an electric motor through a speed variator. At the end of the loading, the kneading body of the kneading machine is hermetically closed with a lid, and the dough is kneaded for 3-5 minutes at a speed of kneading organ of 5 s^{-1}. Then ion-ozone cavitation air is fed into the kneading chamber at a pressure of 0,20, 0,40 and 0,60 MPa and dough is beaten for 3-10 minutes at a speed of kneading organ rotation of 2-3 and 4-5, 7-8 $seconds^{-1.}$ While beating the prescribed components, the dough mass is saturated with air. The dough prepared this way is a foamy mass with stable physical and chemical characteristics. The process of beating dough from wheat flour of 1 and 2 grades was investigated under the pressure of 0.20, 0.40 and 0.60 MPa and the rotation frequency of kneading organ 2-3 and 4-5, 7-8 s^{-1} during 2-3, 4-5 and 7-10 minutes and without giving compressed air.

The process intensifies because during the preparation of dough, there is no need to use a proving cabinet and other machines used in traditional baking, which reduces the production area and the time spent on the preparation of bread.

As a result, using the proposed invention using an ion-ozone technological line and methods of dough preparation will improve the structural-mechanical, rheological and technological properties of dough and bread, bakery and confectionery products obtained from it.

The dough was prepared using mechanical loosening, which requires special equipment. The equipment used in this study included a planetary mixer, a dough-leavening machine, and a bakery oven.

The recipe for the yeast-free bread dough included flour, water, and salt. Flour was obtained from three different dispersions (medium, fine and fine) and was determined to meet the standards of GOST 26574-2017. The amount of water in the dough was adjusted according to the flour's gluten content as determined by a Chopin CD1 gluten meter.

The dough was prepared as follows: first, the flour and salt were mixed in a planetary mixer. Then water and sourdough were added, and the dough was kneaded for a certain time using the MKP-50 dough leavening agent. The dough was then shaped into loaves and baked in the oven.

In the studies, we studied the dependence of quality indicators of dough from fine whole-meal flour "Al-Farabi" using activated ion-ozoned water and bread prepared from it on the technological regimes of dough processing:

- ion-ozone concentration, $C*10^{-9}$ mg/unit;
- pressure P, atm;
- dough kneading time τ, min;
- dough mixer shaft rotation speed, rpm.

Planning methods for multifactorial experiments were applied to reduce the number of experiments and obtain reliable experimental results. The quality of dough and bread prepared from it in the studies were evaluated according to the following indicators:

y_1 - moisture content of the dough, %
y_2 - alkalinity of the test, deg;
y_3 - the mass of the dough, g;
y_4 - total deformation of the dough, mm;
y_5 - plasticity of the dough, mm;
y_6 - elasticity of the dough, mm;
y_7 - moisture content of bread, %;
y_8 - porosity of bread, %;
y_9 - alkalinity of bread, deg;
y_{10} is the volume of 100 grams of bread, see^3 ;
y_{11} - the mass of bread, g;
y_{12} - total deformation of the bread, mm;
y_{13} - plasticity of bread, mm;
y_{14} - elasticity of bread, mm;
y_{15} - protein, %;
y_{16} - starch, %;
y_{17} - fiber, %;
y_{18} - fats, %;
y_{19} - ash, %;
y_{20} - sugar, %.

To reduce the influence of uncontrollable factors on the results of the experiments, the experiments were randomized using random number tables. Conditions of experiments and obtained results of determining the quality parameters of dough from fine whole-meal flour "Al-Farabi" using ion-ozone water and bread prepared from it. Table 1 shows the conditions of the experiments of fine whole-milk flour "Al-Farabi" using ion-ozoned water and bread prepared from it.

Table 1 Conditions of experiments of fine whole-meal flour "Al-Farabi" using ion-ozone water and bread prepared from it.

No.	Factors			
	$C*10^{-9}$ mg/unit	**P, atm**	**τ, min**	**v, rpm**
1	0.5	3	8	600
2	0.003	3	8	600
3	0.5	2	8	600
4	0.003	2	8	600
5	0.5	3	4	600
6	0.003	3	4	600
7	0.5	2	4	600
8	0.003	2	4	600
9	0.5	3	8	300
10	0.003	3	8	300
11	0.5	2	8	300
12	0.003	2	8	300
13	0.5	3	4	300
14	0.003	3	4	300
15	0.5	2	4	300
16	0.003	2	4	300

The appearance of bread samples carried out in multiple planning experiments are shown in Figure 2.

Figure 2 Samples of bread carried out multiple planning experiments.

Number of samples analyzed: 16 samples were analyzed.
Number of repeated analyses: All tests were performed in triplicate.
Number of experiment replication: Replications were conducted 2 times.
Design of the experiment: Experimental design for an accelerated bakery technology study can include a combination of laboratory experiments and sensory analysis. For example, the study may involve changing temperature, hydration, fermentation time, flour type, or other baking process variables and observing changes in the final product. Sensory analysis may include evaluating bread in terms of taste, texture, and other attributes either through surveys or by trained experts.

Statistical Analysis

The work used the ANOVA program, the PLAN sequential regression analysis program, and the Statistika 10.0 software to analyze the data collected during the study. The analysis included data processing using various mathematical and statistical measures to determine significant sample differences. Data processing and calculations were carried out using the PLAN sequential regression analysis program developed at the Odessa

National Technological University **[19]**, **[20]**. The data was analyzed using MS Excel for Windows version 10 Pro, 2010, and various statistical measures such as mean and standard deviation were used to estimate the values.

RESULTS AND DISCUSSION

Sixteen samples of bread made from fine wheat whole-meal flour were examined. The results are shown in Tables 1 and 2 of Figure 3. As a result of multiple planning experiments 2^n ion-ozone according to four criteria, three samples with the best performance were identified. Samples numbered 2, 5, and 9 outperformed the results obtained with the distinctive regimes regarding dough elasticity and volume of the final product. All samples used activated water of ion-ozone type with maximum and minimum values. Sample number 2 had a minimum concentration of ion-ozone water when kneaded at 1.5 atm, for 8 minutes with a shaft rotation of 600 rpm. The volume of the final product was 2.6 g/cm^3. An admixture of the dough was detecte, as the rheological indices of the dough decreased. Sample number 5 was the maximum concentration of ion-ozone water when kneaded at 3 atm, for 4 minutes with a shaft rotation of 600 rpm. The volume of the final product was 2.6 g/cm^3. With multiple planning experiments, the distinctive feature of this mode is the rapidity of kneading and the best performance on all measured parameters. The experiment with finely dispersed wholemeal flour of the first degree from the grain variety Al-Farabi was carried out at the same regimes. The revealed volume of the final product is 2.3 g/cm^3, which is inferior to indicators from fine-dispersed whole-meal flour of the same variety of grain. Sample number 9 was the maximum concentration of ion-ozone water when kneaded at 3 atm, for 8 minutes at 300 rpm. The volume of the final product was 2.5 g/cm^3 . The indicators of this sample were identical to sample number 5. This is explained by the fact that all the modes were similar except for the kneading time and speed of the shaft. The outcome was similar to 4 minutes at 600 rpm in the early sample. This sample was achieved by extending the kneading time, resulting in several turns to 600 rpm. During the baking process, all samples were found to have two criteria affecting the volume and rise of the dough. A pressure of 3 atm saturated the dough more intensely than 1.5 atm, and ion-ozone-activated water with a maximum concentration more effectively affected the final product's volume than the minimum ion-ozone concentration. The quality indicators of the test below are shown in Table 2.

Table 2 Quality indicators of dough from fine whole-meal flour "Al-Farabi" using ion-ozoned water and bread prepared from it.

No.	Dough and bread quality indicators																			
	y_1, %	y_2, deg.	y_3, g	y_4, mm	y_5, mm	y_6, mm	y_7, %	y_8, %	y_9, deg	y_{10}, cm^3	y_{11}, g	y_{12}, mm	y_{13}, mm	y_{14}, mm	y_{15}, %	y_{16}, %	y_{17}, %	y_{18}, %	y_{19}, %	y_{20}, %
1	54.3	3.0	500	13.6	12.0	1.6	53.2	60.1	2.0	210.0	448.96	3.5	1.1	2.2	9.16	33.52	6.87	1.41	1.54	3.63
2	52.2	3.4	500	11.0	8.5	2.1	49.6	64.8	2.0	260.0	442.89	4.5	1.7	3.0	9.03	30.55	6.76	1.88	1.59	4.12
3	54.3	2.5	450	13.6	12.0	1.6	53.2	60.1	2.0	233.3	400.39	3.5	1.1	2.2	9.14	28.55	5.95	1.02	1.65	4.31
4	52.2	3.4	450	11.0	8.5	2.1	49.6	64.8	2.0	266.7	395.83	4.5	1.7	3.0	8.75	29.67	6.92	1.25	1.72	5.04
5	53.0	3.4	500	14.8	13.5	1.2	52.5	59.7	1.4	260.0	457.58	4.2	1.9	2.2	9.07	42.72	7.05	0.93	1.75	2.95
6	50.1	3.0	500	17.2	15.0	2.2	52.0	55.3	2.0	200.0	444.95	3.0	0.9	2.1	8.81	33.88	7.19	0.71	1.71	3.12
7	53.0	3.4	450	14.8	13.5	1.2	52.5	59.7	1.4	233.3	348.16	4.2	1.9	2.2	7.96	25.39	6.53	0.92	1.69	4.71
8	50.1	3.0	450	17.2	15.0	2.2	52.0	55.3	2.0	218.9	394.28	3.0	0.9	2.1	7.52	20.54	5.71	1.52	1.22	5.15
9	52.5	3.6	500	16.8	15.5	1.1	52.0	60.0	2.0	250.0	439.82	4.0	1.5	2.5	8.79	30.76	7.28	1.58	0.92	5.30
10	52.8	3.4	500	26.7	25.0	1.7	51.3	56.1	2.0	210.0	447.45	4.5	2.1	2.5	8.20	42.68	8.11	2.08	1.64	3.87
11	52.5	3.6	420	16.8	15.5	1.1	52.0	60.0	2.0	249.8	352.66	4.0	1.5	2.5	8.05	32.18	6.67	0.66	1.62	4.47
12	52.8	3.4	400	26.7	25.0	1.7	51.3	56.1	2.0	237.5	385.09	4.5	2.1	2.5	9.12	46.66	5.98	1.67	1.55	2.85
13	55.2	3.6	500	21.0	18.5	2.2	52.5	59.8	1.2	200.0	445.91	2.5	0.7	1.3	8.76	34.42	5.87	0.91	1.49	3.24
14	52.1	3.4	500	25.8	24.5	1.1	46.9	58.0	1.4	220.0	410.44	3.3	0.9	2.7	9.17	36.18	6.29	0.87	1.47	5.14
15	55.2	3.6	383	21.0	18.5	2.2	52.5	59.8	1.2	234.6	351.13	2.5	0.7	1.3	9.09	33.75	7.37	1.51	0.78	4.72
16	52.1	3.4	450	25.8	24.5	1.1	46.9	58.0	1.4	233.3	376.80	3.3	0.9	2.7	8.34	30.45	6.43	0.89	1.39	4.85

From the data in Table 2 we can see the quality indicators of dough from fine whole-meal flour "Al-Farabi" using ion-ozone water and bread prepared from it according to the applied modes.

Flour contains magnesium, calcium, iron, copper, zinc, cadmium and other minerals. These Swedish researchers compared several bread from industrial bakeries with sourdough bread from a local bakery, intending to see if the bread makes a difference as it passes through the stomach and intestines. By simulating this process in the lab, they found that time and pH levels are important for the breakdown of phytic acid. In an acidic environment, phytic acid breaks down faster. Phytic acid in flour prevents the body from absorbing these nutrients. The long fermentation process breaks down the phytic acid and releases minerals for the body to assimilate. Results show that the body does not assimilate minerals in industrial bakery bread.

In contrast, almost all nutrients from bakery products can be assimilated by the body through a long fermentation process **[21]**, **[22]**. Based on this, a sourdough starter was added to the recipe for the bread to break down phytic acid. Cooking technology was according to the recipe for 1 kg of flour: 20 g sourdough, 950 ml of water, 25g salt, 20 g sugar, improver 2 g, vegetable oil 10 g. Sourdough was dissolved in warm water at 1 kg of flour (950 ml). In the case of fine-dispersed flour, the first and second-degree water take 100ml more per 500 g of flour, because the moisture absorption is higher than that of wholemeal flour finely ground.

The initial weight of the dough pieces was 500 g. The selected bakery products were as follows:

The main technological characteristics for all objects:

- obtaining (dividing, rounding) the product of a mass of 500 g.
- proofing for 20 minutes at 40 °C and 75% relative humidity.
- baking at 220 °C for 30 minutes with steam; the mass of the finished product is 450 g.

The importance of choosing the right techniques for kneading dough and the influence of the processes of creating dough structure on the quality of the finished products have been established by experimental studies. Given the studies, we can propose the following method of kneading the dough: 4 minutes instead of 8 minutes. Significant deformation was observed when making bread from the dough at a speed of 600 rpm, but the bread quickly acquired a normal shape. Prolonged kneading for more than four minutes is ineffective and harmful to the dough structure. Data analysis showed that prolonged kneading destroys the gluten structure of the dough. Bread made after a long kneading time retains its original shape worse.

Based on the results of the studies, regression equations were obtained, which adequately (by Fisher's criterion) describe the effect of technological modes of dough processing C, P, τ, v on the indicators mentioned above of quality of dough and bread prepared from it.

To determine the error variance (reproducibility), 3 parallel experiments were performed in the center of the experiment plan.

Regression coefficients were calculated using matrices in natural dimensionality, and accordingly, the equations themselves were also obtained in natural dimensionality.

The general form of regression equations for the 4 factors is as follows:

$$y_i = b_0 + b_1 C + b_2 \mathrm{P} + b_3 \tau + b_4 \mathrm{v} + b_{12} CP + b_{13} \mathrm{C}\tau + b_{14} Cv + b_{23} \mathrm{P}\tau + b_{24} Pv + b_{34} \tau v \quad (1)$$

Where:

y_i – *i-th* quality indicators of dough and bread prepared from it; C – ion-ozone concentration, $C*10^{-9}$ mg/d; P – pressure, atm; τ – duration of kneading dough τ, min; v – rotational speed of the dough mixer shaft, rpm.

Summary data on the obtained regression equations in natural variables are given in Table 3. In the same table, the mean square errors of experiments S_e and inadequacy $S_{in.ad.}$, as well as calculated F_c and critical F_{cr} values of the Fisher criterion, testifying that all obtained equations adequately describe the experimental data at confidence probability $p = 0.05$.

More detailed data on the statistical characteristics of the obtained regression equations are given in the listings of their calculations.

The regression equations are mathematical models that allow us to predict the quality indicators of processed dough and bread obtained from it, depending on the values of technological modes of dough processing, i.e. factors C, P, τ, v.

From the data in Table 3 we can see that a brief analysis of the obtained regression equations shows that of the 20 studied indicators of dough and bread quality, only bread porosity (y_8) does not depend on the dough processing modes.

One mode, factor C determines the dough moisture (y_1) and bread moisture (y_7), and factor P determines the dough weight (y_3) and fiber content (y_{17}).

The two-mode factors C, v determines the alkalinity of the dough (y_2), C, P determines the mass of the bread (y_{11}) and C, τ determines the elasticity of the bread (y_{14}).

The three mode factors C, τ, v *determine the* total deformation of the dough (y_4), the plasticity of the dough (y_5) and the elasticity of the dough (y_6). Bread volume (y_{10}) and fat content (y_{18}) depend on factors C, P, τ. Factors C, τ, v determine the alkalinity of the bread (y_9), the total deformation of the bread (y_{12}), and the plasticity of the bread (y_{13}). The factors P, τ, v *determine* the protein content (y_{15}).

And only the starch (y_{16}), ash (y_{19}), and sugar (y_{20}) content depend on all 4 factors C, P, τ, v.

To optimize the technological modes of dough processing, the volume of bread was selected as the target function.

$$y_{10} = 222.772+71.680\text{-}C*10^{-9}-12.175\text{-}P+6.408\text{-}\tau-10.915\text{-}C*10^{-9}\text{-}\tau \rightarrow max \quad (2)$$

Table 3 Regression equations in natural variables and statistical characteristics of dependencies of quality indicators of dough from fine whole-meal flour "Al-Farabi" using ion-ozone water and bread prepared from it on factors C, P, τ, v influencing them.

Regression equations in natural variables	Standard deviation		Fisher's criterion	
	experimental	inadequacies	billing	critical
$y_1 = 51.788+3.924\text{-}C*10^{-9}$	0.90	1.11	1.53	19.42
$y_2 = 3.300+1.654\text{-}C*10^{-9}-0.00351\text{-}C*10^{-9}\text{-}v$	0.15	0.25	2.68	19.42
$y_3 = 294.875+68.375\text{-}P$	21.20	19.25	1.21	3.74
$y_4 = 42.502-29.779\text{-}C*10^{-9}-0.6687\text{-}\tau-0.04065\text{-}v+0.04997\text{-}C*10^{-9}\text{-}v$	0.91	1.64	3.26	19.40
$y_5 = 41.787-33.199\text{-}C*10^{-9}-0.6562\text{-}\tau-0.04351+0.05869\text{-}C*10^{-9}\text{-}v$	0.82	1.54	3.54	19.40
$y_6 = 1.396+4.239\text{-}C*10^{-9}-0.1184\text{-}\tau-0.3018\text{-}C*10^{-9}\text{-}\tau-0.00651\text{-}C*10^{-9}\text{-}v+0.00040\text{-}\tau\text{-}v$	0.082	0.35	18.13	19.39
$y_7 = 49.934+5.231\text{-}C*10^{-9}$	1.13	1.52	1.81	19.42
$y_8 = 59.225$	1.12	2.82	6.34	19.43
$y_9 = -1.534+0.255\text{-}\tau+0.00304\text{-}v+0.1899\text{-}C*10^{-9}\text{-}\tau-0.00039\text{-}\tau\text{-}v$	0.087	0.088	1.03	19.40
$y_{10} = 222.772+71.680\text{-}C*10^{-9}-12.175\text{-}P+6.408\text{-}\tau-10.915\text{-}C*10^{-9}\text{-}\tau$	5.00	20.94	17.54	19.40
$y_{11} = 412.256-439.710\text{-}C*10^{-9}+170.540\text{-}C*10^{-9}\text{-}P$	19.44	24.45	1.58	19.42
$y_{12} = 0.6792\text{-}\tau+0.00402\text{-}v-0.4739\text{-}C*10^{-9}\text{-}\tau+0.00508\text{-}C*10^{-9}\text{-}v-0.00076\text{-}\tau\text{-}v$	0.17	0.38	4.92	19.40
$y_{13} = -2.053+1.006\text{-}C*10^{-9}+0.6265\text{-}\tau+0.00432\text{-}v-0.5030\text{-}C*10^{-9}\text{-}\tau+0.00402\text{-}C*10^{-9}\text{-}v-0.00083\text{-}\tau\text{-}v$	0.053	0.20	14.24	19.38
$y_{14} = 1.866-1.056\text{-}C*10^{-9}+0.1187\text{-}\tau$	0.11	0.35	10.00	19.42
$y_{15} = 7.756+1.224\text{-}P-0.00533\text{-}v-0.1411\text{-}P\text{-}\tau+0.00088\text{-}\tau\text{-}v$	0.21	0.41	3.77	19.40
$y_{16} = 37.935+6.567\text{-}\tau-0.1213\text{-}v-5.224\text{-}C*10^{-9}\text{-}\tau+0.06478\text{-}C*10^{-9}\text{-}v-1.886\text{-}P\text{-}\tau+0.03497\text{-}P\text{-}v$	1.66	2.76	2.76	19.38
$y_{17} = 5.480+0.4825\text{-}P$	0.21	0.61	8.59	19.42
$y_{18} = 3.515+1.393\text{-}C*10^{-9}-1.297\text{-}P-0.4075\text{-}\tau-0.3131\text{-}C*10^{-9}+0.2356\text{-}P$	0.060	0.24	16.37	19.39
$y_{19} = -1.592\text{-}C*10^{-9}+0.5736\text{-}P+0.2445\text{-}\tau+0.00304\text{-}C*10^{-9}\text{-}v-0.09054\text{-}P\text{-}\tau$	0.072	0.20	7.60	19.40
$y_{20} = 5.435-3.576\text{-}C*10^{-9}-0.9116\text{-}\tau+0.01276\text{-}v+0.5621\text{-}C*10^{-9}\text{-}\tau+0.3045\text{-}P-0.00534\text{-}P\text{-}v$	0.19	0.65	11.85	19.38

Analysis of the above equation shows that the bread volume is completely unaffected by the speed of rotation of the dough mixer shaft v. The pressure P linearly changes the bread volume – with increasing P, the bread volume decreases.

The equation also shows that the factors ion-ozone concentration C and duration of kneading dough τ have a joint contradictory pair influence (coefficient -10.915 has a minus sign). Therefore, it is difficult to uniquely analytically determine the effect of each factor on the bread volume.

More clearly, the character of the joint mutual influence of the ion-ozone concentration C and the dough kneading time τ on the bread volume (y_{10}) can be determined from the response surface (Figure 3), constructed by the above equation (1).

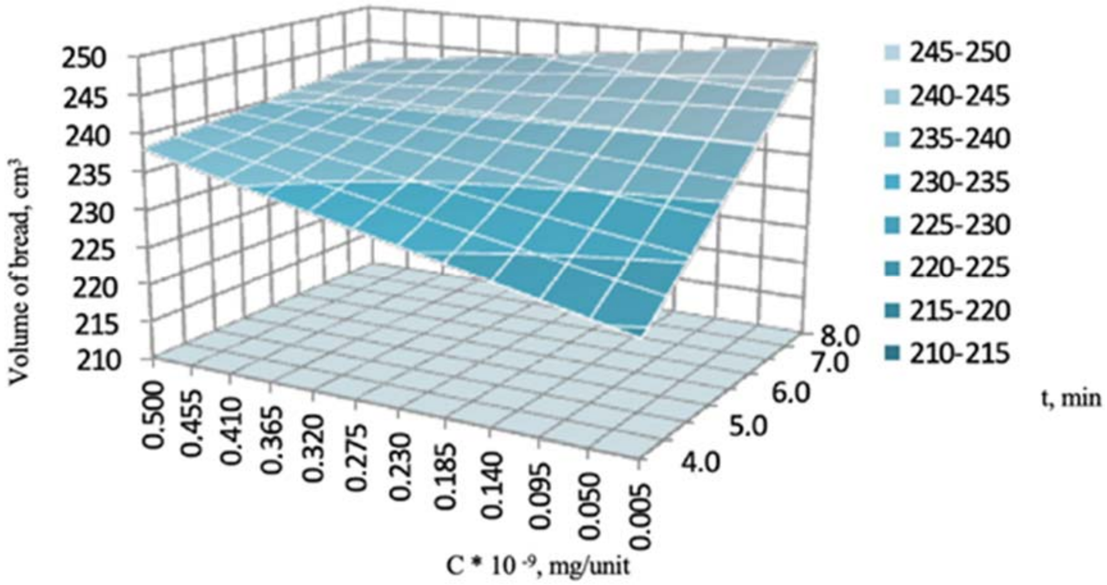
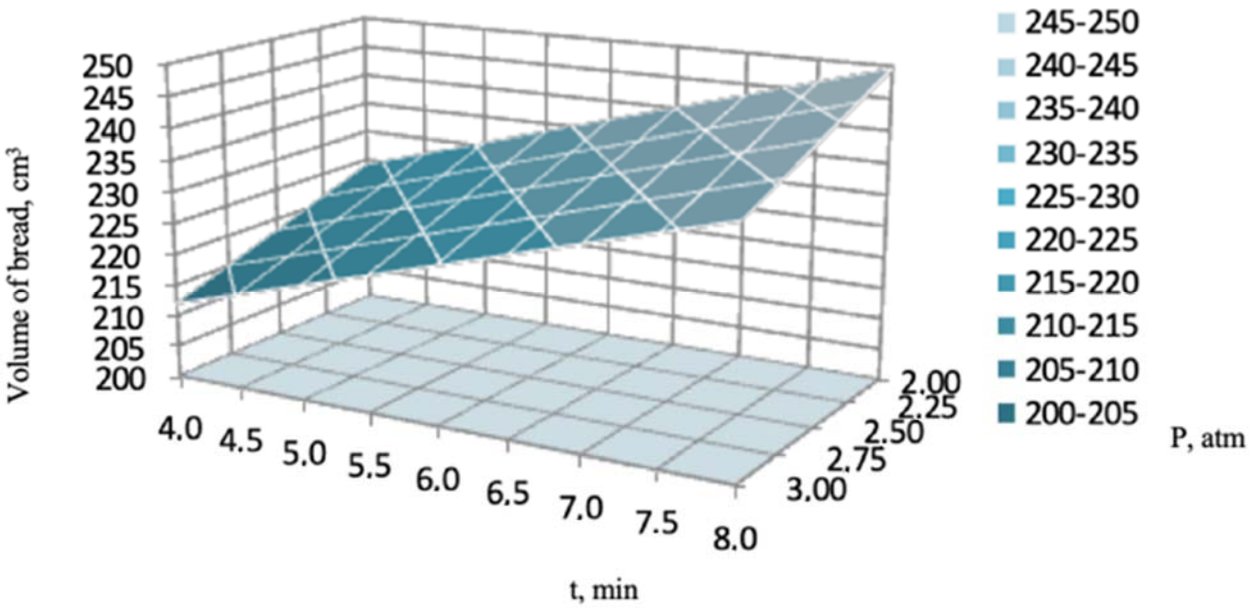


Figure 3 Response surface of nonlinear joint effect of factors C and τ on bread volume (at P = 2 atm).

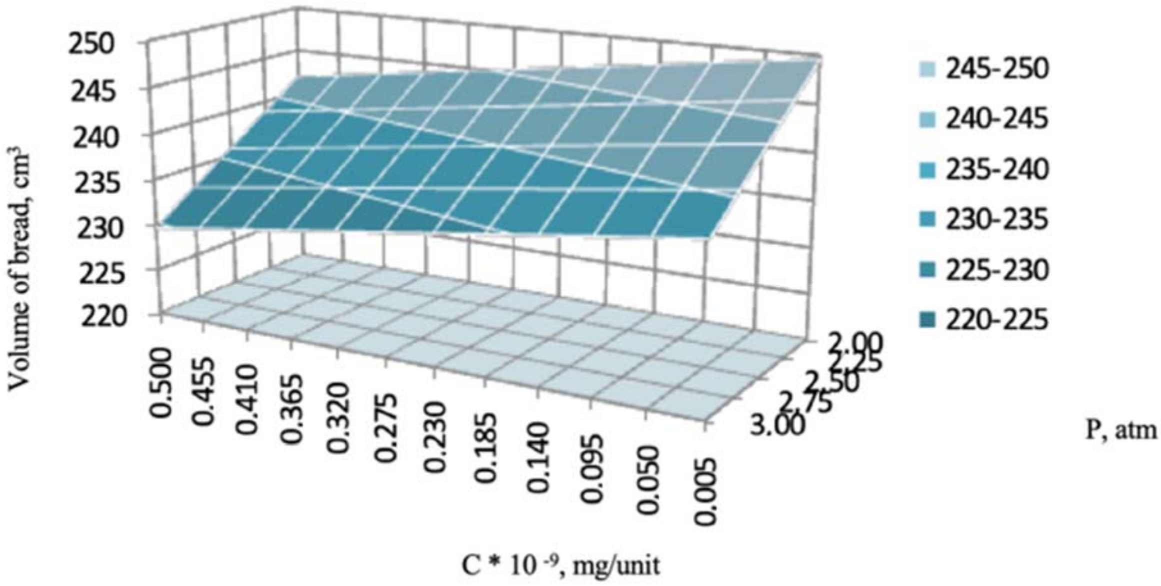
Figure 3 shows that increasing the duration of kneading dough τ unambiguously increases the bread volume. However, at the minimum concentration of ion-ozone (C = $0.003*10^{-9}$ mg/unit), increasing the duration of kneading dough from 4 to 8 minutes increases the volume of bread from 223.1 to 249.6 cm^3 , i.e. by 11.4%, and at a concentration of $C = 0.5*10^{-9}$ mg/unit – only from 238.1 to 241.9 cm^3 , i.e. only by 1.6%.

Considering the effect of kneading duration τ on bread volume at different concentrations of ion-ozone C we can see that due to the mutual influence of factors C and τ a different character of changes in bread volume is observed. Thus, at τ = 4 min, decreasing the concentration of ion-ozone C reduces the bread volume from 238.1 to 224.1 cm^3 (by 6.2%), and at τ = 8 min, on the contrary, increases it from 241.9 to 249.6 cm^3 (by 3.2%). Thus, to increase the bread volume at P = 2 atm, the concentration of ion-ozone C should be reduced, and the dough kneading duration τ should be increased.

Figure 4-a and Figure 4-b show the response surfaces characterizing the linear effect of pressure P and dough kneading duration τ on the bread volume.



a)



b)

Figure 4 Response surfaces of linear dependences of bread volume on pressure *P* and dough kneading duration τ: a) linear influence of factors *P* and τ on bread volume (at *C* = 0.5-10^{-9} mg/d), b) linear influence of factors *C* and *P* on bread volume (at τ = 8 min).

Figure 4-a shows that increasing the dough kneading time and reducing the pressure *P* leads to a linear increase in bread volume. The largest bread volume is observed at the maximum kneading time τ and the minimum pressure *P*. Figure 4-b shows that decreasing the concentration of ion-ozone C and reducing the pressure *P* leads to a linear increase in bread volume. The maximum bread volume is observed at minimum concentration *C* and pressure *P* values. Optimization of the process of bread production was carried out with the following limitations on the quality indicators of the processed dough, taking into account the necessary quality indicators obtained from the bread:

Table 4 Optimization of the process of bread production.

Min				Max
48.0	≤	y_1 =51.788+3.924-C*10^{-9}	≤	58.0
2.0	≤	y_2 =3.300+1.654-C*10^{-9} -0.00351-C*10^{-9} -*v*	≤	5.0
375	≤	y_3 =294.875+68.*375-P*	≤	530
10.0	≤	y_4 =42.502-29.779-C*10^{-9} -0.6687-τ-0.*04065-v+0*.04997-C*10^{-9} -*v*	≤	29
7.0	≤	y_5 =41.787-33.199-C*10^{-9} -0.6562-τ-0.04351++0.05869-C*10^{-9} -*v*	≤	26
0.9	≤	y_6 =1.396+4.239-C*10^{-9} -0.1184-τ-0.3018-C*10^{-9} -τ-0.00651-C*10^{-9} -*v*+ +0.*00040-τ-v*	≤	2.5
44.0	≤	y_7 =49.934+5.231-C*10^{-9}	≤	55
53.0	≤	y_8 =59.225	≤	66.0
0.95	≤	y_9 =-1.534+0.255-τ+0.*00304-v+0*.1899-C*10^{-9} -τ-0.*00039-τ-v*	≤	2.8
100	≤	y_{10} =222.772+71.680-C*10^{-9} -12.*175-P* + 6.408-τ-10.915-C*10^{-9} -τ	≤	360
325	≤	y_{11} =412.256-439.710-C*10^{-9} +170.540-C*10^{-9} -*P*	≤	500
2.2	≤	y_{12} =0.6792-τ+0.*00402-v-0*.4739-C*10^{-9} -τ+0.00508-C*10^{-9} -v- -0.*00076-τ-v*	≤	5.5
0.14	≤	y_{13} =-2.053+1.006-C*10^{-9} +0.6265-τ+0.*00432-v-0*.5030-C*10^{-9} -τ+ +0.00402-C*10^{-9} -*v-0.00083-τ-v*	≤	2.5
1.0	≤	y_{14} =1.866-1.056-C*10^{-9} +0.1187-τ	≤	4.5
7.0	≤	y_{15} =7.756+1.*224-P-0.00533-v-0*.1411-P-τ + 0.*00088-τ-v*	≤	10.5
20.0	≤	y_{16} =37.935+6.567-τ-0.*1213-v-5*.224-C*10^{-9} -τ +0.06478-C*10^{-9} -v- -1.886-P-τ+0.*03497-P-v*	≤	52
2.7	≤	y_{17} =5.480+0.*4825-P*	≤	10.0
0.30	≤	y_{18} =3.515+1.393-C*10^{-9} -1.*297-P-0*.4075-τ-0.3131-C*10^{-9} +0.*2356-P*	≤	2.6
0.42	≤	y_{19} =-1.592-C*10^{-9} +0.*5736-P+0*.2445-τ+ 0.00304-C*10^{-9} -*v* -0.09054-P-τ	≤	1.82
2.2	≤	y_{20} =5.435-3.576-C*10^{-9} -0.9116-τ+0.*01276-v* +0.5621-C*10^{-9} -τ+ +0.*3045-P-0.00534-P-v*	≤	6.6

Protein content was maximized within the range of changes in the regime factors $t_в$, τ, w, and $t_з$ given in the experiment planning matrix (T a Table 5).

Non-linear programming was done to optimise the processing modes of dough from fine whole-meal flour of "Al-Farabi" variety using activated ion-ozone water. The following optimal technological regimes of dough processing were obtained:

- ion-ozone concentration, $C*10^{-9}$ = 0.003 mg/d;
- pressure P = 2 atm;
- dough kneading time τ = 8 min;
- dough mixer shaft rotation speed, v = 300 rpm.

At these optimal modes of grain processing the target function (volume of 100 g of bread) was 249.6 cm^3. The values of other indicators of the quality of dough and bread at the optimal modes of grain processing are shown in Table 5.

Table 5 Values of quality indicators of dough from fine wholemeal flour "Al-Farabi" using ion-ozoned water and bread prepared from it.

Indicators	min		opt		max
y_1 – moisture content of the dough, %	48.0	≤	51.8	≤	58.0
at_2 – alkalinity of the test, deg;	2.0	≤	3.3	≤	5.0
y_3 – the mass of the dough, g;	375	≤	431.6	≤	530
at_4 – total deformation of the dough, mm;	10.0	≤	24.9	≤	29
at_5 – plasticity of the dough, mm;	7.0	≤	23.4	≤	26
at_6 – elasticity of the dough, mm;	0.9	≤	1.4	≤	2.5
at_7 – moisture content of bread, %;	44.0	≤	50.0	≤	55
at_8 – porosity of bread, %;	53.0	≤	59.2	≤	66.0
at_9 – alkalinity of bread, deg;	0.95	≤	2.0	≤	2.8
at_{10} – is the volume of 100 grams of bread, see^3 ;	100	≤	249.6	≤	360
at_{11} – the mass of bread, g;	325	≤	412.0	≤	500
at_{12} – total deformation of the bread, mm;	2.2	≤	4.8	≤	5.5
at_{13} – plasticity of bread, mm;	0.14	≤	2.3	≤	2.5
at_{14} – elasticity of bread, mm;	1.0	≤	2.8	≤	4.5
at_{15} – protein, %;	7.0	≤	8.5	≤	10.5
at_{16} – starch, %;	20.0	≤	44.8	≤	52
at_{17} – fiber, %;	2.7	≤	6.4	≤	10.0
at_{18} – fats, %;	0.30	≤	1.43	≤	2.6
at_{19} – ash, %;	0.42	≤	1.65	≤	1.82
at_{20} – sugar, %.	2.2	≤	3.64	≤	6.6

Thus, the processing of fine whole-meal flour of the "Al-Farabi" variety using activated ion-ozone water according to the optimal technological modes allowed to provide the maximum amount of bread and maintain within the permissible limits of the studied indicators of quality of dough and bread obtained from it.

Unleavened bread has a better effect on the human body. It promotes fast bowel movements and cleanses of unnecessary toxins and toxins. Many believe that yeast, which are living organisms and need vitamins, proteins and other useful substances, when they enter the body, simply take them away from a person. Another disadvantage and difference of yeast bread is that yeast bacteria cause fermentation and flatulence in the human body **[23]**, **[24]**.

Due to its organoleptic properties, it contributes to the smooth functioning of the intestines, stimulates the active work of the muscles of the gastrointestinal tract. It is its rather high density and rigidity that contribute to better absorption of food and the efficient functioning of the digestive system **[25]**, **[26]**.

The results of the study of qualitative, organoleptic, physical, chemical and microbiological parameters, as well as safety indicators, showed that the yeast-free bakery products made from different dispersed flours and ion-ozoned water meet the requirements and norms of Technical regulation of the Customs Union 021/2011 of the Technical Regulations of the Customs Union "On food safety". The results showed that the use of various dispersed flours in the production of yeast-free bakery products could improve the quality and nutritional value of the final product.

Microbiological analysis showed that the total number of microorganisms in the yeast-free bread prepared with ion-ozoned water was significantly lower than in the samples prepared with tap water. This result indicates that ozone water can be used as an effective disinfectant in the production of bakery products **[27]**, **[28]**. Moreover, the use of different dispersed flours can significantly affect the biological value of baked goods, where the highest biological value was found in bread made with wholemeal flour **[29]**, **[30]**. In addition, the energy value was higher in bread made from wheat flour than other flour types.

When gaseous ozone or ozone ion is dissolved, ozonized water or ion ozonated water is obtained, which is a liquid form of ozone for food use. The solubility of ozone and ion-ozone in water is ten times higher than that of oxygen, in addition, when dissolved in water, ozone decomposes much faster **[31]**, **[32]**. It has been established that the rate of ozone decomposition in water is influenced by its concentration, reaction pH, ultraviolet radiation and dissolved anions. Therefore, with an increase in the pH of the medium, as well as a higher content of organic substances and the presence of an insignificant amount of carbonates, the rate of ozone decomposition increases significantly **[33]**, **[34]**.

Sensory evaluation of yeast-free bread products showed that bread made with various dispersed flours and ion-ozoned water had good texture, taste and flavour. Bread made with wholemeal flour had a nutty flavour and was denser than other bread types, which is consistent with the results of previous studies. The use of ozone and ion-ozoned water in producing yeast-free bakery products also improved the flavour and taste of the final product.

Overall, the results show that the use of various dispersed flours and ion-ozoned water can improve the quality and nutritional value of yeast-free bread products. Adding ozone water to the production process can also reduce the number of microorganisms and improve the palatability of the final product **[35]**, **[36]**. Future research could focus on optimizing ion-ozoned water and various dispersion flours to further improve the quality and nutritional value of yeast-free bread products **[37]**, **[38]**.

Over the past decade, significant progress has been made in improving bread products' quality and chemical composition through various methods **[39]**, **[40]**. One of these methods involves mechanically loosening the dough by whipping it in a specialized whisk for 5 minutes, then knead it in a conventional dough mixer, and then cutting and baking. However, these methods have been used only for long-term dough preparation and have not found practical application in the industry **[41]**, **[42]**.

This technology for functional whipped bread offers potential advantages in terms of shorter production cycles, increased efficiency and improved bakery quality. However, further research is needed to optimize the process parameters and ensure the safety and feasibility of the technology for large-scale production.

Accelerated technology of mechanical loosening of dough finds practical application in preparing bakery and flour confectionery products **[43]**, **[44]**. Dough-loosening technology eliminates yeast from the recipe and prepares dietary varieties acceleratedly without yeast bread and flour confectionery products.

The baking properties of the flour undoubtedly influence the amount of optimum mechanical action on the dough during kneading. Flour dough with strong gluten requires more intensive processing; in contrast, flour with weak gluten has a less mechanical influence on the dough during kneading **[44]**, **[45]**. Therefore, the quality of the flour was investigated at the beginning of the experiment. Accordingly, the dough was prepared with a 55-56% moisture content. Recipes and modes of dough preparation for yeast-free bakery products from fine and fine dispersion flours were developed. Further, the qualitative indicators of manufactured yeast-free bakery products were investigated. Organoleptic, physicochemical and microbiological parameters, and the biological and energy value of yeast-free bakery products, were analyzed.

It was found that the technology of yeast-free dough preparation by mechanical loosening under pressure on the experimental laboratory setup allows reducing the duration of the production process of bakery products from 3 to 6 hours, increases labour productivity by 2-3 times, increases the yield of bread by 14-18%, improves organoleptic characteristics of the finished products.

Based on the technology of accelerated dough preparation, allowing to exclude yeast from the formulation, reducing the duration of the production process, improving the quality of finished products, increasing labour productivity, increase socio-economic indicators of bakeries, a new direction in the production of yeast-free bakery products can be developed.

The semi-finished product is intensively saturated with air oxygen when the dough components are whipped under compressed air pressure. This improves the structural and mechanical properties of the dough, reducing its bulk weight. This is associated with a decrease in the number of SH-groups and the formation of bonds in the structure of protein S-S, which contribute to the strengthening of the protein structure and, consequently, the foam film. Thus, intensive mixing and beating of the dough with air saturation with oxygen in the presence of the enzyme preparation GK-106 accelerate the processes of protein hydrolysis, thus increasing their solubility, increasing the foam formation of semi-finished products, intensifying the formation of substances involved in melanoid formation reactions, reducing the specific power per kneading **[46]**, **[47]**, **[48]**.

Consequently, enzymatic hydrolysis of the main components of flour with mechanical loosening and its intensification can allow obtaining dough and bakery products with optimal structural and mechanical properties and rich flavour and aroma. After kneading before cutting, the dough fermentation stage is reduced by intensifying the colloidal and biochemical processes occurring during dough preparation.

CONCLUSION

The study showed that the new method of bread production, which uses mechanical kneading under pressure and activated water, can significantly reduce kneading time by up to 50%, while improving the physical and sensory properties of the bread. The bread produced by this method had a higher specific volume, softer crumb and more elastic texture than traditional bread-making processes. The economic effect can be achieved by reducing the duration of the production process from 3 to 6 hours, reducing the number of pieces of equipment by eliminating the fermentation and proofing processes (dough mixers, barrels, fermentation tanks, proofing cabinet), etc. The advantages of our technology compared to the known ones are: reduction of production cost due to the elimination of yeast and reduction of a technological process; an increase of bread yield by 14-18%; an increase of labour productivity by more than 2-3 times, and also an increase of enterprise income by two times. In this study, the quality of flour and yeast-free dough was studied using an accelerated method. The dough was prepared by mechanical loosening under compressed air pressure. The study results showed that the quality of flour of the highest, first and second grades correspond to GOST 26574-2017 and is recommended for baking yeast-free bakery products. To improve flavour and aroma, sourdough was added to the dough. Yeast-free bakery products made of fine-dispersed flour with ion-ozoned water met the requirements and norms of Technical regulation of the Customs Union 021/2011 of the Technical Regulations of the Customs Union "On food safety". The biological value in the yeast-free bakery products of second-grade flour was the highest (62.4%), and the energy value was higher in the yeast-free bakery products of the highest-grade flour (877 kJ). Accelerated technology of mechanical loosening of dough is practically used to prepare bakery and pastry products. This technology makes it possible to exclude yeast from the formulation and prepare dietary varieties of yeast-free bread and flour confectionery products by an accelerated method. This study used new accelerated technology to quickly intensify the colloidal and biochemical processes occurring during dough preparation. The technology made it possible to eliminate the dough fermentation and proofing process, thereby reducing the duration of the production process of bakery products, increasing labour productivity, and increasing the yield of bread. A new direction in producing yeast-free bakery products can be developed based on accelerated dough preparation technology.

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