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Highly Efficient Technology for Making Bread Using an Ion-ozone Mixture

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Abstract. The article examined the ways of using highly effective technologies for the development of whole-wheat flour bread. Ion-ozone cavitation technology is used, which allows time reduction for dough making and bread baking. The flour used in the experiment is of various kinds of low-quality wheat: non-class wheat, class III, class IV, and class V wheat . During the experiments, the amino acid composition of wheat was determined, which has a large impact on the quality of the test. To obtain a high-quality dough, wheat grains of various lower classes were treated with ion-ozone cavitation treatment. The treatment was carried out using a universal ion-ozone cavitation installation, producing both ozone and molecular ions from oxygen contained in atmospheric air and processed using overpressure of crops. The experiment result shows that the method of processing with ion-ozone cavitation technology allows the improvement of the rheological properties of the dough, the reduction of baking time by 2 times, and the improvement of the quality of bread from whole-ground low-quality soft wheat flour. The obtained bread products in comparison with the control sample had higher organoleptic indices; according to several physico-chemical and organoleptic indices, a sample of bread from whole-wheat wheat of class III appeared in a more favorable light.

Keywords: Bread; Ion; Ozone; Processing; Wheat

1. Introduction

The production of bread and bakery products is one of the main issues in the production of food. It shares 15.3% of the total production of the food industry. The greatest demand among the population is bread and bakery products from wheat flour of the first grade, rye bread, and products from wheat flour of the highest grade. Previously, the 3rd class grain, from which baking flour is obtained, was in a total volume of 80%; now it is only 20%. The problem is not the quality of bread, because the baking industry is ready and is trying to produce quality bread. The problem lies in the quality of flour and grain. In fact, it is not profitable for agricultural producers to produce high-quality grain (Satsaeva

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et al., 2016; Baymagambetova *et al.,* 2014).

Wheat is one of the main sources of calories in daily human nutrition. According to US standards, *T. durum* wheat belongs to class I, which corresponds to GOST R 52554–2006 (GOST R 52554–2006, 2006). Hard-grain wheat of type II, II, III. Class IV in the American standard corresponds to the botanical species *T. aestivum*, while soft-wheat corresponds to separate class IV and VI. The optimal chemical composition and structure of the food matrix of whole wheat grains can contribute to preventive action and reduce the risks of chronic diseases. It was also suggested that, in addition to the effects of dietary fiber, the synergistic effect of some bioactive compounds helps to protect health and maintain the normal functioning of the body (Kokhmetova *et al.,* 2014; Chakraverty and Singh, 2004).

Whole wheat flour is the main source of protein and starch that can be present in bread while retaining the fully original nutritional value of wheat and enriching the composition of bread with macro- and micronutrients as well. In whole-wheat flour, all anatomical components of the grain, such as the endosperm, the germ, and the shell layers, are present in the same proportions as in the grain. Such flour contains significantly more dietary fiber, vitamins, and minerals compared with varietal types of flour (Kalinina and Fatkullin 2016; Yakiyayeva *et al.,* 2016; Slavin, 2004). Studies by scientists from different countries show that consuming whole grain foods can reduce the risk of cardiovascular disease, various types of cancer, and type 2 diabetes, and possibly improve body weight regulation. The technology of preparing bread on cavitation-activated water, accompanied by hydration structuring of gluten proteins, allows the increase of the specific volume of bread, increases its elasticity, slows down the hardening, and reduces the use of baking improvers (Meleshkina, 2018; Mei *et al.,* 2016; Maemerov, 2004).

Ion-ozone processing of products affects the biological and physiological effects, the development and vital functions, produces a disinfecting effect, increases the biological value of bread, increases the shelf life of finished bread by reducing the negative impact of external factors (improving grain safety, reducing the factors that lead to bread diseases, etc.) for storage of finished bread (Munarso *et al.,* 2020; Maemerov *et al.,* 2011; Erkmen, 2001; Kim, Yousef, and Khadre, 2001). We propose ways to improve the quality of bread using innovative ion-ozone cavitation technology in baking with wheat of different classes.

Ion-ozone cavitation plant for accelerated dough preparation simplifies and improves the accuracy of the process of dividing the dough into portions of a given weight, improves the quality of aerated dough, reduces energy consumption, and increases production productivity. Cavitation processing of the dough allows for reducing the technological process of production, in particular, to reduce the process of fermentation of the dough in the preparation of bakery products, and reduce the amount of pressed yeast in the test. The use of cavitation processing of dough makes it possible to reduce the duration of the technological process of bread production from 3 to 6 hours, significantly increase labor productivity by 2-3 times, and increase bread yield by 14-18%.

2. Methods

The use of deep processing of whole meal flour from promising varieties of low-grade wheat and cavitation processing of dough improves the quality, nutritional and biological values, and safety of finished products and reduces the technological process of production. Organoleptic and physico-chemical were used as indicators to prove the quality and nutritional value of the products and were examined in the Accredited Food Safety Testing Laboratory.

To accomplish the tasks, first of all, an analysis of the technique and technology of bakery products from low-grade wheat was carried out. Ways were identified to intensify the production of bakery products based on ion-ozone cavitation technology for making dough from low-grade wheat in order to improve quality, reduce the technological process of production, increase labor productivity, and improve the socio-economic indicators of bakery enterprises. Safety studies of raw materials and developed bakery products are carried out in accredited food safety laboratories.

Whole-ground wheat grain of the following classes was determined as an object of research: III, IV, V, as well as non-class wheat. Grain sampling was carried out according to GOST 13586.3–2015 (GOST 13586.3–2015, 2015). The mass fraction of protein in terms of dry matter was determined according to GOST 10846–91 (GOST 10846–91, 2009). The total amino acid composition was determined according to GOST 32195–2013 (GOST 32195–2013, 2013). The amino acid rate was calculated by comparing the amino acid composition of the grain protein with the scale of the adequacy of the content of essential amino acids in the "ideal protein" according to the UNO/WHO (United Nations Organization/World Health Organization) as applied to human needs in adulthood. The limiting amino acid was determined by amino acid - lysine.

Research and baking of bread products were carried out on the basis of scientific laboratories of Almaty Technological University.

Before grinding, wheat of low grades was processed in an ion-ozone cavitation installation (Figure 1).

In order to receive ions in this installation, oxygen is passed through an ion chamber, in which quiet electric charges act. This process charges oxygen with negative ions. Enriched oxygen enters and grain processing takes place. Oxygen molecules take away electrons and become negatively charged ions and they are significantly ten times more chemically active than uncharged oxygen molecules. The negative ions resulted contribute to the improvement of biochemical and vitamin properties of the product.

Figure 1 Ion-ozone cavitation installation: (1) ion-ozone generator; (2) cavitation capacity

Through the ozone generator, the wheat receives ozone. This method is based on the ability of oxygen molecules to decay into atoms under the influence of electric discharge energy. Atomic oxygen, in turn, immediately combines with an oxygen molecule, turning it into ozone.

By combining the electrical circuits of the ionizer and ozonator installation, an ion-ozonator installation has been developed that neutralizes all harmful synthesized impurities, as a result, a pure ion-ozone mixture is obtained without harmful impurities. Oxides of nitrogen and carbon, together with other harmful impurities and radiation during the synthesis of the ion-ozone mixture in the ion-ozonator installation are neutralized.

In this case, the formation of positive ions and free electrons from atoms or molecules with an appropriate degree of ionization accompanies the origin of impact ionization. The probability of the occurrence of impact ionization is characterized by an effective ionization cross-section and depends on the kind of ionizable and bombarding particles, depending on the kinetic energy with a certain minimum (threshold) value. This minimum value is probably equal to zero and, with an increase in energy above the threshold, it first rapidly increases, reaches a maximum, and then, with corresponding energy potentials, decreases (Zhakatayeva *et al.,* 2020; Iztayev *et al.,* 2018; Kalinina, Naumenko, and Fatkullin, 2018).

The energy that needs to be reported to an atom (molecule) for its ionization is called the ionization energy. If the energy transferred to ionized particles in collisions is large enough, then under certain conditions a particle can ionize in collisions. In this case, only part of the energy necessary for ionization is transferred to it, and first, the atoms (molecules) in the primary collisions are transferred to the excited state, after which shock ionization occurs and it is enough to tell the missing energy (equal to the difference between the ionization energy and the excitation energy), multistage ionization occurs. It is possible if collisions occur so often that the particle in the interval between two collisions does not have time to lose the energy received in the first of them. And also in the same cases when the particle has metastable states, and with the ability to conserve the excitation energy relatively long, multiple ionization occurs.

Ion-ozone cavitation occurs as a result of a local critical increase in excess pressure above 4 atm and a sharp release of excess pressure to the atmospheric environment during product processing. And they can also occur either with an increase in its velocity; or with the creation of a sharp drop in excess pressure during the half-cycle of rarefaction (acoustic ion-ozone cavitation), there are other reasons for the effect. Moving with the flow to a region with a higher overpressure or during the half-compression period, the cavitation bubble filled with the ion-ozone mixture slams, emitting a shock wave with an ozone explosion, which facilitates the interaction of the ion-ozone mixture with the processed product. At the same time, bubbling, instant destruction of microorganisms, pests of products of biological origin, on the basis of quantum-physical processes in comparison with similar technologies occurs intensively, the biological value of the product increases more, resistance to external irritants is acquired, and the time of the positive effect of ion-ozone interaction on the processed product is reduced (Tursunbayeva *et al.,* 2021; da Costa *et al.,* 2018; Li *et al.,* 2013; Sandhu, Manthey, and Simsek, 2011).

Usually, this is achieved due to a critical overpressure of 4 atm or more with a sharp release of excess pressure to atmospheric pressure, the design of hydro turbines, or by passing an ion-ozone mixture through a ring-shaped opening that has a narrow inlet and a significantly larger outlet: a forced decrease in pressure leads to ion-ozone cavitation since the ion-ozone mixture tends to the side of a larger volume (with increasing pressure, ozone acquires potential energy to explode). This method can be controlled by devices that control the size of the inlet, which allows you to adjust the process in various environments. The outer side of the mixing valves, along which the ion-ozone cavitation bubbles move in the opposite direction to cause implosion (internal explosion), is subjected to tremendous pressure and is often made of heavy-duty or rigid materials, for example, stainless steel, or stellite. This device is called the ion-ozone cavitation installation (Tursunbayeva *et al.,* 2019; Masudin, Fernanda and Widayat, 2018; Zapevalov, Kovalenko, and Petrova, 2015).

During ion-ozone treatment, crops are loaded into an ion-ozone cavitation unit pre-filled with an ion-ozone mixture with an ozone concentration of 0.5 mg/dm^3 to 4 mg/dm^3 (or from 0.5 x 10^{-3} to 4 x 10^{-3} mg/cm^3) and molecular ions ranging from 500 to 60,000 units/cm^3. In this case, the ratio of ion concentration (units/cm^3) to ozone concentration (mg/cm^3) $C_{i/o}$ is (1-15) x 10^{-6} units/mg, which is 1-15 million units/mg. Then, ion-ozone treatment is carried out for 10-20 minutes..

In the case of ion-ozone cavitation treatment of grain after ventilation, the cavitation installation is hermetically closed, and the ion-ozone mixture is pumped into the tank until an overpressure of 2 to 4 atm is created, after which the overpressure is sharply discharged, while the ozone tends to explode. In this case, a sharp discharge of excess pressure and the power of an ozone explosion adds up. During the explosion, cavitation processes occur, in which the pores of the treated cultures increase, and the ion-ozone mixture penetrates more efficiently. At the same time, ozone destroys harmful impurities and harmful insects; and molecular oxygen ions based on quantum-physical processes increase the biological value of the product.

After processing, wheat of various classes was ground and whole-ground flour was obtained from them. Then, it is ready to be used to prepare the dough.

The duration of the process of making white bread from wheat flour is as follows. The preliminary stage for dough kneading takes 9 minutes, then the dough kneading takes approximately 18–22 minutes. The next step is the first proofing of the dough piece, which takes around 60–70 minutes. The duration of dough dipping is 20 minutes, then the second stage of proofing the dough takes 70 minutes. This results in an airy and uniform bread structure. Baking the bread takes 63–68 minutes; the final baking process is 10–19 minutes.

For the manufacture prototypes, the following raw materials were used: flour from soft wheat of different classes purchased at Mibeko LLP (Kostanay, Kazakhstan), table salt (GOST R 51574-2000)50, and drinking water (SanPiN 2.1.4.1074-01)51.

The main stage in the preparation of the dough mechanically is the churning of the semi-finished product using cavitation (excessive pressure). The purpose of the study is to study the possibility of obtaining aerated bread from low-quality low-grade flour by mechanical loosening under pressure in an ion-ozone cavitation unit.

The physico-chemical properties, the content of amino acids, grain protein were studied. Organoleptic, physico-chemical, and microbiological indicators of bread indicators are also examined. In whole-wheat flour of different classes, the amino acid composition was determined. The following indicators were determined in finished bread products using innovative technologies: organoleptic properties (GOST R 58233-2018), humidity (GOST 21094-75), acidity (GOST 5670-96), porosity (GOST 5669-96), and shelf life (GOST 8227-56) of finished products. Organoleptic indicators determine the following results: the appearance of the finished bread, the color of the crusts, the nature of porosity, elasticity, and the chewiness of the crumb. Six experts participated in the survey to determine the organoleptic indicators of bread and were evaluated on a 5-point scale.

The experiment was carried out in 3 repetitions. Taking into account the presence of significant coefficients of pairwise interactions in many equations (i.e. the nonlinearity of the objective function and quality assessment criteria), the search for optimal processing modes was carried out using non-linear programming methods –Newton's method included in the "Search for a solution" procedure in MS Office Excel.

3. Results and Discussion

As is known, for the correct assessment of the nutritional value of wheat as a grain, the amino acid composition of proteins and the balance of their amino acid composition are of great importance. Moreover, even the insignificant effect of proteolytic enzymes promote the hydrolysis of proteins with the formation of peptides and amino acids, therefore, the amino acid composition of wheat grain changes. The largest amounts of whole wheat grains contain leucine (75.2 ± 0.7 mg/1 g protein), phenylalanine (52.1 ± 0.6 mg/1 g protein), and glutamic acid + glutamine (219.2 ± 4 mg/1 g of protein), which is typical for this type of wheat.

The smallest values can be noted for lysine (19.8 ± 0.3 mg/1 g protein), tryptophan (10.1 ± 0.3 mg/1 g protein), and threonine (18.7 ± 0.3 mg/1 g protein).

From the studied wheat samples of different classes, bread products were obtained using innovative technologies from whole-grain flour.

To achieve this goal, samples of bread from wheat flour of different classes according to traditional formulations using water for technical purposes and cavitated water using ion-ozone processing were developed.

The traditional recipe for baked bread with a yield of 859 g includes the following ingredients - wheat flour: 465 g, pressed yeast - 7.5 g, salt - 6.5 g, and water - 380 ml. Bread without the use of innovative methods using wheat of the 1st grade was taken as a control sample. The appearance of the obtained products can be estimated in Figure 2.

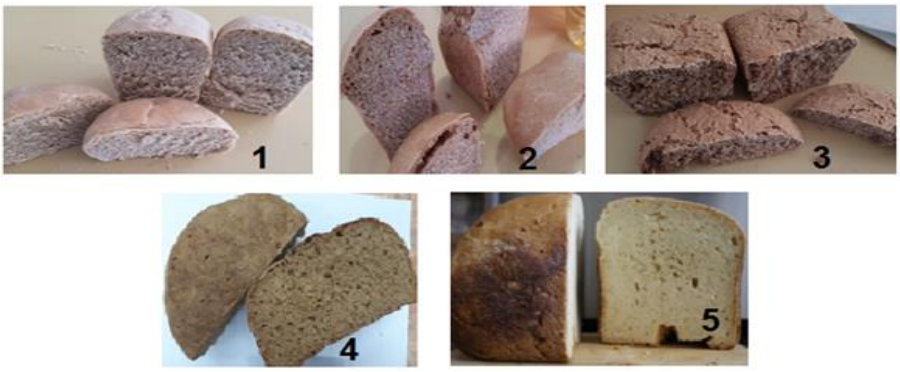

Figure 2 Appearance of the obtained bread products: (1) bread from wheat flour of class III, (2) bread from wheat flour of class IV, (3) bread from wheat flour of class V, (4) bread from non-class wheat flour, and (5) bread from first-grade flour (control sample)

The organoleptic characteristics of the obtained bread samples are shown in Figure 3.

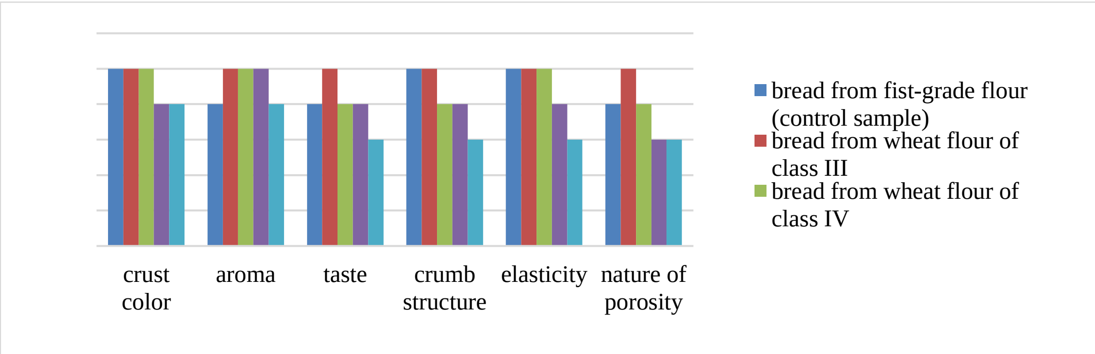

Figure 3 Organoleptic characteristics of the obtained bread samples (please redraw with better quality)

From the results of the assessment, it can be revealed that a sample of bread from the wheat of class III, obtained on the basis of cavitated water, has a total score of at most 25 points, which is significantly higher than that of a control sample obtained from water for technical purposes, the rating of which is 23 point.

The parameter "porosity character" in a sample obtained on the basis of cavitated water from class III wheat is higher than that in a control bread sample. Organoleptic indicators are more characteristic for a sample of class III wheat bread obtained on the basis of cavitated water and ion-ozone treatment and are due to the presence of a regular shape with a slightly convex upper crust without lateral protrusions, an increase in the volume of the product, the presence of developed thin-walled porosity with round pores, without voids and seals, as well as a soft and elastic crumb.

For a sample of wheat bread outside the class, the presence of a dense low crust, uneven thick-walled porosity with compaction and without voids, and the insufficiently elastic and slightly wrinkled crumb was revealed.

When using innovative methods, the pores of the crumb of the finished bread samples became more thin-walled and uniform. Changes in the acidity and humidity of the crumb of wheat bread from classes III and IV did not have a significant difference from the control sample. They differed from the control sample in sufficient porosity (although pores were less pronounced compared to the image from class III wheat). The color of bread-finished products with the increase in the class of whole-wheat became more and more intense. The difference in appearance and tears was also noted: with an increase in the class of whole-ground wheat, the number and depth of tears increase, as well as the height of the finished products decreases.

Despite the fact that the volume of bread from class III wheat is inferior to the control sample, the porosity and other organoleptic characteristics are characterized by improved results. Wheat bread outside the class had the least indicators, where the color turned out to be the darkest; the crumb pores became the least noticeable; and the crumb taste, crumb structure, elasticity, and character of the crumb had the least attractive indicators for the consumer.

As a result, it was proved that innovative ion-ozone cavitation technology allows for improving the organoleptic characteristics of bread, thereby increasing its attractiveness to consumers, but there is also a connection between the class of wheat and the organoleptic properties of the obtained bread samples.

Table 1 shows the results of a study of some physico-chemical parameters of the finished bread using innovative methods in comparison with a control sample.

Table 1 Physico-chemical quality indicators of the obtained wheat bread of different classes using innovative technologies

Quality indicators	Bread from first-grade flour (control sample)	Bread from wheat flour of class III	Bread from wheat flour of class IV	Bread from wheat flour of class V	Bread from non-class wheat flour
Humidity, %	47.4 ± 0.12	49.7 ± 0.06	48.8 ± 0.07	47.4 ± 0.07	45.6± 0.14
Acidity, degrees	3.6 ± 0.08	3.4 ± 0.02	3.4 ± 0.09	3.5 ± 0.11	3.6 ± 0.08
The specific volume of bread, cm^3/100 g	188.4 ± 0.31	179.6 ± 0.54	169.4 ± 0.22	165.2 ± 0.91	158.3 ± 0.43
The porosity of the crumb, %	64.3 ± 0.20	67.3 ± 0.13	66.0 ± 0.41	63.4 ± 0.13	59.7 ± 0.35

Table 1 shows that the moisture content of bread products made from class III flour is 2.3 % higher, from class IV flour is higher by 1.4%, from non-class wheat flour is lower by 1.8 % compared to the control sample, also, the moisture content of bread made from class III flour does not exceed that of the bread of the control sample. The acidity of bread products ranged from 3.3 to 3.6 degrees. There were significant differences in specific volumes: bread from class III flour was lower by 8.8 cm^3/100 g, bread from class IV flour was lower by 19.0 cm^3/100 g, bread from class V flour was lower by 23.2 cm^3/100 g and bread made from non-class flour is lower by 30.1 cm^3/100 g. From this, we can conclude that the lower the quality of flour, the lower will be the specific volume of bread obtained from it. The porosity of bread products from class III flour was higher by 3.0%, from class

IV flour was higher by 1.7 %, from class V flour was lower by 0.9 %, and from non-class wheat flour was lower by 4.6 % than the control sample.

The obtained results of organoleptic and physico-chemical indicators show that high-quality bread products can be obtained from flour treated with ion-ozone flows.

After baking, bread samples were examined for shelf life. Ion-ozone cavitation treatment had a noticeable effect on slowing down the process of stale bread. Only after 48 hours did the test samples increase crumbling, which indicates the process of staling in the bread. The critical hours for storing bread were 96 hours when the unpleasant odor sharply increased, a sour smell appeared with notes of musty, and the structure of the bread crumb and porosity with the volume of bread decreased. Whereas the control bread sample was distinguished by initially low-quality indicators during storage and after 48 hours this type of bread had low indicators.

Assessment of physico-chemical indicators of the quality of bread during storage confirmed the results of the organoleptic evaluation and showed that the samples obtained using ion-ozone cavitation treatment, already in the initial storage period, have a value higher than that of the control sample.

The organoleptic, physico-chemical properties of bread samples obtained using innovative technologies from the wheat of different classes showed that ion-ozone cavitation treatment has a positive effect on the quality of finished products. However, it can be argued that the class of wheat has a significant impact on the quality of finished bread samples.

When processing dough, an overpressure from 2 to 6 atm is created in the cavitator (depending on the parameters of the batch), and as a result of pressure, cavitation bubbles are formed filled with a hydroionoozone mixture, while two phases are distinguished - expansion and collapse, which together form a complete thermodynamic cycle. In the pressure zone, the hydrostatic pressure decreases to such an extent that the forces acting on the molecules of the liquid become greater than the forces of molecular bonds. As a result of a sharp change in hydrostatic equilibrium, the ion oozonized liquid seems to explode, generating numerous tiny bubbles, while ozone, while still under pressure in the bubbles, has the ability to self-explode, in addition to a sharp drop in excess pressure in the cavitator from 2 atm and above to atmospheric. As a result, the pores of the processed products increased and the dough preparation time decreased, while the quality of the products obtained improved.

The results showed that the quantitative and qualitative indicators of bakery products made from wheat flour of III, IV, V class, and non-class wheat do not lag behind the wheat bread of the first grade while also maintaining beneficial properties to the human body.

4. Conclusions

In the process of baking bread with innovative highly effective technology, the number of essential amino acids, such as isoleucine, leucine, lysine, and threonine increase; and the organoleptic and physico-chemical parameters are improved in accordance with the class of wheat. The correct choice of the optimal dosage ratio of rye and wheat bran in the test was confirmed by a series of parallel experiments that showed convergence of the results. The best in almost all investigated indicators compared to the control bread sample is wheat bread of class III. The results allow us to recommend a more thorough study of this topic and a further introduction to the production of technology for producing wheat from class III wheat using ion-ozone cavitation technology. An assortment of bakery products from class III, IV, and V wheat flour and non-class wheat flour was developed based on the ion-ozone cavitation dough preparation technology. The economic effect was achieved by reducing the duration of the production process from 3 to 6 hours, reducing the number of equipment due to the exclusion of fermentation and proofing processes (dough mixers, bowls, fermentation tanks, proofer), increasing the yield of bread by 8-10% and increase labor productivity by more than 2-3 times. The resulting bakery products will allow solving the future issues of improving the health of the nation as a whole by creating products with high nutritional and biological value, based on the deep processing of fine whole meal flour from the wheat of low grades.

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