

Application of a multi-component bakery improver in the technology of wheat bread enriched with the mixture of sprouted grains

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Abstract

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Introduction. The aim of the study was to develop the composition of a multi-component baking improver to preserve the sensory properties and prolong the freshness of bread made from wheat flour with the addition of a mixture of germinated grains.

Materials and methods. The development of the composition of the multi-component baking improver (MBI) was carried out using the influence of individual food additives on the quality of bread. The effect of MBI on bread staling was assessed by changing the deformation of the crumb, the formation of an under crust layer, and the accumulation of aromatic substances and dextrins in the bread.

Results and discussion. The composition of MBI includes whey powder enriched with Mn and Mg, wheat gluten powder, chicory inulin, carboxymethyl cellulose, lactic acid, phosphatide concentrate, and enzyme preparation Deltamalt FN-A50. For the production of wheat bread containing a mixture of sprouted grains, 15% by weight of flour, it is advisable to add the multi-component baking improver in the amount of 1.8% by weight of flour. Addition of MBI ensured the sensory characteristics and specific volume of bread enriched with the mixture of sprouted grains, which did not differ from control. Incorporation of the multi-component baking improver increased the overall, plastic and elastic deformations of the crumb of the bread, reduced the crumb's crumbliness and the thickness of the under crust layer. The deformation of the crumb of bread enriched with a mixture of sprouted grains and developed multi-component baking improver was after 72 hours of storage by two times greater than of the control (wheat bread). In bread containing the mixture of sprouted grains, 15% to the weight of flour, the addition of the multi-component baking improver increased the accumulation of low molecular weight dextrins by 77.6% compared to control.

Conclusions. The use of the developed multi-component baking improver has a positive effect on the quality of wheat bread enriched with the mixture of sprouted grains and prolongs bread freshness up to 72 hours without packaging.

Introduction

According to the American Association of Cereal Chemists with the endorsement of the United States Department of Agriculture “Sprouted grains are malted or sprouted grains containing all of the original bran, germ, and endosperm shall be considered whole grains as long as sprout growth does not exceed kernel length and nutrient values have not diminished” (Benincasa et al., 2019). Sprouting activates grain metabolism resulting in the synthesis of secondary metabolites such as various enzymes, vitamins, and phytochemicals, degradation of macronutrients compounds such as proteins and carbohydrates to increase their digestibility, and has often used as a method to improve the nutritive value of grains (Benincasa et al., 2019; Park et al., 2021; Peñaranda et al., 2021). This is a reason to use germinated grain seeds as a source of biologically valuable components in preparation of functional foods, production of which is one of the modern trends in food technology (Ivanov et al., 2021; Peñas and Martínez-Villaluenga, 2020).

The mixture of sprouted grains (MSG) containing equal amounts of sprouted wheat, oats, barley, and corn grains produced by the company Choice, Ukraine was used as non-traditional raw material in the present study. This mixture of sprouted grains is rich in vitamins (A, E, B1, B2, B3, B5, B6, B9, H, choline, PP), trace elements (boron, molybdenum, selenium, chromium, iron, vanadium, manganese, zinc, iodine, copper, fluorine), minerals (potassium, calcium, silicon, magnesium, phosphorus), essential amino acids (valine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, phenylalanine), and enzymes (lipase, cytase, proteases, phosphatases, α - and β -amylases) (Choice Sprouted Grains, <https://uakrasa.net/en/choice-proroshcheni-zerna-paket-150g/>).

In our previous study based on the results of trial baking, the dosage of the mixture of sprouted grains 15% to the weight of the high-grade flour was recommended to improve the nutritional and biological values of bread (Burchenko, 2018). It was found that addition of the mixture of sprouted grains to wheat flour reduces the volume of bread and its porosity (Burchenko, 2018). The application of bakery improvers allows to eliminate the negative impact of non-traditional raw materials on the quality of dough and bread, as well as intensify the technological process and extend the freshness period of bakery products (Bilyk et al., 2020; 2022).

To increase the quality and prolong freshness of products made with the addition of a mixture of sprouted grains, it is advisable to use multi-component baker improvers containing fillers (wheat flour, soybean flour, starch), oxidizers, reducing agents, enzymes, emulsifiers, malt flour, malt extract, modified starches, calcium sulfate, calcium carbonate, calcium propionate, calcium phosphate, ammonium chloride, carbohydrates (sucrose, glucose), lecithin, soy flour, acids (citric, lactic), protein supplements (dry gluten, dry milk, vegetable protein), and hydrogenated vegetable oils (Codina et al., 2007; Courtin and Delcour, 2002; Liang et al., 2021; Zhygunov et al., 2019).

The aim of the present study was the development of a multi-component baking improver that will increase the quality of products and extend their freshness period when using an addition to wheat flour the mixture of sprouted grains of wheat, oats, corn, and barley. To create multi-component baking improver the components, which belong to food additives, which are Generally Recognized as Safe (GRAS), were used.

Materials and methods

Materials

The mixture of wheat, oats, barley, and corn sprouted grains produced by the company Choice, Ukraine, was used in the study. Dough was prepared using high grade wheat flour.

Preparation of dough samples

Dough samples were prepared according to the recipe, g: high grade wheat flour, 100.0; pressed baker's yeast, 3.0; salt, 1.5; the mixture of wheat, oats, barley, and corn sprouted grains, 15.0. The dough was kneaded in a two-speed Escher kneading machine (Italy) straight with a moisture content of 44.0%. The fermentation period was replaced by a 20-minute proofing period. Dough processing was carried out manually, the proofing was carried out at a temperature of $38 \pm 2^\circ\text{C}$ and a relative humidity of $78 \pm 2\%$ until ready. Bread was baked in a Sveba-Dahlen cabinet oven (Italy) at a temperature of $200\text{--}220^\circ\text{C}$ in a humidified baking chamber for 30 minutes. All experiments were performed at least in triplicate.

Methods

Specific volume of bread

The specific volume of bread was determined by dividing the volume of bread by its weight and expressed in cm^3/g (Zhu et al., 2016).

Porosity of bread

The porosity of bread reflects the volume of the pores in a certain volume of the crumb, expressed as a percentage to the total volume (Verheyen et al., 2015).

Complex quality indicator

Quality evaluation of finished products was carried out based on sensory, physical, and chemical properties of bread, and expressed as a calculated complex quality indicator. The complex quality indicator is the total number of points that the experimental sample receives during its analysis. For its calculation, each product was evaluated by the following properties: correct form, specific volume, shape stability, crust color, crust surface condition, crumb color, porosity structure, crumb rheological properties, staling after 72 hours, bread aroma, bread taste, crumb chewiness. The obtained values were evaluated on a five-point scale, taking into account the weighting factor, which was established for each indicator through expert evaluation. That is, the number of points assigned to the indicator was multiplied by the weighting factor. Next, the sum of the obtained values was found. The greater the number of points the sample receives as a result of the calculation, the better its quality indicators (Bilyk et al., 2022). The expert commission included seven candidates of technical sciences, three post-graduate students for a doctor of philosophy degree and 15 students of higher education in the specialty "Food Technologies".

Crumb deformation

The duration of freshness preservation of the products was studied by the changes in the structural and mechanical properties of the crumb. Its total deformation after 48 hours of storage was determined using an AP 4/1 penetrometer "Finemass" (Germany) (Bilyk et al., 2022).

Content of aromatic substances

The content of aromatic substances in finished products was estimated by the amount of bisulfite-binding compounds (Bilyk et al., 2022).

Condition of the under crust layer

The degree of staleness was assessed by hand through the area and hardness of the under crust layer. Using scanning and graphic editors, the average thickness of the under crust layer was determined (Petrusha et al., 2018).

Microscopy of bakery products

Microscopy of bakery products was carried out after 72 hours of storage. The samples were stored without packaging at a temperature of 20 ± 0 °C. Preparation of samples was carried out by freezing, freeze-drying, and spraying carbon on a dried sample in a vacuum chamber. The samples were examined using an electron scanning microscope IEOLJSM-200 (Japan) at 1000 magnification, and the most visible areas were photographed.

Dextrin content

Dextrin content was determined by their mass fraction, based on the ability of dextrans to precipitate at different concentrations of ethyl alcohol in the solution (Bilyk et al., 2022).

Results and discussions

Development of a multi-component baking improver

A multi-component baking improver for bread from high-grade medium strength wheat flour containing 15% of a mixture of sprouted wheat, oats, barley, and corn grains to the weight of flour was proposed. Such food additives with GRAS status were chosen for the multi-component mixture: (1) apple pectin (Zhang et al., 2019), dry wheat gluten, carboxymethyl cellulose (Ammarab et al., 2020), chicory inulin, dry whey enriched with Mg and Mn (Kochubei-Lytvynenko et al., 2023) as moisture-retaining additives; (2): phosphatide concentrate (Gómez et al., 2004) as surface-active substances (3) amylolytic enzyme preparation Deltamalt FN-A50, and (4) lactic acid as a natural oxidizer.

Based on the results of trial baking, complex quality indicators of high-grade wheat bread with different multi-component baking improvers were calculated (Table 1).

According to the complex quality indicator, the best amounts of the components in wheat bread, % to the weight of flour, were: 0.5% for dry whey enriched with Mn and Mg; 0.004% for enzyme preparation Deltamalt FN-A50; 0.4% for carboxymethyl cellulose; 0.5% for dry wheat gluten; 0.6% for apple pectin; 1.0% for chicory inulin; 0.3% for phosphatide concentrate, and 0.2% for lactic acid (Table 1). During the preparation of multi-component baking improver, it is recommended to halve the found dosage of the component due to the synergistic effect in case of simultaneous their application (Bilyk et al., 2020). As a result, a recipe included 15% mixture of sprouted grains to the mass of flour, for a multi-component baking improver was developed. This improver intended to intensify the technological process, improve consumer properties, and extend the freshness of wheat bread (Table 2).

Table 1

Determination of the best dosage of ingredients in multi-component baking improver

The complex quality indicator		Dosage of component, %, to the mass of flour				
Control	15% mixture of sprouted grains					
84.6	76.2	Dry whey enriched with Mn and Mg				
		0.25	0.5	0.75	1.0	1.25
		80.6	82.1	82.2	82.6	82.8
84.6	76.2	Enzyme preparation Deltamalt FN-A50				
		0.001	0.002	0.004	0.006	0.008
		78.2	81.6	86.4	86.4	86.4
84.6	76.2	Carboxymethyl cellulose				
		0.1	0.2	0.3	0.4	0.5
		80.6	82.9	84.3	86.7	86.2
84.6	76.2	Dry wheat gluten				
		0.2	0.3	0.4	0.5	0.6
		79.2	80.6	81.4	82.3	82.3
84.6	78.4	Apple pectin				
		0.2	0.4	0.6	0.8	1.0
		80.8	82.2	84.9	84.8	84.5
84.6	76.2	Chicory inulin				
		0.2	0.4	0.6	0.8	1.0
		82.2	83.1	84.3	86.6	86.8
84.6	76.2	Phosphatide concentrate				
		0.10	0.20	0.30	0.40	0.50
		80.5	81.9	82.6	82.6	82.5
84.6	76.2	Lactic acid				
		0.1	0.15	0.2	0.25	0.3
		80.8	81.6	81.6	81.5	81.4

Table 2

Composition of multi-component baking improver

Component	Amount, kg per 100 kg
Chicory inulin	28.5
Dry whey enriched with Mn and Mg	14.3
Dry wheat gluten	14.3
Apple pectin	17.1
Carboxymethyl cellulose	11.4
Phosphatide concentrate	8.6
Deltamalt FN-A 50 enzyme preparation	0.1
Lactic acid	5.7
Total	100.0

To further study the effect of the developed polycomponent mixture on the structural and mechanical properties of dough and biochemical processes in it, the recipe with 15 % mixture of sprouted grains (MSG) and 1.8% multi-component baking improver (MBI) to the mass of flour was chosen (Table 3, Figure 1).

Table 3

Effect of a multi-component baking improver on the technological process and quality of wheat bread

Indicator	Control (without additives)	15% MSG to the mass of flour	15% MSG and 1.8% MBI to the mass of flour
<i>Dough</i>			
Moisture, %	44.0		
Titrated acidity, degrees:			
initial	1.6	2.0	2,2
final	2.0	2.4	2.6
Proofing time, min	60	50	50
Gas formation in the dough during fermentation and proofing, cm ³ /100 g of dough	812	992	1058
<i>Bread</i>			
Specific volume, cm ³ /100 g	298	263	312
Shape stability, H/D	0.47	0.25	0.48
Acidity, degrees	1.8	2.4	2,2
Porosity, %	78.0	64.0	82.0
Total crumb deformation, penetrometer units: 4 hours	84	98	106
72 hours	42	74	88
Crumb condition and color	Smooth without cracks and tears, light yellow color	Smooth without cracks and tears, golden color	
Correct form	Bread with a noticeably convex upper crust	Bread with a dome-shaped upper crust	
Crumb color	Light white	Gray	Light gray
Porosity structure	Small, thin- and medium-walled pores, distributed fairly evenly	Pores of different sizes, medium thick, unevenly distributed	Small, thin- and medium-walled pores, distributed fairly evenly
Taste and aroma	Typical for this type of product without extraneous taste and smell	Typical for this type of product with a pleasant taste and aroma, the aftertaste of sprouted grains can be felt	



Figure 1. Breads:

**1, control (without additives); 2, with 15% mixture of sprouted grains to the mass of flour;
3, with 15% mixture of sprouted grains and 1.8% multi-component baking improver to the
mass of flour.**

It was found that the mixture of sprouted grains added in amount of 15% to the mass of flour leads to a deterioration of the sensory, structural, and mechanical properties of the finished product that can be explained by the excessive activity of amylolytic and proteolytic enzymes in the germinated cereals. The developed multi-component baking improver increased the quality of wheat bread prepared with the addition of the mixture of sprouted grain. Multi-component baking improver has a positive effect on the rheological properties of the dough. The duration of dough proofing with the mixture of sprouted grains and with mixture of sprouted grains and multi-component baking improver was 50 minutes, which was 10 minutes less than for the control sample. The initial and final acidity of dough increases in comparison with the control sample by 0.6 degrees. Gas formation in the dough with multi-component baking improver increases by 23.3%, which is a base for the increasing of the specific volume in the breads. Due to using the developed multi-component baking improver, the specific volume of breads increases by 15.7% and by 4.5% compared to the control sample. The dimensional stability of flour products approaches the results of the control sample. The acidity of the breads increased compared to the control sample by 0.6 degrees and 0.8 degrees, respectively, but did not exceed the permissible values. When adding multi-component baking improver, the porosity of the breads improves. Thus, the bread with the mixture of sprouted grains and multi-component baking improver had a porosity of 82%, which is by 22% more than for the bread with mixture of sprouted grains and by 4.9% more than of the control sample. When adding the mixture of sprouted grains and multi-component baking improver to the dough, the total, plastic, and elastic deformations of the crumb have been improved.

Application of the developed multi-component baking improver helps to preserve of freshness of bread. Thus, the deformation of the crumb of bread enriched with a mixture of sprouted grains and developed multi-component baking improver was after 72 hours of storage by two times greater than of the control (wheat bread). The application of multi-component baking improver enhanced the sensory properties of bread: the crumb color of the bread lightens; the porosity structure becomes uniform, the pores are thin-walled and medium in size; the crumb becomes elastic, the lumpiness and stickiness disappear. Bread has a pleasant taste and aroma, and the taste of sprouted grains can be felt.

Effect of a multi-component baking improver on the quality and prolongation of the shelf life of wheat bread with the mixture of sprouted grains

The taste and aroma of bread are important consumer properties (Meziani, 2012). Therefore, the effect of the mixture of sprouted grains and a developed multi-component baking improver on the flavor of bakery products was studied. The formation of taste and aroma depends on the recipe composition and the fermentation process. Incorporation of the mixture of sprouted grains and multi-component baking improver in the dough changes the content of proteins, carbohydrates, and fats, which leads to the changes in aroma formation, namely, due to increase in the amount of carbonyl compounds.

The improved aroma of bread, namely, the increased content of bisulfite-binding compounds, is explained by the fact that the mixture of sprouted grains increases the content of sugars and amino acids. Ingredients of multi-component baking improver, namely dry milk whey, dry wheat gluten, and apple pectin additionally increase the content of protein that increases the number of carbonyl compounds and slow down their release during the storage of bread. The composition of the developed multi-component baking improver includes apple pectin, phosphatide concentrate, dry whey enriched with Mg and Mn, and chicory inulin, which accelerate the fermentation process and contribute to the accumulation of aromatic substances. So, the content of carbonyl compounds in finished product increases by 2.1 times caused the improvement of crust color and bread aroma.

During cooling and storage, the internal process of moisture migration takes place in bread due to the driving force, which is the gradient of relative moisture content between structurally different parts of the product, namely, the crumb and the crust. The gradient of relative moisture content is formed due to the baking process where the crust, which is exposed to high temperatures, is crispy, and the crumb, which is formed at lower temperatures, is soft. This causes parts of the same product to have different moisture content, therefore, its equalization takes place during the storage period. This leads to the crust softening, the crumb staling, and a thicker under crust layer forming.

Table 4
Content of bisulfite-binding substances, mg-eq/100 g of bread

Part of bread	Control (without additives)	15% MSG* to the mass of flour	15% MSG and 1.8% MBI** to the mass of flour
After 4 hours			
Crumb	6.2	11.8	13.6
Crust	18.9	26.1	29.2
After 24 hours			
Crumb	5.2	10.1	12.3
Crust	16.2	26.1	27.2
After 48 hours			
Crumb	4.4	9.1	11.4
Crust	14.1	20.2	25.3
After 72 hours			
Crumb	3.1	7.2	9.1
Crust	12.8	15.1	20.8

*MSG, mixture of sprouted grains; **MBI, multi-component baking improver.

Addition of the mixture of sprouted grains and combined use of mixture of sprouted grains and developed polycomponent mixture reduce the formation of the under crust layer, and therefore have a positive effect on slowing down the staling process of bakery products (Figure 2).

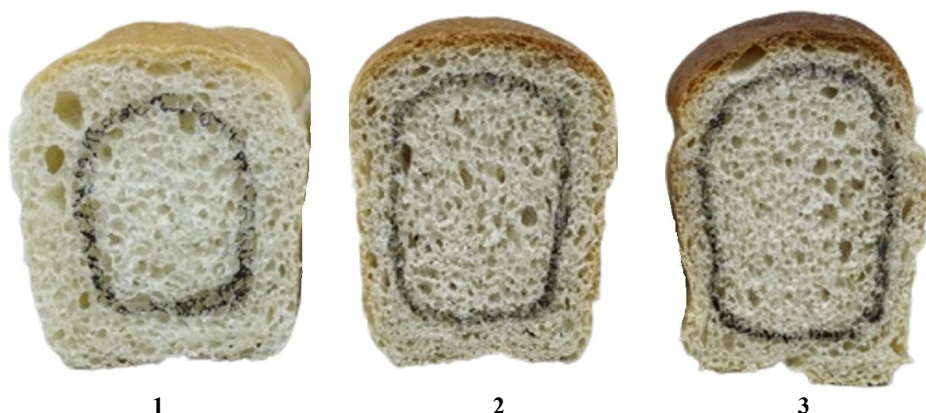


Figure 2. Formation of under crust layer during the storage of bakery products after 72 hours:
1, control (without additives);
2, with 15% mixture of sprouted grains to the mass of flour;
3, with 15% mixture of sprouted grains and 1.8% multi-component baking improver to the mass of flour.

It was shown that the under crust layer in the bread with mixture of sprouted grains or mixture of sprouted grains and multi-component baking improver after 72 hours of storage was thinner compared to the under crust layer of the control. To confirm it, a section of breads was scanned and the thickness of the under crust layer was measured. It was found that the under crust layer was 10.4 mm in the control bread, 8.5 mm in the bread with 15% mixture of sprouted grains, and 3.24 mm in the bread with 15% mixture of sprouted grains and multi-component baking improver (Figure 2).

To confirm the positive effect of addition of the mixture of sprouted grains and the combined use of the mixture of sprouted grains and multi-component baking improver on the crumb, microscopy of bakery products was carried out after 72 hours of unpacked storage at a temperature of 20 °C. Prepared samples were examined using an electron scanning microscope IEOLJSM-200 with a magnification of 1000 and the most revealing, characteristic areas were photographed. The analysis of microphotographs showed that when using the mixture of sprouted grains or the mixture of sprouted grains combined with developed multi-component baking improver, the crumb consists of swollen and partially pasteurized starch grains, which are interspersed in a solid mass of coagulated proteins, with few visible layers of air (Figure 3).

The microphotograph analysis of the control sample showed that the crumb is characterized by the presence of voids formed due to the transition of starch from an amorphous to crystalline state and protein compaction. Thus, addition of the developed multi-component baking improver showed positive effect on the sensory properties of wheat bread with the mixture of sprouted grains, the formation of the under crust layer decreases when storing the products in unpackaged form for 72 hours, and the structure of their crumb improves.

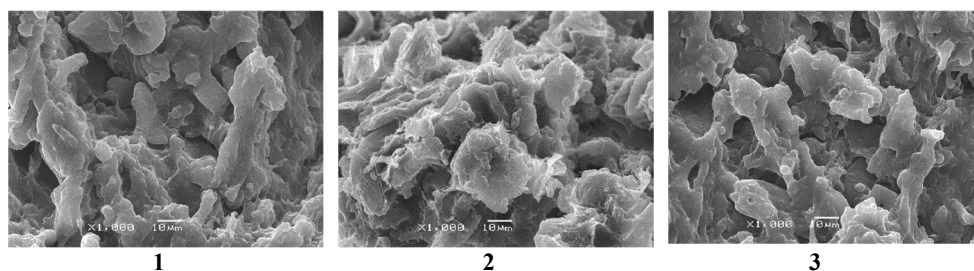


Figure 3. Microstructure of wheat bread after 72 hours of storage:

- 1, control (without additives);**
- 2, with 15% mixture of sprouted grains to the mass of flour;**
- 3, with 15% mixture of sprouted grains and 1.8% multi-component baking improver to the mass of flour.**

An increase in sugar content leads to improved porosity of bakery products: it becomes more thin-walled and uniform, the taste of the products improves, and the shelf life is extended (Müller et al., 2021). It is also known that increased autolytic activity contributes to the accumulation of dextrins during baking, which in turn extends the shelf life. Due to the fact that mixture of sprouted grains has high autolytic activity and high content of its own sugars (Lazaridou, 2027), and multi-component baking improver includes the enzyme preparation Deltamalt FN-A50, which reduces the autolytic activity of the dough system, it was expedient to study the change in the amount of dextrins in wheat bread. Determination of dextrin content was carried out 4 hours after cooling (Table 5).

Table 5

Dextrin content in breads

Bread samples	Dextrin content of by fractions, % to dry matter			Total dextrin content
	Amylo-dextrins	Erythro-dextrins	Malto- and macro-dextrins	
Control (without additives)	0.786	0.274	0.634	1.694
15% SGM to the mass of flour	1.426	0.542	1.246	3.214
15% SGM and 1.8% MCM to the mass of flour	1.236	0.421	1.126	2.783

The results confirmed an increase in the amount of dextrins compared to the control when using the mixture of sprouted grains or the mixture of sprouted grains combined with multi-component baking improver. It is known that low molecular weight dextrins, namely malto-dextrins and acro-dextrins, extend the shelf life of bakery products due to the formation of a three-dimensional network that prevents starch from giving off moisture and thus slows down its retrogradation. Thus, in bread with 15% mixture of sprouted grains to the weight of flour, the use of multi-component baking improver increases the accumulation of low molecular weight dextrins by 77.6% compared to the control. Therefore, the developed multi-component baking improver contributes to the accumulation of low molecular weight dextrins, which slow down the process of wheat bread going stale.

Conclusions

1. To produce wheat bread with increased nutritional and biological values, a mixture of sprouted wheat, oats, barley, and corn grains was included in the recipe. With the dosage of mixture of sprouted grains being 15% to the mass of flour, there is some deterioration of the sensory, structural, and mechanical properties of the finished product, which can be explained by the excessive activity of amylolytic and proteolytic enzymes of mixture of sprouted grains. In order to increase the quality of wheat bread, it is recommended to use multi-component bakery improvers.
2. A composition of multi-component baking improver has been developed, which is intended for intensifying the technological process and improving the quality of finished products. The composition of the multi-component baking improver includes food additives that are Generally Recognized as Safe. The developed multi-component baking improver has a positive effect on the quality of wheat bread enriched with the mixture of sprouted grains.
3. In the production of wheat bread which contains 15% of the mixture of sprouted grains to the mass of flour, it is advisable to use the developed multi-component baking improver in the amount of 1.8 % to the mass of flour.
4. Application of the developed multi-component baking improver extends the freshness of bakery products. The mixture of sprouted grain and the developed multi-component baking improver contribute to the accumulation of low molecular weight dextrans, which slow down the staling process due to the formation of a three-dimensional network that prevents the loss of water by starch. It has been confirmed that in the bread with a multi-component baking improver, the crumb of products stored for 72 hours without packaging consists of a solid mass of proteins coagulated during baking, in the middle of which swollen, partially gelatinized starch grains are interspersed with few layers with visible air, which confirms the slower starch retrogradation.

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