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## **DEVELOPMENT OF A COMPLEX BAKERY IMPROVER «FRESHNESS SMS SUPER» TO EXTEND THE FRESHNESS OF WHEAT BREAD**

*Об'єктом дослідження у роботі є пшеничний хліб, одним з найбільших недоліків якого є черствіння під час зберігання. Інтенсивність перебігу процесів в готовому виробі, що зумовлюють черствіння, залежать від якості сировини, зокрема хлібопекарських властивостей борошна.*

*Вирішення проблеми подовження свіжості пшеничного хліба можливе використанням нетрадиційної сировини, харчових добавок та комплексних хлібопекарських поліпшувачів.*

*В ході розроблення комплексного хлібопекарського поліпшувача «Свіжість СМС Супер» було обрано як функціональну основу суху молочну сироватку, збагачену Mn та Mg, технологія якої розроблена науковцями Національного університету харчових технологій (Київ, Україна). До складу активної частини поліпшувача включено карбоксиметилцелюлозу, емульгатор, ферментний препарат амілолітичної дії з мальтогенною амілазою, аскорбінову кислоту, мальтодекстрин, яблучний пектин.*

*За симплекс-центроїдним планом Шеффе отримано графічні моделі, за якими можна передбачувати оптимальне дозування комплексного хлібопекарського поліпшувача «Свіжість СМС Супер» у разі переробки борошна з різними хлібопекарськими властивостями. Відповідно до графічних моделей встановлено, що у разі використання борошна середнього за силою, що має нормальну газоутворювальну здатність та водопоглинальну здатність в межах 59–61 %, оптимальне дозування комплексного хлібопекарського поліпшувача «Свіжість СМС Супер» становить 1,5 % до маси борошна.*

*Встановлено, що у разі використання комплексного хлібопекарського поліпшувача «Свіжість СМС Супер» виробі черствіють повільніше. Це пов'язано з тим, що до у рецептуру комплексного хлібопекарського поліпшувача входять вологоутримуючі харчові добавки, які під час зберігання хлібобулочних виробів повільніше віддають вологу, ніж біополімери борошна. Також до складу поліпшувача входить ферментний препарат з мальтогенною  $\alpha$ -амілазою, яка уповільнює процес ретроградації крохмалю, знижуючи втрату вологи крохмалем.*

*Завдяки використанню комплексного хлібопекарського поліпшувача «Свіжість СМС Супер» хлібобулочні виробі зберігають свіжість до 72 год зберігання в неупакованому вигляді незалежно від хлібопекарських властивостей борошна.*

**Ключові слова:** свіжість пшеничного хлібу, комплексний хлібопекарський поліпшувач, функціональна основа, активна частина.

### **1. Introduction**

Bakery products in Ukraine are traditional food products. Significant competition in the market of these products prompts manufacturers to produce high quality bakery products and with a long shelf life.

The quality of bakery products and the rate of stagnation depend mainly on the baking properties of flour, the technological process, additional raw materials, storage conditions. Bakery properties of flour do not always meet the necessary requirements, therefore at bakery enterprises they are regulated by mixing different quantities of flour, using food additives [1].

In most cases, each food supplement has its own functional purpose. It can be a food additive of oxidative or reducing action, a surfactant, enzyme preparations, a structure-forming agent. To use individually each food additive is technologically and economically impractical, therefore it is better to use complex baking improvers.

The actual for today is the development of complex baking improvers of directional action, in particular for slowing the process of staling, and setting its optimal

dosage in the case of processing flour with various baking properties.

### **2. The object of research and its technological audit**

*The object of research* is bread made from wheat flour of the highest grade and the following component improvers:

- dry whey enriched with Mn and Mg;
- food additives, namely the enzyme Novamyl 1500 MG, carboxymethyl cellulose, apple pectin, maltodextrin, lecithin and ascorbic acid.

Bread «Milk freshness» was made from wheat flour of the highest grade by an accelerated method according to the recipe:

- extra fine wheat flour – 100 kg;
- pressed bakery yeast – 3.0 kg;
- food salt – 1.5 kg.

To develop a complex bakery improver «Freshness SMS Super» as a functional basis, dried milk whey enriched with Mn and Mg (developed by the National University

of Food Technologies, Kyiv, Ukraine) was used [2]. The active components of the improver are:

- enzyme preparation Novamil 1500 MG of the Danish firm Novozymes;
- carboxymethyl cellulose of the Ukrainian company «Khimpostach»;
- apple pectin produced in Ukraine;
- maltodextrin of the Polish company;
- fat-free lecithin made from sunflower produced by the Ukrainian company «BIOLER»;
- ascorbic acid produced in China.

The biggest shortcoming of the research object is staling during storage. The intensity of the processes in the finished product, which determine the staling, depend on the quality of the raw materials, in particular, the baking properties of the flour.

The solution to the problem of prolonging the freshness of wheat bread is possible using non-traditional raw materials, food additives and complex bakery improvers.

Taking into account the synergism of the action of food additives, it is necessary, when using a complex bakery improver, to take into account the baking properties of flour and, on the basis of their indicators, use their optimal dosage.

### 3. The aim and objectives of research

The aim of research is development of a complex bakery improver «Freshness SMS Super» to extend the freshness of bread made from wheat flour with various baking properties.

To achieve the aim it is necessary to:

1. Establish an optimum parity of ingredients in the recipe of the complex baking improver.
2. Develop graphic models for determining the optimal dosage of the complex bakery improver «Freshness SMS Super» in the formula of «Milk freshness» bread when using flour with various baking properties.
3. Investigate the influence of the complex bakery improver «Freshness SMS Super» on the preservation of freshness products.

### 4. Research of existing solutions of the problem

Complex baking improvers are multi-component mixtures consisting of a functional base in which the active part is uniformly distributed [3]. As the active part, enzymes, structurants, food additives of oxidizing or reducing action, emulsifiers [4, 5] are used. The functional basis is flour, starch, dry wheat gluten [3, 6, 7].

In work [7] it is indicated that complex baking improvers consist of several food additives that are selected in the optimal ratio, which allows simultaneously to act on the main components of flour. Synergism of the action of all components of complex bakery improvers [8] promotes a better stabilization of the quality of bakery products when using flour with low baking properties [9].

In the development of complex baking improvers, scientists [10] recommend the use of pumpkin flour as a functional basis, and as an active part – ascorbic acid, phosphorus-acid calcium, ammonium sulphate. The obtained improver is recommended to be used only in case of processing of wheat flour of the first and second grades of medium or weak in strength.

The complex baking improver developed in [7] consists of dry wheat gluten as a functional base, and as an active part we use ascorbic acid, enzyme preparations of amyolytic and pentosanase activity, and an emulsifier. This improver positively affects the increase in porosity, volume, the production of a homogeneous elastic crumb and the lengthening of the freshness of the finished products. However, this work does not provide recommendations on the optimal dosage when processing flour with unsatisfactory baking properties.

The authors of [11] propose to use buckwheat malt as a functional basis for a complex baking improver, and phosphoric acid calcium, ammonium sulphate as an active part. The obtained improver is recommended to be used in the case of processing flour of strong strength.

The authors of [12] recommend a compound of dry wheat gluten, an enzyme preparation of amyolytic action, and a mixture of xanthan and guar gum for a complex bakery improver to extend the freshness of bakery products. The developed improver prolongs the freshness of bakery products up to 72 hours of storage not packed. But the work does not specify recommendations for its optimal dosage in the case of processing flour with various baking properties.

Therefore, it is promising to develop a complex bakery improver to extend the freshness of bakery products in the case of processing flour with various baking properties. As a functional basis, dry whey enriched with Mn and Mg, which is used as an additional raw material in bakery products [2], and nutritional supplements of different directional action is proposed.

### 5. Methods of research

Testing laboratory baking was carried out to develop a complex bakery improver. To determine the quality of the obtained products, a scoring was used and a complex indicator was calculated. The dough was kneaded in a kneading machine Esher (Italy) for 4 minutes at the first speed and 7 minutes for the second. The dough was prepared in an accelerated way with a mass fraction of test moisture – 43 %. The fermentation period was replaced by a resting, which lasted 30 minutes. The dough was handled manually, the test billets were tested in a cabinet at a temperature of  $38 \pm 2$  °C and a relative humidity of  $78 \pm 2$  % until ready. The products were baked in a cabinet oven at 220–240 °C with humidification of the baking chamber.

The quality of bread was assessed by the physicochemical (specific volume, shape stability, structural and mechanical properties of the crumb) and organoleptic characteristics (appearance, crustal surface condition, porosity structure, taste, odor). The duration of preservation of freshness products was investigated with a change in the structural and mechanical properties of the crumb. Its general deformation was determined after 4, 24 and 48 hours of storage per penetrometer AP 4/1 («Fainmass», Germany) [13].

The complex quality score was assessed by the score of the quality of bakery products [13].

The degree of staling was also investigated for crumbling of crumb. Crumbling was determined by the amount of crumbs formed due to friction of two pieces of bread crumb of 5 g weight, cut in the form of a parallelepiped, with shaking for 5 minutes. on vibration shakers IKA HS 501 digital (IKA®-Werke GmbH&Co. KG, Germany). Crumbliness was expressed as the ratio of the crumb mass to the mass of the weight of the bread in percent [14].

The results of the experimental studies were subjected to mathematical-statistical processing, realized with the help of the MS Excel spreadsheet processor and the mathematical package MathCAD.

## 6. Research results

To develop a complex bakery improver, laboratory baking was carried out to determine the optimal dosage of each ingredient in the bread dough «Milk Freshness» along a complex bakery improver. The dosage of each ingredient was carried out according to the manufacturer's recommendations. As a functional basis, it is proposed to use dry whey enriched with Mn and Mg. For the active component, the following are selected:

- as water-retaining additives – carboxymethyl cellulose, maltodextrin and apple pectin;
- as an enzyme amyolytic action (maltogenous amylase) – an enzyme preparation Novamil 1500 MG;
- as a surfactant – lecithin;
- as a natural oxidizer it is suggested to use ascorbic acid.

The quality of finished products was estimated by such indicators as:

- specific volume;
- form correctness;
- crust color;
- staling after 72 hours;
- surface condition of the crust;
- crumb color;
- structure of porosity;
- form stability of baked bread;
- rheological properties of crumb;
- bread aroma;
- bread taste;
- crumb roasting.

Based on the obtained data, the complex quality index was calculated, the obtained data are given in Table 1.

**Table 1**

Determination of the optimal dosage of the formulation components of a complex baking improver according to the complex quality index,  $n=3$ ,  $p \leq 0.95$

Indicator	Control without additives	Dosage (%) to flour mass				
		Dry whey enriched with Mn and Mg				
Integrated quality score	81.5	0.5	1	1.5	2	2.5
		83.6	87.1	90.2	93.6	93.1
Integrated quality score	81.5	Enzyme preparation Novamil 1500 MG				
		0.005	0.010	0.015	0.020	0.025
Integrated quality score	81.5	84.8	88.2	91.2	94.5	93.9
		Carboxymethyl cellulose				
Integrated quality score	81.5	0.1	0.2	0.3	0.4	0.5
		83.6	85.9	88.3	90.7	90.2
Integrated quality score	81.5	Apple pectin				
		0.01	0.02	0.03	0.04	0.05
Integrated quality score	81.5	82.8	84.2	87.9	90.8	90.1
		Maltodextrin				
Integrated quality score	81.5	0.05	0.06	0.07	0.08	0.09
		83.2	85.1	87.8	90.6	90.4
Integrated quality score	81.5	Lecithin				
		0.12	0.18	0.24	0.30	0.36
Integrated quality score	81.5	83.5	85.9	89.6	89.6	89.5
		Ascorbic acid				
Integrated quality score	81.5	0.01	0.015	0.02	0.025	0.03
		81.8	82.6	83.8	83.7	83.4

It is found that the optimal dosage of the functional basis, namely, whey enriched with Mn and Mg, is based on a complex quality index of 2 % to the weight of flour, the active part:

- enzyme preparation Novamil 1500 MG – 0.02;
- carboxymethyl cellulose – 0.4;
- apple pectin – 0.04;
- maltodextrin – 0.08;
- lecithin – 0.24;
- ascorbic acid – 0.02 % to the weight of flour.

When composing the compound bakery improver, it is recommended to reduce the dosage of the active part by half with respect to the optimal dosage in connection with the synergistic effect when applied together [7].

The recipe for the developed bakery improver «Freshness SMS Super» is given in Table 2.

**Table 2**

The recipe for the complex bakery improver «Freshness SMS Super»

Raw material	Optimal dosage (%) to the weight of flour in the bread formula «Milk freshness»	Raw material consumption (%) to the mass of dry whey enriched with Mn and Mg
Dry whey enriched with Mn and Mg	2.0	100.0
Enzyme preparation Novamil 1500 MG	0.01	0.5
Carboxymethyl cellulose	0.2	10.0
Apple pectin	0.02	1.0
Maltodextrin	0.04	2.0
Lecithin	0.12	6.0
Ascorbic acid	0.01	0.5

Consumer properties of bakery products depend primarily on the baking properties of flour, such as the strength of flour, gas-forming and water-retaining abilities.

From the strength of flour depends the ability to form dough, which has certain structural and mechanical properties. By force flour is divided into strong, medium and weak. Flour for strength in the ratio of spreading balls with 100 grams of dough for 3 hours fermentation (mm) are: strong up to 83, medium – 84–96, weak from 97. Gas capacity describes the ability of flour to supply sugars for yeast during fermentation and proofing billets and coloring of crusts of bakery products. Gas blowing capacity of the flour can be (cm<sup>3</sup> of CO<sub>2</sub>/100 g): low to 1300, normal 1300–1600 and high from 1600. The ability of flour to bind a certain amount of water depends on the water-retaining ability. Water-retaining capacity (%) can be: low to 58, normal 59–61, high from 62 [15].

It is advisable to establish the optimal dosage of the developed integrated bakery improver when processing flour with various baking properties.

Variation intervals, the lower and upper level of baking properties for the development of possible combinations were stabilized in terms of the strength of the flour, are presented in Table 3.

To determine the effectiveness of using the developed integrated bakery improver and its optimal dosage in the case of processing various qualities of flour, a series of studies was carried out with the implementation of the Sheffe's simplex centroid plan. Graphic models have been

constructed on which it is possible to determine the expected effect of the quality of bakery products with a certain dosing of the improver when processing flour with specified baking properties in the form of «composition-properties» diagrams.

Table 3

Range of factor space

Investigated factors	Variation levels			Variation interval
	lower	upper	zero	
	0	0.5	1	
Weak-strange flour				
$X_1$ – strength of flour, mm	83			
$X_2$ – gas-forming ability, cm <sup>3</sup> of CO <sub>2</sub> /100 g of flour	1300	1450	1600	150
$X_3$ – water-retaining capacity, %	58	60	62	2
Middle-strange flour				
$X_1$ – strength of flour, mm	90			
$X_2$ – gas-forming ability, cm <sup>3</sup> of CO <sub>2</sub> /100 g of flour	1300	1450	1600	150
$X_3$ – water-retaining capacity, %	58	60	62	2
Strong-strange flour				
$X_1$ – strength of flour, mm	97			
$X_2$ – gas-forming ability, cm <sup>3</sup> of CO <sub>2</sub> /100 g of flour	1300	1450	1600	150
$X_3$ – water-retaining capacity, %	58	60	62	2

As varied factors, doses of a complex baking improver and baking properties of flour were chosen. Response functions (dependent variable) are a complex quality indicator. The design experiment consisted in obtaining the response surface from the model in the case of varying the values of the variables throughout the factor space. A series of supporting experiments was performed in which the value of the response function was determined in various fixed dosages of a complex baking improver and various variations of the baking properties of the flour.

According to the received model the «Warehouse-properties» diagram is constructed. Lines of the response function are plotted in the area of the rectangle to illustrate the changes in parameters in the case of variation of the complex baking improver and baking properties of the flour. This allows in practice to predict the quality of finished products when using flour with certain baking properties and different dosing of the improver. The obtained diagrams of dose dependence of a complex baking improver (CBI) and indicators of baking properties of flour:

- in case of  $X_1$  stabilization at the lower level (the flour is weak in strength) are shown in Fig. 1;
- in the case of  $X_1$  stabilization at the average level (flour is average in strength) – Fig. 2;
- in the case of  $X_1$  stabilization at the upper level (flour is strong in strength) – in Fig. 3.

Modeling and processing of the experimental data was carried out using the mathematical package MathCad 15. To optimize the research process, the methodology of the response surface with the employer of the two-dimensional approximation of the experimental data is chosen. The resulting equations of mathematical models are described by the following polynomial:

$$\hat{y}(x, b) = b_0 + \sum_{i=1}^n b_i x_i + \sum_{k=1}^n b_k x_k^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^n b_{ij} x_i x_j,$$

where  $x \in R^n$  – a vector of variables,  $b$  – a vector of parameters.

Fig. 1–3 show the response surfaces and their contour graphs, described by polynomials of the second degree. Contour graphics are a collection of lines, each of which corresponds to the same value of a function that depends on two variables (isolines).

From the graph in Fig. 2 it is established that the optimal dosage of the complex bakery improver «Freshness SMS Super» is 1.5 % to the weight of flour. This dosage is optimal if the flour is average in strength, has a normal gas-to-oil capacity, and water-retaining ability is within the range of 59–61 %.

The main indicator of consumer properties of bakery products is their freshness.

The stale bread is primarily associated with the processes of changing the state of starch, which during storage from an amorphous state turns into a crystalline state. There is a retrogradation of starch, which is associated with the aggregation of molecules with amylopectin and amylose.

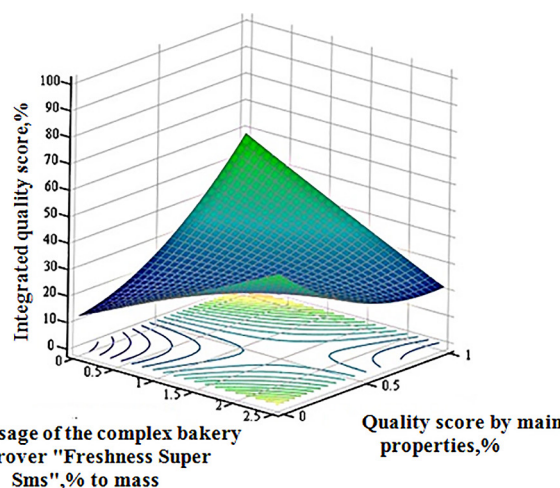


Fig. 1. 3D-graph of the dependence of the complex quality index on the dosage of the complex bakery improver «Freshness SMS Super» and baking properties of weak-strange flour

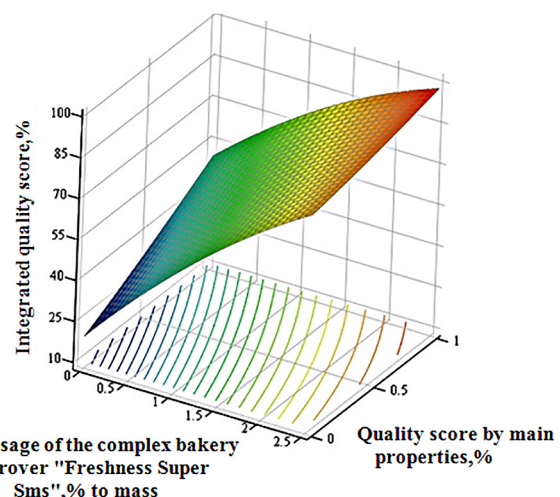
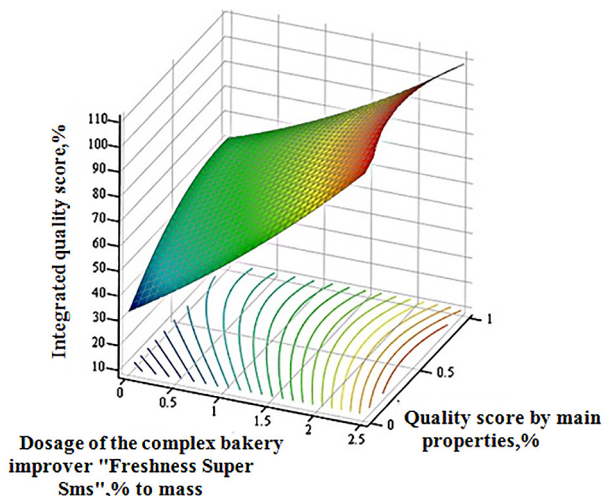


Fig. 2. 3D-graph of the dependence of the complex quality index on the dosage of the complex bakery improver «Freshness SMS Super» and baking properties of middle-strange flour



**Fig. 3.** 3D-graph of the dependence of the complex quality index on the dosage of the complex bakery improver «Freshness SMS Super» and baking properties of weak-strange flour

An important role in this process is the aging of the denatured gluten during baking, which gives off moisture and, as a consequence, its hydration capacity decreases, which leads to a consolidation of the crumb structure.

With the loss of freshness, physico-chemical changes in the crumb occur –resistance to compression increases, and elasticity decreases. Therefore, the duration of preservation of freshness products was investigated by changing the structural and mechanical properties of the crumb. Its crumbling, swelling, general, elastic i plastic deformation were determined after 4, 24, 48 and 72 hours of storage on a penetrometer AP 4/1.

Bakery products were prepared in an accelerated way without additives i with the addition of a complex bakery improver «Freshness SMS Super» in the amount of 1.5 % to the weight of flour. The determination was carried out at 4, 24, 48 and 72 hours after the baking of the bakery products. It is established (Table 4), the total deformation of the crumb of products from improvers is higher than in the control.

During storage, the structural and mechanical properties of the crumb with a complex baking improver decreased more slowly than in the control one. Thus, after 24 and 72 hours of storage, the total deformation in the control sample decreased by 22 and 36 %, respectively, while samples with a complex baking improver decreased by 16 and 45 %, respectively.

**Table 4**

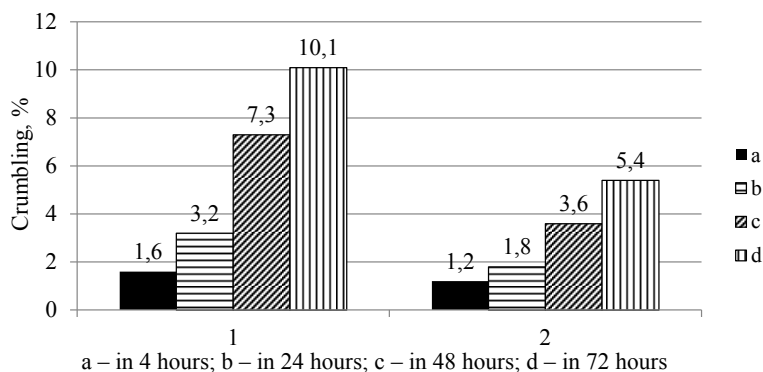
Changes in the structural and mechanical properties of the bread crumb with a complex bakery improver

Indicators	Control without additives	1.5 % of the weight of the flour of the complex bakery improver «Freshness SMS Super» are added
Crumb deformation, units of device in 4 hours:		
total	72	77
in 24 hours:		
total	50	61
freshness preservation degree, %	69	79
in 72 hours:		
total	26	32
freshness preservation degree, %	36	41

The slowdown of staling of bakery products with the use of the complex bakery improver «Freshness SMS Super» is associated with the improvement of the elastic properties of the crumb of the product and the retardation of starch retardation. This is due to the use of water-retaining additives in the complex bakery improver, namely maltodextrin, carboxymethyl cellulose and apple pectin, which, during storage, give less bound water than biopolymers of flour. The use of maltogenic  $\alpha$ -amylase results in the accumulation of more dextrans, which in turn slow down the process of starch retrogradation and a lower return of bound osmic moisture.

During storage, the physical and mechanical properties of the crumb change, the walls of the pores lose their strength, which is accompanied by an increase in the crumbling of the crumb. The research results testify (Fig. 4) that the value of the crumbling decreases with the use of the complex baking improver «Freshness SMS Super» in comparison with the control – by 50–54 %, provided that 24 and 48 hours and are stored for 57 % – 72 hours.

So, studies have shown that the use of the integrated improver «Freshness SMS Super» is advisable, since all the indicators of the bread and dough improve, and most importantly – the bread «Milk freshness» keeps fresh for 72 hours.



**Fig. 4.** Crumbling %: 1 – control; 2 – complex bakery improver «Freshness SMS Super»

## 7. SWOT analysis of research results

**Strengths.** A complex bakery improver «Freshness SMS Super» is developed to extend the freshness of bread from wheat flour to 72 hours of storage not packed. Graphic charts for determining the optimal dosage of the complex baking improver «Freshness SMS Super» when using flour with various baking properties are also developed.

**Weaknesses.** Using a complex bakery improver «Freshness SMS Super» will cause an increase in the cost of products.

**Opportunities.** Analysis of the results of studies indicates the effectiveness of using a complex bakery improver in the formulation of wheat bread and the expediency of further research on:

- deepening the study of the influence of a complex bakery improver on the process of staling bread products;
- influence of a complex bakery improver on the process of intensification of the technological process;
- effect of a complex bakery improver on the microbiological performance of articles during storage.

The introduction of new bread «Milk freshness» at bakery enterprises will help expand the range of products with extended shelf life.

**Threats.** Considering the fact that maltodextrin is produced in Poland, ascorbic acid in China, and the enzyme preparation in Denmark is likely to fluctuate the price of these ingredients and the timeliness of their supplies. These force majeure circumstances will be the main factors that affect the stability of the production of the complex bakery improver «Freshness SMS Super».

## 8. Conclusions

1. On the basis of the studies, a complex bakery improver «Freshness SMS Super» was developed. On a functional basis, dried milk whey enriched with Mn and Mg was selected. The active part consists of: Novamil enzyme preparation 1500 MG – 0.5; carboxymethyl cellulose – 10.0; apple pectin – 1.0; maltodextrin – 2.0; lecithin – 6.0 and ascorbic acid – 0.5 % to a functional basis.

2. With the help of the Sheffe's centrifugal plan, graphic models have been developed that predict the optimal dosage of the complex bakery improver «Freshness SMS Super» when using flour with various bakery improvers. So, if the flour is average in strength, has a normal gas-forming and water-retaining ability within the range of 59–61 %, the optimal dosage of the complex bakery improver «Freshness SMS Super» is 1.5 % to the weight of flour.

3. It is proved that as a result of introducing a complex bakery improver, «Freshness SMS Super» is prolonged by the preservation of freshness products. This is evidenced by a decrease in the crumbling of the crumb and a slowing of the changes in the structural and mechanical properties of the crumb during storage.

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