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THE USE OF GLUCAN-CONTAINING GRAIN MATERIALS IN THE TECHNOLOGY OF FOAM-LIKE PASTRIES

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Abstract. This article shows the prospects of using glucan-containing cereal grain materials in the production of baked goods. The results of the research are presented of how oat and barley flours and the method and stage of adding them effect on the quality of foam-like dough and semi-finished sponge-cakes. During the research, these types of flour were introduced at two stages: while churning the mixture of sugar and eggs, after wetting them and replacing part of the mélange (15%, 25%, 35%) with flour-water mixtures with the equivalent amount of dry substance, and while making the dough (mixed with 25%, 50%, and 75% of wheat flour). It has been determined that replacing mélange with oat and barley flour-water mixtures results in an increase in the viscosity of the dough due to the increased content of starch polysaccharides in it, which helps stabilize its structure, and allows obtaining dough with the required moisture and density. It has been demonstrated that replacing up to 25% of mélange with these types of flour mixes is followed by increased porosity of the sponge cakes. The specific volume of the samples with 15% of mélange replaced with the oat flour-water, and 25% with the barley flour-water mixture increased by 5–7% on average compared to the control sample. In the further research, to increase significantly the nutritional value of baked goods, these mixtures, besides being used to replace the mélange, were also introduced at the stage of making the dough (mixed with wheat flour). It has been established that the high quality of sponge cakes (determined by their porosity and specific volume) is achieved in the presence of up to 50% of oat or barley flour in the mixture.

Key words: semi-finished sponge-cake products, oat and barley flour, glucan-containing raw materials, quality parameters, nutritional value.

ВИКОРИСТАННЯ ЗЕРНОВОЇ ГЛЮКАНВМІСНОЇ СИРОВИНИ В ТЕХНОЛОГІЇ ПІНОПОДІБНИХ БОРОШНЯНИХ КОНДИТЕРСЬКИХ ВИРОБІВ

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Анотація. У статті показано перспективність використання зернової глюканвмісної сировини при виробництві борошняних виробів. Наведено результати досліджень впливу вівсяного і ячмінного борошна, способу та стадії їх внесення на показники якості піноподібного тіста і випечених бісквітних напівфабрикатів. При проведенні досліджень дані види борошна вносили на двох стадіях – при збиванні яєчно-цукрової суміші після їхнього замочування замість частки меланжу та на стадії замісу тіста в суміші з пшеничним борошном у кількості 25%, 50%, 75%. Визначено, що заміна 15–35% меланжу на водно-борошняні суміші з вівсяним або ячмінним борошном супроводжується підвищенням в'язкості бісквітного тіста, сприяє стабілізації його структури, а заміна ними 15–25% меланжу дозволяє підвищити пористість, питомий об'єм бісквітів на 5–7%. Встановлено, що у разі внесення глюканвмісного борошна на стадії замісу тіста, висока якість бісквітів за показниками пористості і питомого об'єму забезпечується при наявності їх у складі сумішей до 50%. Визначено вплив вівсяного і ячмінного борошна на органолептичні показники та харчову цінність розроблених бісквітів.

Ключові слова: бісквітні напівфабрикати, вівсяне і ячмінне борошно, глюканвмісна сировина, показники якості, харчова цінність.

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Introduction. Formulation of the problem

Introduction. World and national experience proves conclusively that the most effective and economically affordable way of better providing people with micronutrients not readily available is the systematic inclusion of foods containing a lot of these substances into the diet [1]. The methodology of designing healthy food products consists in

selecting the combinations and types of ingredients that provide the maximum effectiveness of these substances, taking into account their chemical stability during the production and storage of the product, the potential interaction of the ingredients with each other as well as with other ingredients in the product, and the methods and stages of introducing them into the food system. Today, the development of

healthy food products is directed towards enriching traditional products (particularly pastries, which are constantly consumed by people and are quite numerous and diverse) with vitamins, minerals, and food fiber.

The analysis of the chemical composition and nutritional value of pastries produced in Ukraine today and having a significant share in confectionery and baking industry's total production indicates the imbalance of their chemical composition (high levels of fats and carbohydrates and relatively low levels of micro-nutrients, food fibers, etc.). A promising direction for creating products with high nutritional value and specific purpose is expanding the range of plant raw materials used, namely flour from various cereals and grains. The use of oat and barley flour, which has high fiber content, fairly balanced chemical composition, and large number of minerals and vitamins, is of practical interest. A distinctive feature of the food fibers in these types of flour is a significant content of β -glucan, which is characterized by high technological functionality, particularly, its moisture retention capacity, and largely determines the potential usefulness of these cereals for therapeutic and preventive nutrition [2,3].

Analysis of recent research and publications

Oat and barley flour and products of their processing contain insoluble and soluble food fibers, and including them into the recipe of flour products has positive physiological effect on the human body, especially considering their shortage in modern diet. Thus, replacing wheat flour with oat in biscuits resulted in an increase in total ash and dietary fiber, including β -glucans. The biscuit samples made with oat flour had a low glycemic index (46 to 50 %), and a low glycemic load (less than 10) [4,5]. A number of scientists have investigated the effect of oat β -glucan on the quality, structure, consumer perception, and glycemic index of steam bread. It has been established that samples with 1–3 g of β -glucan per 100 g of wheat flour have the best consumer and qualitative characteristics. Besides, the presence of oat β -glucan contributed to slowing down (*in vitro*) the hydrolysis of starch by amylolytic enzymes, and adding it to the recipe in the amount of 5 g/100 g resulted in a decreased glycemic index of the product [6]. The introduction of oat and barley flour into the recipes, despite some reduction in its volume, allowed obtaining high quality products and enriching them with healthy non-digestible prebiotic ingredients. The suggested product containing 40% of barley flour was characterized by a 67% increase in food fiber content and 160% increase in β -glucan compared to the control sample, and it was highly rated during the sensory analysis [7-9]. A significant increase in β -glucan and in antioxidant activity in biscuits and chapatti has also been observed when their composition included 30% of bare-grained barley flour (*Hordeum distichon*). Thus, the phenol content in finished products increased to 135–287 $\mu\text{g/g}$ [10]. Replacing 20% of high quality

wheat flour with biomodified oat products can improve the quality and nutritional value of wafers [11].

Investigating the technological properties of barley β -glucan has made it possible to recommend using it as a fat substitute, since most of the fats used in the food industry today are characterized by high content of saturated fatty acids. Studying the effect of partially replacing fat with barley β -glucan in the muffin recipe on the physical properties of muffins has shown that its introduction into the product with fat content decreased by 10% does not significantly affect the quality and makes it possible to obtain products with high nutritional value [12].

Also, it has been established that introducing products of processing oat and barley into the recipe of flour products, besides enriching them with biologically active compounds, improves their storageability [13, 14]. Thus, replacing wheat bran with barley bran increased the moisture absorption of the dough and slowed down starch retrogradation during storage. Composite flour contained significantly more β -glucan and phenolic substances, including flavonoids [13]. Replacing up to 10% of wheat flour with whole-grain oat flour improves the storage of partially baked frozen bread, which allows meeting the growing demand for products with prolonged shelf-life [14].

The technological basis of using raw materials with high β -glucan content is their foaming ability in the production of sponge dough pastries [15,16]. Thus, the authors [15] have shown that a high content of non-starch polysaccharides and a lower content of gluten-forming ones in barley flour, compared to that made from wheat, contributes to the formation of small air bubbles in the foam-like dough during its churning, which positively influences the formation of fluffy, porous crumb in sponge cakes. The quality of barley flour products was equivalent to that of wheat flour products, but using this type of flour made it possible to obtain products with a higher nutritional value.

The literature analysis shows how promising is using barley and oat products when making flour-based food, and how important is further research aimed at widening the range of their use, including the production of sponge-cake semi-finished products.

The purpose of this work is to determine how glucan-containing grain materials, namely oat flour (OF) and barley flour (BF), and the stage and method of adding them effect on the quality of foam-like dough and sponge-cake semi-finished products, as well as to determine the nutritional value of baked goods.

To achieve the goal, the following **tasks** were set:

1. To determine how barley and oat flour effects on the rheological, physical, and chemical characteristics of sponge-cake dough and on the quality of baked semi-finished products when the flour is added after wetting at the stage of churning the egg and sugar mixture.

2. To determine the physical, chemical, and sensory qualities of sponge-cake semi-finished products when adding glucan-containing flour raw materials mixed with wheat flour at the dough mixing stage.

3. To determine the nutritional value of the sponge cakes made using barley or oat flour.

Research materials and methods

Wheat (Kulindorovsky baking factory), oat (trademark *Dobrodiia*), and barley (*Olimp* Ltd. TDV *Vasylkivska agrocompany*) flour, as well as foam-like dough and sponge-cake semi-finished products were used in this study.

The recipe of the basic sponge cake was used for the research. The dough was prepared in two phases by the cold method [17].

The moisture content of the dough and sponge-cake semi-finished products was determined by the accelerated method according to DSTU 4910:2008 [17]. The dough density was determined by measuring the ratio of the mass of the dough to its volume [17]. The rheological properties of the dough were measured with a rotational viscometer *Reotest-2*. The volume of sponge-cake semi-finished products was determined by the volume of the displaced grain. Specific volume was calculated as the ratio of the volume of baked semi-finished products to their mass. The porosity of the sponge-cakes was measured with Zhuravlova's probe on the device VPH-1 [17].

A qualitative and quantitative analysis of the amino acid composition of the products was carried out by distribution chromatography [18].

The amino acid score of the flour was calculated as the ratio of the actual amount of essential amino acids to its content in the reference protein [19]. The calculation of the chemical composition and energy value of the products was carried out [19] basing on the determined chemical composition of flour materials and on reference tables of the chemical composition of food products [20].

Results of the research and their discussion

The sponge cake dough is a structured dispersed system that belongs to food foams. In the food industry, the assortment of components used to prepare foam-like dispersed systems is quite wide. Some are aimed at obtaining highly dispersed systems, while others contribute to the preservation of their stability [21]. When in oat and barley flour, there are pectin substances, pentosans, natural hydrocolloid β -glucan (Fig. 1) [22-24], capable of binding water, while forming colloids and gels, as well as starch and fiber, which are foam stabilizers, it allows suggesting the feasibility of their use in the technology of semi-finished sponge-cake products.

Earlier studies showed the differences in the foaming properties of oat and barley flour depending on the method of preparation of this glucan-containing flour material [25]. Thus, the best conditions of their wetting to provide better foam stability were determined. The samples with 30% of oat flour in the flour-water mixture, wetted for 1 hour, and the ones with 20% of barley flour, wetted for 3 hours, had the best parameters.

The water temperature in both cases was 20°C. In the course of the research, the wetted flour was added to the churned egg and sugar mixture, where part of *mélange* (15%, 25%, 35%) was replaced with flour-water mixtures with an equivalent quantity of dry substance. The recipe was based on that of a sponge cake.

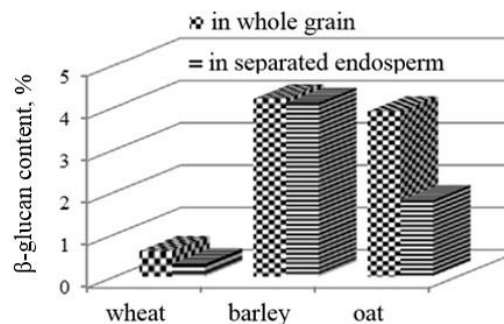


Fig. 1. β -glucan content in cereal grains

The rheological characteristics of the sponge dough are closely related to its internal structure, and the changes in it during the technological process of making sponge cakes will also lead to changes in its viscosity. Therefore, the study of the rheological properties of the foam-like dough will make it possible to direct the technological process and thus obtain the product with the required properties. According to the data obtained, the viscosity of the sponge-cake dough with *mélange* replaced with the water-flour mixture was higher by 22–26 Pa·s (with $\gamma=0.81 \text{ s}^{-1}$) than that of the control sample (Fig. 2).

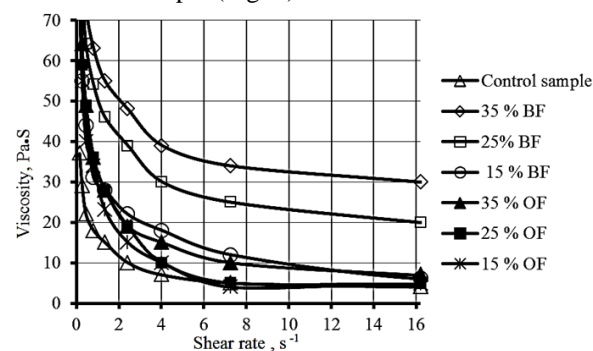


Fig. 2. Sponge dough viscosity: control sample; samples where *mélange* was replaced with water-flour mixtures.

This could be due to the higher water-solubility of oat and barley flour (254% and 271%, respectively), as compared to wheat flour (172%), which results in a decreased amount of free moisture in the dough and leads to more contacts between the biopolymers of flour particles and cohesion forces. Additionally, β -glucan is capable of forming gels with rheological properties similar in nature to those of such polysaccharides as, for example, guar gum [2]. Comparing the viscosity of dough samples where *mélange* was replaced with an oat and barley flour-water mixture shows that this indicator was higher when using barley flour. This could be due to the fact that, though there are more

food fibers in oat than in barley, the β -glucan amount is higher in barley grain (see Fig. 1). And it is known that this polysaccharide contributes to the increased stability of the foam system due to its ability to form viscoelastic solutions, which leads to increased viscosity of the dispersion medium.

The important technological characteristics of foam-like dough are its moisture and density. Reducing the moisture content of the dough can lead to decreased thickness of the aquatic membranes around the protein micelles and starch grains and, consequently, to their adhesion, and cause decreased porosity of the product. As the moisture increases, the viscosity of the dough decreases, the consistency of the dough changes and becomes more fluid. An increase in free moisture accelerates the swelling of gluten proteins, which is undesirable for foam-like dough. The moisture content of the dough where *mélange* was replaced with the water-flour mixture practically did not change and was within the technologically approved limits (36–38%). A slight decrease in the moisture content of the test samples could have been due to a lower moisture content of barley and oat flour (13.5%), a high content of fiber and β -glucan in these types of flour, and the presence of a large number of pentosans that have high hydrophilic capacity, which contributes to strong binding of moisture.

The density of foam-like dough is one of the important physical characteristics of a foam system, which determines the structure of the finished product. The dough with too high a density is characterized by a high content of large air bubbles that expand during the baking process and form large air pores with thin walls, thus the products can settle down after baking. Too low a density of foam-like dough indicates a significant content of small air bubbles in it. The smaller the gas bubbles are, the higher is the pressure in them, which leads to the involuntary process of gas

diffusion from smaller bubbles into larger ones, which, consequently, changes foam stability. Products made from this dough will settle after baking and will have uneven pores. It has been established that the density of sponge cake dough with 25% of *mélange* replaced with a water-flour mixture is 450–500 kg/m³, that is, it stays within the recommended limits.

The hydration of flour particles and the swelling of colloids takes place during the sponge-cake dough formation (mixing the egg and sugar mixture with flour and starch), which has a stabilizing effect on the foam-like mass and allows obtaining more uniform dough, finely porous and of a dispersed structure. Studying the stability of sponge-cake dough has shown that replacing up to 25% of *mélange* with the flour-water mixture decreases the initial volume by only 10% after 3 hours. This could be due to the fact that pentosans and β -glucans that oat and barley flour contains contribute to the increase in foam stability, since they swell and increase the viscosity of the system. The fiber, which determines the main composition of fine particles contained in the bran, is adsorbed on the surface of foam films, interacts with egg proteins, and fixes them, which makes the foam more stable by increasing the shell strength of the air bubbles in the sponge-cake dough.

The air phase proportion, or the proportion of the pore volume to the total volume of the sponge cake crumb can be estimated by determining its porosity and specific volume. The porosity of semi-finished sponge-cake products with up to 25% of *mélange* replaced with a water-flour mixture has increased by 2–3% (Fig. 3). The specific volume of samples with 15% of *mélange* replaced with an oat flour-water mixture and 25% with a barley flour-water mixture increased by an average of 5–7%, as compared to the control samples.

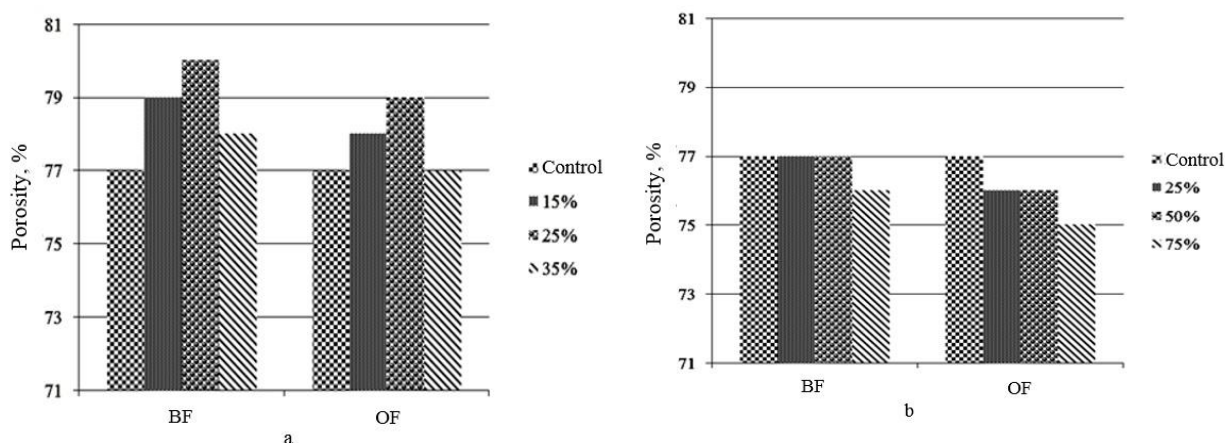


Fig. 3. Sponge cake porosity with *mélange* (a) and wheat flour (b) replaced

Thus, the study of the impact of glucan-containing flour materials on the rheological, physical, and chemical properties of foam-like dough has shown that replacing *mélange* with water-flour mixtures, with oat and barley flour used, leads to its increased viscosity, facilitates the stabilization of the foam-like dough structure, allows obtaining the dough with the required

humidity and density, and replacing 15 to 25% of *mélange* with these types of flour-water mixtures is accompanied by an increase in the porosity and specific volume of sponge products. However, a small amount of oat and barley flour in the egg and sugar mixture when replacing *mélange* (10 g per 100 g of the product) does not allow significantly regulating the chemi-

cal composition of the product and, consequently, does not enable us to increase the nutritional value of finished products. That is why the further research included adding oat and barley flour during dough mixing (with wheat flour in the amount of 25%, 50%, and 75%), along with mélange replacement.

The porosity of semi-finished sponge-cake products with up to 50% of barley flour remained at the same level as that of the control sample and decreased when the oat flour content increased (Fig. 3). The volume of products with up to 50% of barley and oat flour practically did not change. The decrease in the porosity and specific volume of sponge cakes based on the mixtures could be due to the fact that oat and barley flour (unlike wheat) has no gluten proteins involved in the formation of the structure of the product. Barley flour proteins form a coherent, but less elastic mass than wheat proteins, and have little gluten. This gluten is short, with low elasticity. Oat glutelin molecules are not able to form a continuous structure in the dough due to the large number of transverse bonds in the protein molecule [1]. An increased fraction of oat or barley flour in mixtures reduces the proportion of elastic gluten proteins. It leads to some dilution of the dough, which further determines this change in the quality of sponge cakes.

The higher porosity and specific volume of the samples with oat and barley flour added during the churning of the egg and sugar mixture (compared to the control sample and samples with flour mixes) could be related to the technological preparation of these types of flour before their use, namely wetting, which allows exhibiting the functional and technological properties of β -glucans more fully.

The sensory evaluation of sponge products on a 30-point scale showed that all samples had small, thin-walled, uniform pores with even thickness of up to 1 mm. The crumb of the products is elastic and easily compressed, immediately restoring its shape after compression. Increasing the amount of oat and barley flour in a mixture with wheat resulted in darkened crumb. Semi-finished sponge-cake products with barley flour had a light astringent flavor of the walnut. Replacing more than 25% of mélange resulted in the lower quality of sponge cakes due to the decrease in the amount of egg products.

Oat and barley flour is a source of vegetable protein, lipids, vitamins, minerals, and food fibers [26]. The use of these types of flour in the production of sponge products could regulate the chemical composition and thus increase the nutritional value of finished products. The increased biological value of the product made from flour of various grain cultures is directly related to their amino acid composition (Table 1).

The amino acid score analysis has shown that lysine and threonine are the limiting amino acids for wheat, oat, and barley flour. But the amino acid score of the oat flour is higher than that of wheat flour by 19 % and barley flour by 16%. A better balance of the amino acid composition in these types of flour, com-

pared to wheat, contributes to an increased nutritional and biological value, as well as the expansion of variety of semi-finished sponge-cake products. The research has resulted in developing the semi-finished sponge-cake product recipes *Ovsianika N* and *Kolosok N* with oat and barley flour (Table 2).

Table 1 – Amino acid content and scores of essential amino acids in oat and barley flour

Amino acids	Flour types		
	Wheat flour	Oat flour	Barley flour
Valine	$\frac{4.57}{92}$	$\frac{3.97}{79}$	$\frac{4.62}{92}$
Isoleucine	$\frac{4.17}{105}$	$\frac{3.34}{95}$	$\frac{4.47}{128}$
Leucine	$\frac{7.83}{112}$	$\frac{5.88}{84}$	$\frac{4.9}{70}$
Lysine	$\frac{2.43}{45}$	$\frac{3.53}{64}$	$\frac{3.37}{61}$
Methionine + cysteine	$\frac{3.43}{98}$	$\frac{3.11}{89}$	$\frac{3.46}{99}$
Threonine	$\frac{3.02}{76}$	$\frac{2.94}{74}$	$\frac{2.4}{60}$
Tryptophan	$\frac{0.97}{97}$	$\frac{1.43}{143}$	$\frac{1.15}{115}$
Phenylalanine + tyrosine	$\frac{7.28}{121}$	$\frac{8.4}{140}$	$\frac{7.88}{131}$

numerator – amino acid fraction in 100 g of protein, g
denominator – amino acid score, %

Table 2 – The recipes of new types of semi-finished sponge-cake products

Raw materials	Sponge (raw materials per 1 ton of the semi-finished product, kg)	
	<i>Ovsianika N</i>	<i>Kolosok N</i>
Wheat flour, high grade	168.7	112.5
Oat flour	112.5	–
Barley flour	–	168.7
Potato starch	69.42	69.42
Crystal sugar	347.11	347.11
Mélange	491.73	433.93
Essence	3.47	3.47
Total	1294.03	1294.03
Yield	1000.0	1000.0

Considering that food is a source of substances that regulate the complex processes of life, providing the human body with materials for constructing new cell structures, it was necessary to determine the nutritional value of the products developed that characterizes all the beneficial properties of the product. The chemical composition and energy value of the new types of semi-finished sponge-cake products are presented in Table 3.

The data analysis has shown that the incorporation of oat and barley flour into the recipe enriches the sponge cake products with mineral substances, as evidenced by a higher content of ash and food fibers (17 times higher than in the control sample).

Table 3 – Chemical composition and energy value of the new types of sponge-cake products

Parameters	Control	Ovsianika N	Kolosok N
Moisture content, %	24.0	24.0	24.0
Proteins, %	10.25	10.55	10.12
Fats, %	5.02	5.02	5.21
Carbohydrates, % including fibers, %	59.96 0.03	59.51 0.5	59.87 0.5
Ash, %	0.77	0.92	0.80
Minerals, mg:			
Na	79.12	81.1	81.2
K	117.36	134.76	131.68
Ca	40.35	44.54	51.05
Mg	11.43	21.79	17.31
P	40.62	69.68	84.96
Fe	1.89	2.06	1.89
Vitamins:			
β -carotene, μ g	0.14	0.14	0.14
B ₁ , mg	0.09	0.11	0.11
B ₂ , mg	0.26	0.27	0.27
PP, mg	0.35	0.42	0.7
Energy value, kcal	328	354	328

Conclusion

Studying the influence of glucan-containing grain materials on rheological properties of foam-like dough has shown that the introduction of water-flour mixes after the preliminary treatment (wetting) of oat and barley flour at the stage of making the egg and sugar mixture, results in increased dough viscosity, which contributes to the stabilization of the foam-like dough structure and positively affects the quality of the sponge cakes. Thus, replacing up to 25% of mélange with the flour-water mixture decreases the initial volume of the sponge dough by only 10% after 3 hours. It has been determined that the specific volume of sponge products with 15% of mélange replaced with an oat flour-water mixture and 25% replaced with a barley flour-water

mixture increased by an average of 5–7%, and their porosity increased by 2–3%. It will, in turn, reduce the cost of egg products in the production process. It has been experimentally established that increasing the amount of oat flour in the flour mixture somewhat decreased the porosity of semi-finished sponge-cake products while it remained at the same level as the control sample when adding up to 50% of barley flour. The specific volume of the products with up to 50% of barley and oat flour in the mixture practically did not change. Using oat and barley flour has a positive effect on the porosity structure and flavor characteristics of sponge cakes (the products acquire a light walnut taste), and allows enriching them with food fibers, expanding the variety of healthy semi-finished sponge-cake products.

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