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THE INFLUENCE OF THE RATIO OF WHEAT AND FLAX ON THE QUALITY OF PAN BREAD FROM WHOLE-GRAIN WHEAT-FLAX FLOUR

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ABSTRACT

In the Russian Federation, the main food product made from grain is bakery products. For the production of white wheat bread, high-grade and first-grade flour is mainly used. One of the advanced challenges for specialists working in the field of developing new food products is to increase their nutritional value. The purpose of the presented work is to study the effect of mill-grist of different ratios of wheat grain and flax seeds on the quality of flour samples produced from them, as well as to study the baking properties of the obtained samples of whole-grain wheat-flax flour of different ratios in comparison with first-grade wheat baking flour. Flour-milling and baking indicators of wheat-flax flour were determined using generally accepted standard determination methods. Statistical processing of the obtained experimental data was carried out using Microsoft Excel software. A technological scheme for obtaining whole-grain wheat-flax flour has been developed, which consists of only 2 systems, while it is very effective, because the yield of wheat-flax flour was more than 89 %. It was found that with an increase in the amount of flax seeds in the milled wheat-flax grain mixture, the yield of wheat-flax flour increases. A recipe for pan bread from whole-grain wheat-flax flour of various ratios was developed. It was found that with an increase in the amount of flax seeds in whole-grain wheat-flax flour, its moisture content decreases, which is explained by an increase in the content of plant membrane that absorb moisture. At the same time, there is an increase in the acidity of the flour with a simultaneous decrease in the gluten content and its strengthening due to the content of polyunsaturated fatty acids. It was found that the highest yield of wheat-flax flour is obtained with the addition of 10 % flax seeds and is 93.8 %. The optimal ratio of whole-grain wheat-flax flour for the production of pan bread was determined to be 92:8. At the same time, the nutritional value of pan bread increased in terms of protein content by 17.9 % and in terms of fat content by almost 481.8 %. Because of the studies, a positive effect of adding flax seeds to the mill-grist on the nutritional value of bread was established.

Key words: Wheat, flax, ratio, whole-grain wheat-flax flour, bread, quality

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INTRODUCTION

In the Russian Federation, the main food product made from grain is bakery products. For producing white wheat bread, high-grade and first-grade flour is mainly used. In flour milling, high-grade and first-grade flour is produced mainly from the endosperm of the grain, at the same time, 60 to 90 % of B vitamins, vitamin E, folic acid, niacin, as well as microelements concentrated in the outer membrane of the grain, and the germ are lost [1, 2, 3].

According to generally accepted terminology, the nutritional value of food products is a set of properties that provide for the physiological needs of a person for energy and nutrients. Nutritional value is assessed by the biological and energy value of the product [4].

The biological value of bread is characterized by its amino acid composition, composition and content of ash elements, vitamins, and polyunsaturated fatty acids. Bread proteins are inferior to animal proteins in terms of the content of such essential acids as lysine, threonine, methionine, and tryptophan. The deficiency of these amino acids is more present in bread made from wheat flour than in bread made from rye flour. The proteins of bread made from lower grades of flour are more complete than those from higher grades, while the most complete of all grades and types of wheat flour are whole-meal and whole-grain flour [5, 6, 7].

To assess the quality of the product protein, the World Health Organization introduced the concept of "ideal protein", with which the protein under study is compared using an amino acid score. The score of the essential amino acid lysine fluctuates in the range from 39 to 63 %, and threonine - from 68 to 89 % in various types of wheat bread. In addition to the deficiency of the above-mentioned essential amino acids in bread, the ratio of essential nutrients, proteins and carbohydrates is 1:6 instead of the recommended 1:4 [9, 10].

Mainly, the type of flour determines the number of vitamins and minerals contained in bread. When processing wheat and rye grains, up to 65 % of vitamins and micronutrients are lost, removed with the membrane, and the higher the grade of flour, the greater the loss, since B vitamins and minerals are mainly concentrated in the membrane of the grain [11, 12, 13].

Based on this, the priority areas for increasing the biological value of bakery products are enrichment of the product with the most deficient amino acids, lysine and threonine, as well as the introduction of protein fortifiers to increase the total protein content [14, 15].

Due to their unique properties, flax seeds are of interest as a source of biologically active substances necessary for human health. They are rich in essential

polyunsaturated fatty acids, dietary fiber, complete protein, polypeptides and, no less important, lignans, which belong to the class of phytoestrogens, which support the most important physiological functions of the human body [15, 16, 17, 18].

The conducted studies confirm the antioxidant activity of flaxseed lignans and the prospect of using flax seeds in the development of new drugs and biologically active food additives. The above-mentioned biologically active compounds have a very wide range of health effects [19, 20].

According to research, because of their consumption, the likelihood of blood clots in the heart decreases, the risk of heart attacks, microinfarctions and other cardiovascular diseases reduces. There is also evidence of the possibility of using flax seeds to prevent atherosclerotic and hypercoagulation risks after a past COVID infection due to the increased content of ω -3 and ω -6 acids, which reduce blood cholesterol and triglyceride levels. ω -3 promotes normal function of the adrenal and thyroid glands and brain function, tissue repair in burns [21, 22, 23].

Numerous scientific studies aimed at studying the composition and effect of adding flax seeds and its processed products on the quality of the product confirm the need for widespread introduction of this crop in the food industry and bakery in particular. The fiber contained in flax seeds stimulates intestinal peristalsis and normalizes microflora, and is able to absorb and remove toxic substances and waste from the body [24, 25, 26].

Flaxseed contains 40-54 % oil, and the ratio of ω -3 (linolenic) and ω -6 (linoleic) fatty acids can vary widely. The composition and amount of the lipid fraction of flax seeds depend on the variety and conditions of flax cultivation [27, 28, 29].

The optimal ratio in the daily diet of ω -6 to ω -3 fatty acids should be 5-10:1. However, the need for ω -3 fatty acids may increase with increased physical activity and the development of several diseases [30, 31, 32].

The objective of the presented work is to study the effect of mill-grist of different ratios of wheat grain and flax seeds on the quality of flour samples produced from them, as well as to study the baking properties of the obtained samples of whole-grain wheat-flax flour of different ratios in comparison with first-grade wheat baking flour.

To achieve this purpose, it is necessary to complete the following tasks: to study the effect of the ratio of wheat-flax grain milling mixture on the yield and quality of whole-grain wheat-flax flour; to determine the quality indicators of pan bread and the optimal ratio of whole-grain wheat-flax flour, which increases the nutritional value to the greatest extent without deteriorating its quality, using the method of trial laboratory baking; to calculate the energy and nutritional value of bread from whole-

grain wheat-flax flour with the most optimal consumer qualities and nutritional value for the production of pan bread.

The scientific novelty of the work lies in the development of a new technology for the combined milling of wheat grain and flax seeds into whole-grain wheat-flax flour, as well as its use as a replacement for first-grade wheat baking flour in the preparation of pan bread in order to expand the range.

MATERIALS AND METHODS

The quality and quantity of gluten in whole-grain wheat-flax flour were determined in accordance with GOST 27839-2013. The falling number was determined according to the state standard - GOST 27495-87. Flour acidity was determined according to GOST 27493-87. Flour moisture content was determined using an accelerated method on a Sartorius MA100 device (Sartorius AG, Germany). The standard does not provide for the determination of the whiteness of whole wheat flour and whole wheat-flax flour of different ratios. In addition, studies were conducted on a Mixolab 2 analyzer (Chopin Technologies, France) to determine the water absorption properties of flour and dough rheology.

Chemical and physicochemical parameters of the obtained control whole-grain wheat flour and whole-grain wheat-flax flour were determined using the infrared grain and flour analyzer SpectraStar 2500 XL (made in the USA). Determination of chemical and physicochemical parameters of all obtained flour samples was performed in two replicates and the average value of the parameters.

Baking properties of the obtained whole-grain wheat-flax flour were determined by the method of trial laboratory baking with subsequent determination of bread quality parameters, including specific volume of the product, weight, crumb porosity, and elastic deflection value. Evaluation of bakery products by organoleptic and physicochemical parameters was carried out 16-18 hours after baking. Crumb acidity was determined by an accelerated method according to GOST 5670-96. Crumb moisture content was determined by an accelerated method. The crumb porosity was determined using Zhuravlev's device in accordance with GOST 5669-96. The specific volume of finished products was determined by the amount of displaced millet.

The dough preparation and cooking of bakery products were carried out in the laboratory of the Department of Grains, Bakery and Confectionery Technologies in Russia. A test of molded bread made of first-grade wheat flour was used as a control sample.

The objects of the study were spring wheat grain of the "Radmira" and "Yubileinaya" varieties, as well as winter wheat grain of the "Nemchinovskaya" 85 and

"Nemchinovskaya" 24 varieties, harvested in 2022, from which the grinding mixture was composed in an equal ratio of 25:25:25:25. The second component of the mill-grist was white flax seeds grown in the Altai Territory [24].

Before milling, the wheat grain was subjected to hydrothermal treatment by the cold conditioning method, in which the grain was moistened to a moisture content of 14-14.5 % and tempered for 16 hours. Flax seeds were added to the prepared wheat grain to obtain the following ratios: 96:4, 94:6, 92:8, 90:10, and milling wheat-flax mixtures were obtained. Then the composed mill-grist was ground in an Ormismart GM-800s1 laboratory mill, the mechanical and kinematic characteristics of which are presented in Table 1.

Studies on the influence of various ratios of wheat-flax flour on the quality of pan bread were carried out in the following areas: preparation of milling wheat-flax grinding mixtures for laboratory grinding; study of the effect of various ratios of wheat-flax grinding mixture on the physicochemical quality indicators of whole-grain wheat-flax flour; study of the effect of various ratios of whole-grain wheat-flax flour on the organoleptic and physicochemical indicators of semi-finished and finished products; selection of the optimal ratio of whole-grain wheat-flax flour based on the organoleptic and physicochemical indicators of the finished bread; and calculation of the nutritional value of the finished bread from whole-grain wheat-flax flour.

Statistical processing of the obtained experimental data was carried out using Microsoft Excel 2010.

RESULTS AND DISCUSSION

At the first stage of the research laboratory milling of wheat-flax mixtures into flour was carried out. The obtained intermediate product of milling was sent to the laboratory plan sifter with the installed sieve. The technological scheme of obtaining whole-grain wheat-flax flour was developed, which consists of only 2 systems, and is very effective, because the yield of wheat-flax flour was more than 89 %. In the first technological system, the initial wheat-flax milling grain mixture is ground, followed by dressing of intermediate products of grinding and sifting of wheat-flax flour. A polyamide sieve with a cell size of 224 µm was used as a flour sieve; the passage through it was the finished product. In the second milling system the by-product from the first stage was ground and the intermediate products of grinding were then sifted on the flour sieve to obtain wheat-flax flour and wheat-flax bran. The grinding modes and parameters for all samples of milled wheat-flax mixtures remained unchanged. The yields of whole-grain wheat-flax flour of different ratios are presented in Table 2.

As can be seen from Table 2, with an increase in the amount of flax seeds in the milled wheat-flax grain mixture, the yield of wheat-flax flour increases. The highest yield of wheat-flax flour is obtained by adding 10 % of flax seeds to the milled mixture and is 93.8 %.

The physicochemical quality indicators of the obtained samples of whole-grain wheat-flax flour of various ratios are presented in Table 3.

As can be seen from Table 3, the higher the flaxseed content in the milling mixture, the higher the acidity of the whole-grain wheat-flax flour, while the gluten content decreases and its quality improves, and the falling number decreases.

The results of studies of the chemical properties of whole-grain wheat-flax flour of various ratios are given in Table 4.

As can be seen from the table, with an increase in the flaxseed content, the protein and fat content increase, while with an increase in the flaxseed content in wheat-flax flour, the starch content decreases.

The dependence of the protein and fat content in whole-grain wheat-flax flour of different ratios on the flax seed content in the grinding mixture is shown in Figure 1.

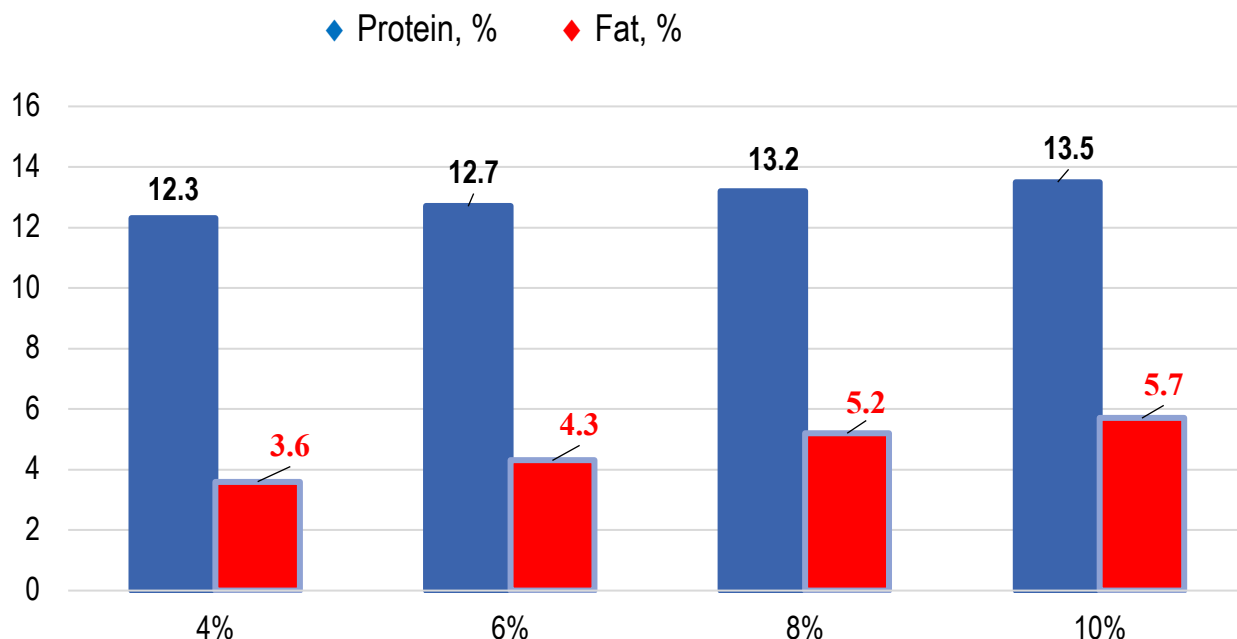


Figure 1: Dynamics of changes in protein and fat content in whole-grain wheat-flax flour of different ratios

As can be seen from Figure 1, the higher the flaxseed content in whole-grain wheat-flax flour, the higher both the fat content and the protein content in the flour.

At the next stage of our research, to study the effect of different ratios of whole-grain wheat-flax flour on the quality of finished bread, laboratory baking was carried out. For this, wheat-flax flour was used in different ratios: 96:4, 94:6, 92:8, 90:10, obtained after grinding in a laboratory mill. The dough for the trial laboratory baking of bread from the control wheat flour of the 1st grade and whole-grain wheat-flax flour of various ratios was prepared according to the generally accepted method and according to the recipes presented in Table 5. The control sample was a sample of bread prepared from wheat flour of the 1st grade. The baking properties of the obtained bread samples were determined 18 hours after baking the bread according to the generally accepted methods.

The dough was mixed in a Kenwood dough mixer with a spiral kneading organ. The raw materials were loaded in the following order: flour, yeast suspension, salt and water. The mixing was carried out for 4 minutes at medium speed. In accordance with GOST 27669-88 the semi-finished product was fermented in a thermostat at a temperature of 30°C for 150 minutes with kneading 60 minutes after the start of fermentation. After fermentation was complete, pieces of dough weighing 400 g were measured out. The dough pieces were divided manually. The formed pieces were placed in baking tins greased with vegetable oil, which were sent to an Allen-Bradley proofing cabinet at a temperature of 40°C and a relative humidity of about 75-80 %. The end time of proofing was determined organoleptically and was about 50 minutes.

After proofing, the semi-finished product was sent for baking in a MIWE condo laboratory oven heated to 240°C. Additionally, when baking tin bread, the oven chamber was moistened. The tin bread was baked for 25 minutes. The baked products were cooled at room temperature.

Organoleptic indicators are assessed by means of the senses (smell, touch, sight) on the basis of a 5-point assessment taking into account the weighting coefficient. The developed methodology is presented in the textbook [20]. A special commission of bread tasters was created, consisting of 7 people. The tasters were presented with a table on the basis of which an expert assessment of the organoleptic indicators of finished products from control wheat flour of the 1st grade and whole-grain wheat-flax flour of various ratios was made (Table 6).

The results of the conducted studies are presented in Table 7 and in Figures 2-3, as well as Figures 4-6 for a visual display of changes in the quality indicators of bread from the control wheat flour of the 1st grade and whole-grain wheat-flax flour of various ratios.

As can be seen from the table, adding flax seeds to the grinding mixture increases the acidity of the pan bread made from wheat-flax flour, reduces the specific volume

of the pan bread and its elastic deflection, while not having a significant effect on the moisture content and porosity of the finished product.



Figure 2: Bread made from control wheat flour of the 1st grade and wheat-flax flour in different ratios: 1 - control sample, 2 - 96:4, 3 - 94:6, 4 - 92:8, 5 - 90:10

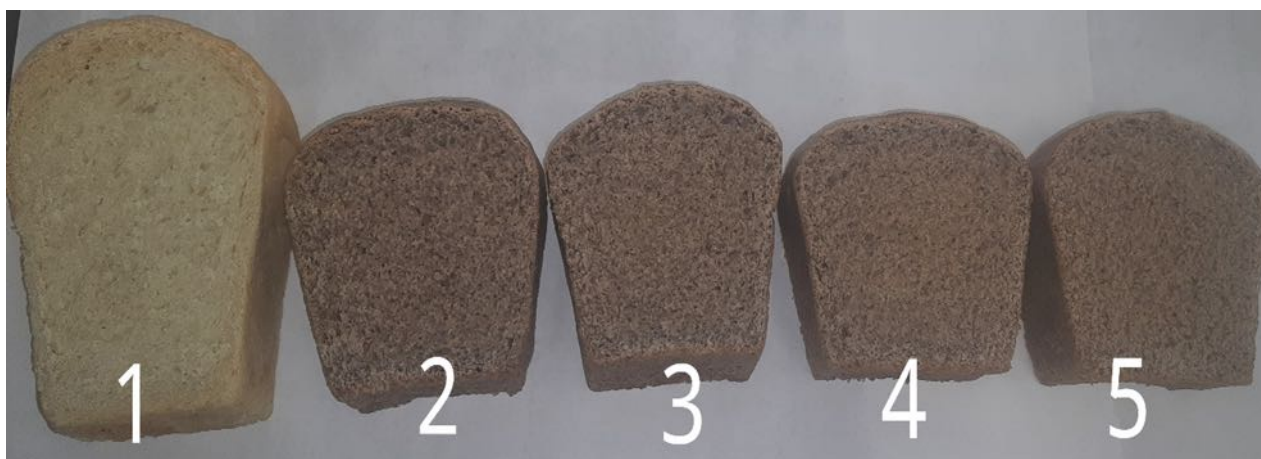


Figure 3: Bread made from control wheat flour of the 1st grade and wheat-flax flour of different ratios in cross-section: 1 - control sample, 2 - 96:4, 3 - 94:6, 4 - 92:8, 5 - 90:10

As can be seen from the figures, pan bread made from whole-grain wheat-flax flour of different ratios has a good marketable appearance and, in general, can be recommended to enterprises for the production of this type of bakery product and expansion of its range.

Figure 4 shows the effect of the ratio of whole-grain wheat-flax flour on the porosity of pan bread.

◆ Porosity of bread, % - Control

◆ Porosity of bread, % - Wheat-flax flour of various ratios

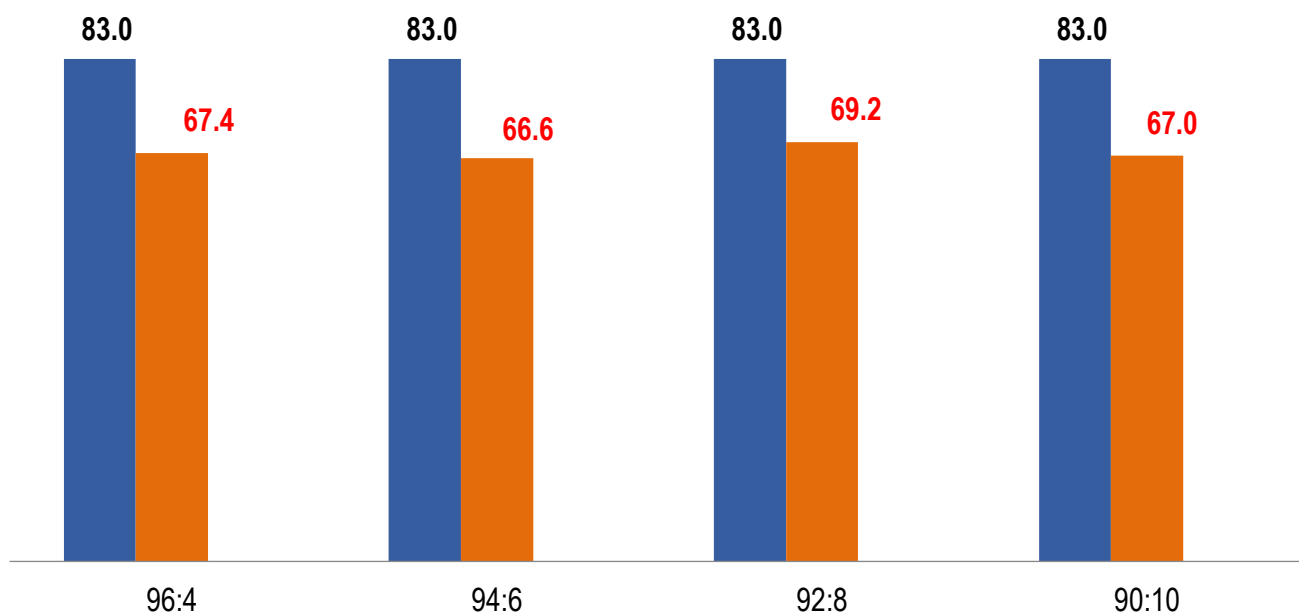


Figure 4: The influence of whole-grain wheat-flax flour ratio on bread porosity

As can be seen from Figure 4, adding flax seeds to wheat-flax flour significantly reduces the porosity of pan bread.

Figure 5 shows the effect of the ratio of whole-grain wheat-flax flour on the specific volume of pan bread.

- ◆ Specific volume of bread, cm3 - Control
- ◆ Specific volume of bread, cm3 - Wheat-flax flour of various ratios

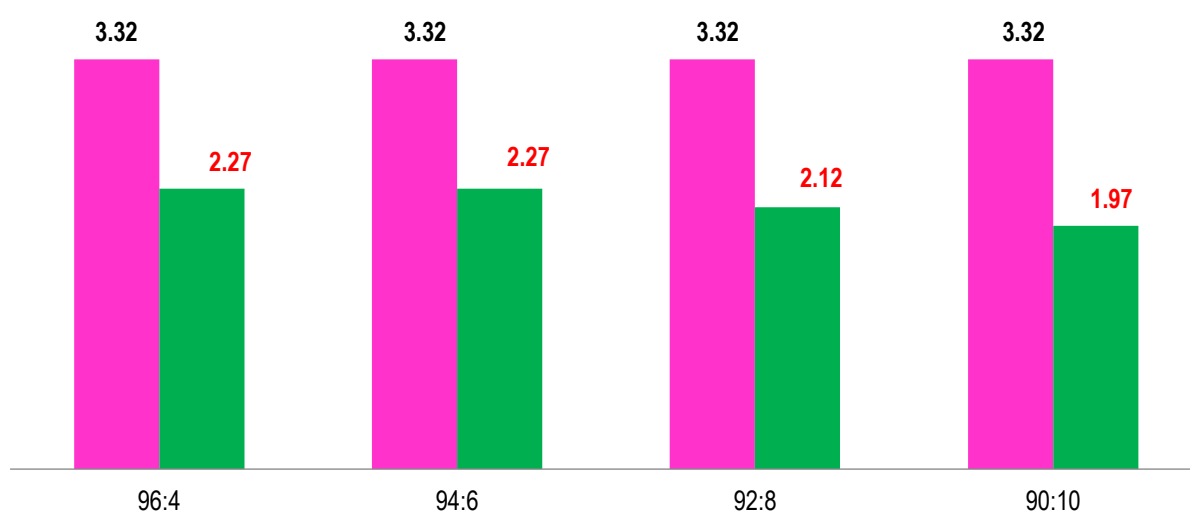


Figure 5: The influence of whole-grain wheat-flax flour ratio on the specific volume of bread

As can be seen from Figure 4, adding flax seeds to wheat-flax flour significantly reduces the specific volume of pan bread, and the more flax, the lower the specific volume of bread. Figure 6 shows the effect of the ratio of whole-grain wheat-flax flour on the elastic deflection of pan bread.

◆ Elastic deflection, mm – Control

◆ Elastic deflection, mm - Wheat-flax flour of various ratios

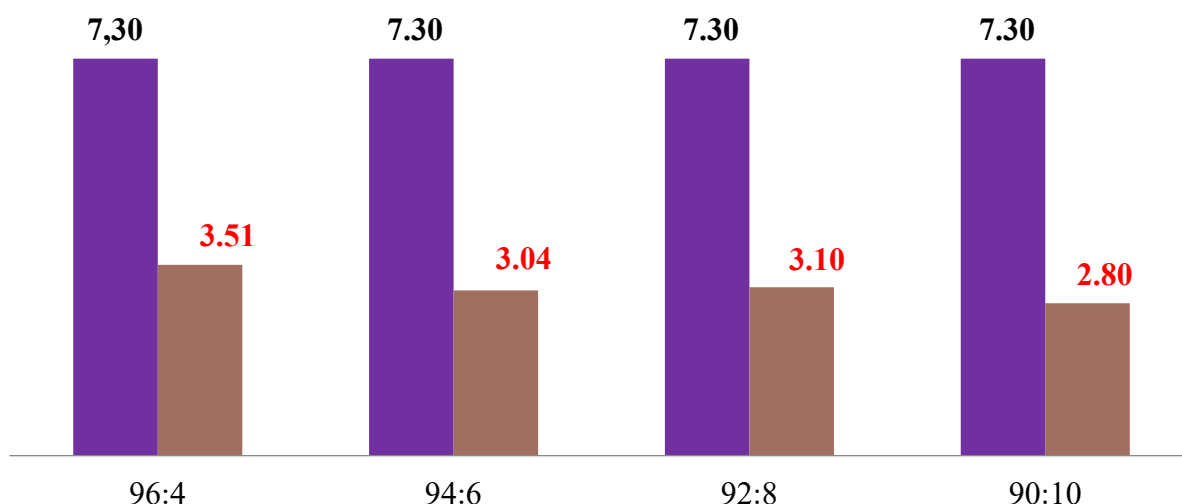


Figure 6: The influence of whole-grain wheat-flax flour ratio on elastic deflection of bread

The data presented in Figure 6 show that in terms of its physicochemical quality indicators, wheat-flax flour is more similar to rye peeled flour, which is due to the peculiarity of the milling scheme, high content of mucous substances in flax seeds and membrane particles. Nevertheless, bread obtained from this type of wheat-flax flour has good quality indicators, developed thin-walled porosity of the crumb, and a pleasant aroma.

At the next stage of the research, an organoleptic score assessment of the quality of bread from the control wheat flour of the 1st grade and whole-grain wheat-flax flour of various ratios was carried out, the results of which are presented in Table 8 and Figure 7. Based on the results of the assessment by the tasting committee of all the presented samples, it was established that the bread obtained from wheat-flax flour at a ratio of 92:8 received the highest score according to the results of the organoleptic assessment. In this regard, this sample was selected for further studies aimed at calculating the energy and nutritional value of bread.

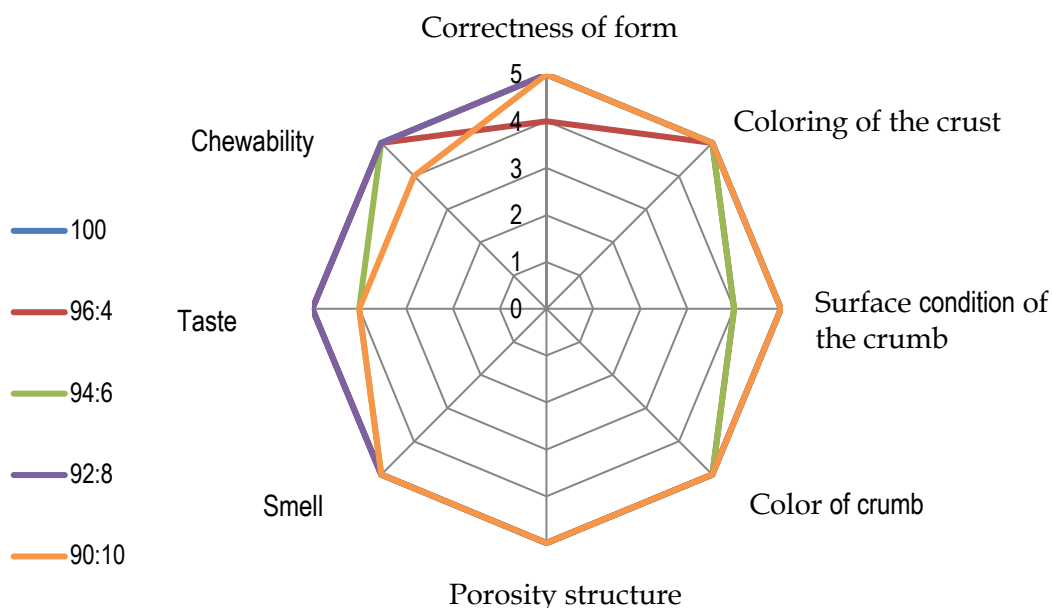


Figure 7: The influence of different ratios of whole-grain wheat-flax flour on the organoleptic properties of the finished product

At the final stage of the study, the energy and nutritional value of bread made from whole-grain wheat-flax flour was calculated in a ratio of 92:8, since this ratio of whole-grain wheat-flax flour is the most optimal in terms of consumer benefits and nutritional value for the production of pan bread. The nutritional value was calculated using the author's method described in the guidelines [19]. The data obtained on the basis of the calculations are presented in Table 9.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Based on the results of the research, a technology for obtaining whole-grain wheat-flax flour and a recipe for molded wheat-flax bread from it has been developed. It has been established that with an increase in the amount of flax seeds in the milled wheat-flax grain mixture, the yield of wheat-flax flour increases. The highest yield of wheat-flax flour is obtained with the addition of 10% flax seeds and is 93.8%. It has been revealed that with an increase in the amount of flax seeds in whole-grain wheat-flax flour, its moisture content decreases, which is explained by an increase in the content of plant membrane that absorbs moisture. At the same time, there is an increase in the acidity of the flour with a simultaneous decrease in the gluten content and its strengthening due to the content of polyunsaturated fatty acids. The optimal ratio of 92:8 whole-grain wheat-flax flour for the production of pan bread was determined, using sensory evaluation. At the same time, the nutritional value of the

bread increased in protein content by 17.9% and in fat content, including due to polyunsaturated fatty acids of the ω -3 and ω -6 family, by almost 481.8%. As a result of the studies, a positive effect of adding flax seeds to the grinding mixture on the nutritional value of bread made from whole-grain wheat-flax flour was established. A patent for the invention of the Russian Federation No. 2810098 "Method for obtaining whole-grain wheat-flax flour" was received for the developed technology for the method of obtaining whole-grain wheat-flax flour, which indicates not only the scientific, but also the practical significance of the results obtained. The developed whole-grain wheat-flaxseed flour cannot replace other presented various types and grades of flour, but can serve as a supplement to other enriching grain-based food products.

Conflict of interest

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

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Table 1: Technical characteristics of the laboratory mill

Power, W	Speed, rpm	Grinding coarseness, μm	Capacity, g
1400	30000	50-300	800

Table 2: Yield of whole-grain wheat-flax flour of different ratios

Parameters	Ratio of wheat-flax grinding mixture, technological system							
	96:4		94:6		92:8		90:10	
	I system	II system	I system	II system	I system	II system	I system	II system
amount of grinding mixture supplied for grinding, %	100	25.2	100	28.6	100	24.6	100	25.0
passable product, g	74.8	14.6	71.4	18.2	75.4	13.8	75.0	18.8
similar product, g	25.2	10.6	28.6	10.4	24.6	10.2	25.0	6.2
total yield of whole-grain wheat-flax flour, %	89.4		89.6		89.8		93.8	

Table 3: Physicochemical quality indicators of whole-grain wheat-flax flour of various ratios

Ratio of wheat and flax	Quality indicators to be determined				
	Humidity, %	Acidity, degrees	Gluten content, %	Gluten quality, unit device IDK	Falling number, s
96:4	14.68	6.8	22.0	85	230
94:6	14.07	7.0	21.8	80	217
92:8	14.00	8.0	20.7	77	209
90:10	14.22	7.4	20.1	71	201

Table 4: Chemical properties of the control wheat flour of the 1st grade and the obtained whole-grain wheat-flax flour of various ratios

Ratio of wheat and flax	Determined quality indicators		
	Protein, %	Starch, %	Fat, %
First-grade wheat flour	11.2	69.2	1.1
96:4	12.3	66.3	3.6
94:6	12.7	66.0	4.3
92:8	13.2	65.2	4.8
90:10	13.5	64.7	5.3

Table 5: Recipe for preparing bread from the control wheat flour of the 1st grade and whole-grain wheat-flax flour of various ratios

Name of raw material	Amount of added raw materials, % of the mass of flour of different samples				
	Control sample	96:4	94:6	92:8	90:10
first-grade wheat flour	100	–	–	–	–
wheat-flax flour 96:4	–	100	–	–	–
wheat-flax flour 94:6	–	–	100	–	–
wheat-flax flour 92:8	–	–	–	100	–
wheat-flax flour 90:10	–	–	–	–	100
baker's yeast	5.0				
edible salt	1.5				
water	According to calculations based on dough humidity of 43.5%				

Table 6: Point assessment of the quality of bakery products taking into account the weighting of the main indicators

Name of the indicator	Weight coefficient	Assessment, points	Assessment taking into account weight, points
volume of pan bread	3.0	1-5	3-15
correctness of shape	1.0	1-5	1-5
crust color	1.0	1-5	1-5
crust surface condition	1.0	1-5	1-5
crumb color	2.0	1-5	2-10
porosity structure	1.5	1-5	1.5-7.5
structural and mechanical properties of crumb	2.5	1-5	2.5-12.5
smell	2.5	1-5	2.5-12.5
taste	1.0	1-5	1-5
chewability	-	-	20-100

Table 7: Physicochemical indicators of pan bread from the control wheat flour of the 1st grade and whole-grain wheat-flax flour of various ratios

Name of the indicator	Control	Wheat-flax flour ratio			
		96:4	94:6	92:8	90:10
humidity, %	40.5	40.8	40.9	40.8	40.8
acidity, degrees	2.2	4.8	5.0	5.2	6.0
porosity, %	83.0	67.4	66.6	69.2	67.0
specific volume, cm ³ /g	3.32	2.27	2.27	2.12	1.97
elastic deflection, mm	7.30	3.51	3.04	3.10	2.80

Table 8: Organoleptic score assessment of the quality of bread made from control wheat flour of the 1st grade and whole-grain wheat-flax flour of various ratios

Name of the indicator	Weighting factor	Control 100	Wheat-flax flour ratio			
			96:4	94:6	92:8	90:10
correctness of form	3.0	5	4	5	5	5
coloring of the crust	1.0	5	5	5	5	5
surface condition of the crust	1.0	5	4	4	5	5
color of crumb	2.0	5	5	5	5	5
porosity structure	1.5	5	5	5	5	5
smell	2.5	5	5	5	5	5
taste	2.5	5	5	4	5	4
chewability	1.0	5	5	5	5	4
sum of all indicators	–	65.0	61.0	61.5	65.0	61.5

Table 9: The number of components per 100 g of the edible part of bread made from whole-grain wheat-flax flour in a ratio of 92:8

nutritional value, g	value of the indicator
proteins	13.2
fats	4.8
carbohydrates	60.7
energy, value, kcal	227.8

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