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Using fish protein in innovative technologies of bakery and flour confectionery products

Nataliya Yu. Klyuchko, Dariya A. Pozdnyakova, Ilmira R. Romazyaeva, Ekaterina D. Kovaleva

Kaliningrad State Technical University,
Kaliningrad, Russia, natalya.kluchko@klgtu.ru✉

Annotation. The article presents research on improving the technology of bakery and flour confectionery products by enriching them with fish protein. There are presented the data of a survey of the dietary preferences of schoolchildren aged 15-16. It is noted that most teenagers prefer bakery and flour confectionery products as a snack. It is also established that children do not consume enough fish protein, which is complete and easily digestible. In this regard, the study solves the problem of improving the technology of wheat biscuits and rye-wheat loaves by enriching with a protein-mineral additive. In the first case, the problem is solved by introducing fermented minced cod into the dough, obtained by keeping the crushed muscle tissue of the fish in water at the specified parameters. In the case of obtaining loaves, a protein-mineral additive is a composition obtained by the destruction of muscle, integumentary and bone tissues of fish raw materials in a subcutaneous whey. To determine the optimal parameters of the process there was carried out mathematical planning of the experiment by using the central composition plan of the second order for two factors: the degree of grinding of fish raw materials (2 times) and the duration of disaggregation (4 times). The resulting protein-mineral additive is used in the production of rye-wheat loaves by introducing it into the dough. The baked finished product was an attractive bakery product from light gray to light brown, well baked, with a uniform structure, without signs of non-kneading, with a pleasant taste and smell with slightly pronounced fishy shades. The results of physico-chemical studies showed an increase in the amount of protein by 47.3%, mineral substances – by 96.3%. The indicator of the biological value of the protein was 124%, which characterizes its balance. It has been established that the loaves are characterized by a high content of mineral elements significant in nutrition (potassium, calcium, magnesium, sodium, phosphorus), so the new food product is functional.

Keywords: fortified products, bakery and flour confectionery products, loaves, krayushki, biscuits, protein-mineral supplement, Baltic cod, sour milk whey

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Научная статья

Использование рыбного белка в технологии инновационных хлебобулочных и мучных кондитерских изделий

Наталия Юрьевна Ключко*✉*, Дарья Александровна Позднякова, Ильмира Равильевна Ромазяева, Екатерина Дмитриевна Ковалева

Калининградский государственный технический университет,
Калининград, Россия, natalya.kluchko@klgtu.ru✉

Аннотация. Представлены исследования по совершенствованию технологии хлебобулочных и мучных кондитерских изделий путем их обогащения белком рыбы. Представлены данные опроса школьников 15–16 лет об их предпочтениях в рационе питания. Отмечается, что в качестве перекуса большинство подростков предпочитают хлебобулочные и мучные кондитерские изделия. Установлено также, что дети недостаточно употребляют рыбный белок, являющийся полноценным и легкоусваиваемым. В связи с этим в работе решается проблема совершенствования технологии пшеничных галет и ржано-пшеничных хлебцев (краюшек) путем обогащения белково-минеральной добавкой. В первом случае задача решается за счет введения в состав теста ферментированного фарша трески, полученного путем выдерживания измельченной мышечной ткани рыбы в воде при заданных параметрах. В случае получения хлебцев белково-минеральная добавка представляет собой композицию, полученную путем деструкции мышечной, покровной и костной тканей рыбного сырья в подсырной молочной сыворотке. Для определения оптимальных параметров указанного процесса проведено математическое планирование эксперимента с использованием центрального композиционного плана второго

порядка для двух факторов: степень измельчения рыбного сырья (2 раза) и продолжительность дезагрегации (4 ч). Полученная белково-минеральная добавка использована при производстве ржано-пшеничных хлебцев (краюшек) путем ее введения в состав теста. Выпеченный готовый продукт представлял собой привлекательное хлебобулочное изделие от светло-серого до светло-коричневого цвета, хорошо пропеченное, с равномерной структурой, без признаков непромеса, с приятным вкусом и запахом с неярко выраженными рыбными оттенками. Результаты физико-химических исследований показали увеличение количества белка на 47,3 %, минеральных веществ – на 96,3 %. Показатель биологической ценности белка составил 124 %, что характеризует его как сбалансированный. Установлено, что хлебцы отличаются высоким содержанием значимых в питании минеральных элементов (калий, кальций, магний, натрий, фосфор), таким образом, новый продукт является функциональным продуктом питания.

Ключевые слова: обогащенные продукты, хлебобулочные и мучные кондитерские изделия, хлебцы, краюшки, галеты, белково-минеральная добавка, треска балтийская, подсырная молочная сыворотка

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Introduction

Bakery and flour confectionery products are an integral part of daily nutrition for the majority of the population. Snacks occupy an increasing place in the structure of modern person's nutrition, which are primarily resorted to by the most mobile segments of the population: schoolchildren, students, office employees and others. Their diet, as a rule, does not correspond to the physiological needs of the body. The Ministry of Health of Russia notes insufficient intake of animal protein, deficiency of vitamins and minerals, predominance of carbohydrate-fat component and animal fats, excess of simple carbohydrates [1].

Our survey of teenagers aged 15-16 showed that most of them eat 3 meals a day (45%), although there are also those who are limited to 1-2 meals a day (32%) [2]. The main snack of the interviewed children are fruits, pizza, sandwiches, buns and sweets (Fig. 1).

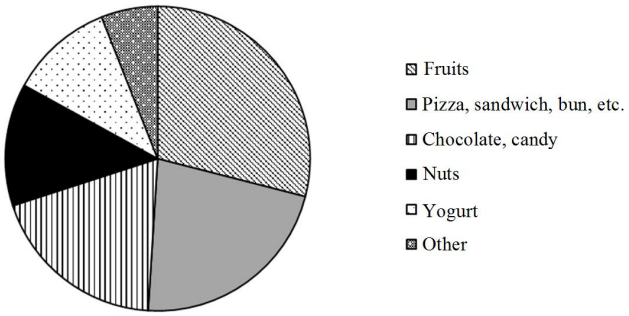

Fig. 1. Types of snacks for teenagers aged 15-16

Fig. 1 shows that 22% are bakery and flour confectionery products (BaFCP), which, in addition to school, are also consumed in sufficient quantities at home. Therefore, it is important to increase the biological value of these products as the most popular among young people. Bakery and flour confectionery products are predominantly carbohydrate products, so it is advisable to enrich them with protein, minerals, and vitamins.

Recently, as the main sources of protein in the enrichment of BaFCP scientists suggest using supplements of plant origin (oilseed meal, concentrates and protein isolates of soybean seeds, sunflower, cotton, peanuts, sesame, beans, canola, potato products) and animal origin (milt of salmon fish species, surimi, kefir starter, whey of milk) [3].

Fish protein is of particular interest as a complete protein. Our analysis of teenagers' diets showed that fish, unfortunately, is popular with only 17% [2].

Research works of the Russian scientists A. P. Chernogortsev, R. G. Razumovskaya, A. S. Lysova, I. A. Bessmertnaya on use of washed or fermented fish mince in technology of flour confectionery [3-9], M. E. Tsibizova's, N. D. Averjanova's on the influence of milk whey on intensity of partial disaggregation of protein of fish muscle tissue [10] are well known. However, in the production of BaFCP, the method of introducing fish protein-mineral mass into the whey-based dough has not been previously used.

The purpose of this work is to improve the technology of BaFCP by enriching them with fish protein, protein-mineral additive (PMA) based on fish and dairy raw materials.

Objects and research methods

The main object of the study was Baltic cod (*Gadus morhua*), corresponding to GOST 814-2019 “Chilled fish. Technical conditions”. In addition, there was used whey (GOST 34352-2017 “Milk whey - raw materials. Technical conditions”), high-grade wheat flour (GOST 26574-2017 “Baking wheat flour”), whole-grain rye flour (GOST 7045-2017 “Baking rye flour”). In terms

of safety, the raw materials met the requirements of TR EAEU 040/2016, TR CU 033/2013, TR CU 021/2011.

In the research there were used standard and generally accepted organoleptic, physico-chemical, biochemical and microbiological methods. Organoleptic evaluation of the finished products included score and profile methods. The amino-acid, fatty-acid and mineral compositions of the rye-wheat bread were determined by the optical method by using a spectral analyzer "NIRS DS2500F" (laboratory of the Veterinary Research Center, Kaliningrad region).

Modeling and optimization of the formulation of enriched wheat galettes, rye-wheat breads were carried out by experimental planning method by using orthogonal central composite plan of the second order for two factors.

Statistical processing of the data was performed using conventional methods at a confidence probability of 0.95. The main experiments were conducted in threefold repeatability. Microsoft Word 2010 and Microsoft Excel 2010 were used to process the results.

Research results and discussion

At the initial stage of the work there was investigated the possibility of protein enrichment of fish flour confectionery products (FCP). Wheat biscuits were chosen as an object for upgrading the formulation. The latter are FCP of layered structure with mass fraction of moisture not exceeding 11%, sugar (sucrose in terms of dry matter) – not less than 11%. Products can be considered as snack products.

In determining the taste preferences of the most common recipes for biscuits by baking trials and organoleptic evaluation allowed to choose the recipe "Simple", which includes wheat flour, water, leavening agent, salt, sugar, sunflower oil and starch. The latter is used to improve the rheological properties of the dough, organoleptic characteristics and the persistence of FCP.

Analysis of literature data showed that fermentolysis of minced fish leads to decomposition of proteins of the fish muscle tissue into the large-molecule compounds: albumin, peptones, peptides [4, 5]. Fermentolysis contributes to the acquisition of fish protein mass of the properties necessary for its use as a filler of food products in order to increase their biological value. After fermentolysis a PMA can be obtained with rheological properties that contribute to a better combination with the dough prepared on the basis of wheat flour at baking. The PMA obtained in this way and introduced into the dough provide good viscosity, stickiness and appropriate hydrophilic properties.

To improve the recipe of biscuits it was proposed to introduce in the dough the fermented minced fish obtained in the following way. The Baltic cod muscle tissue was ground on a cutter and sent for fermentolysis, which was carried out in the presence of water at the minced fish: water as 1 : 1, temperature 22 ± 2°C and duration of 20 minutes. Then the water was removed and injected into the dough.

To establish the optimal parameters of the process of preparation of wheat biscuits of high biological value the experiment was mathematical planned. There was used the amount of introduced starch (x_s) and fermented fish mince (x_m) as varying particular factors subject to regulating and optimizing. A dimensionless generalized indicator that combines two partial responses: porosity and adhesion was selected as a parameter of optimizing the mathematical model ***y*** to improve the objectivity of the results of the study. Processing of the obtained data allowed to calculate the parameters of the equation adequately linking the generalized optimization parameter with the variable factors, which helps predict the quality of the product:

$$y = 0.266x_s^2 + 0.0096x_m^2 - 0.0177x_s x_m - 0.5996x_s - 0.0952x_m + 0.4793.$$

Calculation of optimum values of factors, namely starch content (x_s) – 5.5 g/100 g product, minced fish (x_m) – 18 g/100 g product, allowed to develop a recipe for wheat biscuits "Kaliningrad" enriched with fish protein (Fig. 2).

Fig. 2. Wheat biscuits "Kaliningrad" enriched with fish protein

Organoleptic evaluation of enriched biscuits showed that they are rectangular-shaped FCP, with a smooth surface without bloat and cracks, with a uniform color from straw-yellow to light brown, the appearance in the break – layered, baked, with uniform porosity, without bloat, hardening and traces of unmixed, taste and smell - pleasant, typical of this type of products, fish tones are almost not expressed. Physico-chemical indices are presented in Table 1, where we can see that protein content in enriched biscuits increased by 47.5%, mineral substances – by 38.8 %.

Table 1

Physico-chemical indicators of the quality of biscuits

Indicator name	Biscuits “Simple” (control sample)	Biscuits “Kaliningrad” (experimental sample)
Mass fraction of moisture, %	9.55	10.05
Mass fraction of protein, %	10.15	14.97
Mass fraction of fat, %	1.80	1.60
Mass fraction of carbohydrates, %*	77.24	71.95
Mass fraction of minerals, %	1.26	1.43
Alkalinity, deg.	0.6	0.6

*Data were obtained by calculation.

The results obtained show the promise of the work and require further research.

Another area of research carried out at the Department of Food Biotechnology of Kaliningrad State Technical University is to improve the technology of bakery products – rye-wheat bread [11]. Introducing the fish protein additive into the dough allowed obtaining a product with attractive organoleptic properties. Studying the chemical composition showed an increase in protein, but not any significant increase in minerals. That is why it was suggested to use not only fish muscular tissue but also its supporting-framework and covering tissues. The latter are a source of calcium, phosphorus, collagen protein, which are the building blocks for the growing body of a teenager strengthening his musculoskeletal system. Table 2 presents the results of studies of the chemical composition of the carcass of Baltic cod (*Gadus morhua*).

Table 2

General chemical composition of the carcass of Baltic cod (*Gadus morhua*)

Type of fish	Mass fraction, %				Energy value, κDg/100 g
	Water	Protein	Fat	Mineral substances	
Baltic cod, carcass	78.65	14.15	2.75	4.45	81.43

It can be seen that the minced meat of the Baltic cod carcass by the mass fraction of protein is at the level of the most used marine fish species. In terms of protein content, cod is included in the group of protein fish (15-20%), and in terms of fat content – to dietary (low-fat) (0.1-4%), which indicates its high biological value and the prospect of use in bakery technology.

A high calcium content has been experimentally proven (Table 3) in the carcass of cod, due to its high content in the bones of fish, including vertebrates.

Table 3

Content of calcium and phosphorus in the carcass of Baltic cod (*Gadus morhua*)

Type of fish	Calcium, mg/kg	Phosphorus, mg/kg
Baltic cod, carcass	1 555.2	860

The Ca : P ratio is 1 : 0.6, which is potentially beneficial for the human body.

Acid-enzymatic hydrolysis in milk serum (whey) was used to soften fish tissues. The latter is characterized by the low caloric value and high biological value: it contains milk protein, B vitamins, as well as a complex of such mineral compounds as potassium, sodium, calcium, magnesium, iron and others.

To optimize the process of fish raw material disaggregation the cod carcass was passed through the spinner from 1 to 3 times. Disaggregation time varied from 2 to 4 hours. Hydromodule of the ratio “fish mince: milk whey” was 1 : 1 at temperature 20-22°C. pH of the initial fish-milk mixture was 5.8-6.0, that was close to optimal value of work of cathepsins of fish raw muscle tissue, milk-acid microflora and chymosin – rennet enzyme remaining in whey after cheese making.

Implementation of the experimental plan and processing of the obtained data allowed to calculate the equation adequately linking the generalized optimization parameter with the factors being changed, which allows for maximum degradation of protein-mineral mass while maintaining attractive organoleptic indicators. Fig. 3 shows a geometric model of the optimization process of fish raw material disaggregation in milk whey.

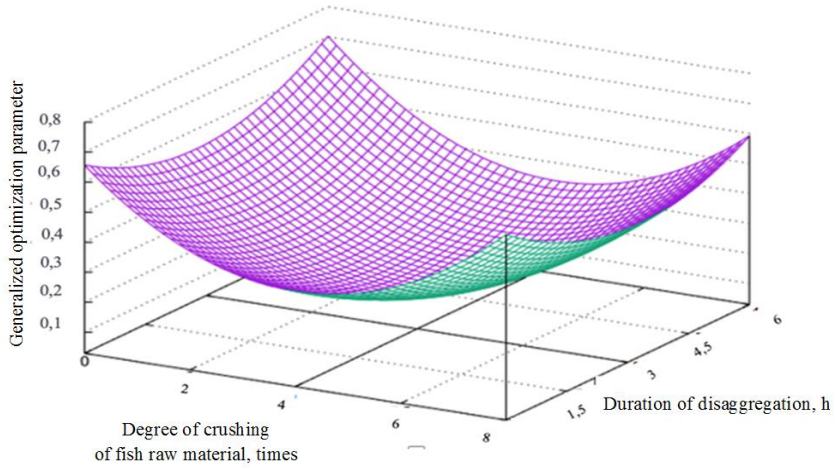

Fig. 3. Geometric model of optimizing the disaggregation of fish raw materials in dairy whey

Optimal parameters were: 2.05 times – degree of crushing of fish raw material, we take accordingly 2 times, 3.92 h – duration of disaggregation, we take 4 h.

The resulting protein-mineral mass was tested in the manufacture of rye-wheat bread, which was introduced directly when kneading dough. The baked finished product was a bakery product of regular shape, without indentations, with even edges, surface smooth, without swellings and cracks, color – uniform from light gray to light brown, crumb condition – well baked, with a uniform structure, without signs of unmixed, taste and smell – pleasant with a vague fishy tones.

Tasters evaluated the control and experimental samples of products (respectively, without and with the introduction of PMA) by the intensity profile method using the developed characteristics. Individual evaluations of the experts were recorded in the tasting sheets, after which the taste profile of these samples of bakery products was built (Fig. 4).

Physico-chemical quality parameters of the control and experimental samples of bakery products are presented in Table 4.

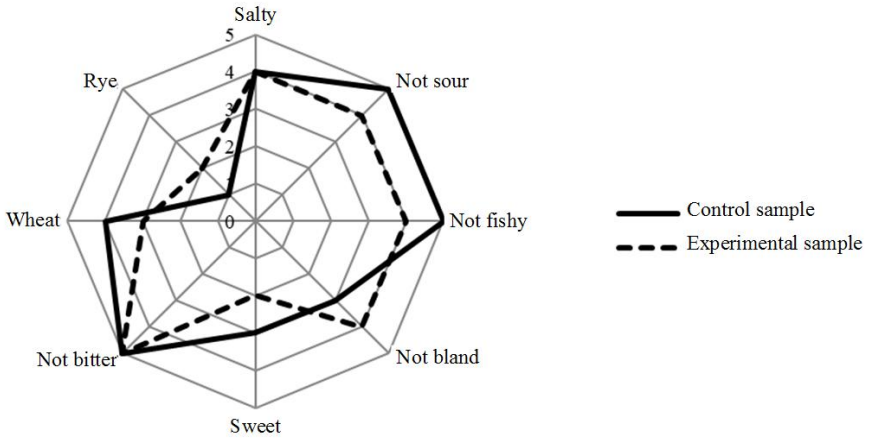

Fig. 4. Bread flavor profile

Table 4

Physico-chemical parameters of experimental and control samples of bread

Indicator name	Experimental samples (with a protein-mineral supplement)	Control samples (without protein-mineral supplement)
Mass fraction of moisture , %	31.10	31.00
Mass fraction of protein, %	15.10	10.25
Mass fraction of fat, %	0.70	0.85
Mass fraction of carbohydrates, %*	50.45	56.55
Mass fraction of minerals, %	2.65	1.35
Acidity, gram/L	0.2	0.1
Energy value of the product, kcal *	262.99	265.65

*Data were obtained by calculation.

The research results showed an increase in the amount of protein by 47.3%, minerals – by 96.3%.

Table 5 shows the results of the amino acid (AA) content and comparative analysis of the amino acid scoring of experimental and control samples.

Table 5

Calculated indicators of amino acid score of experimental and control bread samples

Essential AA	Amino acid content of FAO/WHO "reference" protein g/100g	Control samples (without protein-mineral supplement)		Experimental samples (with a protein-mineral supplement)	
		AA content, g/100g protein	AA score*, %	AA content, g/100g protein	AA score*, %
Valin	5.00	4.5	90.00	4.89	97.80
Isoleucine + leucine	11.00	9.18	83.45	10.19	92.64
Lysine	5.50	2.52	45.81	3.60	65.45
Methionine + cystine	3.50	2.60	74.29	3.59	102.57
Threonine	4.00	2.30	57.50	3.27	81.75
Trypophan	1.00	0.91	91.00	1.03	103.00
Phenylalanine + tyrosine	6.00	7.39	123.16	7.44	124.00
Sum	36.00	29.4	–	34.01	–
Biological value, %		86.81		96.76	
Utility coefficient of the AA composition*, debt units		0.62		0.79	

*Data were obtained by calculation.

The table shows that the protein of breads with the addition of PMA is more balanced in composition. The index of biological value of protein is 124%, which characterizes its balance. The amino acid utilitarian coefficient increased with the addition of PMA to the standard bread recipe, which indicates the advisability of its introduction into the recipe to enrich the product with wholesome animal protein, which is so necessary for the growing organism.

Tables 6 and 7 present the results of the study of minerals and the calculation of the satisfaction of their daily requirement in the classic and enriched bakery products at the consumption of 150 g of bread per day.

Table 6

Content of mineral substances in bread

Mineral content	Experimental samples (with a protein-mineral supplement)	Control samples (without protein-mineral supplement)	Daily requirement*
Potassium, mg, %	270.00	220.00	2 500 mg
Calcium, mg, %	110.00	50.00	1 000-1 200 mg
Magnesium, mg, %	50.00	29.40	400 mg
Sodium, mg, %	730.00	720.00	1 300 mg
Phosphorus, mg, %	220.00	200.00	800 mg
Iron, mg, %	1.50	1.50	10-18 mg
Manganese, mg, %	0.09	0.09	2 mg
Zinc, mg, %	0.55	0.55	12 mg
Copper, mg, %	0.01	0.01	1 mg
Selenium, mcg, %	4.44	4.44	5-70 mcg
Chromium, mcg, %	20.00	20.00	50-200 mcg

*Based on MR 2.3.1.2432-08 "Norms of physiological requirements for energy and nutrients for various groups of population of the Russian Federation".

Table 7

Calculated indicators in meeting the daily requirement of minerals in rye-wheat bread enriched with protein-mineral supplement

Mineral content	Quantity, mg/150 g of rye-wheat bread	Daily requirement	Meeting the daily requirement*	Product functionality for this component
Potassium, mg, %	405.00	2 500 mg	16.2	Functional
Calcium, mg, %	165.00	1 000 mg	16.5	
Magnesium, mg, %	75.00	400 mg	18.75	
Sodium, mg, %	1 095	1 300 mg	84.23	
Phosphorus, mg, %	330	800 mg	41.25	
Iron, mg, %	2.25	14 mg	16.0	
Manganese, mg, %	0.135	2 mg	6.75	Not functional
Zinc, mg, %	0.81	12 mg	6.75	
Copper, mg, %	0.015	1 mg	1.5	
Selenium, mcg, %	6.66	50 mcg	13.32	
Chromium, mcg, %	30.00	150 mcg	2.00	

*Use of 150 g of bread per day, %.

The analysis of the obtained data showed that the content of calcium in enriched bread exceeds 2.2 times, potassium – 1.2 times, magnesium – 1.7 times. It can be seen that the ratio of Ca : P and Ca : Mg in the experimental sample is 1 : 2 and 1 : 0.19, respectively, whereas in the control 1 : 4 and 1 : 0.13, which indicates a good balance in the enriched products.

It is known that the most favorable ratio of calcium and phosphorus in food is 1 : 1.2-1.5, calcium and magnesium – 1 : 0.25-0.3. Excess phosphorus leads to the leaching of calcium from bones, reduces iron absorption, increases the load on the kidneys. Excess magnesium negatively affects the absorption of calcium. In food products, in general, the ratio with phosphorus and magnesium, necessary for better absorption of calcium, is not maintained.

The data in Tables 6 and 7 show that the enriched breads have a high content of the most important mineral elements in the diet (potassium, calcium, magnesium, sodium, phosphorus), that is, the product is functional. Of particular importance are trace elements that are not synthesized by the body (copper, zinc, manganese).

Microbiological tests of the finished product, as well as the safety of the main and auxiliary raw materials, were carried out to assess the storage capacity of the products. As a result of the research, it was found that it is necessary to carefully control the raw ingredients of the formulation, especially the contamination of minced meat from cod carcass and whey. Also, a guaranteed shelf life for enriched loaves was established – 72 hours at a temperature not lower than 6°C, it is also possible to store at a temperature of –18°C for 3 weeks, followed by heating in the oven at 180°C for 5 minutes.

Conclusions

1. It has been inferred that introducing the fish protein-mineral additives into the composition of bakery and flour confectionery products increases their biological value while maintaining attractive organoleptic indicators.

2. The technology of wheat biscuits enriched with fish protein has been developed, the optimal parameters of the formulation have been determined using the method of mathematical planning, an increase in the content of the mass fraction of protein by 47.5%, mineral substances – by 38.8% has been proved.

3. The technology of rye-wheat loaves enriched with a protein-mineral additive obtained by partial disaggregation of cod carcass in whey (subcutaneous), occurring under the action of enzymes of fish muscle tissue, rennet enzyme and lactic acid for 4 hours at a natural pH of the reaction mixture equal to 5.9 ± 0.1, hydromodule 1 : 1 and the temperature is 22 ± 2°C.

4. It is shown that the enrichment of rye-wheat bread with a protein-mineral composition increases the protein content by 70.2%, mineral substances – by 60.9%, reduces the amount of carbohydrates – by 13.3%. The content of calcium in enriched bread compared to traditional products is 2.2 times higher, potassium – 1.2 times, magnesium – 1.7 times.

5. Analysis of the functionality of the finished product showed that the consumption of 150 g of enriched bread satisfies the daily requirement (%): potassium – by 16.2; phosphorus – 41.25; magnesium – 18.75; sodium – 84.23; iron – 16.0; calcium – 16.5. The ratio of Ca : P and Ca : Mg in the experimental sample is respectively, 1 : 2 and 1 : 0.19, whereas in the control 1 : 4 and 1 : 0.13, which indicates a good balance in the enriched products and allows us to recommend it for the nutrition of various segments of the population, including adolescents.

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Information about the authors / Информация об авторах

Nataliya Yu. Klyuchko – Candidate of Technical Sciences, Assistant Professor; Assistant Professor of the Department of Food Biotechnology; Kaliningrad State Technical University; natalya.kluchko@klgtu.ru

Наталия Юрьевна Ключко – кандидат технических наук, доцент; доцент кафедры пищевой биотехнологии; Калининградский государственный технический университет; natalya.kluchko@klgtu.ru

Dariya A. Pozdnyakova – Master's Course Student of the Department of Food Biotechnology; Kaliningrad State Technical University; dakrup1202@gmail.com

Дарья Александровна Позднякова – магистрант кафедры пищевой биотехнологии; Калининградский государственный технический университет; dakrup1202@gmail.com

Ilmira R. Romazyaeva – Postgraduate Student of the Department of Food Biotechnology; Kaliningrad State Technical University; romazyaeva@mail.ru

Ильмира Равильевна Ромазяева – аспирант кафедры пищевой биотехнологии; Калининградский государственный технический университет; romazyaeva@mail.ru

Ekaterina D. Kovaleva – Master's Course Student of the Department of Food Biotechnology; Kaliningrad State Technical University; kovaleva_k_30@mail.ru

Екатерина Дмитриевна Ковалева – магистрант кафедры пищевой биотехнологии; Калининградский государственный технический университет; kovaleva_k_30@mail.ru