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DEVELOPMENT OF SCIENCE-BASED TECHNOLOGIES AND RECIPES OF GLUTEN-FREE FLOUR CONFECTIONERY PRODUCTS WITH THE USE OF RICE BRAN

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Abstract:

The article touches upon the problem of food production for people suffering from the celiac disease. The aim of the study is the development of gluten-free cookie recipes and technologies and the determination of the influence of rice bran on the nutritional and biological value of new products. Organoleptic characteristics of quality of the cookies were determined using a scoring system based on descriptive and profile methods for assessing the quality of finished products. To determine the content of gluten in cookies, the authors applied enzyme immunoassay using monoclonal antibodies to gliadin. The relative biological value of the developed products was determined by the microbiological method using the test-organism of the infusoria Tetrahymena pyriformis. The developed recopies show possibility of using corn flour and rice bran instead of wheat flour in the production of gluten-free products. The authors studied the effect of dosages of alternative raw materials on organoleptic and physicochemical characteristics of quality of the cookies and proposed optimal variant of the recipe of a gluten-free cookie based on a composite mixture of corn flour and rice bran in the optimal ratio (60:40). The selected recipes provide high organoleptic and physicochemical characteristics of quality of the finished products, corresponding to the requirements of CODEX STAN 118-19-79 and Technical Regulations of the Customs Union 027/2012. The biological and nutritional value of the finished products was determined.

Keywords: *celiac disease, corn flour, rice bran, gluten-free products, quality, biological, nutritional value.*

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INTRODUCTION:

In the modern world, the production of food reducing the negative factors of various diseases has a priority character [2, 4, 7, 11, 18, 19]. One of the diseases that requires a strict gluten-free diet is celiac disease [1, 3, 20, 21, 22, 25]. The celiac disease is a result of the negative reaction of the organism to gliadin, the protein that is part of the gluten of wheat grain. In addition to wheat, similar proteins are present in the grain of barley and rye [23, 24]

The results of the studies on this problem show that 1% of world population has a genetic predisposition to gluten enteropathy [8, 12, 13, 14].

The main way to treat the disease is elimination diet therapy, a strict life-long gluten-free diet. Its aim is to remove food products containing gluten (at all forms, including its traces) from the diet. Therefore, it is necessary to take into account the content of gluten in raw materials selected for production of gluten-free food. According to CODEX STAN 118-19-79 and Technical Regulations of the Customs Union 027/2012, gluten-free products should contain less than 20 mg/kg of gluten in terms of product weight [17].

Flour confectionery accounts more than 40% of the total production of confectionery products. Different ways of production and large number of recipes make it very diverse. Therefore, studies on development and expansion of assortment of gluten-free confectionery produced from alternative raw materials instead of gluten-containing grain of wheat, rye, or barley is topical [6, 9, 10].

On the basis of theoretical studies, the goal was set to develop recipes and technologies for baking gluten-free cookies and to determine the effect of rice bran on nutritional and biological value of the new products.

MATERIALS AND METHODS:

The objects of the study in carried out scientific experiments were rice bran (a secondary product of processing rice, obtained by milling grain in cereal plants), corn flour of technical standard TU 9293-002-43175543-03, control samples of cookies produced by traditional technologies using wheat flour, and prototypes of non-gluten cookies produced from a mixture of corn flour and rice bran.

To study the quality of raw materials, semi-finished products, and finished products, the authors used general methods of the food industry and special techniques: organoleptic, physicochemical, and microbiological. Assessment of organoleptic quality of finished products was carried out on a scoring basis according to the descriptive and profile methods. To determine the content of gluten in cookies, the authors applied enzyme immunoassay using monoclonal antibodies to gliadin. The relative biological value of the developed products was determined by the microbiological method using the test-organism of infusoria Tetrahymena pyriformis

RESULTS AND DISCUSSION:

Wheat flour is considered as the main raw material for production of flour confectionery products. One of its components is gluten, which is unacceptable in the gluten-free diet. Therefore, the selection of raw materials for production of new types of gluten-free products should take into account chemical composition of the materials, as well as the requirements of CODEX STAN 118-19-79 and Technical Regulations of the Customs Union (TR CU) 027/2012 [9]. According to these requirements, a technological decision was made to use corn flour and rice bran in the recipe, since prolamines of corn (zein) and rice (orizenin) are not toxic for people having celiac disease [17].

There are two main groups of methods for production of gluten-free flour products:
- production based on natural gluten-free plant raw materials (gluten-free cereals, legumes, pseudocereals, etc.);
- biocatalytic direction focused on the removal of gluten or its modification in gluten-containing raw materials. This direction is in the stage of research development [3].

To develop a new gluten-free product, the authors used basic recipe of the cookie “Little Corn” and replaced wheat flour with corn flour and rice bran. The composite mixtures used for the research consisted of corn flour and rice bran mixed in the ratios: 80:20, 60:40, 50:50, 40:60, and 20:80 respectively.

The quality of the cookies was assessed by organoleptic characteristics using descriptive analysis (Figure 1) and physicochemical parameters.

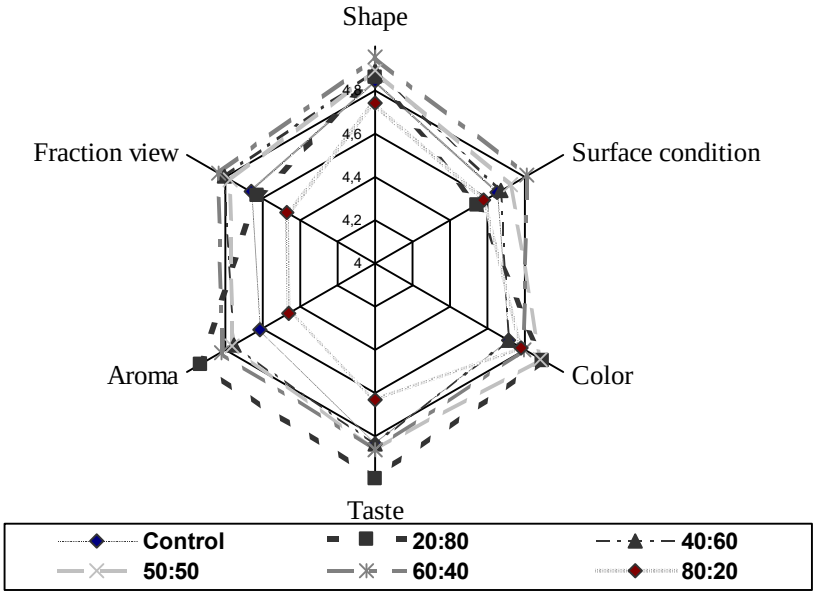

Figure 1. The profilogram of organoleptic quality characteristics of gluten-free cookie samples

The cookies produced from corn flour and rice bran had better organoleptic characteristics compared to the control sample made of wheat flour. Among the samples with different ratios of corn flour and rice bran, a sample produced from the composite mixture of 60:40 ratio was the best one.

Table 1 presents the results of evaluation of the physicochemical characteristics of quality of the cookies for all variants examined in the experiment.

Table 1. The influence of dosages of corn flour and rice bran on physicochemical quality characteristics

Characteristic	Control	Corn flour and rice bran ratio, %				
		20:80	40:60	50:50	60:40	80:20
Water content, %	5.0	5.1	5.3	5.5	5.6	5.8
Alkalinity, deg.	0.7	0.8	0.8	0.8	0.8	0.8
Water absorption, %	148.0	150.0	153.0	155.0	158.0	164.0
Density, g/sm^3	0.8	0.9	1.0	1.0	1.0	1.1

The results of the research showed that an increase of rice flour portion in the composite mixture leads to an increase of water content in finished products. It can be explained by the peculiarity of rice starch. Its amylose occupies an intermediate position between amylose of other types of starch and amylopectin. The presence of large number of branches contributes to a stronger binding of water and provides low retrogradation, thereby reducing the fragility of cookies during transportation.

Alkalinity of the tested samples was close to the level of control sample and lay within acceptable limits of experimental error.

During the research, it was established that an increase in the dosage of rice bran in the dough leads to an increase of water absorption capacity of the cookie, due to the hydrocolloid properties of the rice flour.

According to the complex of organoleptic and physicochemical parameters of the finished product, the authors chose the optimal variant of the composite mixture with the ratio of corn flour and rice bran 60:40. Cookies with this ratio of ingredients have pleasant taste, aroma, attractive appearance, and better water content and water absorption indices. However, this variant, as well as all the other variants examined in the experiment, had small cracks on the surface and the inner structure of the cookie showed layering, presumably because of poor dough extensibility. This negative factor was caused by the lack of gluten proteins and the presence in the recipe of increased content of chemical leveling agent used to

impart porous structure.

To eliminate the defect, the authors decided to reduce the dosage of baking soda added during the kneading of dough. The kneading of the dough for the samples of the gluten-free cookies was carried out with sodium bicarbonate at dosages of 20%, 40%, 60%, 80%, and 100% of the amount defined by the recipe. Figure 2 presents organoleptic characteristics of quality of the cookies produced with different dosages of baking soda.

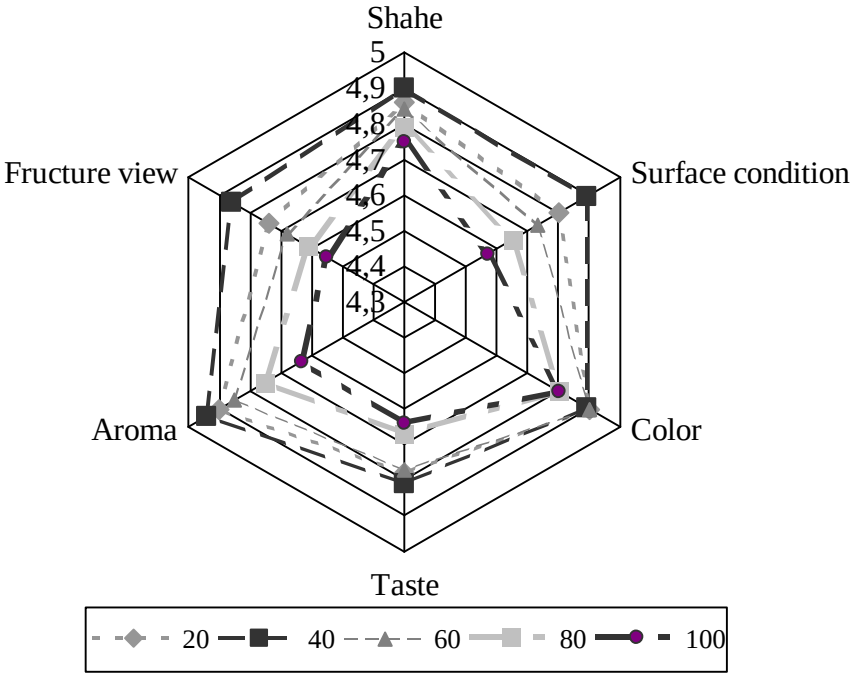

Figure 2. The organoleptic characteristics of quality of cookies produced with different dosages of sodium bicarbonate

The results of the organoleptic evaluation showed that all the samples have correct shape, golden-yellow color, pleasant aroma and taste. With the use of sodium bicarbonate in dosages of 40% and 20%, the surface of the cookies was smooth and there were no cracks.

With initial (100%) dosage of baking soda, the biscuit crumbled a lot. Reduction of amount of leveling agent decreased crumbliness. However, at 20% dosage of sodium bicarbonate, the finished product became thick.

According to the results of testing of the cookie samples, the best quality characteristics had cookies with 40% dosage of sodium bicarbonate added at kneading of the dough. Average quality score of these samples was 4.86 points. The average quality score of the control sample was 4.72 points.

Table 2 shows physicochemical quality characteristics of the cookies with a different dosage of sodium bicarbonate.

Table 2. The physicochemical characteristics of quality of the of cookies with various dosages of sodium bicarbonate

Characteristic	Amount of sodium bicarbonate, % of the basic recipe value				
	20	40	60	80	100
Water content, %	5.8	5.7	5.7	5.6	5.5
Alkalinity, deg.	0.5	0.6	0.7	0.8	0.8
Water absorption, %	194.0	188.0	175.0	163.0	158.0

The results of the studies showed that increase in the dosage of sodium bicarbonate in the dough led to

decrease in the mass fraction of moisture. It also reduced water absorption and increased alkalinity of the products.

On the basis of the conducted studies and the results of the evaluation of the quality of cookies with various dosages of corn flour, rice bran, and sodium bicarbonate, a new recipe and technological scheme for the production of gluten-free sugar cookie "Bright Sun" was developed (Figure 3).

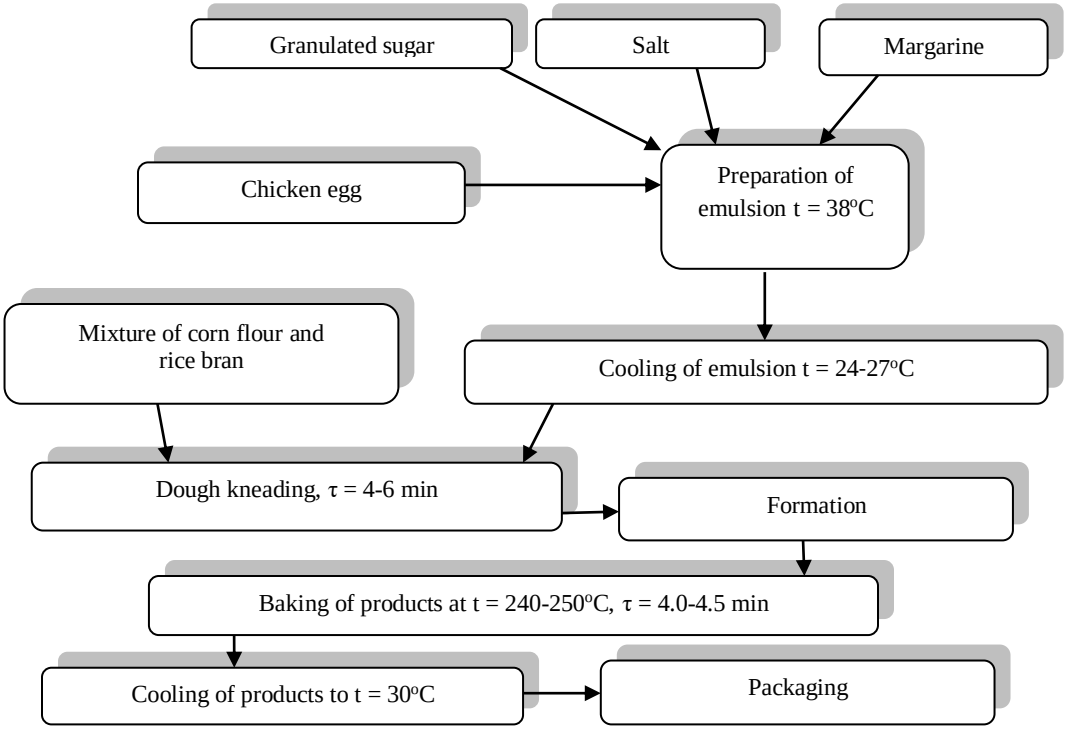

Figure 3. Technological scheme of production of gluten-free cookies "Bright Sun"

In order to expand the assortment of gluten-free cookies, the authors developed a new kind of product based on the recipe of the cookie "Biyskoe" with addition of corn flour and rice bran.

Experimental mixtures used as a basis for the dough contained rice flour and corn bran in the following proportions: 20:80, 40:60, 50:50, 60:40, and 80:20 respectively.

The authors carried out experimental baking of dough kneaded from the mixtures and evaluated finished products by organoleptic characteristics.

Figure 4 shows the results of organoleptic evaluation of quality of the cookies.

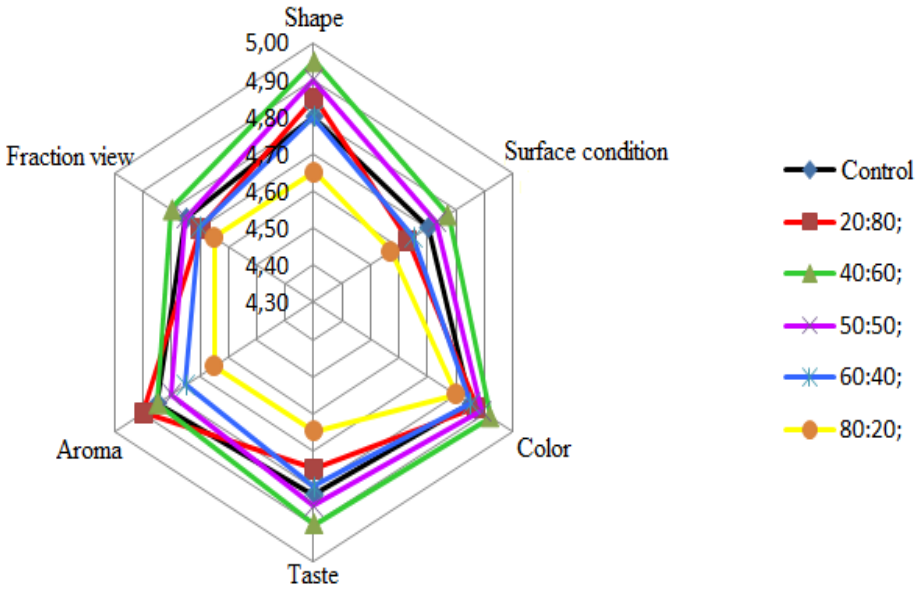

Figure 4. Organoleptic characteristics of quality of gluten-free products based on the recipe of the cookie "Biyskoe"

According to the data presented in the profilograms, the average quality score of cookies produced from corn flour and rice bran mixed in a ratio of 40:60 was 4.87. The average score of the control sample in this experiment was 4.79.

Table 3 shows the results of evaluation of quality by physicochemical characteristics of cookies produced from mixture of corn flour and rice bran.

Table 3. The physicochemical characteristics of cookies produced from corn flour and rice bran mixed in different ratios

Characteristic	Control	Ratio of corn flour and rice bran, %				
		20:80	40:60	50:50	60:40	80:20
Water content, %	8.3	8.5	8.7	8.9	9.1	9.2
Water absorption, %	136.0	148.0	159.0	165.0	170.0	176.0

Data of the Table 3 show that the best variant is the sample with the 40:60 ratio of rice bran and corn flour meal. This sample had the best organoleptic characteristics.

The performed studies allowed the authors to develop the recipe and technological scheme for production of gluten-free cookie "Holiday". Figure 5 demonstrates the scheme.

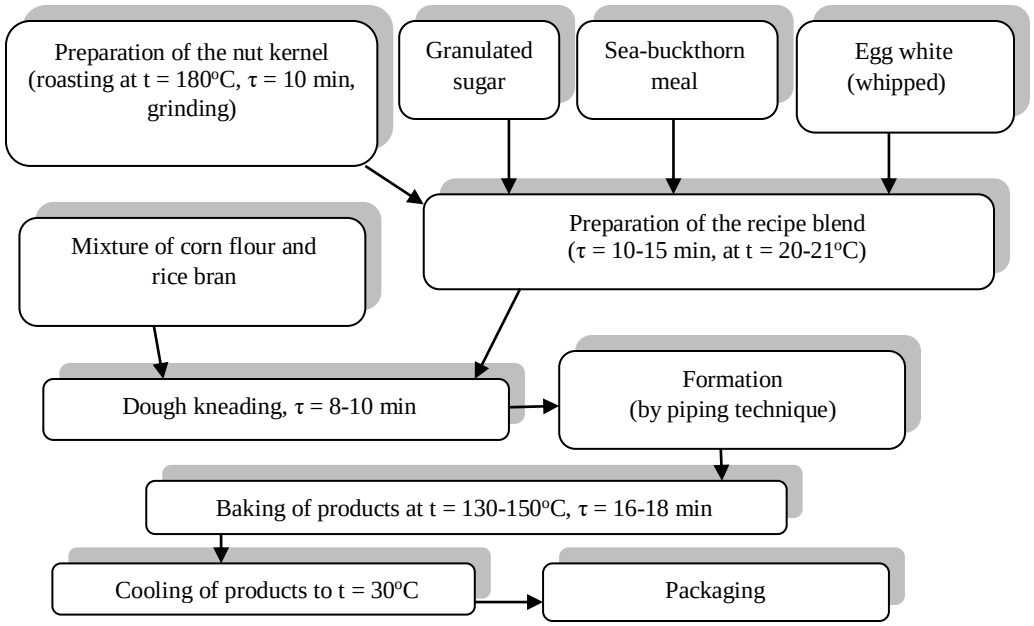

Figure 5. Technological scheme of gluten-free cookie "Holiday"

To determine the term of storage of gluten-free cookies, the authors carried out sanitary and epidemiological assessment of the quality of finished products. Prototypes were stored for 30, 60, 90, and 105 days taking into account the reserve coefficient for non-perishable products. According to the methodological guidelines MUK 4.2.1847-04 "Sanitary-epidemiological assessment of the justification of the shelf life and storage conditions of food products", the reserve coefficient is 1.15 [16].

The samples were stored in sealed plastic bags at the temperature of (18 ± 5)°C and relative humidity of no more than 75%. Then the quality of the products was evaluated.

Evaluation of the quality of the cookie samples during the storage was carried out on a 5-point scale (Figure 6).

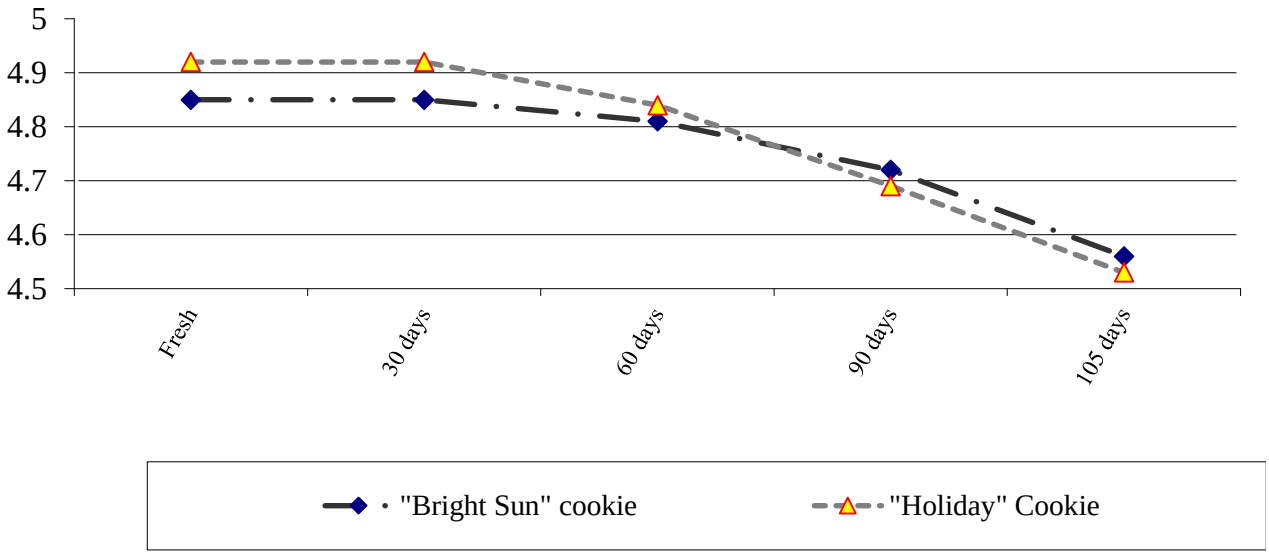

Figure 6. The change in quality of the cookie samples during the storage

The organoleptic evaluation of the quality of cookies showed that during the entire term of storage, the product retained its shape, surface condition, and color. The intensity of the smell changed. On the 90th day, a bitter taste appeared that indicated oxidative processes occurred due to the presence of rice bran in the products.

Table 4 shows the data on change in physicochemical quality characteristics of the gluten-free cookies during the storage.

Table 4. The change in physicochemical characteristics of quality of gluten-free cookies during the storage

Characteristic	Cookie recipe	
	"Bright Sun"	"Holiday"
Fresh baked product		
Water content, %	5.7	8.7
Water absorption, %	189.0	156.0
Alkalinity, deg.	0.5	–
30 days of storage		
Water content, %	5.6	8.6
Water absorption, %	188.0	156.0
Alkalinity, deg.	0.5	–
60 days of storage		
Water content, %	5.5	8.4
Water absorption, %	188.0	154.0
Alkalinity, deg.	0.5	–
90 days of storage		
Water content, %	5.4	8.3
Water absorption, %	185.0	153.0
Alkalinity, deg.	0.5	–
105 days of storage		
Water content, %	5.3	8.2
Water absorption, %	182.0	151.0
Alkalinity, deg.	0.5	–

The analysis of the data showed that fragility of the cookies increased during the storage time and such characteristics as water content and water absorption decreased.

One of the characteristics of good quality is microbiological safety [5]. Therefore, after removal of the experimental samples from storage, characteristics of microbiological safety were determined. The characteristics of microbiological safety of all experimental samples corresponded to the norm and met the requirements of TR CU 021/2011. Therefore, it allows the authors to recommend the studied terms of storage in technical regulations and technological instructions. Taking into account the requirements of CODEX STAN 118-19-79 and TR CU 027/2012, the authors evaluated the content of gluten in all cookie samples. It was less than 2 mg/kg. Normative documents for industrial production of new types of gluten-free cookies "Bright Sun" and "Holiday" were developed. It is evident from data analysis that after long-time term of storage, fragility of the product increased and such characteristics as moisture content and wettability decreased.

The relative biological value of gluten-free flour confectionery products was determined using the test organism infusoria Tetrahymena pyriformis. Table 5 shows the results obtained in the experiment.

Table 5. The reproduction degree of infusoria Tetrahymena pyriformis and relative biological value of the developed gluten-free cookies

Product	Number of cells per 1 ml	Relative biological value, %
Cookie "Little Corn" (control)	$61 \cdot 10^4$	70.9
Cookie "Bright Sun"	$78 \cdot 10^4$	90.7
Cookie "Biyskoe" (control)	$57 \cdot 10^4$	66.3
Cookie "Holiday"	$74 \cdot 10^4$	86.0
Casein (standard protein)	$86 \cdot 10^4$	100.0

As one can see from the Table 5 data, the developed gluten-free cookies have higher biological value than the cookies produced from wheat flour according to the basic recipes. The reason is that human body absorbs rice proteins better. Moreover, these proteins partially compensates the deficiency of essential amino acids.

In order to increase the competitive ability of gluten-free cookies as a product of functional purpose, the authors studied the chemical composition of the cookies and determined the percentage of daily norm of consumption for functional ingredients (Table 6).

Table 6. The chemical composition and nutritional value of the developed gluten-free cookies

Food ingredients	APN*	Content in 100 g of the product			
		"Bright Sun"		"Holiday"	
		content	percentage of APN	content	percentage of APN
Proteins, g	75.0	5.63	7.82	12.94	17.98
Fats, g	83.0	33.44	41.28	14.53	17.94
Carbohydrates, g	365.0	44.91	12.54	90.47	25.27
Dietary fiber, g	30.0	2.09	10.45	3.45	17.25
Minerals, mg, incl.:	3500.0	453.90	18.15	344.84	9.86
potassium	2400.0	160.78	12.37	74.29	5.70
sodium	1000.0	31.33	3.13	32.68	3.27
calcium	14.0	6.22	62.20	2.99	29.90
iron	400.0	219.02	54.70	66.66	16.70
magnesium	1000.0	548.03	68.50	210.96	26.40
phosphorus					
Vitamins, mg, incl.:					
B_1 (thiamine)	1.5	0.86	57.33	0.72	48.00
B_2 (riboflavin)	1.8	1.03	57.20	0.39	21.70
PP (niacin)	20.0	7.56	37.80	6.22	31.10
B_6	2.0	1.18	59.00	0.58	29.00
E	10.0	7.50	75.00	4.24	28.30
Energy value, kcal	2500.0	503.13	20.13	544.43	21.77

Note: *Approximate physiological need (according to methodical recommendations MR 2.3.1.2432-08)

The use of corn flour and rice bran as dough ingredients of flour confectionary allowed the authors to enrich the products with vitamins of group B, E, PP and with mineral substances, such as potassium, magnesium, iron, phosphorus.

CONCLUSION:

The complex of carried out theoretical and experimental studies allowed the authors to develop recipes and technologies for production of gluten-free cookies on the basis of composite mixture of corn flour and rice bran. These ingredients were used in the ra-

tio (60:40) for the recipe of “Bright Sun” cookie and in the ratio (40: 60) for the recipe of “Holiday” cookie, providing high organoleptic and physicochemical characteristics of quality of the finished products.

Introduction of the developed technologies and recipes of gluten-free cookies into production will help to satisfy the need for affordable flour confectionery for specialized nutrition of people with celiac disease. It will also expand assortment of functional nutrition by new flour confectionery products with increased nutritional value.

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