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Research Article

Development of Enriched Gluten-Free Cookies with A Balanced Amino Acid and Fatty Acid Composition

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Abstract

Every year the number of people suffering from celiac disease or other pathologies grouped under the term "gluten-related disorders" increases. The only therapy for diseases associated with gluten intolerance is strict adherence to a diet with restriction of the use of cereals: wheat, rye, barley, some varieties of oats and their derivatives. The aim of the work is to develop gluten–free cookies enriched with dietary fiber and omega-3 fatty acids while achieving a balanced amino acid and fatty acid composition of cookies.

Objects of research: various types of flour (premium wheat, amaranth, buckwheat rice, corn, lupine and chia seeds); butter and milk fat substitute; control and experimental samples of cookies. Generally accepted and special methods of analysis of raw materials and finished products were used in the work. The content of dietary fiber was determined by the enzymatic-gravimetric method.

It has been established that lupine flour and chia seed flour can be used to produce gluten-free cookies enriched with dietary fiber and essential omega-3 fatty acids. The introduction of these types of flour in addition to rice and corn flour also contributed to the achievement of a more balanced amino acid composition of the protein fraction of cookies (amino acid score 92%, biological value -76%). The use of a milk fat substitute with omega-3 fatty acids made it possible to increase the content of omega-3 fatty acids in the product and bring the fat fraction of cookies closer to physiologically complete fat by the ratio of the main groups of fatty acids (1,2:1:0.8), and by the ratio of polyunsaturated fatty acids of the omega-6 and omega-3 classes (3:1).

As a result of the conducted research, enriched gluten–free cookies with acceptable consumer characteristics have been developed, which, in accordance with the current Russian legislation, is a source of dietary fiber (3.2 g/100g) with a high content of omega-3 fatty acids (0.75 g/100g), with a balanced composition of protein and fat fractions.

Keywords: Enriched Gluten-Free Cookies; Lupine Flour; Chia Seed Flour; Dietary Fiber; Omega-3 Fatty Acids; Amino Acid Score; Physiologically Complete Fat

Introduction

About 1% of the world's population suffers from celiac disease [1-3], and its number continues to grow, primarily in Europe, Australia and North America [3,4]. Celiac disease or celiac enteropathy is a chronic disease characterized by atrophy of the mucous membrane of the small intestine as a result of intolerance to gliadin, a component of the gluten protein of wheat, rye, barley and oats and their crosfemoral variants [5]. Celiac disease is not the only disease associated with increased sensitivity to gluten. In fact, gluten also causes other pathologies grouped under the term "gluten-related disorders": gluten sensitivity without celiac disease; dermatitis herpetiformis; gluten ataxia; allergy to wheat and others [1]. To date, the only therapy for diseases associated with gluten intolerance is strict adherence to a diet with a restriction of the use of cereals: wheat, rye, barley, some varieties of oats and their derivatives. The diet consists of foods such as: cereals and gluten-free

pseudocereals; fruits and vegetables; legumes; lean meats; dairy products; butter and vegetable oils [5]. Carbohydrates in the diet are mainly represented by starch, mono- and disaccharides. Often, the diet of celiac patients is unbalanced due to its high content of saturated fatty acids, easily digestible carbohydrates with a lack of dietary fiber, omega-3 fatty acids, iron, zinc, magnesium, calcium, vitamin B_{12}, and folic acid [2,5-8].

The analysis of the gluten-free flour confectionery market showed an almost complete absence of products enriched with functional ingredients in this segment. In the diet of all groups of the population of the Russian Federation, there is a deficit in the consumption of omega-3 polyunsaturated fatty acids and dietary fibers [5,9-12]. The relevance of introducing these functional food nutrients into food products is reflected by their allocation to a separate category of fortified products in the Technical Regulations of the Customs Union TR CU 022/2011 [1].

The aim of this study was to develop gluten-free cookie enriched with dietary fibre and omega-3 fatty acids while achieving a balanced amino acid and fatty acid composition of cookie . Gluten-free flour and fat raw materials were considered as a source of these functional food ingredients. The main stages of research are presented in figure 1.

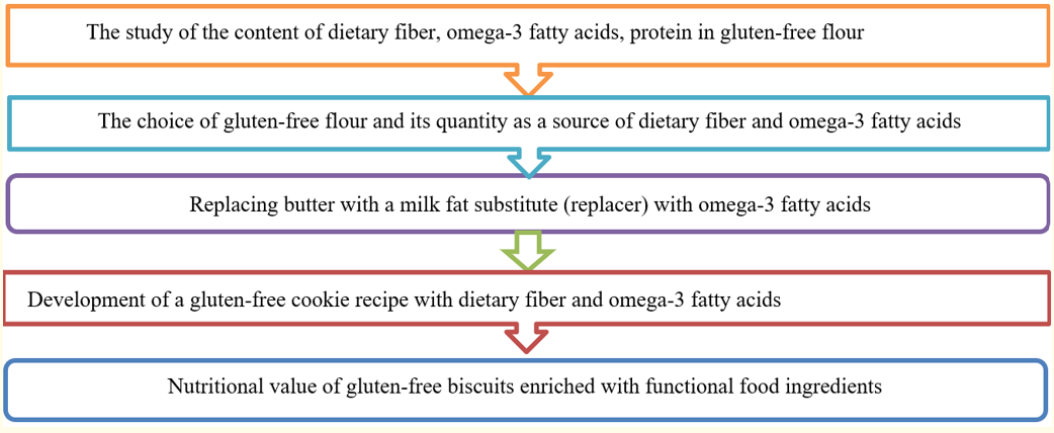

Figure 1: The main stages of development gluten-free cookie formulation with functional food ingredients.

Objects and Methods

The objects of research were: wheat baking flour of the highest grade according to GOST 26574-2017[1]; corn flour (KHLEBZERNOPRODUCT LLC, RUSSIA); rice flour (KHLEBZERNOPRODUCT LLC, RUSSIA); buckwheat flour (GARNETS LLC, RF); amaranth flour (Obraz Zhizni LLC, Russia); lupine flour Lupisan ("Soja Austria", Austria); black chia flour (LLC "POLEZNO", RUSSIA); butter (82.5%) according to GOST 32261-2013[2]; milk fat substitute (milk fat replacer) according to GOST 31648-2022[3] (grade 1), as well as experimental and control (according to the basic recipe) samples of cookie.

[1]GOST 26574-2017 "Wheat baking flour. Specifications"
[2]GOST 32261-2014 "Butter. Specifications"
[3]GOST 31648-2022 "Milk fat substitute. Specifications"

The mass fraction of protein in flour was determined according to GOST 10846-91[4], in cookies – according to GOST 26889-86[5]; mass fraction of fat in butter – according to GOST 5867-90[6], in milk fat replacer – according to GOST 32189-2013[7], in flour and cookies – according to GOST 31902-2012[8]; fatty acid composition of flour – by gas chromatography according to GOST 30418-96[9], cookies, butter and milk fat replacer – according to GOST 31663-2012[10]. The content of total, soluble and insoluble dietary fibers was determined by the enzymatic-gravimetric method in accordance with MI 01.00282-2008/0174.01.07.13 (FR 1.31.2020.37150)[11] Cookies were analyzed for moisture content according to GOST 5900-2014[12], alkalinity according to GOST 5898-87[13], wettability according to GOST 10114-80[14]. Amino acid composition of proteins and cookies was carried out according to R 4.1.1672 – 03[15]. Organoleptic assessment of cookie samples was carried out according to GOST 24901-2014[16]. The caloric content of cookies was calculated on the basis of the formulation.

As a basic formulation (control) from the "Recipe Book" developed by VNIIKP, the recipe No190 "Amber cookies" was chosen[17] - cookies based on high-grade wheat flour with the addition of gluten-free corn flour in a ratio of 70:30 (% of the total flour weight). In the subsequent stages of the development of the gluten-free cookies formulation, wheat flour was replaced with other types of gluten-free flour. The algorithm for changing the basic formulation (option 1 - control) of cookies is presented in table 1.

№ var.	Formulation Components								
	butter	milk fat replacer	sugar	wheat flour	corn flour	rice flour	lupine flour	chia seed flour	salt, baking soda, cinnamon, vanilla
1	+	–	+	+	+	–	–	–	+
2	+	–	+	–	+	+	–	–	+
3	+	–	–	–	+	+	+	–	+
4	+	–	–	–	+	+	+	+	+
5	–	+	–	–	+	+	+	+	+

Table 1: The main formulation components of cookies by variants.

[4]GOST 10846-91 "Grain and Products of Its Processing. Protein Determination Method"

[5]GOST 26889-86 Food and Flavor Products. General instructions for the determination of nitrogen content by the Kjeldahl method"

[6]GOST 5867-90 "Milk and dairy products. Methods for determining fat"

[7]GOST 32189-2013 "Margarines, fats for cooking, confectionery, bakery and dairy industries. Rules of acceptance and methods of control"

[8]GOST 31902-2012 "Confectionery products. Methods for determining the mass fraction of fat"

[9]GOST 30418-96 "Vegetable oils. Method for determining the fatty acid composition"

[10]GOST 31663-2012 "Vegetable oils and animal fats. Determination of the mass fraction of methyl esters of fatty acids by gas chromatography"

[11]MI 01.00282-2008/0174.01.07.13 (FR 1.31.2020.37150). Determination of soluble and insoluble dietary fiber content in food products and dietary supplements. Developed by the Federal Research Institute of Nutrition of the Russian Academy of Medical Sciences, certified, approved and registered in the Federal Register of Measurement Techniques in 2013 by the Federal Center for Hygiene and Epidemiology of Rospotrebnadzor https://bazanpa.ru/rospotrebnadzor-metodicheskie-rekomendatsii-ot26092019-h4848019/

[12]GOST 5900-2014 "Confectionery products. Methods for Determining Moisture and Dry Substances"

[13]GOST 5898-87 "Confectionery products. Methods for Determining Acidity and Alkalinity"

[14]GOST 10114-80 "Flour confectionery products.

[15]R 4.1.1672 – 03. Rukovodstvo po metodam kontrolya kachestva i bezopasnosti biologicheskikh aktivnykh addadditel'nykh k pische: [utverzhdeny glavnom gosudarstvennym sanitaritarym vrach RF G.G. Onishchenko 30 iyunya 2003 g.] – M.: Federal'nyy tsentr Gossanepidnadzor Minzdrava Rossii, 2003. – 183 p. https://docs.cntd.ru/document/1200034795;

[16]GOST 24901-2014 "Cookies. General specifications"

[17]Summary recipe No190 of Yantarnoye biscuits https://kondidoc.com/recipes/2399/summary (14.03.2023)

In the experimental part, the arithmetic mean values of the data obtained were given. The experimental data were statistically evaluated for homogeneity in order to exclude the results aggravated by gross errors. Differences in the mean values of the samples using the Student's t-test were recognized as statistically significant with a confidence probability of $p \leq 0.05$.

Results and Discussion

Based on the data on the presence of deficiencies in the consumption of various nutrients in the diet of Russians, omega-3 fatty acids and dietary fiber were chosen as functional food ingredients for fortifying gluten-free cookies [5,9-12]. The prospects of using whole-grain and pseudograin raw materials, as well as legumes as a source of dietary fiber, protein, and omega-3 fatty acids in the development of flour confectionery and bakery products with increased nutritional value have been proven [13-17]. Taking into account this trend and consumer preferences for food products with a minimum set of ingredients, the so-called "clean label", it was decided to use the main raw materials (flour, fat product) as a source of natural functional food ingredients.

At the first stage of research in model cookie samples, wheat flour was replaced by rice flour, which is the main component of gluten-free product formulations [17-24].

A study of the chemical composition of rice and corn flour compared to wheat flour showed that these types of flour contain almost two times less protein, less dietary fiber and, and like wheat flour, almost not contain deficient omega-3 fatty acids (Table 2). A study of the amino acid composition of rice and corn flour proteins showed that they, like wheat flour proteins, have a low amino acid score (AAS) and are limited in lysine (Table 3). At the same time, compared to corn flour, rice flour is less balanced and has a 1,5 times lower AAS. These results are correspondence with the data of other researchers [13,17,22,25]. In the formulations of gluten-free flour confectionery products, rice and corn flour are mainly a source of starch, which acts as a structure-forming agent in the absence of the traditional structure-forming component of wheat flour - gluten.

Parameter	The content of certain nutrients, g/100 g flour						
	Wheat	Rice	Corn	Amaranth	Buckwheat	Lupine	Chia seed
Pronein	12,0 ± 0,6	6,0 ± 0,3	7,0 ± 0,4	12,8 ± 0,6	8,2 ± 0,4	43,7 ± 2,2	29,0 ± 1,5
Dietary fiber	3,5 ± 0,3	2,4 ± 0,2	2,5 ± 0,2	1,5 ± 0,1	2,0 ± 0,2	15,3 ± 0,1	32,7 ± 0,3
lipids	1,1 ± 0,1	1,0 ± 0,1	1,5 ± 0,2	4,3 ± 0,5	3,7 ± 0,4	9,7 ± 1,2	33,7 ± 4,0
ω-3 fatty asids	traces	traces	traces	traces	traces	1,4 ± 0,28	19,9 ± 3,98

Table 2: The content of protein, dietary fiber, lipids and omega-3 fatty acids in various types of flour.

Based on the analysis of the results obtained (Tables 3), we considered the additional use of other gluten-free flours for the development of gluten-free cookies with functional food ingredients. Taking into account the lower biological value of rice flour proteins compared to corn flour, it was decided to introduce additional types of flour instead of part of rice flour.

Essential amino acids	Rice flour		Corn flour		Protein standard	
	mg/g protein	AAS, %	mg/g protein	AAS, %	mg/g protein	AAS, %
Leucine	63	90	118	169	70	100
Phenylalanine+Tyrosine	66	110	71	118	60	100
Lysine	22	40	34	62	55	100
Valine	46	92	54	108	50	100
Tryptophan	8	80	12	124	10	100
Isoleucine	32	80	35	88	40	100
Methionine+cysteine	37	106	38	109	35	100
Threonine	35	88	37	93	40	100
Total	309	-	399	-	360	-

Table 3: Amino acid composition and amino acid score (AAS) of rice and corn flour proteins.

The criteria for choosing gluten-free flour were the content of dietary fiber, omega-3 fatty acids, protein and its amino acid composition. Amaranth and buckwheat flour, which are often used in the production of gluten-free food products, were considered [26-34]. Lupine flour is considered as a promising source of protein, which is also used in the production of gluten-free food products [35-37]. For the study, Lupisan flour was chosen, produced from the grains of narrow-leaved lupine (*Lupinus angustifolius* L.), approved for the production of food products, characterized by the absence of bitterness and the presence of a nutty flavor.

Another type of flour that is becoming increasingly popular in the preparation of food products is chia seed flour [15,16,36,39]. The high content of essential omega-3 fatty acids in chia seeds due to the deficiency of these polyunsaturated fatty acids in the diet of the population of the European Union was reflected in the EU Commission Decision 2009/827/EC of October 13, 2009 on the recommendation to fortify bakery products with flour or chia seeds up to 5% [40]. Chia seed flour is gluten-free and has also been considered by us as a raw material for the production of fortified gluten-free cookies.

The analysis of the content of protein, dietary fibers, lipids and omega-3 fatty acids in the listed types of flour was presented in Table 2. The amino acid composition and AAS of proteins of buckwheat, amaranth, lupine flour and chia seed flour used in the work are shown in table 4.

Essential amino acids	Buckwheat flour		Amaranth flour		Lupine flour		Chia seed flour	
	mg/g protein	AAS %	mg/g protein	AAS %	mg/g protein	AAS %	mg/g protein	AAS %
Leucine	69	99	23	33	68	97	83	119
Phenylalanine+Tyrosine	42	70	33	55	72	121	96	160
Lysine	46	84	37	67	53	96	59	107
Valine	62	124	22	44	40	81	58	116
Tryptophan	14	140	11	110	8	80	1,6	160
Isoleucine	42	105	17	43	45	114	49	123
Methionine+cysteine	43	122	15	43	26	73	55	157
Threonine	38	95	19	48	34	86	43	108
Total	356	-	177	-	346	-	459	-

Table 4: Comparative characteristics of amino acid composition and amino acid score (AAS) of buckwheat, amaranth, lupine flour and chia seed flour proteins.

The presented data indicate that all the studied types of flour contain more protein compared to rice and corn flour. The protein content in amaranth flour is 2 times higher, in chia seed flour more than 4 times, and in lupine flour - 6-7 times. Analysis of the amino acid composition of these types of flour showed that they contain significant amounts of lysine and are limited in other amino acids: amaranth flour in leucine, valine, isoleucine and sulfur-containing amino acids; buckwheat flour by the sum of phenylalanine and tyrosine; lupine flour in sulfur-containing amino acids. The AAS of chia seed flour exceeds 100%, which is consistent with the data cited by other researchers [34,37,38]. Therefore, all these types of flour can be used in combination with rice and corn flour to obtain flour products with a more balanced amino acid composition.

A comparison of the studied types of flour for the content of selected enriching nutrients showed the presence of significant amounts of dietary fiber in lupine flour and chia seed flour. Chia seed flour was also characterized by a very high content of omega-3 fatty acids, represented by **α**-linolenic acid. Based on a comprehensive analysis of the chemical composition, Lupisan flour and chia seed flour were selected as a source of natural functional food ingredients – dietary fiber and omega-3 fatty acids – to develop the formulation of gluten-free enriched cookies.

Additional studies on the composition of dietary fiber made it possible to establish that insoluble dietary fiber prevailed in lupine flour, as in chia seed flour, accounting for 65-75% of the total amount of dietary fiber (Table 5).

Parameter	Chia seed flour	Lupine flour
Dietary fiber (total), g/100g	32,7 ± 3,27	13,3 ± 1,33
Insoluble dietary fiber, g/100g	21,3 ± 2,13	10,1 ± 1,01
Soluble dietary fiber, g/100g	11,4 ± 1,14	3,2 ± 0,32

Table 5: The content of dietary fiber in lupine flour and chia flour.

A study of the fatty acid composition of lipids of rice, corn, lupine flour, as well as chia seed flour was carried out. It has been established that unsaturated fatty acids prevail in the lipids of all types of flour, making up more than 55-90% of the total fatty acids. At the same time, the content of polyunsaturated fatty acids (PUFAs) in the lipids of corn flour and chia seed flour exceeded 50% (Table 6). The largest amount of saturated fatty acids was contained in rice flour. Therefore, replacing part of the rice flour with lupine flour and chia seed flour should also contribute to obtaining a more balanced composition of the fatty fraction of cookies.

Main groups of fatty acids, % from total fatty acids	Rice flour	Corn flour	Lupine flour	Chia seed flour
Saturated fatty acids	46,2 ± 4,6	14,4 ± 1,4	17,6 ± 1,8	9,0 ± 0,9
Monounsaturated fatty acids	29,1 ± 2,9	27,5 ± 2,8	42,6 ± 4,3	6,1 ± 0,6
Poliunsaturated fatty acids	24,6 ± 2,5	58,1 ± 5,8	39,7 ± 4,0	85,0 ± 8,5

Table 6: The content of the main groups of fatty acids in the lipids of various types of gluten-free flour.

After selecting additional types of flour in accordance with the research scheme (Figure 1), a series of one-factor experiments was carried out with the addition of lupine flour from 5% to 20% and chia seed flour in the amount of 1% to 5% of the total weight of flour. As a result, a quantitative ratio was established between corn, rice, lupine flour and chia seed flour in the formulation of the product (48:30:20:2), leading to the maximum enrichment of cookies with dietary fiber and omega-3 fatty acids, while maintaining acceptable organoleptic characteristics. With such a ratio of different types of flour, cookies were enriched with dietary fibers at the level of the "source" (at least 3g/100g) with a high content of ω-3 fatty acids (at least 0.4g/100g). Comparison of the organoleptic characteristics of the experimental and control cookies showed differences only in the color of the product (Table 7).

Parameter	Control	Enriched gluten-free cookies using the developed formulation
Taste and odors	Pronounced, characteristic of the taste and odor of the components included in the cookie formulation, without extraneous taste and odor.	Pronounced, characteristic of the taste and odor of the components included in the cookie formulation, without extraneous taste and odor. The presence of a nutty aftertaste.
Shape	Slightly vague, without dents, swellings or damage to the edge.	It is not vague, without dents, swellings or damage to the edge.
Surface	Rough, interspersed with particles of the components used. Not burnt, no bloating. The bottom surface is smooth.	Rough, interspersed with particles of the components used. Not burnt, no bloating. The bottom surface is smooth.
Color	Uniform, light straw color with darker coloring of cookie edges and underside.	Uniform, bright yellow with darker coloring of cookie edges and underside.
View in the kink	Baked cookies with a porous structure, without voids and traces of non-kneading.	Baked cookies with a porous structure, without voids and traces of non-kneading.

Table 7: Organoleptic parameters of experimental and control cookie samples.

Figure 2: Appearance of cookies: a - control sample on wheat flour; b – experimental sample on gluten-free flour.

The presence of additional lupine flour in the cookie formulation in addition to corn flour gave it a more pronounced yellow color (Figure 2). Also, the surface of the cookie prototype was characterized by the presence of deeper cracks than the surface of the control sample, due to the absence of gluten in the food system.

The absence of gluten, which plays an important role in the formation of the structure of flour confectionery, often leads to the spread of the dough and the loss of volume of the final product, in our case, cookies. In the production of cookies based on rice and corn flour, the diameter of the product increased from 55 to 68 mm compared to the control with a decrease in height from 17.5 to 13 mm (Table 8). The addition of flour with a high content of dietary fiber contributed to the additional structuring of the food system and led to a decrease in diameter and an increase in the height of the finished product. As a result, the cookies made at the selected ratio of different types of gluten-free flour had dimensions comparable to the control sample.

Parameter	Control	Experimental cookie samples with lupine flour and chia flour							
		Lupine flour, % from total flour					Chia flour, % from total flour		
		0	5	10	15	20	1	2	3
Fiber content, g/100g	1,6 ± 0,2	1,3 ± 0,1	1,7 ± 0,2	2,1 ± 0,2	2,5 ± 0,3	2,9 ± 0,3	3,1 ± 0,3	3,2 ± 0,3	3,4 ± 0,3
Diameter,mm	55,2 ± 3,4	68,2 ± 3,5	60,0 ± 3,0	58,5 ± 3,0	58,1 ± 2,9	57,5 ± 2,9	56,4 ± 2,8	55,7 ± 2,8	54,5 ± 2,7
Height, mm	17,5 ± 0,9	13,0 ± 0,7	17,0 ± 0,9	17,4 ± 0,9	17,9 ± 0,9	18,4 ± 0,9	16,6 ± 0,8	17,0 ± 0,9	17,3 ± 0,9

Table 8: Fiber content, diameter and height of control and experimental cookie samples.

To increase the content of essential omega-3 fatty acids in cookies, the next step was to replace butter in the formulation with a milk fat substitute containing omega-3 fatty acids. The content of the main groups of fatty acids in butter and milk fat substitute is given in table 9.

As a result of the studies, it was found that the use of milk fat replacer instead the butter did not lead to a deterioration in the quality of experimental samples of gluten-free cookies (Table 10). This is due to the fact that the melting curve of the selected milk fat replacer was close to milk fat. In both cases, all indicators met the requirements of GOST 24901-2014.

The fatty acid composition of the fat fraction of experimental cookies prepared on milk fat replacer was investigated. The content of the main groups of fatty acids is shown in figure 3.

Main groups of fatty acids, % from total fatty acids	Butter	milk fat substitute (replacer)
Saturated fatty acids	69,2 ± 6,9	45,8 ± 4,6
Monounsaturated fatty acids	27,1 ± 2,7	30,2 ± 3,0
Poliunsaturated fatty acids	3,6 ± 0,4	20,7 ± 2,1
ω-3 fatty asids, g/100 g product	Traces	2,4 ± 0,2
trans fatty asids, g/100 g product	5,6 ± 0,6	0,9 ± 0,1

Table 9: The content of the main groups of fatty acids in various fat-and-oil products.

Parameter	Cookies	
	With butter	With milk fat replacer
Mass fraction of moisture, %	6,7 ± 0,1	6,5 ± 0,1
Wettability, %	161,6 ± 1,6	165,0 ± 1,7
Alkalinity, you.	0,36 ± 0,1	0,35 ± 0,1

Table 10: Quality indicators of experimental samples of cookies made with butter and milk fat substitute.

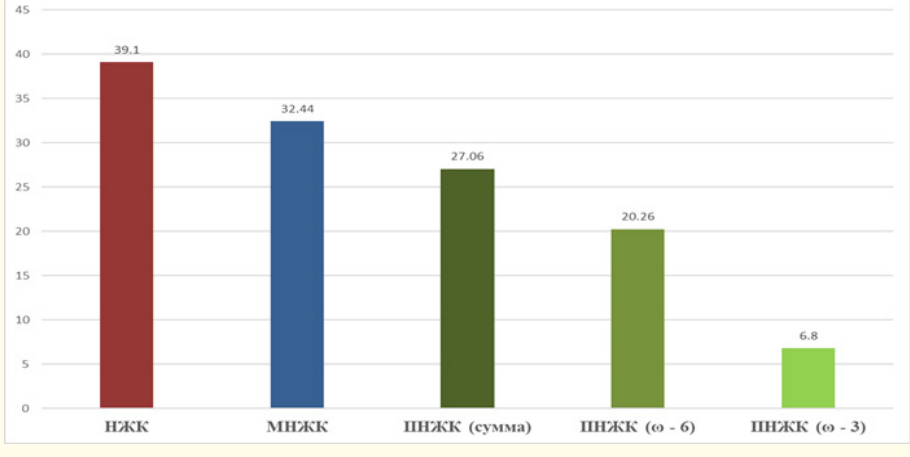

Figure 3: The main groups of fatty acids in the fat fraction of experimental cookie samples on a milk fat substitute.
Designations: НЖК: Saturated fatty acids; МНЖК: Monounsaturated fatty acids; ПНЖК (сумма): Poliunsaturated fatty acids (total)

The balance of the fatty acid composition of the fatty fraction of cookies was assessed by comparing it with physiologically complete fat, in which the ratio between saturated, monounsaturated and polyunsaturated fatty acids is 1:1:1 [5]. As can be seen from the presented data, the ratio between saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids in the fat fraction of the developed cookies is 1.2:1:0.8, that is, it is close to physiologically complete fat. At the same time, the ratio between different classes of polyunsaturated fatty acids ω-6 and ω-3 is 3:1, which is recommended for therapeutic foods [5].

The balance of the amino acid composition of the protein fraction of the developed cookies was evaluated by comparing it with the standard (chicken egg white). Table 11 presents data on the amino acid score and biological value of the protein fraction of the control and developed cookie samples.

Essential amino acids	Control		Enriched gluten-free cookies using the developed formulation	
	mg/g protein	AAS, %	mg/g protein	AAS, %
Leucine	10,0	143	8,7	124
Phenylalanine+Tyrosine	8,4	140	8,4	140
Lysine	3,0	55	5,1	92
Valine	5,6	111	5,2	104
Tryptophan	1,4	135	1,1	115
Isoleucine	4,7	118	4,8	120
Methionine+cysteine	4,7	135	4,7	133
Threonine	3,7	92	4,1	103
Total	41,5	-	42,1	-
Biological value of protein, %	39		76	

Table 11: Amino acid score (AAS) and biological value of proteins of control and experimental cookie samples.

It was established that the developed gluten-free cookies, due to the selection of different types of flour, had, in comparison with the control, a more balanced amino acid composition of the protein fraction. Although protein remained limited in lysine, its amino acid score increased from 55 to 92%. As a result, the biological value of cookie proteins has increased almost 2 times.

The final stage in the development of a food product is the calculation of its nutritional value. Table 12 provides comparative data on the nutritional value of a control cookie samples, a cookie prototype with rice and corn flour and a developed gluten-free cookies enriched with natural functional ingredients.

As can be seen from the data presented, the complete replacement of wheat flour with rice flour in the recipe of the product led to a decrease in its protein content. The introduction of additional types of flour instead of part of rice flour, lupine flour and chia seed flour led to an increase in protein content not only relative to the experimental sample on rice and corn flour, but also in comparison with the control.

Parameter	Control	Prototype (based on rice and corn flour)	Enriched gluten-free cookies using the developed formulation
Mass fraction, g/100g:			
proteins	4,7 ± 0,2	2,9 ± 0,1	6,6 ± 0,3
fats	15,0 ± 1,8	15,0 ± 1,8	17,0 ± 2,0
ω-3 fatty acid (α –inolenic acid)	0,08 ± 0,02	0,09 ± 0,02	0,75 ± 0,15
dietary fiber	1,6 ± 0,2	1,3 ± 0,1	3,2 ± 0,3
Energy value, kcal/kJ	470/1950	470/1960	460/1930

Table 12: Nutritional value of control and experimental cookie samples.

Experimental data prove that cookies with a developed formulation ratio of 4 types of flour, in accordance with the current legislation, are a source of dietary fiber (at least 3.0g/100g) and are characterized by a high content of essential ω-3 fatty acids (at least 0.4g/100g). In accordance with GOST R 52349-200519 (ed. 03.01.2011), the developed cookies are a functional food product (exclusion of gluten and enrichment with functional food ingredients), which has an additionally balanced fatty acid and amino acid composition.

Conclusions

As a result of a study of the chemical composition of different types of gluten-free flour, lupine flour and chia seed flour were selected to produce gluten-free cookies enriched with dietary fiber and essential omega-3 fatty acids. The addition of these types of flour in addition to rice and corn flour also contributed to the achievement of a more balanced amino acid composition of the protein fraction of cookies due to the compensation of the limiting amino acid lysine in the proteins of rice and corn flour.

It has been proven that the high content of dietary fiber in gluten-free flour compensates absence of gluten (the structurizer in flour confectionery products) due to additional structuring of the food system, which ultimately led to a decrease in diameter and an increase in height of the finished product to the level typical for products based on wheat flour.

The use of milk fat replacer containing omega-3 fatty acids instead of butter in the formulation of the developed gluten-free cookies made it possible not only to increase the content of omega-3 fatty acids in the final product, but also to bring the fatty fraction of cookies closer to physiologically complete fat in terms of the ratio of the main groups of fatty acids, as well as in the ratio of polyunsaturated fatty acids of the omega-6 and omega-3 classes.

Thus, as a result of the research, enriched gluten-free cookies with acceptable consumer characteristics have been developed, characterized in accordance with the current legislation as a product - a source of dietary fiber with a high content of omega-3 fatty acids, with a balanced composition of protein and fat fractions.

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