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Research Article

Fortification of Bakery Products with Omega-3 Fatty Acids

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Abstract

A deficiency in the consumption of polyunsaturated fatty acids omega-3 (PUFA ω-3) in the diet of the population of many countries of the world, including the Russian Federation, has been established. PUFA ω-3 are important structural components of cell membranes, but they are not synthesized in the human body. Adequate intake of PUFA ω-3 helps prevent cardiovascular and many other diseases. The main route of PUFA ω-3 intake is food products. One of the sources of PUFA ω-3 (α-Linolenic acid) are chia seeds (Salvia hispanica). To eliminate the deficiency in PUFA ω-3, EU Commission Decision 2009/827/EC of 13 October 2009 recommended enriching bakery products with chia flour or seeds up to 5%.

The aim of the work was to study the effect of chia flour containing 33% lipids with 61.6% omega-3 fatty acids from the total fatty acids, as well as 25% dietary fiber, on the physicochemical, organoleptic quality indicators and nutritional value of various types of bakery products.

It has been established that the addition of chia flour in the amount of 1-5% of the mass of wheat flour contributes to increase the nutritional value of bakery products due to their enrichment with deficient PUFA ω-3, as well as dietary fiber. In addition, the organoleptic properties of bread during its shelf life are improved. Adding a milk fat replacer with PUFA ω-3 helps to further increase the content of PUFA ω-3 in the bakery product, and also increase its porosity and specific volume. It has been proven that the use of chia flour in the production of such specialized bakery products as achloride bread and gluten-free bread contributes to enhance the preventive effect of these types of bread by additionally supplying the body with deficient nutrients. To preserve omega-3 fatty acids in long-life breads with high levels of these nutrients, good results can be achieved using modified atmosphere.

Keywords: Chia Flour; Omega-3 Fatty Acids; Dietary Fiber; Milk Fat Replacer; Wheat Bread; Bakery Product; Achloride Bread; Gluten-Free Bread; Modified Atmosphere; Shelf Life

Introduction

Every year, the percentage of people with excess body weight and obesity increases worldwide, which in turn increases the risk of developing cardiovascular diseases and diabetes mellitus of the II type [1]. The prevalence of excess body weight and obesity in children and adolescents in Russia is higher than in European countries, and is approaching the prevalence of these forms of nutritional status disorders in Arab countries [2], which further contributes to the growth of obesity among the adult population. The growth of these diseases is associated with an imbalance of nutrients in the daily human diet, and, in particular, with the predominance of saturated fats, trans fatty acids, salt and sugar in the diet [1].

At the same time, in the diet of the population of many countries, with the exception of countries adhering to the Mediterranean diet, there is a deficit in the consumption of polyunsaturated fatty acids of the omega-3 family (PUFA **ω-3**). PUFA ω-3 are important structural components of cell membranes, participating in the formation of the phospholipid bilayer, they affect the fluidity, flexibility and permeability of membranes, ensuring the activity of membrane-bound enzymes. At the same time, alpha-linolenic acid is not synthesized by the human body, and eicosapentaenoic and docosahexaenoic acids are synthesized from alpha-linolenic acid in small quantities. Therefore, the main route of PUFA ω-3 intake into the human body is food products.

Adequate intake of PUFA ω-3 helps prevent cardiovascular diseases, reduces the risk of stroke [3-5], and has a normalizing effect on lipid and carbohydrate metabolism in patients with diabetes mellitus of the II types [6]. The important role of PUFA ω-3 in the formation and functioning of the central nervous system, visual organ, and immune system in children has been proven [7]. In older people, a diet enriched with PUFA ω-3 helps maintain cognitive and mental functions; in combination with vitamin D, PUFA ω-3 are the necessary component for the treatment of sarcopenia [8]. A positive effect of PUFA ω-3 on the biochemical parameters of the body of northerners during seasonal changes has been noted [9].

The World Health Organization provides recommendations for total PUFA intake, as well as for PUFA ω-3 and PUFA ω-6 separately (Table 1).

Fatty acid	% of total energy
Σ PUFA	6-11
Σ ω-3 fatty acids	2,0-3,0
α-Linolenic acid	> 0,5
Σ ω-6 fatty acids	2,5-9,0
Linoleic acid	2,5

Table 1: Recommended dietary intakes for polyunsaturated fatty acids: Adults [10].

In the Russian Federation, the following recommendations are given for the consumption of various fatty acids. The consumption of saturated fatty acids (SFA) for adults and children should not exceed 10% of the daily caloric intake; monounsaturated fatty acids (MUFA) - 10% of the daily caloric intake; PUFA - 6-10% of the daily caloric intake. The physiological requirement for adults is 5-8% of the daily caloric intake for PUFA ω-6 and 1-2% for PUFA ω-3. The optimal ratio in the daily diet of PUFA ω-6: PUFA ω-3 should be 5-10 [11]. In therapeutic diets, it should be 1-5. However, a number of scientists believe that the ratio of PUFA ω-6: PUFA ω-3 should be closer to 1 for all groups of people [12,13].

One of the sources of PUFA ω-3 (α-Linolenic acid) are the seeds of the chia plant (Salvia hispanica), an ancient crop grown by the Mayans, Incas and Aztecs. The oil content in chia seeds is 32-39%, PUFA ω-3 accounts for up to 64% from the total fatty acids. The high content of tocopherols (150-480 **μg**/kg) in chia seeds prevents oxidation of PUFA ω-3. Chia seeds are also characterized by a high content of dietary fiber (18-30%) [14]. Considering the unique properties of chia seeds and the fact that bakery products form the basis of the human food pyramid, EU Commission Decision 2009/827/EC of 13 October 2009 recommended fortifying bakery products with chia flour or seeds up to 5% to eliminate the deficiency in PUFA ω-3 [15].

The aim of the work was to study the effect of chia flour containing 33% lipids with 61.6% PUFA ω-3 from the total fatty acids, as well as 25% dietary fiber, on the physicochemical, organoleptic quality indicators and nutritional value of various types of bakery products.

Objects and Methods

The mass of control and experimental samples of bakery products in each experiment was 300g. The quality of bakery products was assessed by their physical, chemical and organoleptic indicators. The crumb moisture content was determined according to GOST 21094 “Bakery products. Method of moisture determination”. The titratable acidity of the crumb was analyzed using the accelerated method according to GOST 5670 “Bred, rolls and buns. Method for determination acidity". The porosity of the crumb was measured using the Zhuravlev tester according to GOST 5669 "Bakery products. Method for determination porosity." Bread quality indicators were analyzed 16-18 hours after baking. The swelling of the crumb in water and its crumbliness after mechanical sifting (15 min at 190 rpm) on a sieve were assessed using the methods given in [16].

The protein content was determined according to GOST 26889 "Food and food additives. General directions for determination of nitrogen by the Kjeldahl method" by breaking down organic matter by heating with sulfuric acid in the presence of a catalyst, adding excess sodium hydroxide, distilling and titrating the released ammonia. The amount of nitrogen was calculated from the amount of released ammonia.

The mass fraction of fat was determined according to GOST 5668 "Bakery products. Methods for determination of fat content". The method is based on extracting fat from a pre-hydrolyzed sample of the product with a solvent and determining the amount of fat by weighing after removing the solvent from a certain volume of the resulting solution. The qualitative and quantitative fatty acid composition of the extracted fat was determined according to GOST 31663 "Vegetable oils and animal fats. Determination of methyl esters of fatty acids by gas chromatography method" based on the analysis of methyl esters of fatty acids obtained according to GOST 31665 "Vegetable oils and animal fats. Preparation of methyl esters of fatty acids".

The content of dietary fiber was determined by the enzymatic-gravimetric method according to GOST R 54014 "Functional food. Determination of soluble and unsoluble dietary fiber by enzymatic-gravimetric method".

The organoleptic evaluation of the control and experimental samples of bakery products was carried out by a commission of bright tasters consisting of 11 people. The following descriptors were determined: product shape, bread aroma, crust color, bread taste, crumb color, crumb aroma, crumb pore structure, crumb chewiness. The descriptors were assessed on a five-point scale: a score of "5" meant excellent, a score of "4" meant good quality, a score of "3" meant satisfactory quality, a score of "2" meant moderately satisfactory quality, a score of "1" meant unsatisfactory quality. Based on the tasting results, average scores were calculated for each organoleptic indicator.

Results and Discussion

To establish the effect of chia flour on the quality characteristics of bread, a formulation of bread made from premium wheat flour was selected as a control (C). Chia flour was added in an amount of 1-5% of the weight of premium wheat flour (Table 2). Dough from wheat flour was prepared using a straight-dough method, with fermentation for 90 minutes. The results on the effect of added chia flour on the physicochemical properties of wheat bread are presented in the table 3.

Ingredients	Amount of ingredients by variants, % of the mass of wheat flour				
	C	1	2	3	4
Premium wheat flour for bread making	100,0	100,0	100,0	100,0	100,0
Pressed baker's yeast	3,0	3,0	3,0	3,0	3,0
Table salt	1,5	1,5	1,5	1,5	1,5
Chia flour	-	1	3	4	5
Drinking water	calculated based on dough humidity of 43.5%				

Table 2: Dough formulation for preparation wheat bread.

Physicochemical indicators	Values of physicochemical indicators, by variants				
	C	1	2	3	4
Crumb moisture, %	40,8	39,7	40,1	40,2	40,2
Crumb acidity, grad.	2,2	2,2	2,2	2,3	2,6
Crumb porosity, %	76	77	78	79	78
Specific volume of bread, cm^3/g	2,93	3,17	3,29	3,52	3,30

Table 3: Effect of chia flour on the physicochemical properties of wheat bread.

As can be seen from the presented data, the addition of chia flour had a positive effect on the physicochemical properties of wheat bread. The best results were obtained with the addition of 4% chia flour from the mass of wheat flour (variant 3). In this case, the specific volume of bread increased by 20%, the porosity of the crumb - by 4%, compared with the control. This sample also received maximum points during the organoleptic assessment (4,9). (shape of the product, aroma of bread, color of the crust, taste of bread, color of the crumb, aroma of the crumb, structure of the pores of the crumb, chewiness of the crumb).

The control and experimental bread samples were packed in polyethylene bags and stored at a temperature of 22 ± 2°C for 5 days. After this time, changes in crumbliness and swelling of the crumb were assessed (Table 4).

Quality indicators	**Values of bread crumb quality indicators, by variants**				
	C	**1**	**2**	**3**	**4**
16 hours					
Crumbliness, %	3,09	2,48	2,50	2,72	2,80
Swelling of the crumb, cm^3	30	31	34	36	40
5 days					
Crumbliness, %	7,31	6,28	6,33	6,53	6,80
Swelling of the crumb, cm^3	25	27	29	32	33

Table 4: Effect of chia flour on changes in the crumb properties of wheat bread during storage.

It was found that the addition of chia flour led to a decrease in the crumbliness of fresh bread crumbs compared to the control by 9-19%. The hydrophilic properties of the bread crumb (swellability) increased by 3-33% compared to the control, which is due to the high content of dietary fiber in chia flour (25g/100g), which have moisture-retaining properties.

During storage, the crumbliness of the bread increased significantly, while the hydrophilic properties of the crumb changed to a lesser extent compared to fresh bread. The addition of chia flour to the product formulation contributed to a decrease in the crumbliness of the crumb and the preservation of its hydrophilic properties. After 5 days of storage, the crumbliness of bread with chia flour (1-5%) was 7-14% lower, and the hydrophilic properties of the crumb were 8-32% higher compared to the control.

Thus, the dietary fiber contained in chia flour had a positive effect on increasing the shelf life of bread.

A study of the fatty acid composition of lipids in bread prepared without addition (Control) and with the addition of chia flour in an amount of 4 and 5% of the mass of wheat flour showed an increase in the total PUFA content by 17%, which indicates an increase in the nutritional value of bread (Table 5).

Bread samples, by variants	**SFA**	**MUFA**	**PUFA**	**ω-6: ω-3**	**ω-3, g/100 g bred**
	% of total fatty acids				
Control	20,6	15,4	64,0	21	0,02
1 (4 % chia flour)	14,58	9,81	74,78	0,88	0,50
2 (5 % chia flour)	14,32	9,66	75,19	0,84	0,57

Table 5: Fatty acid content in control and experimental wheat bread samples.

At the same time, the ratio of PUFA **ω**-6:PUFA **ω**-3 decreased from 21 (control) to 0.8-0.9. In the diet of Greenland Eskimos, the ratio of PUFA **ω**-6:PUFA **ω**-3 is close to 1 with the highest life expectancy and the lowest mortality rate from cardiovascular diseases in the world, they also have a low level of coronary heart disease, asthma, type I diabetes, sclerosis, oncology, rheumatoid arthritis [12].

Addition of chia flour in an amount of at least 4% of the wheat flour weight increased the content of essential PUFA **ω**-3 in bread to a level of more than 0.4g/100g. In accordance with the legislation of the Eurasian Economic Community (Technical Regulations of the Customs Union TR CU 022/2011 "Food Products in Part of Their Labeling") this bread can be labeled as a product with a high content of PUFA **ω**-3. It was found that after 5 days of storage, the loss of PUFA **ω**-3 was no more than 6%, which is due to the high content of tocopherols in chia flour.

Thus, the conducted studies allowed us to establish that the addition of chia flour in the amount of 1-5% of the weight of wheat flour in accordance with EU Commission Decision 2009/827/EC helps to increase the nutritional value of wheat bread due to its fortification with deficient PUFA **ω**-3, and also improves the organoleptic properties of bread during its storage.

Next, the introduction of chia flour into various bakery products was considered. Taking into account that the composition of bakery products often includes a fat product, it was decided to use a milk fat replacer containing PUFA **ω**-3 to increase the amount of PUFA **ω**-3 (GOST 31648 «Milk fat replacer. Specifications», mark 1).

The most common bakery product made from premium wheat flour in Russia is the sliced loaf, manufactured according to GOST 27844 "Rolls and buns. Specifications". Therefore, it was used as a control (C) in conducting studies on the effect of chia flour on the organoleptic and physicochemical characteristics of the bakery product. Milk fat replacer with a melting point of 32 ºC, containing 15% PUFA from the total fatty acids at a ratio of PUFA ω-6:PUFA ω-3 equal to 10 (MFR+PUFA ω-3) was used as a fat product. The formulation for the sliced loaf by variants are presented in table 6. The dough was prepared from wheat flour using a straight-dough method, with fermentation for 90 minutes.

It was found that the addition of MFR+PUFA **ω**-3 and sugar contributed to a further increase in the porosity of the product by 6%, the specific volume by 14-22% relative to wheat bread that did not contain these ingredients (Table 7 and 3). The addition of chia flour to the formulation of sliced loaf, as in the case of wheat bread, increased the specific volume of the loaf and improved its porosity. The best results were obtained with the addition of chia flour in an amount of 4% of the wheat flour weight. The specific volume of the loaf increased by 18%, the porosity of the crumb by 4%, compared to the control. This sample also received the highest results in the organoleptic analysis.

Physicochemical indicators	**Values of physicochemical indicators, by variants**				
	C	**1**	**2**	**3**	**4**
Crumb moisture, %	38,4	39,8	40,4	40,4	40,8
Crumb acidity, grad.	2,2	2,0	2,2	2,4	2,5
Crumb porosity, %	81	82	83	84	84
Specific volume of bread, cm^3/g	3,61	3,67	3,84	4,27	4,22

Table 7: Effect of chia flour on the physicochemical properties of sliced loaf.

The study of the fat phase of the product showed that in case of a loaf with MFR+PUFA ω-3 without the addition of chia flour PUFA ω-6:PUFA ω-3 ratio was 12.5, but the content of PUFA ω-3 remained low (Table 8). The addition of chia flour to the formulation of sliced loaf in an amount of 4-5% of the weight of wheat flour, as in the case of wheat bread, made it possible to obtain bakery products with a high content of PUFA ω-3 (more than 0.4g/100g).

Considering the positive effect of MFR+PUFA **ω**-3 on the physicochemical and organoleptic characteristics of sliced loaf, a conclusion was made about the advisability of their combined use in the production of bakery products enriched with PUFA **ω**-3.

Elimination of deficiency in essential PUFA ω-3 is of particular importance for people with metabolic disorders and alimentary-dependent diseases. Therefore, we considered the possibility of obtaining special-purpose bakery products by simultaneously using chia flour and MFR+PUFA ω-3 as enriching ingredients.

Cardiovascular diseases are the main cause of death worldwide, including in the Russian Federation. Excessive salt consumption contributes to the development of hypertension, stroke, and atherosclerosis. The European Society of Cardiology recommends limiting salt intake to 3 g per day for their prevention, while in

Samples of sliced loaf, by variants	SFA	MUFA	PUFA	ω-6: ω-3	ω-3,g /100 g bred
	% of total fatty acids				
Control	42,54	28,88	27,55	12,5	0,03
1 (4 % chia flour)	32,94	22,88	43,29	1,24	0,55
2 (5 % chia flour)	30,77	21,94	46,24	1,27	0,67

Table 8: Fatty acid content in control and experimental samples of sliced loaf.

Russia, salt intake should be less than 5g per day [4]. It is important to note that about 80% of salt is consumed with processed foods. Bread products are a common source of salt. Therefore, it is recommended for patients with cardiovascular diseases consume salt-free bakery products, such as achloride bread. On the other hand, adequate intake of PUFA ω-3 and dietary fiber helps to prevent these diseases [3-5,17].

Achlorid bread was prepared using the straight-dough method from first-grade wheat flour with the addition of 4.5% fat product, 2.7% dry milk whey, and 3% pressed baker's yeast by weight of flour. A mixture of sunflower oil and MFR+PUFA **ω**-3 in a 45:55 ratio was used as the fat product. Chia flour was added as a source of PUFA **ω**-3 and dietary fiber at a rate of 1-2.5% by weight of wheat flour. Experimental samples of achloride bread with different chia flour contents were tested for compliance with GOST 25832 "Dietary bakery products. Technical conditions" (Table 9).

It was found that all samples of achlorid bread met the regulatory documentation. The addition of chia flour, as in previous studies, increased the specific volume of the bread and the porosity of the crumb. The organoleptic analysis of the bread samples showed that the color of the crumb and crust became richer and darker as the amount of chia flour increased. The sample with 2.5% chia flour had the best aroma and taste.

Physicochemical indicators	Values of physicochemical indicators of achloride bread				
	GOST 25832	Amount of chia flour, % of wheat flour weight			
		1,0	1,5	2,0	2,5
Crumb moisture, %	≤43	40,4	40,5	40,5	40,4
Crumb acidity, grad.	≤3,0	2,25	2,3	2,25	2,25
Crumb porosity, %	≥70	73,4	74,2	74,9	75,6
Specific volume of bread, cm^3/g	-	3,4	3,6	3,8	4,1

Table 9: Effect of chia flour on the physicochemical properties of achloride bread.

The analysis of the fatty acid composition confirmed the high content of PUFA in the fat fraction of experimental samples of achloride bread (Table 10).

With an increase in the amount of chia flour from 1 to 2.5% of the weight of wheat flour, the ratio of PUFA **ω**-6: PUFA **ω**-3 decreased from 6 to 3.7, the total content of PUFA **ω**-3 in bread with 1% chia flour was 0.25g/100g of bread, and with 2.5% chia flour - about 0.5g/100g of bread, that, in accordance with the current legislation of the EurAsEC countries, allows labeling this product as " the source of PUFA **ω**-3" (at least 0.2 g of PUFA **ω**-3/100g) or "the product with a high PUFA ω-3 content (at least 0.4 g of PUFA **ω**-3 /100g).

Experimental samples of bread	SFA	MUFA	PUFA	ω-6: ω-3	ω-3, g/100 g bread
	% of total fatty acids				
With 1 % chia flour	28,2	23,9	46,9	6	0,25
With 2,5 % chia flour	24,7	22,1	52,3	3,7	0,49

Table 10: Fatty acid content in experimental samples of achloride bread.

It has been established that the addition of chia flour in an amount of at least 1% of the mass of wheat flour contributes to the content of dietary fiber in the product of at least 3g/100g.

In accordance with the legislation of the EurAsEC countries (Technical Regulations of the Customs Union TR CU 022/2011 "Food products in terms of their labeling"), this bread can be labeled as "the source of dietary fiber". When adding at least 2.5% chia flour from the mass of flour, a product with a total content of dietary fiber of at least 6g/100g was obtained, which allows labeling it as a product "with a high content of dietary fiber" (Table 11).

Achloride bread	Dietary fiber	Content, g/100g
with 2,5 % chia flour	total	6,09
	insoluble	1,51
	soluble	4,58
with 1,0 % chia flour	total	4,87
	insoluble	1,32
	soluble	3,55

Table 11: Dietary fiber content in achloride bread with chia flour.

The ratio of soluble dietary fiber to insoluble fiber was approximately 3:1. The predominance of soluble dietary fiber in the resulting product is an additional advantage due to its beneficial effect on intestinal microflora, as well as radioprotective action due to the binding of radionuclides and divalent metals.

Thus, the developed achloride bread was additionally fortificated with nutrients important for the prevention of cardiovascular diseases - PUFA **ω**-3 and dietary fiber.

One of the serious diseases is celiac disease or gluten enteropathy, caused by a deficiency of enzymes that break down gluten and related proteins. In accordance with the legislation of the EurAsEC countries (Technical Regulations of the Customs Union TR CU 027/2012 "On the safety of certain types of specialized food products, including dietary therapeutic and dietary preventive nutrition"), gluten-free food products should not contain wheat, rye, barley, oats or their crossbred variants obtained by crossing them. In celiac disease, the metabolism of many nutrients is disrupted, in particular carbohydrates, fats and vitamins, so the development of fortificated gluten-free bakery products is relevant. In the EurAsEC countries, these dietary products are manufactured in accordance with GOST 34835 «Foods for special dietary uses. Gluten-free bakery products. General specifications».

We set the task of developing a gluten-free bakery product fortificated with such deficient nutrients as PUFA **ω**-3, dietary fiber and protein.

The main raw materials for the production of gluten-free flour products are corn and rice flour, as well as various types of starch (corn, potato, rice and others). Corn and rice flour contain 6-7% protein, no more than 2.5% dietary fiber and don't contain PUFA **ω**-3 [18]. Chia flour is characterized by a high content of PUFA **ω**-3 and dietary fiber, and also contains about 30% balanced protein, lupine flour is characterized by a high protein content (up to 45%) and additionally contains about 15% dietary fiber [18]. Therefore, these types of flour were chosen to perform the task.

The absence of gluten, which plays the role of a structure-forming agent in bakery products, leads to a decrease in the specific volume of bread, the porosity of the crumb and its elastic properties. Therefore, it is recommended to add various polysaccharides and proteins to the formulation for gluten-free products. The use of a protein-polysaccharide mixture (PPsM) for these purposes, consisting of sodium caseinate, sodium alginate, carboxymethylcellulose, and xanthan gum, was considered [19]. To further increase the PUFA ω-3 content as a fat ingredient, MFR + PUFA **ω**-3 was used in an amount of 4-5% instead of vegetable oil.

As a result of the conducted studies, it was found that the addition of chia flour in the amount of 2-5% and lupine flour in the amount of 4-20% of the weight of gluten-free raw materials to the formulation allows obtaining a gluten-free bakery product characterized by a high PUFA ω-3 content (at least 0.4 g / 100 g of product) with a PUFA ω-6: PUFA ω-3 ratio of 2.4-3.2, corresponding to therapeutic nutrition, as well as a high content of dietary fiber (at least 6 g / 100 g of product). The protein content in the product was 5.2-6.7 g / 100 g. Thus, consumption of 300 g of the developed gluten-free product allows providing the body with protein in the amount of 15-22% of the daily requirement [20]. It should be noted that the addition of lupine flour in an amount of at least 10% gives the product a pleasant nutty aroma.

The best results in organoleptic analysis were obtained with a bread sample containing 3% chia flour and 10% lupine flour of the total flour mass.

It is important to remember that PUFAs are subject to oxidative damage during storage, leading to the formation of both peroxides and hydroperoxides, from which aldehydes and ketones are further formed, many of which can have a carcinogenic effect on the human body. In the case of bakery products with a shelf life of up to 5 days, the natural antioxidants tocopherols present in chia flour and MFR + PUFA **ω**-3 help preserve unsaturated acids. However, in the case of bakery products with a long shelf life, it is necessary to provide additional methods to prevent oxidative processes. Besides the adding antioxidants to food products, a modern way to extend their shelf life is to package them using a modified atmosphere (MA). In the last decade, many studies have shown the benefits of using MA for storing baked goods [21-29]. The most commonly used gas mixture for this purpose is nitrogen and carbon dioxide. Carbon dioxide (CO2) has fungistatic and bacteriostatic properties, preventing the growth of microorganisms in packaged food products during long-term storage. Nitrogen (N2) is an inert gas, colorless, tasteless, and odorless, and is used as a filler. The ratio between these gases depends on the type of product. For example, in studies conducted by Egyptian scientists, the best results were achieved when storing pita bread in a mixture of CO2 and N2 in a 85:15 ratio [24]. In a study conducted by French scientists, it was found that the best mixture for storing Sangak bread was a 50:50 mixture of CO2 and N2 [25].

We have conducted research on the effect of MA on extending the shelf life of flour confectionery products, including gluten-free cookies with a high PUFA ω-3 content without addition of antioxidants to the product formulation [30,31]. As a result, it was found that the highest preservation of cookies is achieved when using MA: mixture of gases CO2:N2 in the ratio 50:50. The use of MA also contributed to the preservation of PUFA ω-3, extending the shelf life of the product by 1.5 times compared to cookies packaged without the use of MA [31].

Conclusions

As a result of studies of the chia flour effect on the physicochemical, organoleptic properties and nutritional value of various types of bakery products, the feasibility of using chia flour in the production of both mass and specialized types of bakery products has been proven.

It has been established that the addition of chia flour in an amount of 1-5% of the weight of wheat flour, in accordance with the recommendations of the EU Commission (2009/827/EC), helps to increase the nutritional value of bakery products by enriching them with the scarce PUFA ω-3, as well as dietary fiber. In addition, the organoleptic properties of bread are improved during its storage.

It has been shown that the additional use of MFR+PUFA ω-3 as a fat ingredient not only increases the PUFA ω-3 content in the bakery product, but also further increases its porosity and specific volume.

It has been proven that the use of chia flour in the production of specialized bakery products such as achloride bread and gluten-free bread enhances the preventive effects of these types of bread by providing additional nutrients to the body.

To preserve PUFA ω-3 in long-term storage bread with a high content of these nutrients, good results can be achieved using a modified atmosphere.

Adding chia flour does not require any changes to the technological process. The maximum amount of chia flour added to the formulation without worsening the organoleptic properties is 5% of the wheat flour weight, which increases the cost of ingredients for the production of the bakery product by 22 cents/kg. At the same time, the consumer receives a product that meets the principles of healthy eating with improved physicochemical properties.

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Bibliography

1. World Health Organization. European Food and Nutrition Action Plan 2015-2020. Regional Committee for Europe. 64th session. Copenhagen, Denmark (2014).
2. Martinchik AN., *et al*. "Prevalence of overweight and obesity in children". *Problems of Nutrition* 91.3 (2022): 64-72.
3. Shikh EV and Makhova AA. "Long-chain **ω**-3 polyunsaturated fatty acids in the prevention of diseases in adults and children: a view of the clinical pharmacologist". *Problems of Nutrition* 88.2 (2019): 91-100.
4. Smetneva NS., *et al*. "The role of optimal nutrition in the prevention of cardiovascular diseases". *Problems of Nutrition* 89.3 (2020): 114-124.
5. Abdelhamid AS., *et al*. "Omega-3 fatty acids for the primary and secondary prevention of cardiovascular disease". *Cochrane Database Syst. Rev* 3 (2020): CD003177.
6. Isayev VA., *et al*. "PUFA ω-3 in the correction of disturbances at the diabetes mellitus of the II type". *Storage and Processing of Agricultural Raw Materials* 11 (2017): 30-33.
7. Ozerskaia IV., *et al*. "The role of ω-3 polyunsaturated fatty acids in child development". *Problems of Nutrition* 93.2 (2024): 6-18.
8. Puzin SN., *et al*. "Optimization of the diet should be considered as one of the areas of prevention and rehabilitation of these diseases and the prevention of premature aging". *Problems of Nutrition* 87.4 (2018): 69-77.
9. Averyanova IV and Alyoshina OO. "The effect of **ω**-3 polyunsaturated fatty acids on carbohydrate metabolism in northern men". *Problems of Nutrition* 93.4 (2024): 31-38.
10. "Fats and fatty acids in human nutrition. Report of an expert consultation" (10-14 November 2008, Geneva). FAO food and nutrition paper, 91/Food and Agriculture Organization of the United Nation. – Rome (2010): 189.

11. Nutritionology and clinical dietetics: national guidelines/ edited by V.A. Tutelyan, D.B. Nikityuk – M.: GEOTAR-Media (2020): 656.

12. A balanced omega-6/omega-3 fatty acids ratio, cholesterol and coronary heart disease : World review of nutrition and dietetics 100/Ed".: A.P. Simopoulos, F. De Meester – Basel [et al.] : KARGER (2009): 125.

13. Kalinchenko SYu., *et al*. "Prevalence of omega-3 fatty acid deficiency in different age groups". *Questions of Dietology* 8.1 (2018): 11-16.

14. Sharma V and Mogra R. "Effect of chia (*Salvia hispanica* L.) seeds incorporation on nutritional quality of muffin mix". *Nutrition and Food Science* 50.6 (2020): 1151-1161.

15. COMMISSION DECISION 2009/827/EC of 13 October 2009 authorising the placing on the market of Chia seed (Salvia hispanica) as novel food ingredient under Regulation (EC) No 258/97 of the European Parliament and of the Council". *Official Journal of the European Union* 294 (2009): 14-15.

16. Puchkova LI., *et al*. "Bread technology-Saint Petersburg: GIORD" (2005): 357-358.

17. Pyryeva EA and Safronova AI. "The role of dietary fibers in the nutrition of the population". *Problems of Nutrition* 88.6 (2019): 5-11.

18. Zaytseva LV and Matunina AV. "Development of enriched gluten-free cookies with a balanced amino acid and fatty acid composition". *Acta Scientific Nutritional Health* 9.5 (2025): 49-60.

19. Russian Federation Patent No. 2693092. Method for producing gluten-free bread (2019).

20. Zaytseva LV., *et al*. "Modern approaches to the development of gluten-free bakery formulations". *Problems of Nutrition* 89.1 (2020): 77-85.

21. Degirmencioglu N., *et al*. "Influence of modified atmosphere packaging and potassium sorbate on microbiological characteristics of sliced bread". *Journal of Food Science and Technology* 48.2 (2011): 236-241.

22. Fik M., *et al*. "Quality and shelf-life of calcium-enriched wholemeal bread stored in a modified atmosphere". *Journal of Cereal Science* 56 (2012): 418-424.

23. Hempel AW., *et al*. "Use of smart packaging technologies for monitoring and extending the shelf-life quality of modified atmosphere packaged (MAP) bread: application of intelligent oxygen sensors and active ethanol emitters". *European Food Research and Technology* 237 (2013): 117-124.

24. Hasan SM., *et al*. "Shelf-life extension of pita bread by modified atmosphere packaging". *Journal of Food and Dairy Sciences* 5.2 (2014): 55-62.

25. Khoshakhlagh K., *et al*. "Quality and microbial characteristics of part-baked Sangak bread packaged in modified atmosphere during storage". *Journal of Cereal Science* 60 (2014): 42-47.

26. Morren S., *et al*. "Effect of product microstructure and process parameters on modified atmosphere packaged bread". *Food Bioprocess Technology* 10 (2017): 328-339.

27. Kurek MA., *et al*. "Effect of modified atmosphere packaging on the quality of wheat bread fortified with soy flour and oat fiber". *Journal of Food Measurement and Characterization* 13 (2019): 1864-1872.

28. Kwasniewska-Karolak I and Mostowski R. "The influence of storage conditions on the staling rate and starch retrogradation in wheat rolls packaged in a modified". *Journal of Microbiology, Biotechnology and Food Sciences* 8.5 (2019): 1188-1193.

29. Debonne E., *et al*. "Technological and microbiological evaluation of different storage conditions of par-baked bread". *LWT - Food Science and Technology* 131 (2020): 1-8.

30. Matyunina AV., *et al*. "Influence of gas modified medium on the safety of flour confectionery products". *Food Industry* 12 (2021): 91-94.

31. Matyunina AV., *et al*. "Predicting the shelf life of high ω-3 fatty acid biscuits". *Food Industry* 6 (2020): 43-46.