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Technology of Production, Nutritional Value and Food Safety of Gluten Free Bread

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Abstract*: The development of the production of foods, enriched with irreplaceable components, specialized foods and foods of functional purpose, as well as dietary (therapeutic and prophylactic) is one of the priorities of the state policy in the field of healthy nutrition. The problem of creating gluten-free products is urgent one. The article discusses the use of amaranth flour in the production of composite flour for the production of gluten-free bread. Standard research methods of bakery products were applied. Formulations of composite flour bread were developed which included: amaranth flour, chickpea flour, wheat powder. Physical and chemical and organoleptic characteristics of finished product were studied. The bakery product in terms of the content of essential amino acids such as valine, isoleucine, lysine, threonine, phenylalanine exceeded the ideal protein. The concentration of toxic elements, microbiological indicators and pesticides are not detected

***Index Terms*: gluten, composite mixture, amaranth flour, bread, chickpea, technology**

I. INTRODUCTION

In recent years, the need for gluten-free foods has increased. Currently, the production of specialized foods is rapidly developing, including foods that are free from certain ingredients, whose presence in food is not recommended for certain medical reasons (allergens, certain types of proteins, oligosaccharides, polysaccharides, etc.). Taking into account the success of nutrigenomics and nutrigenetics, the trend towards individualization of diets will increase, which will lead to an increase in the market of specialized foods.

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Gluten-free foods (prolaminsof cereal grains) are one of the segments of this market.The first time about problems with gluten started talking in the 1930s, and already in 1950 celiac disease was discovered. And since that time, the number of people suffering from this disease is growing. From a medical point of view, celiac disease is a digestive disorder in the small intestine, which occurs as a result of an autoimmune reaction to gluten [1, 2]. A study of celiac disease in Kazakhstan was conducted only among children. Conducted epidemiological studies in the country revealed the prevalence of celiac disease in the child population with a frequency of 1: 262. The research results allowed to establish clinical and laboratory criteria for typical, atypical and latent forms of celiac disease in children. In a typical form, the prevalence of enteropathic syndrome (polyfecalia, steatorrhea, dysplasia, marked metabolic disorders) is observed. The diagnosis is established, as a rule, in age from 2 to 14 years. The atypical form of the disease occurs without obvious signs of malabsorption syndrome, hiding under various clinical “masks”, with a predominance of any symptom complex: hypocalcemic, convulsive, anemic, short stature, etc. Atypical form in the ratio of typical meets with a frequency of 6: 1.

Figure 1 shows in percentage the disease of celiac disease in the territory of the Republic of Kazakhstan, both in children and in young people aged 20 to 35 years [3].

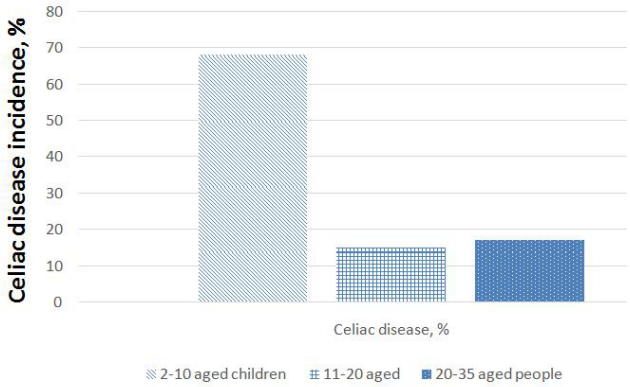

Fig. 1: The incidence of celiac disease in Kazakhstan among the younger generation

As can be seen, in Figure 1, children aged 2 to 10 years old accounted for 68% for the incidence of celiac disease, 15% for people aged 11 to 20 years old and 17% for people aged 20 to 35 years old.

According to the study, it can be said that most patients with celiac disease are children from 2 to 10 years old. Celiac disease causes growth retardation, bones fragility, anemia, as well as psycho-neurological disorders and an allergic reaction in children. About 1% of the population suffers from latent celiac disease. In women, celiac disease occurs 2-3 times more often than in men; this is because women are more susceptible to autoimmune diseases. Often, patients with celiac disease are observed and treated for irritable bowel syndrome, thyroid disease, chronic diarrhea, functional constipation, etc. [4].

According to the Codex Alimentarius Food Standards (Codex Alimentarius), adopted by an international commission with a membership of WHO (World Health Organization) and FAO (United Nations Food and Agricultural Organization), gluten-free foods are dietary foods:

a) consisting of, or produced solely from, one or more ingredients that do not contain wheat, rye, barley, oats or hybrids, and in which the gluten content does not exceed the level of 20 mg / kg in the whole food product, as it is sold or transferred to the consumer;

b) consisting of one or more ingredients derived from wheat, rye, barley, oats or their hybrids, which have been specially processed to remove gluten, and in which the gluten content does not exceed the level of 20 mg / kg in the whole food product, in the form as it is sold or transferred to the consumer [5].

In the past few years alone, a gluten-free diet has increased dramatically in popularity. Gluten-free foods have become synonymous with healthy eating, along with low-carbohydrate and low-carbohydrate foods.

An important component in the production of dietary, healthy products with new taste is the amaranth flour.

There are various inventions for the production of confectionery.

The composition for the production of cracker includes buckwheat flour, chestnut flour, taken in relation to buckwheat flour 1: 2, rosehip powder, yeast, gluten-free egg substitute, pan-salt, refined corn oil, flour corrector in the form of protease, emulsifier and water in the amount of moisture content of the dough is 28-31%. [6].

There was developed gluten free confection. The method involves churning of margarine and granulated sugar to form a homogeneous mass within 10-15 minutes. Then eggs, salt are added and churned for 20 minutes. Sifted cornmeal and rice flour, starch and baking powder are gradually added to the finished mass. Next, the candied fruit and chopped lemon are introduced. The molding is carried out in processed non-stick coating forms. Muffins are baked at 200 ° C for 20-25 minutes and cooled naturally to room temperature. The invention allows obtaining a balanced amino acid composition product that does not contain gluten and is enriched with dietary fiber [7].

The pasteurized food product, which contains a proline specific protease, has a water activity of at least 0.85. The enzyme used is a protease isolated from Aspergillus or belonging to the S28 family of serine proteases. The optimum activity of the indicated protease has a pH value of from 1 to 7, preferably at a pH value of from 2 to 6. The specified food product is obtained by adding them a proline specific protease. The use of such products provides cleavage of gluten peptides and is recommended for patients suffering from gluten intolerance [8].

For the manufacture of gluten-free wafer sheet the following source components are used, mass %: rice flour 12.0, buckwheat flour 48.0, sugar 18.4-19.0, fat component 8.0-10.0, chicken egg 3.3 -3.7, invert syrup 2.4-2.7, salt 0.3-0.5, drinking soda 0.3-0.5, ammonium salt 0.1-0.3, potato starch 2.0 -3.0, drinking water to 100, and the ratio of rice and buckwheat flour by weight is 1: 4. Herein this filling consists of the following initial components, mass %: fat component 44,20, sugar 5.4, milk 50.4. The invention is aimed at expanding the range of gluten-free flour confectionery products and the possibility of using them in the nutrition of patients suffering from celiac disease, due to increased nutritional value and the lack of gluten [9].

Composite flour is often used to produce gluten-free products. Amaranth flour is not only a valuable biologically active food product, but also has a fortifying and healing effect on the human body due to a complex of various therapeutic and prophylactic properties. The amaranth flour contains substances that normalize the acidity of the gastric juice and enhance the secretory function of the stomach and intestines (vitamins B1 and B2), which have an anti-inflammatory and wound-healing effect on the mucous membranes of the gastrointestinal tract, as well as preventing the development of inflammation processes in the liver, gallbladder and biliary ducts (vitamins A, E, C, magnesium, squalene, omega-6 linoleic acid, phytosterols). Also amaranth flour has high content of choline, phospholipids and methionine - substances that normalize the process of bile secretion and prevent fatty infiltration of the liver [10].

Analyzing the sources of technical information, it can be concluded that rice, buckwheat, and amaranth flour are used in the production of gluten-free products. The experimental work will consider the possibility of using amaranth flour in the production of bakery products.

The aim of the work was to develop the formulation and technology of gluten-free composite flour and the development of technology of gluten-free bread.

II. MATERIALS AND METHODS

For the experimental work the following tasks were set:
- selection of components for gluten-free composite flour;
- formulation and technology development of gluten-free flour;
- study of the fermentation process of gluten-free bread;
- study of physico-chemical indicators of the quality of bread;
- study of the nutritional and biological value of gluten-free bread.

When performing experimental work, the following methods were used: GOST 18321-73 Statistical quality control. Methods of random selection of samples of piece products GOST 5669-96 Raw materials and food products. Methods for the determination of mercury;

GOST 21094-75 Bread and bakery products. Method for determination of humidity; GOST 5670-96 Bakery products. Methods for determination of acidity; GOST 29138-91 Fortified wheat flour, bread and bakery products. Method for the determination of vitamin B (1) (thiamine); GOST 29140-91

Vitaminized wheat flour, bread and bakery products. Method for the determination of vitamin PP (nicotinic acid); GOST 5669-96 Determination of the porosity of bread; GOST 27669-88 Baking wheat flour. Method for test laboratory bread baking; GOST 32195-2013 (ISO 13903: 2005) Feed, mixed feed. Method for determination the content of amino acids; GOST 26927-86. Raw materials and food. Methods for determination of mercury; GOST 26930-86.Raw materials and food. Methods for determination of arsenic; GOST 26931-86. Raw materials and food. Methods for determination of copper; GOST 26932-86. Raw materials and food. Methods for determination of lead; GOST 26933-86. Raw materials and food. Methods for determination of cadmium; GOST 26934-86.Raw materials and food. Methods for the determination of zinc; GOST R 53150-2008 Food products. Determination of microelements. Sample preparation by salinity at elevated pressure.

III. RESULTS AND DISCUSSION

The result of the work was the development of gluten-free bread technology. At the first stage of research work, the formulation and production technology of gluten-free composite flour was developed.

New gluten-free composite flour is enriched with protein, dietary fiber, B-group vitamins, macro- and microelements. The composition of the composite flour included various ingredients such as wheat starch, amaranth flour, chickpea flour.

Wheat starch is used in the baking industry to improve the quality of flour products, their porosity, volume, consistency and slowing down the hardening.

The main properties of starch obtained from wheat are neutral taste, specific viscosity, hygroscopicity, high heat treatment resistance, ability to stabilize emulsions, long shelf life. One of the most important properties of starch is the ability of its grains to swell in water with increasing temperature, giving a viscous colloidal solution (paste). The gelatinization temperature of wheat starch is 60-62 ºC. A distinctive feature of wheat starch is its ability to form pastes, which are stable during thermal exposure, mixing and long-term storage.

Amaranth flour contains protein consisting of more than 30% of essential amino acids, fat, 50% of omega-6 polyunsaturated fatty acid, significant amounts of vitamins E, A, B1, B2, B4, C, D, which increases the nutritional and the biological value of the target product.

In addition, amaranth flour contains phospholipids, phytosterols, the strongest natural antioxidants, squalene and vitamin E, which helps to prevent obesity, diabetes, cardiovascular and oncological diseases, and provides preventive properties to the target product.

Chickpea flour has a unique vitamin and mineral composition. It contains dietary fibers that contribute to the normal functioning of the intestine, as well as unsaturated and saturated fatty acids, which have an invaluable complex effect on the human body.

The chemical composition of the product is also rich. It contains vitamins A, K, PP, E, C, B complex. The composition is also represented by beta-carotene, manganese, potassium, magnesium, selenium, calcium, zinc, chlorine, iron, iodine, phosphorus, sulfur, sodium, molybdenum, tin, vanadium, silicon, titanium, cobalt.

Eating chickpea flour reduces insulin concentration, sugar and cholesterol levels, minimizes the risk of developing diabetes. The useful composition of the product is shown to people with dermatitis, sclerosis, autoimmune diseases, autism, attention deficit disorder and other ailments. Regular consumption of chickpea dishes contributes to the prevention of cancer.

A common property characteristic of all three components of the composite flour is the absence of gluten in their composition. This is especially important for people who experience its intolerance, as well as for people with diabetes. Composite flour formulation is shown in Table 1.

Table 1 Formulation of composite flour

Ingredient	Formula1	Formula 2	Formula 3
Wheat starch	70	70	70
Amaranth flour	21	20	19
Chickpea flour	9	10	11

Composite flour is produced by mixing homogeneously in a blender wheat starch, amaranth flour and chickpea flour in prescription quantities, followed by packing in containers. A patent has been obtained for this invention [11].

The production technology of composite flour consists of the following processes: wheat starch, amaranth flour and chickpea flour are mixed in mass ratios: 7: 2: 1. The resulting composite flour is packaged in polypropylene bags of 450 g and stored at + 6-10 ° C for no more than 8 months.

The next stage in the research work was the development of gluten-free bread technology. Bread was produced by traditional straight technology. The following ingredients were used in the bread recipe: composite flour, yeast, salt, water.

Three experimental formulations were made, wheat bread was used as a control sample.

Table 2 shows the experimental formulas of gluten-free bread with composite flour.

Table 2 Formulas of experimental samples of bread

Name	Wheat starch	Amarant hflour	Chickpea flour	Wheatf lour	Yeast	Salt	Water	Vegetable oil for forms lubrication	Total	Output of finished products

Sample 1	70	21	9	-	0,7	1,3	52	0,15	102,15	132
Sample 2	70	20	10	-	0,7	1,3	52	0,15	102,15	132
Sample 3	70	19	11	-	0,7	1,3	52	0,15	102,15	132
Control	-	-	-	100	0,7	1,3	52	0,15	102,15	132

As a result of the control baking of bread, the following samples were obtained, the results of the test baking are shown in Figure 2.

a) wheat bread

b) composite flour bread (70% of wheat starch, 21% of amaranth flour, 9% of chickpea flour)

c) composite flour bread (70% of wheat starch, 20% of amaranth flour, 10% of chickpea flour)

d) composite flour bread (70% of wheat starch, 19% of amaranth flour, 11% of chickpea flour)

Fig. 2: Baked bread cuts prepared with different type of composite flour

The finished products were examined for organoleptic and physicochemical parameters. Table 3 shows the organoleptic characteristics of bread samples.

Table 3 Organoleptic characteristics of experimental samples

Samples	Appearance: Shape and surface	Colour	Crumb state	Porosity	Taste and smell
Control (wheat bread)	The form is not correct, smooth, without major cracks	Light brown	Baked, elastic, not moist to the touch.	Developed without voids and seals	Peculiar to this type of products without foreign taste and smell
sample1	The form is not correct, smooth, without major cracks	Light brown	Baked, elastic, not moist to the touch.	Developed without voids and seals	Peculiar to this type of products without foreign taste and smell
sample2	The form is not correct, smooth, without major cracks	Light brown	Baked, elastic, not moist to the touch.	Developed without voids and seals	Peculiar to this type of products without foreign taste and smell
sample3	The form is not correct, smooth, without major cracks	Light brown	Baked, elastic, not moist to the touch	Developed without voids and seals	Peculiar to this type of products without foreign taste and smell

Analysis of organoleptic indicators showed that sample 2 has more improved organoleptic characteristics.

At the next stage of the research work, the process of fermentation of the bakery product was studied.

During the fermentation of the dough, complex biochemical processes take place, in which the interaction of the enzymes of flour, yeast and other microorganisms plays an essential role, which ultimately determines the ripening of the dough. Figure 3 shows the comparative characteristics of the main fermentation time and the baking time of the control and experimental samples of the bakery product.

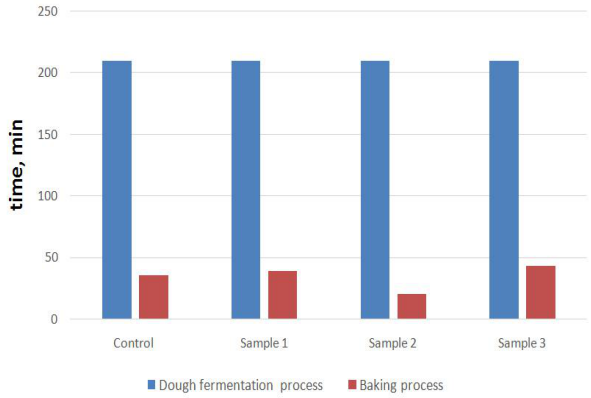

Fig. 3: Fermentation and baking time of control and experimental bread samples

Chart analysis shows that the main fermentation time was the same in all samples and was 210 minutes, the baking time in the experimental sample 2 was the shortest and amounted to 20 minutes compared with the control variant and samples 1, 3, which reduces the production process.

In the finished samples physical and chemical parameters were examined. The results of physical and chemical indicators are given in table 4.

Table 4 Physical and chemical indicators of bakery products

Sample	Bread weight, g	Bread volume, cm^3	Grain of bread, %	Bread acidity, ^{0}
Control	110	140	36,6	2,2
Sample 1	110	110	30	2,2
Sample 2	115	150	37,35	2,2
Sample 3	100	85	25,5	2,2

The results of the study showed that the experimental sample 2 had higher volumes of bread - 110 cm3, porosity 37.35%, the bread yield was also higher and amounted to 115 grams compared with other samples. The acidity of the bakery products did not change and amounted to 20.

Analyzing the obtained data, for further research the experimental sample 2 was selected, which had higher organoleptic physical and chemical parameters.

The result of further research was the study of the vitamin, amino acid, mineral composition of the experimental sample of bread. Table 5 and chart 4 show the results of the study of the vitamin composition of the bakery product.

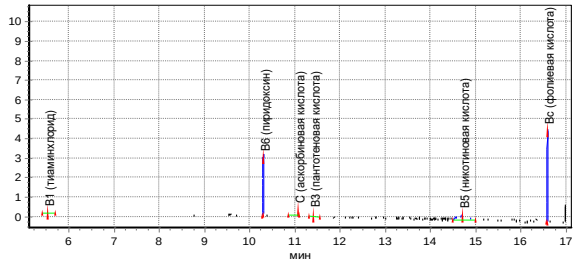

Fig. 4: Chromatogram of the content of vitamins in a bakery product

Table 5 Content of vitamins in the bakery product

Vitamin	mg/l	g/kg	mg/100g
B1 (thiamine)	0.0017	0,0000093	0,00093±0,00019
B6 (pyridoxine)	0.01	0,000055	0,0055±0,0011
C (ascorbic acid)	0.029	0,00016	0,016±0,005
B3 (panthothenic acid)	0.0071	0,000039	0,0039±0,00078
B5 (nicotinic acid)	0.0067	0,000037	0,0037±0,00066
Bc (folic acid)	0.0033	0,000018	0,0018±0,00036

Diagram 5 and table 6 show the results of the study of the amino acid composition of a prototype bakery product.

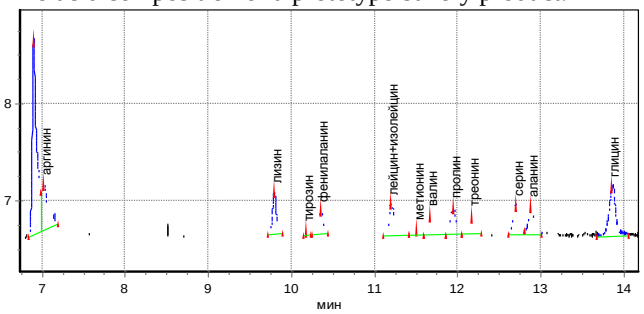

Fig. 5: Chromatogram of the content of amino acids in the bakery product

Table 6 The content of amino acids in the bakery product

Amino acid	mg/l	Weight percent
Arginine	28.0	0,177±0,071
Lysine	6.60	0,042±0,014
Tyrosine	2.00	0,013±0,004
Phenylalanine	9.70	0,061±0,018
Leucine + isoleucine	8.40	0,053±0,014
Methionine	2.90	0,018±0,006
Valine	6.70	0,042±0,017
Proline	7.50	0,047±0,012
Threonine	5.30	0,034±0,013
Serine	8.10	0,051±0,013
Alanine	6.30	0,040±0,010
Glycine	11.0	0,070±0,024

Figure 6 shows the comparative characteristic of the content of amino acids in experimental sample of a bakery product in comparison with the FAO / WHO indicator of the essential amino acid content of an ideal protein.

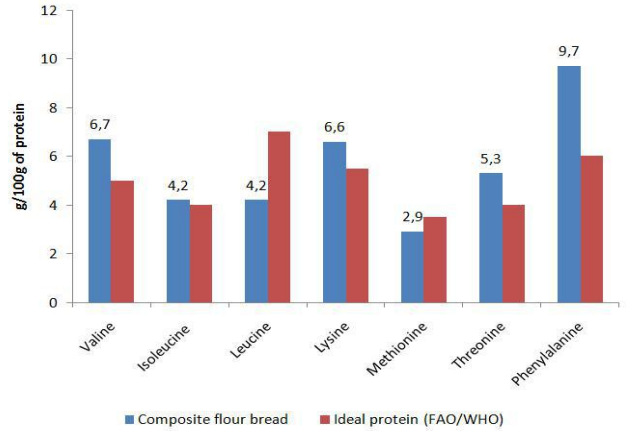

Fig. 6: Essential amino acid content in composite flour bread

Analysis of the data obtained shows that the valine content is higher by 1.7 g, the isoleucine content is higher by 0.2 g, the lysine content is higher by 1.1 g, the threonine content is higher by 1.3 g, the phenylalanine content is higher by 3.7 g by compared to the perfect protein. Amino acids such as leucine are less by 3.2 g, methionine is less by 0.6 g compared to the ideal protein.

The obtained data allow concluding that the bakery product has high quality indicators for the content of essential amino acids and has an increased biological value.

In the test sample of bread, minerals were identified. The results of the study are shown in table 7.

Table 7 The content of mineral substances in the bakery product in comparison with wheat bread

Mineral	Composite flour bread, mg/%	Wheat bread, mg/%
Mg	62	41
Na	480	473
P	146	129
K	283	141
Ca	130	125

Analysis of the content of mineral substances in the bakery product in comparison with wheat bread showed that the experimental sample exceeded wheat bread in the following elements: magnesium by 21 mg /%, phosphorus by 17 mg/%, potassium by 142 mg /%, calcium by 5 mg /%, sodium by 8 mg /%.

The bakery product was examined for food safety (toxic element content, microbiological indicators, pesticides), the research was conducted at a temperature of –2 ° C, a relative air humidity of 81%. The results of the study are shown in Table 8.

Table 8 Indicators of food safety of bakery products

Indicator	Regulation rate	Determined data
Toxic elements, mg/kg		
Lead	0,5	Not detected
Cadmium	0,1	Not detected
Mercury	0,015	Not detected
Arsenic	0,2	Not detected
Microbiological indicators:		
Total viable count, CFU/G	$1*10^3$	Not detected
Escherichia coli group bacteria – CGB in 1 g	Prohibited	Not detected
Fungi, CFU/G	50	Not detected
Pesticides, mg/kg		
- 4,4'-dichlorodiphenyltrichloroethane	0,1	Not detected
- 2,4-dichlorophenoxyacetic acid	Prohibited	Not detected

The food safety of the bakery product complied with safety standards. The results of the study of physical and chemical and organoleptic indicators show that sample2 can be used both for widespread consumption and for preventive nutrition. In samples 1, 2, 4 by organoleptic characteristics the appearance did not meet the requirements of the standard.

IV. CONCLUSION

The objectives of the scientific and experimental work were achieved. Components for gluten-free composite flour were selected: wheat starch, chickpea flour, amaranth flour; formulas and technologies of gluten-free flour were developed; Patent RK No. 3150 Composite gluten-free flour was obtained / 5 /, formula and technology of gluten-free bread was developed, bread contains (100 kg of flour) (kg): amaranth flour 20, wheat starch 70, chickpea flour 10, salt 1.3, yeast 0 , 7, water 52, vegetable oil 0.15; the process of fermentation of bread and baking time were investigated, the optimal fermentation time is 210 minutes, the baking time is 20 minutes. Studies of physical and chemical parameters showed that experimental sample 2, which has acidity 20, bread porosity 37.35%, bread volume 150 cm3, is the best option. The study of nutritional and biological value showed that bread contains vitamins B1 B6 B3 B5 B9, C. The amino acid composition of essential amino acids such as valine, isoleucine, lysine, threonine, phenylalanine is higher than in an ideal protein, which significantly increases its biological value.

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