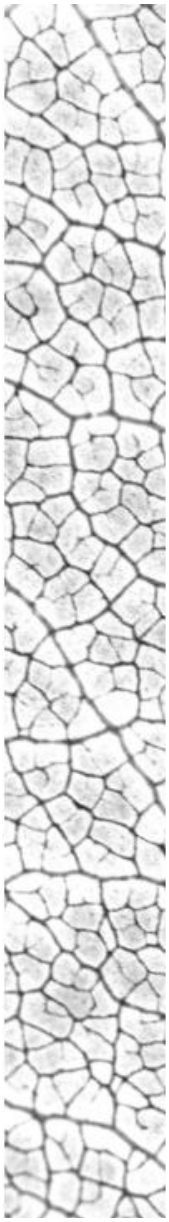

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Development of technology for producing gluten-free dry mixes for confectionery products based on Kazakhstani raw materials

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Abstract

The article presents data on the production of gluten-free dry mixes. At the beginning, gluten-free crops of corn and rice grains were selected, which were refined according to the climatic conditions of our country. All selected crops were tested for the presence of gluten using the IFA analyzer of Rider Multiscan FC. Before setting the temperature conditions in three parameters on the extruder, the degrees of gelatinization are considered and investigated using differential scanning calorimetry (DSC) equipment. Based on the thermodynamic melting parameters, the optimal extrusion mode for rice and corn flour is selected. Extrusion was performed on a double-screw extruder, DS32-II – Double-screw testing extruder. The morphology of extruded corn and rice flour was studied, and micrographs revealed that extrusion destroys their granular structure and creates a link between starch and free lipids in the raw material. The ratios of dry mixtures for obtaining gluten-free products based on mathematical modeling have been developed. Based on the study of quality characteristics, the ratios of dry mixes for cakes were worked out (rice flour - X_1-24,25%, corn flour - X_2-59,5%, extrusion flour - X_3-16.25%). As a result of the study of the gluten content in dry mixes from grain crops and obtained confectionery products, it was revealed that gluten does not exceed 20 mg/kg. During the experiments, the energy value of gluten-free cakes (406,66 kcal) was studied.

Keywords: gluten-free extruded rice, corn, mathematical modeling of dry mixes, confectionery products

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INTRODUCTION

Introduce the Problem

Currently, one of the most important directions in the prevention of genetic and allergic diseases is dietary-functional nutrition, since it determines the health of the population.

Alimentary-dependent diseases that arise from an unbalanced diet are progressing all over the world, including in Kazakhstan. One of these diseases is celiac disease (gluten enteropathy), a chronic autoimmune disease that affects the small intestine of genetically predisposed patients in response to contact with a toxic cereal protein – gluten (Rai et al. 2018). A gluten-free diet should be followed throughout life (Barsukova et al. 2011). Only strict lifelong adherence to a gluten-free diet ensures the quality of patient life, adequate physical and intellectual development, as well as prevents the development of complications and can ensure a normal standard of life for patients with celiac disease.

In the global market, interest in gluten-free products arose initially as products that can solve a specific medical problem, namely intolerance to one of the components of protein – gluten. In addition, the production of specialized food products with ingredients whose presence in food is unacceptable for certain medical reasons (allergens, certain types of proteins, oligosaccharides, polysaccharides, etc.) is being developed. Unfortunately, in Kazakhstan, gluten-free products are imported from Europe and they are expensive and are not sold everywhere. The range of consumers of gluten-free flour products is not wide, but it is necessary to provide this category of people with specialized food products constantly (Petysh 2018).

Currently, in Kazakhstan, all grains, legumes and oilseeds, such as buckwheat, corn, rice, millet, flax, etc., are grown in sufficient volume, which can be a full-

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fledged raw material for obtaining flour for the production of gluten-free products. In Kazakhstan, it is possible to cultivate and develop a technology for obtaining gluten-free products on the basis of agricultural cereals, work in this direction is not carried out in the proper volume.

In connection with the above, given the variety of grain raw materials grown in Kazakhstan, it is necessary to create a domestic innovative technology for the production of gluten-free products, which is a critical task for the science of Kazakhstan in order to saturate the domestic market and create competitive products with a lower cost compared to imported ones.

The aim of this study is to develop a technology for the production of gluten-free flour confectionery dry mixes for the production of confectionery products based on domestic raw materials.

The task is to conduct a study to determine the optimal ratio of components for creating mixtures for the production of gluten-free flour mixtures of confectionery products. Conducting a study of the quality and chemical composition of the obtained gluten-free products of the obtained dry mixes using the developed technology. For the development of new types of gluten-free flour dry mixes for the production of confectionery products, the use of extruded flour is proposed.

The main technological properties of extrudates, which are based on starch - the ability to quickly dissolve and absorb water. Flour - a product with high biological value. Extrusion - increases shelf life, as well as maintains the freshness and microbiological stability of products by reducing water activity indicators.

When developing modern technologies for deep processing of grain crops, an important aspect is the study of the morphological structure of raw materials and the finished product, since it significantly affects the technological process of production. Particle sizes determine the functional properties of the product, which requires special attention of researchers (Chanvrier et al. 2015).

Scientists of the Astana branch of the Limited Liability Partnership “Kazakh Research Institute of processing and food industry” conducted research and analyzed the problem of the spread of celiac disease among the population, studied the needs of residents of Kazakhstan in gluten-free products by conducting a sociological survey of the population using the questionnaire method. The authors conducted an experiment that allows to generalize the research materials in the form of a mathematical model and give them a statistical assessment with a significant reduction in the number of experiments, and determined the optimal conditions for performing a homogeneous mixing of the extruded grain and the solution of mineral salts added by the dispenser.

Despite the fact that the world has developed various technologies for the production of gluten-free products that are produced on an industrial scale, research on the development of new technologies and optimization of existing ones in accordance with the requirements of the markets is a critical task.

Thus, the analysis of literature sources and patent research have shown that one of the promising areas of scientific research worldwide is the development of highly effective technologies for the production of gluten-free products from domestic raw materials intended for consumption by celiac patients. The developed technology allows solving the problem of providing celiac patients with gluten-free products.

METHOD

Objects of research: grain of corn, rice, cakes and extruded flour mixtures of corn and rice.

Research Methods

Sampling of grain crops - GOST 13586.3-2015, GOST 29142-91. Technological properties of grain and oilseeds are defined according to the following standards: corn - ST RK 2118-2011; buckwheat - GOST R 56105-2014; rice - GOST 6293-90; millet - GOST 22983-88. Chemical composition: protein content - GOST 10846-91; fat content - GOST 32749-2014; fiber content - GOST 32040-2012; ash content - GOST 10847-74; starch content - GOST 10845-98; acidity determination - GOST 10846-9, alkalinity determination - GOST 5898-87; density determination - GOST 5902-80; determination of total ash in confectionery products - GOST R 51411-99, determination of gluten in cereals and products of their processing - the R-Biopharm AG method on the system RIDASCREEN Gliadin AOAC Research Institute Performance Tested Method 12060 and on the IFA analyzer Rider Multiscan FC.

Study of the Quality Characteristics of Gluten-Free Flour

The quality characteristics of gluten-free flour are evaluated in accordance with the standards: buckwheat, rice, millet flour - GOST 31645-2012; corn flour - GOST 14176-69. Water absorption capacity of flour according to the generally accepted method (Kiryukhina et al. 2006). As additional materials were used corn starch - according to GOST 32159-2013 and wheat flour of the highest grade according to GOST 26574-85. Assessment of the quality of cakes according to GOST 15052-2014.

Methods of Examining the Test Laboratory Pastries and Optimization of Formulations in Mathematical Modeling

Test laboratory baking of the cake was performed according to (Koryachkina et al. 2011), options for combining the composition of mixes for producing gluten-free cakes are presented in **Table 3**. Mathematical modeling was proposed to determine the percentage of components that make up the mixes for producing gluten-free cakes. Rice, corn and corn

Table 1. Percentage of components included in the composition of the mixes to obtain gluten-free cupcakes

Sample No.	Rice flour, %	Corn flour, %	Extruded corn flour, %
1	100%		
2		100%	
3			100%
4	50%	50%	
5	50%		50%
6		50%	50%
7	25%	75%	
8	25%		75%
9		25%	75%
10	75%	25%	
11	75%		25%
12		75%	25%
13	50%	25%	25%
14	25%	50%	25%
15	25%	25%	50%

extrusion flour are used as the main raw materials for modeling and optimizing the composition of the gluten-free mix. The implementation and planning of a full-factor experiment based on certain optimization criteria was performed according to the Scheffe matrix (Pavlov 1998, Atanov et al. 2019, Oboturova et al. 2016). The mathematical planning of experiments and the matrix is shown in **Table 1**.

As can be seen from **Table 1**, a matrix of experimental data was used to model and optimize the formulation – ratio of dry mixes.

Study of Thermodynamic Parameters

Determination of the value of thermodynamic melting parameters (initial gelation temperature (T_i), maximum gelation temperature (T_m) and final gelation temperature(T_f), gelation enthalpy (ΔHg)) was performed on a differential scanning calorimeter DSS 1/200W of Mettler toledo using the method (Grashchenkov 2018).

Methodology for the Study of Morphological Structure

The morphological structure of gluten-free dry mixes was evaluated using the Quanta 200i 3D scanning electron microscope using the technique attached to the microscope (Emelina 2009).

To obtain extrusion, whole-ground flour (corn and rice) was extruded on a double-screw extruder of the DS32-II brand - Double-screw testing extruder. Moistened mixtures were extruded at various temperatures from 100^0C to 180^0C (Litvyak 2013, Magomedov et al. 2003). To establish the optimal grinding size, the grain was ground at the laboratory mill (laboratory-grain mill) and sifted through a sieve No. 27 (fine grinding), as well as at the mill brand Novital Molino Macinapane Magnum 4V with built-in sieves Ø1 mm and at the mill brand Hawus Pegasus 380 V.

The grinding of extrudates and the control of the grinding size were carried out in the same way as in the production of whole-ground flour. The quality of the extrudate structure was evaluated by the “expansion” coefficient, which is defined as the ratio of the extrudate

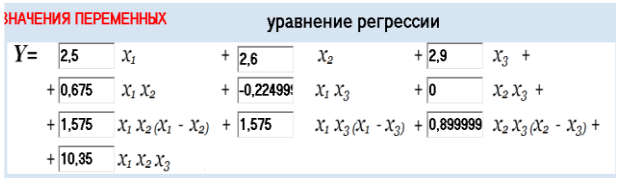


Fig. 1. Regression equations for the simplex-lattice Scheffe plan program

diameter to the diameter of the output hole of the extruder matrix.

Mathematical processing of measurements was performed using MS Offiece Excel 2010 computer programs based on Scheffe lattice plans. When studying the properties of mixes, we proposed formulations that depend only on the ratio of components, the factor space is a (q – 1)-dimensional simplex. A special feature of planning experiments for mixtures is the condition (1):

$$\sum_{i=1}^{q} x_i = 1 \qquad (1)$$

where *xi* — concentration of the component;

q — number of the components.

The above process of optimizing the formulation composition of a gluten-free mix according to the specified criteria was carried out using the program of simplex-lattice Scheffe plan for processing experimental data. This mathematical processing is also used in the development of formulations for the ratio of ingredients of various confectionery products.

According to the compiled planning matrix, it is necessary to study the qualitative characteristics of the studied raw materials. Then the program outputs the results of multidimensional optimization with automatic calculation of the absolute value of the parameters using the regression equation. The regression equations are shown in **Fig. 1**.

Statistical Processing of Materials and Methods for Studying the Carbohydrate Composition to Determine the Nutritional Value of Products

The carbohydrate composition of the obtained gluten-free confectionery products was studied according to GOST 25832-89 - GOST 25832-89 - Bakery dietary products. Based on the results obtained, the nutritional value of gluten-free products was established.

Statistical processing of the experiments was carried out in accordance with the composite plan of the three-factor experiment according to the program of the IBM personal computer with various characteristics (with a clock frequency of 233 MHz and higher). Programming language Object Pascal, Borland Delphi 7 environment. IBM - compatible PCs with a clock frequency of 233 MHz or higher. The program is supported by the operating system - Microsoft Windows XP, 7, 8.10.

RESULTS

Preparation of raw Material and Dry Mix Extrusion Technology

Extrusion technology is the most common method for producing dry mixes that have a porous macrostructure. It is necessary to set the temperature regime for obtaining extrusion products from various gluten-free crops.

The qualitative characteristics of the selected gluten-free crops for the research were studied, which described uniformity, uniform texture, taste and color, as well as smell. Gluten-free crops of corn and rice grains were selected for the study, which were refined according to the climatic conditions of the Republic of Kazakhstan.

Gelation and Gelatinization of dry Gluten-Free Mixes

Before working out the temperature regime in three parameters, it is necessary to consider the modes of gelattion and gelatinization. The degree of gelatinization was studied on DSC equipment. We studied the content of lipids, as their content affects gelatinization. The results showed that grain starches with a higher lipid content have a lower viscosity of gelation and the appearance of gelatinization. Based on the data, the researchers hypothesized a correlation between the results of lipid content and an increase in gelatinization temperature. This hypothesis is consistent with the literature that reports that lipids significantly increase the gelatinization temperature, slowing the swelling of granules and preventing leaching of amylose during gelatinization (Emelina 2009).

Study of the Morphology of Developed Dry Mixes

Further, in order to determine the effect of the double-screw extruder modes on the microstructure features of rice and millet flour extrudates, we studied their microscopic structures. Milled extrudates and milled cereals from rice and corn were taken for analysis. Microstructure analysis was performed using a SEM (scanning electron microscope).

Starch melting involves physical, chemical, and biochemical changes on the surface of the contact phases. SEM plays an important role in understanding the granular structure of starches. SEM was used to detect structural changes caused by various impacts (Litvyak 2013).

Mathematical Modeling and Optimization of the Ratio of Gluten-Free Mix for the Production of Confectionery Products

Therefore, the formulation ratio of the gluten-free mix has been determined, which provides a high organoleptic indicator and structural-mechanical properties for the model test systems produced on its basis. The above process of optimizing the formulation composition of a gluten-free mix according to the specified criteria was carried out using the simplex-lattice Scheffe plan program for processing experimental data.

Table 2. Thermodynamic parameters of melting gluten-free flour starch

Name of flour	Lipids, %	Ti, ^{0}C	Tm, ^{0}C	Tf, ^{0}C	Tf-Ti (^{0}C)	ΔH (J/g)
Rice	1.2	59.66	91.90	110.43	50.77	-57.08
Corn	4.4	114.64	131.17	147.53	32.89	-63.50

Obtaining Gluten-Free Confectionery Products according to the Recommended Composition of Dry Mixes

From the obtained data of the recommended composition, to check and clarify the area of optimal values of the studied factors, a trial laboratory baking of the cake was carried out, during which a complex indicator of the quality of the cake was determined. When optimizing, the program produces the minimum and maximum composition, but we choose the composition based on the results of quality indicators.

Calculation of the Energy and Nutritional Value of Gluten-Free Products

Carbohydrates occupy a central place in metabolism. Although carbohydrates cannot be formally attributed to the irreplaceable factors of nutrition (carbohydrates can be synthesized in the human body), they make up a significant share in the daily diet - 250-500 g, or 50-60% of the caloric content of food and more than half of the daily energy expenditure. Most of the glucose is used by the body for energy production (Stoin et al. 2018).

DISCUSSION

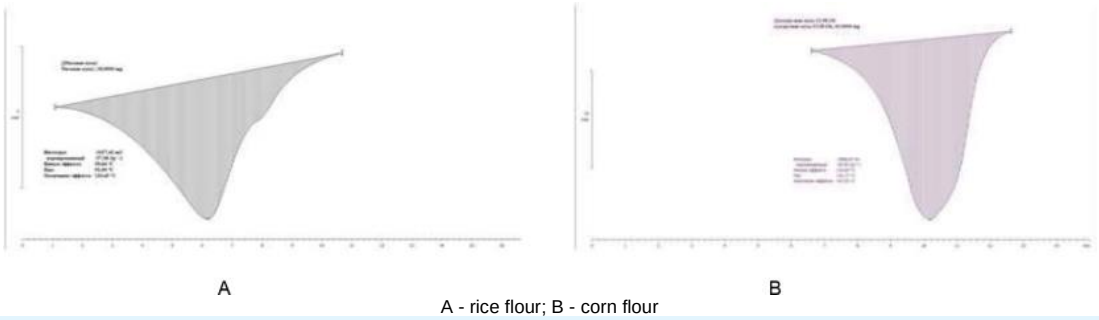
Preparation for Carrying out the Extrusion of Dry Mixes

We conducted research to determine the initial temperature of extrusion based on the determination of the melting parameters of starches that are part of grain crops by differential scanning calorimetry (DSC). The cylinder temperature is controlled by a special system. For technological thermal methods of processing starch-containing raw materials, including the production of extrusion products, the characteristics of starch –the temperature and heat (enthalpy) of gelation - are of great importance.

Gelation and Gelatinization of Dry Mixtures

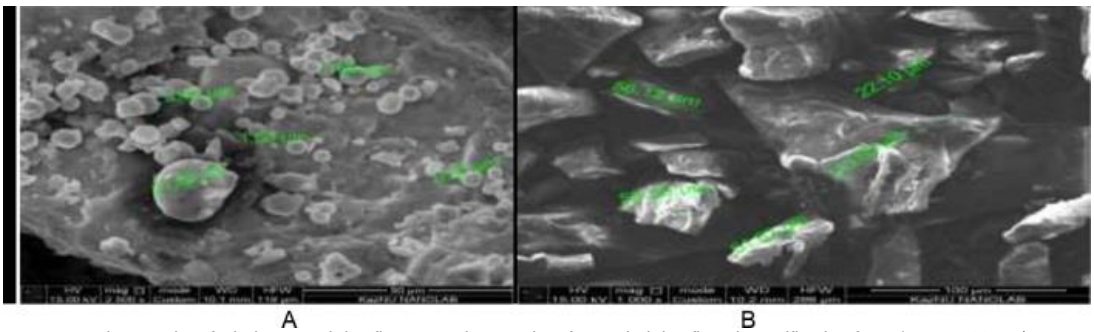
The degree of gelatinization and the temperature of transition (T_i – the initial temperature, T_m - the maximum temperature and T_f - the final temperature) and melting enthalpy (ΔHg), studied various types of flour are presented in **Table 2** and thermodynamic parameters of the melting gluten-free flour is shown in **Fig. 2**.

Table 2 shows that the melting temperatures of starches vary within different limits for the studied crops. This is due to the fact that grains of different origin have



A - rice flour; B - corn flour

Fig. 2. Thermodynamic parameters of melting gluten-free flour



A - Micrographs of whole-ground rice flour, B - Micrographs of extruded rice flour (magnification from 1μm to 100 μm);

Fig. 3. Scanning electronic micrographs of whole-ground and extruded rice flour

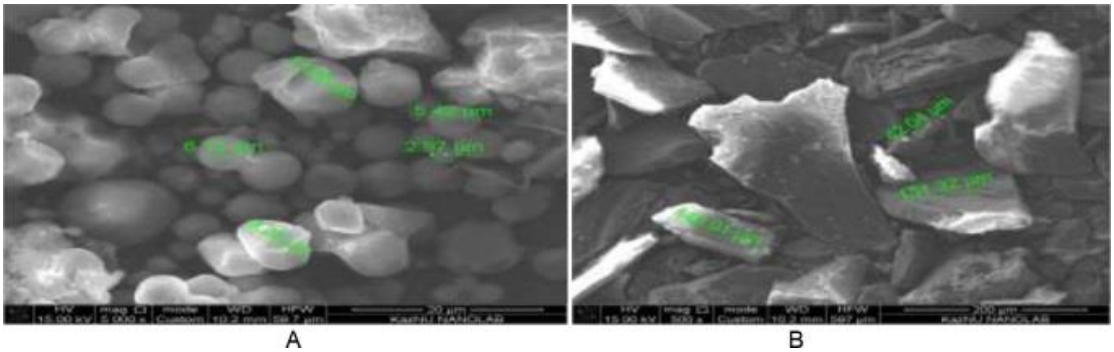
different structures and, accordingly, behave differently in the processes of heating and cooling (**Fig. 1**). As a result of determining the thermodynamic parameters of melting, taking into account the melting of the amylose-lipid complex, the temperature limits of the extrusion of gluten-free flour are tentatively determined. Extrusion was performed on a double-screw extruder according to certain parameters, based on the determination of thermodynamic parameters of grain starch (Arufe et al. 2015, Gat and Ananthanarayan 2015).

We obtained separately extrusion and non-extrusion grinding of cereals in order to obtain flour dry mixes for the development of confectionery products. To calculate and optimize the process, 10 experiments were performed, according to the planning matrix (Botbayeva 2019). To set the parameters for the extrusion of whole-ground corn flour in order to develop the ratio of dry mixes. When studying humidity, the extrusion temperature in the input zone in the extruder is 120^0C and the extrusion temperature in the plasticization and compression zone is 145^0C and the extrusion temperature in the output zone was 165.0^0C for corn and with these parameters, the exposure coefficient of the resulting product is very high, which reached 10 coefficient. For the humidity of the finished product, the best indicator is 6.7% for rice, then the optimization calculation parameters are 60.7^0C inlet temperature, 80^0C inside the cylinder temperature and 118.5^0C outlet temperature of the extruder.

Study of the Morphology of Developed Dry Mixes

Most of the structural changes under physical influences occur in the relatively less organized central region of the starch granule core. From **Fig. 2**, which are made in the SEM (scanning electron microscope), it can be seen the external structure of individual starch granules of crops and the structural difference between the extrusion and non-extrusion flour of gluten-free crops is noticeable. Different morphological patterns were observed before and after extrusion. Micrographs of flour from both crops (rice and corn) are polygonal and rounded. The granular surface of rice and corn flour is smooth, without any cracks in the case of natural grain flour, while the granules after extruding lost their individuality and smoothness. SEM illustrates that when extruded under different conditions, the extruded modes (temperature, humidity, and screw rotation speed) differ in shape from the sizes of non-extruded grain flour. In the extruded flour, various grooves and cracks were visible on the outer surface of the granules. The discontinuous structure of the extruded flour is probably associated with a greater degree of gelatinization at a higher temperature, which caused a greater unevenness of the particle structure.

From **Figs. 3** and **4**, it can be seen that micrographs demonstrate heterogeneity of the morphological structure after extrusion: within a single sample, the particles differ significantly from each other both in shape and size. Studies show that the processing of thermal moisture reduces the relative crystallinity and



A - Micrographs of whole-ground corn flour, B - Micrographs of extruded corn flour (magnification from 1 μm to 200 μm)

Fig. 4. Scanning electronic micrographs of whole-ground and extruded corn flour

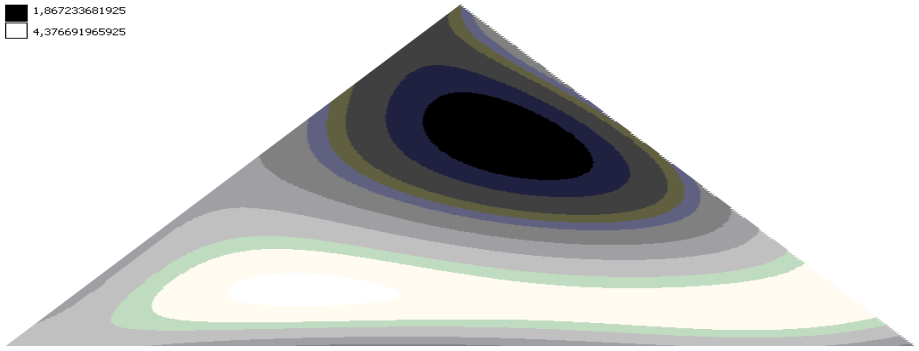


Fig. 5. Graph of the three-component mix simplex-lattice cake

increases the humidity of crops (Stepanov et al. 2002) the formation of cracks on the surface of the extrusion flour is observed. Since the extrusion process causes a number of visible changes in the structure of rice and corn flour. For example, high internal pressure and temperature limits in the extruder tunnel create decompression and account for water evaporation at the product exit, leads to changes in the microparticles of extrudates, as well as at gelatinization, plasticization is destroyed, intramolecular bonds of molecules and their structure forms a polyhedron shape with some surface marks, this is likely due to the impact of various processes during extrusion.

Due to modified microstructures, extrudates have high solubility and water absorption capacity (Giuberti et al. 2018, Navarro-Cortez et al. 2014, Pichkur et al. 2015, Reznichenko 2011, Sharma et al. 2015, St. Petersburg Trade and Economic Institute 2014).

Thus, the extrusion process affects the morphology of cereals, since extrusion destroys their granular structure and creates a bond between starch and free lipids. The formation of these complexes it is possible to obtain high-quality products for agriculture in the food industry.

Mathematical Modeling and Optimization of the Ratio of Gluten-Free Mixture for the Production of Confectionery Products

Mathematical planning of the experiment was carried out in accordance with the composite plan of the three-factor experiment. For the optimization process, the level of addition of raw ingredients taken as a percentage of the total weight of flour was determined (**Table 1** in the methodology section). To carry out the process of modeling and optimizing the formulation composition of a gluten-free mixture, flour compositions were used as the main raw materials and objects of research, including rice, corn and corn extruded flour in their composition.

The implementation and planning of the study on the experiment matrix depends on the change in compositions and on the level of addition of flour components, according to the compiled matrix, the number of experiments is 15 samples. The control samples are a cake made of wheat flour of the 1st grade and gluten-free flour from the Italian company “Schar”. In all samples, qualitative characteristics were studied: organoleptic and physico-chemical parameters in accordance with regulatory documents.

As a result of determining the quality indicators of the samples, the data obtained were added into the program for the simplex-lattice Scheffe plan. When solving the problem of obtaining the optimal composition of the mix formulations, the simplex method was used, which allows to obtain the exact ratio of each component of the mixes that meet the requirements of regulatory documents in terms of quality characteristics. The Y_6 data for the cake in the simplex-lattice Scheffe plan program is shown in **Fig. 5**.

Fig. 6. Cake prepared according to the recommended composition of mathematical planning

When adding these qualitative indicators into the computer, the program of simplex-lattice Scheffe plan automatically calculates 160 000 experiments and displays the most optimal version of the experiment, with maximum and minimum values for each Y values. As can be seen from **Fig. 5**, the data obtained from organoleptic indicators can be further added into other results obtained by qualitative characteristics, then the calculation and the program will minimize the number of experiments without loss of information. Interpretation of the regression equation is performed after statistical processing obtained using the mathematical modeling program. The properties of the mix were studied at the specified points of the simplex lattice, in which the vertices correspond to pure substances, the sides to double mixes, and the points inside the simplex to triple mixes.

According to organoleptic indicators, the program showed optimization of the recommended composition of the maximum and minimum ratio of components. The recommended maximum composition is X_1 – 24,25%, X_2 – 59,5%, X_3 – 16,25%. Recommended minimum composition X_1 – 24,75%, X_2 – 14,5%, X_3 – 60,75%. In this case, the maximum value for Y_6 corresponds to the standards.

Obtaining Gluten-Free Confectionery Products based on the Recommended Composition of Dry Mixes and Studying their Organoleptic Properties

Obtaining gluten-free confectionery products according to the recommended composition of dry mixes. As can be seen from **Fig. 6**, the cake meets all regulated quality requirements.

Also, the developed mix can be used to make waffles and other confectionery products, since in the future the optimized composition for dry mixes will be offered as a universal gluten-free flour for celiac patients.

We have studied ogranoleptic indicators and conducted sensory analyses on methods (Giuberti et al. 2018). Organoleptic data of gluten-free cakes, which are prepared on a mathematically optimized ratio of mixes of rice corn and corn extrusion, flour in the ratio of X_1 – 24.25%, X_2 – 59.5%, X_3 – 16.25%, respectively, scores a high score (4.9 points).

Thus, we have proposed the ratio of dry mixes from rice and corn, and extruded corn mixes, which can be developed and offered for the production of domestic products from gluten-free raw materials.

Table 3. Influence of added components on the chemical composition and energy value of products

Nutrients	Cakes		
	GF cake from the mix and with starch	GF cake from the mix	GF cake from the mix with pectin
Carbohydrates, %	54.16	71.3	65.8
Fats, %	15.12	11.16	15.19
Proteins, %	6.0	6.1	5.8
Energy value, kcal	363.18	392.21	406.66

Calculation of the Energy and Nutritional Value of Gluten-Free Products

Carbohydrates occupy a central place in metabolism. Although carbohydrates are not formally considered essential nutrition factors (carbohydrates can be synthesized in the human body), they make up a significant proportion of the daily diet — 250-500 g, or 50-60% of the caloric content of food and more than half of the daily energy consumption.

The chemical composition was calculated and the data are summarized in **Table 3**. The table shows the results of nutritional values with the addition of starch and pectin enrichment (Al–Taai 2016).

As can be seen from **Table 3**, it can be concluded that the energy value increases with the addition of pectin. We have established the mass fraction of carbohydrates in gluten-free confectionery products. In the course of experiments, it was revealed that of the three samples of cakes, the highest energy value has cakes with the addition of pectin, which is 406.66 kcal.

Thus, we can conclude that with the various additives, it is possible to increase the nutritional and energy value of gluten-free confectionery products. All confectionery products and extrusion mixes were tested for gluten content using the Ridascreen Gliadin AOAC Research Institute Performance Tested Method 12060 on the Rider Multiscan FC IFA analyzer. For comparison, wheat flour of the highest grade with a gluten content of 28.8% was used.

CONCLUSION

Thus, we selected gluten-free crops of corn and rice grains that are refined according to the climatic conditions of our country. Based on the determination of thermodynamic melting parameters, the optimal mode of

extrusion was selected for rice flour (120^0C; 145^0C; 165.0^0C) and corn flour (60.7^0C, 80^0C, 118.5^0C). Micrographs taken under a scanning electron microscope show the destruction of the granular structure of crops, which creates a link between starch and free lipids in them. The ratios of dry mixes for obtaining gluten-free products based on mathematical modeling have been developed. Based on the study of quality characteristics, the ratios of dry mixes for cakes were worked out (rice flour - X_1-24.25%, corn flour - X_2-59.5%, extrusion flour - X_3-16.25%).

The nutritional and energy value of gluten-free products is calculated. The experiments revealed that of the three samples of cakes, the highest energy value has cakes with pectin, which is 406,66 kcal. As a result of studying the gluten content in confectionery products and dry mixes from grain crops, it was found that the gluten content does not exceed 20 mg per 1 kg of product.

We see prospects for further research of the problem in expanding the range of gluten-free products, improving production technology, and increasing the demand for this segment.

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