The nutritional value of food is one of the most important factors that determine the health of the population. In the macaroni market, dietary and functional products, fortified macaroni products and products of high nutritional value occupy a small segment that does not exceed 1 %. In this regard, the development of an assortment of pasta with increased nutritional value, with a directionally changed chemical composition, is relevant. In the pasta industry, an increase in the nutritional and biological value of products is achieved through the introduction of non-traditional types of raw materials and special food additives into the recipe. To reduce the deteriorating effect of corn and amaranth flour on the pasta properties of flour from durum wheat, ionized water was used with a concentration of ions of 1,000, 2,000, 3,000, 4,000 units/cm³ and ozone of 2 mg/l. It was found that ionized water has a positive effect on the properties of gluten and the quality of pasta with the addition of corn and amaranth flour. It was determined that the best quality of pasta is achieved when using ionized water with an ion concentration of 3,000 units/cm³ and ozone 2 mg/l and at dosages of amaranth flour 17.5 %, corn flour – 20 % to pasta flour. Summing up the results of the experimental study, the amount of prescription components for the production of pasta with high nutritional and biological value was optimized

Keywords: macaroni, ionized water, corn, amaranth, flour, additives, powder, gluten, dough, dry matter

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DEVELOPMENT OF TECHNOLOGY FOR MACARONI PRODUCTS BASED ON FLOUR OF GRAIN CROPS AND ION-ZONED WATER

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1. Introduction

One of the main objectives of state policy in the field of nutrition is the production of food enriched with essential ingredients, special baby food, functionally oriented products, dietary (therapeutic and prophylactic) foods and public health, prevention of diseases caused by incomplete and unbalanced nutrition – development of biologically active additives to food.

Worldwide, a small part of pasta is produced using additional raw materials – additives. Additives are divided into enrichments and spices. Enriched additives increase the nutritional value of products, as well as often change their color and odor.

In macaroni production, eggs and egg products (egg powder, melange), dairy products (milk powder, cottage cheese, milk powder), vegetable products (concentrated tomato products, tomato powder, spinach puree, sorrel and their mixtures, natural carrots and beet juices), some vitamins and non-traditional raw materials (products of wheat processing and seed crops, tubers, as well as intermediates processed from them) are often used as enrichment additives [1, 2].

In the pasta industry, the problem of increasing the nutritional value of pasta products, creating a group of products with a changed chemical composition and functional orientation is mainly solved by using new non-traditional types of raw materials as a recipe component.

To obtain biologically complete pasta, it is recommended to use amaranth seeds, which contain up to 20 % easily digestible protein with a balanced amino acid content. The content of essential amino acids in amaranth protein, expressed by lysine, isoleucine and phenylalanine tyrosine, is 28–35 %. In addition, when added to wheat protein, amaranth seed protein is able to form additional hydrogen absorption and other bonds, strengthening it.

Recently, large-scale research has been carried out on the use of ozonated and ionized water in the production of food, including bread and pasta. The bactericidal and redox properties of ozonized water contribute to an increase in environmental cleanliness, strengthening of the spatial structure of gluten proteins, which improve baking properties.

In connection with the above, it is relevant to conduct a comprehensive study aimed at developing the technology of pasta with high nutritional value, which includes the study of the chemical composition of pasta products, rheological properties of pasta dough, the influence of technological factors on the quality of pasta products, made from soft and hard wheat flour using powdered additives.

2. Literature review and problem statement

The need to increase the nutritional value of pasta is due to the low protein content of high-grade wheat flour, the main raw material for their preparation, as well as a lack of essential amino acids, low content of vitamins, especially fat-soluble and minerals.

Currently, there is a growing consumer interest in pasta made from non-traditional raw materials, including specially ground corn flour. The peculiarity of pasta made from wheat flour is that they contain gluten, which has a negative effect on the stomach. In this case, corn flour is an effective additive to products due to all the beneficial properties of the raw material.

Corn composition is very rich in mono- and disaccharides, unsaturated fatty acids, water, starch. It also contains vitamins B, E, PP, C, niacin and choline. In addition, the iron content of corn products is very high [3].

The caloric content of corn flour is 331 kcal, and fats, proteins and carbohydrates accordingly (in grams per 100 g of product): 1.5; 7.2; 72.1. Corn flour also contains: 2.1 g of dietary fiber; 292 mg of potassium; 104 mg of magnesium; 301 mg of phosphorus; 46 mg of calcium; 4.1 mg of iron; 4 mg of zinc; 0.3 mg of manganese; 1.03 mg of copper; 2.4 mg of cobalt; provitamin A up to 0.32 mg; 0.38 mg of vitamin B1; 0.14 mg of vitamin B2; 2.10 mg of vitamin PP; up to 10 mg of vitamin E. It helps to restore intestinal and gastric function, the formation of internal microflora [4, 5].

We should also not forget about the economic aspect, because corn flour is a local and very cheap raw material for pasta compared to flour from durum wheat. Therefore, the preparation of pasta using corn flour is optimal and economically justified.

It was found that the composition of pasta with the addition of 20 % lean corn germ consists of 14.2 % protein [6].

The use of corn flour up to 10 % leads to the production of pasta with a pleasant yellow hue with a high content of essential amino acids. With an increase in the amount of corn, the content of the yellow component of the color of pasta products decreases, and the physico-chemical properties of pasta products have changed slightly compared to observations [7, 8].

For the production of biologically full-value pasta, the use of amaranth seeds, which contain up to 20 % easily digestible protein with a balanced amino acid composition, is advanced. The proportion of essential amino acids in amaranth protein expressed in lysine, isoleucine and phenylalanine tyrosine is 28–35 %. In addition, when added to wheat protein, amaranth seed protein additionally absorbs hydrogen and is able to form other bonds, strengthening it [9–12].

Improving the nutritional value of pasta with the introduction of additives is often accompanied by a deterioration in the quality of products. For example, an increase in the dosage of amaranth products leads to a deterioration of pasta quality, including an undesirable darkening of pasta color [13].

The possibility of using light-colored amaranth seeds of the Shuntuk A. cruenthus variety – whole ground flour from seeds – together with beta carotene and the Prima-yantar macaroni improver in macaroni production has been found. Adding 5–7 % to the mass of flour protein fortifiers helps to increase the elasticity of pasta dough, improve the conditions of its pressing. However, a further increase in the dosage leads to a deterioration of the cooking and structural and mechanical properties of finished products.

There is a known method for the production of pasta, which includes kneading dough from wheat flour, food processing additives and water with a corrective additive. As a food processing additive, products of processing amaranth of grain and vegetable varieties are used, and as a corrective additive, phosphoric acid salts are used in an amount of 0.03–1.00 % by weight of flour. The disadvantage of this method is the introduction of chemicals – phosphoric acid salts, which reduce the biological value of the product.

The paper developed a technology for cooking noodles from amaranth flour. The conducted research confirms the feasibility of carrying out work aimed at increasing the content of amaranth flour to increase the biological value of pasta, while not compromising the quality of finished products [14].

The works describe their nutritional and biological value based on the analysis of the chemical composition of corn, chickpea, barley, and lentil flour. Flour from cereals and legumes is rich in proteins, essential amino acids, vitamins, micro- and macronutrients. The possibility of using this flour in the production of pasta is studied. The inclusion of a large amount of these additives in the pasta recipe is one of the areas that still need to be studied [15].

In addition to reducing the shortage of essential components in finished products, corn, chickpeas, amaranth and processed products can affect the course of technological processes. To justify the use of corn, chickpeas, amaranth flour in the production of pasta due to the introduction of additional substances into the dough, it is necessary to thoroughly master the technological parameters and modes of pressing the dough, determine its rheological properties, relationships, moisture content of the dough and speed of its compression, organoleptic and physico-chemical parameters of the products.

In this regard, to create products with high nutritional value, a comprehensive study of pasta production technology should be conducted, aimed at adjusting the parameters and modes of pasta dough preparation.

3. The aim and objectives of the study

The aim of the study was to determine the effect of vegetable powder additives and ion-ozoned water used in pasta production on the quality of semi-finished and finished products and to optimize the recipe components.

To achieve this aim, the following objectives are accomplished:

– to investigate the effect of fine additives from vegetable raw materials on the properties of gluten;

– to investigate the effect of fine additives from vegetable raw materials on the quality of pasta;

– to study the effect of ion-zoned water on the macaroni properties of macaroni grits, justify optimal dosages;

– to justify the use of additives-fortifiers in the production of pasta.

4. Materials and methods of research

The study examined the effect of pulverized additives from vegetable raw materials on the adhesive properties, rheological properties of pasta dough and quality of pasta, as well as the effect of ionizing water on the properties of pasta flour.

General physicochemical and organoleptic methods, as well as special methods, were used in the study of the properties of raw materials, semi-finished products and quality of finished products.

The effect of ionized water on the quality of gluten and the product of durum wheat was determined [16].

According to GOST 27839-2013, the composition of raw gluten was determined by the standard method and calculated as a percentage by weight of flour. The quality of the adhesive was determined on the MDG-1 device and expressed in units of the device [17, 18].

Methods of organoleptic and physicochemical research carried out in accordance with ST RK GOST R 51865-2010 were used to assess the quality of pasta [19].

The objects of research are high-grade wheat flour from Irtysh 97 wheat varieties and pasta flour (cereals) from Kargala 69 wheat varieties; of these, 237 grains of corn, A cruentus amaranth and corn, amaranth flour obtained by grinding; drinking water (GOST R 51232-98) and ionized water.

Ionozonized water was obtained by treating drinking water in a hydroozonator installation developed by ATU scientists and immediately used to prepare the dough.

To increase the quality of pasta, the ion concentration in the work to increase the amount of corn and amaranth flour added to the recipe is 1,000 units/cm^3, 2,000 units/cm^3, 3,000 units/cm^3, 4,000 units/cm^3.

Ozone concentration was 2 mg/l of water, which was previously considered optimal by researchers of the Almaty Technological University [20].

Pasta flour (cereals), ground corn and amaranth flours were used for experimental research 5; 7.5; 10; 12.5; 15; 17.5. The effect of 20 % on the adhesive properties was determined. The results of the study showed that the adhesive properties of corn and amaranth flour deteriorate with the increasing amount, which is observed with a decrease in the weight and quality of raw gluten.

5. Results of the study on the optimization of recipe components in the production of pasta

5. 1. Amount and quality of gluten added

When using ionized water of different concentrations, the amount of gluten was at the same level as when using ordinary drinking water, the change was very small, and the quality of gluten in MDG has improved, there is a significant increase in the strength characteristics of gluten (Table 1).

Table 1

Effect of additives on the adhesive properties of pasta flour

Indicators	Control	Composition of additives, %						
		5	7,5	10	12,5	15	17,5	20
with corn flour								
Amount of gluten, %	37.6	37.0	36.4	35.8	35.1	34.6	34.0	33.0
Adhesive properties, MDG, instrument unit	90	92	93	95	101	115	118	120
with amaranth flour								
Amount of gluten, %	37.6	37.3	36.4	35.7	34.7	34.0	33.8	32.3
Adhesive properties, MDG, instrument unit	90	93	95	101	110	117	121	123
with corn flour and ionic water, concentration 3000 units/cm^3								
Amount of gluten, %	37.6	37.5	36.9	36	36.2	35.5	35	33.6
Adhesive properties, MDG, instrument unit	90	80	82	83	86	95	100	102
with amaranth flour and ionized water, ion concentration 3000 units/cm^3, ozone concentration 2 mg/l.								
Amount of gluten, %	37.6	37.5	36.7	36.2	35.4	34.5	34.3	33.2
Adhesive properties, MDG, instrument unit	90	83	86	88	90	98	101	108

Table 1 shows that very good results were obtained with the use of ionizing water with an ozone concentration of 2 mg/l and an ion concentration of 3,000 units/cm^3. At the same time, it was found that the quality of gluten, including up to 20 % by weight of pasta flour, corn flour, 17.5 % amaranth flour, is better than ionized anhydrous samples.

5. 2. Quality indicators of macaroni products with additives

5 powdered amaranth and corn flours were used in the study; 7.5; 10; 12.5; 15; 17.5. The effect of ionized water on the quality of pasta, consisting of 20 %, was studied. The research used pasta flour with qualitative indicators and ionic water with a concentration of 1,000, 2,000, 3,000, 4,000 units/cm^3. A sample of pasta made from unadulterated pasta flour was taken as a control. The results of the study of samples using ionized water with an ion concentration of 3,000 units/cm^3, selected as good quality, are given in Table 2.

The use of ionized water in the kneading of pasta dough from ground amaranth and corn flour improved the organoleptic, physicochemical, cooking properties of pasta, while the ion concentration was higher when using ionized water with 3,000 units/cm^3.

As shown in Table 2, the weight gain of products with the use of ionized water with increasing the content of ground impurities is from 1.83 to 1.89 when using corn flour; in amaranth flour from 1.83 to 1.92, while the control is 1.83.

One of the main quality indicators of pasta products is the amount of dry matter released into the water during cooking, which is shown in Fig. 1 for the preparation of samples with ionized water with the addition of corn flour. The pattern of change in the samples with amaranth flour is similar. From the figure, the low content of dry matter during cooking with the addition of up to 20 % of corn flour is explained by the improved properties of the dough with the addition of ionized water and an increase in the strength of the finished product.

Table 2

Effect of ionizing water on the quality of pasta and macaroni pasta

Indicators	Control	Corn flour content, %						
		5	7.5	10	12.5	15	17.5	20
Organoleptic characteristics:								
surface condition	Smooth	smooth						
– shape	characteristic of a given species	characteristic of itself						
– color	amber-yellow	amber-yellow						
– taste	characteristic of the product, tasteless	characteristic of the product, tasteless						
– smell	characteristic of the product	character-istic of the product		characteristic of the prod-uct, the smell of corn flour is barely noticeable				the smell of corn flour
Physicochemical parameters:								
– moisture, %	12.7	12.6	12.7	12.7	12.8	12.8	12.9	12.9
– acidity, deg	2.5	2.6	2.6	2.8	2.8	3.2	3.4	3.6
cooking prop-erties: – preservation of shape	unchanged, not sticky	unchanged, not sticky						
– product weight gain (Km)	1.83	1.83	1.83	1.84	1.85	1.86	1.86	1.87
– amount of pulp transferred to boiled water, %	6.25	5.55	5.62	5.8	6.0	6.28	6.37	6.63
– boiled water state	Transparent	transparent						transpar-ent
– cooking time until ready, min	10	10	10	10	10	10	10	10

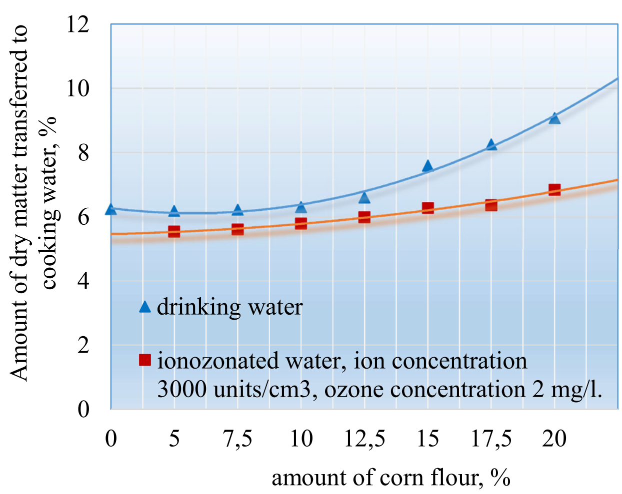


Fig. 1. Mass of dry matter passed into the cooking water when cooking pasta with the addition of corn flour

5. 3. Optimization of the amount of ionized water and vegetable additives added to the recipe

Methods of mathematical processing of experimental data. Mathematical models that allow increasing the nutritional and biological value of pasta were implemented on the basis of experimental data, which allowed studying the indicators of its quality in mathematical models.

During the experiment, the physical properties and quality characteristics of corn and amaranth flours from domestic cereals will be studied, which will increase the nutritional and biological value of pasta.

To determine the patterns of influence of corn and amaranth flours on the physical and chemical quality of pasta, the pasta properties of pasta and baked wheat flour with the addition of ground additives were evaluated.

The effect of ionized water on the properties of pasta products with the addition of ground corn flour to pasta flour, the quality of pasta products were studied here.

The purpose of planning the experiment is to determine optimal process conditions, to ensure a high level of physical and chemical characteristics of pasta.

If we denote the optimized characteristics (flour additives, parameters of the chemical process in it, etc.), then the extremum of the following function is determined:

$$y = f(x_1, x_2, ..., x_n). \quad (1)$$

Factors (experimental conditions: impurity content, %, ion concentration, etc.). Factors are considered independent variables. Each definition has only one value of the function.

The above (1) is a multi-parameter linear function:

$$y = a + b_1x_1 + b_2x_2 +, ..., + b_nx_n. \quad (2)$$

The first experiments were performed on several different values of the given factor x_i, and then the results were obtained using the least squares method.

The function (2) is obtained. The values of the coefficients b_i in the equation indicate which factor has the greatest effect on the achievement of the maximum (or minimum) of the function (y). In this regard, the experiment was continued, and several series of experiments were performed until the optimum (extremum) was reached.

Equation (2) determines only the direction of the function to the extremum, and the point where the maximum (minimum) is located cannot be found. For this reason, second-order or higher-order polynomials are used:

$$y = a + b_1x_1 + b_2x_2 +, ..., + b_nx_n + \\ + b_{11}x_1^2 + b_{12}x_{12} +, ..., b_{nm}x_n. \quad (3)$$

It is more difficult to apply the least squares method to solve the equation (1), but the result is accurate. In this work, the STATISTICA and Excel application packages [21, 22] were used to solve equations (2), (3) by the least squares method.

In order to process the information obtained at the beginning of the experiment, it is necessary to determine the change in the values of the function (Y), in the values of the independent variables (Xi). From this we can see the direction of the first experiment.

To do this, of course, the objects of research are different physical (for example, the composition of impurities, %, ion concentration, etc.), chemical, technical and economic (for example, the cost of the required reagents, the parameters of the process conditions, etc.) were determined in advance.

In the initial experiment, two values of the factor were obtained at the basic level, and at the upper and lower levels more or less than two equal values. In this case, there were two levels for each factor, and the total number of experiments was 2^n.

And then there is the plan matrix. As a result, a 3-factor experiment was identified, the total number of which was 2^2. The values of the variables are not included in the plan matrix. Such an experiment is called a complete experiment. The matrix here consists of two columns and twenty-seven rows.

We determined the amount of ground flour (additives), the properties of ground flour and gluten, MDG, instrument unit, amount of gluten, %, amount of dry matter released into the water during cooking, %, weight gain of the baked product. As a result, when using ionized water, pasta with 20 % corn flour and 17.5 % amaranth flour by weight of pasta flour was obtained.

In the first stage, when using ionized water as an experiment, pasta products with 20 % corn flour added to the pasta flour were obtained, and the following indicators and factors were obtained by the proposed method as an optimization parameter:

– Y_1 – adhesive properties, MDG, instrument unit;
– Y_2 – amount of gluten, %;
– Y_3 – amount of dry matter released into the water during cooking, %;
– Y_4 – product weight gain.

The following quality indicators were taken as factors:

– X_1 – composition of impurities, %;
– X_2 – concentration of ionozone, units/cm^3.

The following methods of economics were used in the processing of experimental data and their qualitative assessment: statistical distribution characteristics, variance, correlation and regression analysis. The scope of application of statistical modeling methods was tested by the following statistical criteria: verification of normal distribution – the criterion of agreement, the criterion of homogeneity.

The following distribution characteristics were determined for each of the proposed efficiency parameters: arithmetic mean (M), standard error (m), median (med), mode (mod), standard deviation (s), variance (s^2), excess (A), asymmetry (E), variation rate (R), minimum (min), maximum (max). The calculated values of these statistics are given in Table 3.

These data are the necessary conditions for correlation and regression analysis.

As can be seen from Table 3, the standard error of the experiment deviates from its mean value Y_3, the absolute value of the others in most cases does not exceed 1 %. In this case, the values of excess and asymmetry in all experimental cases, it is clear that the absolute value of the others Y_3 does not exceed 1.

Table 3

Statistical indicators of quality indicators of 20 % corn flour (with ionized water) in pasta flour

Statistical indicators	Quality indicators of pasta flour			
	Y_1	Y_2	Y_3	Y_4
Arithmetic mean	101.33	34.41	25.25	1.87
Standard error	1.55	0.30	18.56	0.01
Median	99.00	34.60	6.40	1.86
Mode	93.00	37.00	6.28	1.85
Standard deviation	9.29	1.79	111.39	0.03
Variance	86.29	3.19	12407.46	0.00
Excess	–1.00	–1.29	36.00	0.14
Asymmetry	0.56	–0.14	6.00	0.91
Variation rate	30.00	5.20	669.38	0.12
Minimum	90.00	31.80	5.62	1.83
Maximum	120.00	37.00	675.00	1.95

Fig. 2 shows a diagram of uniform distribution density $N(\mu, \sigma)$ with the qualitative characteristics of pasta with the addition of 20 % corn flour to pasta flour with the use of ionized water. It is determined by the function (4).

$$\varphi(x) = N(\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right], \quad (4)$$

where, μ is the arithmetic mean, σ is the standard deviation.

The obtained empirical distribution, as shown in the figure, is similar to the uniform distribution curve. This is the sum of many independent factors that affect the quality of the adhesive under study.

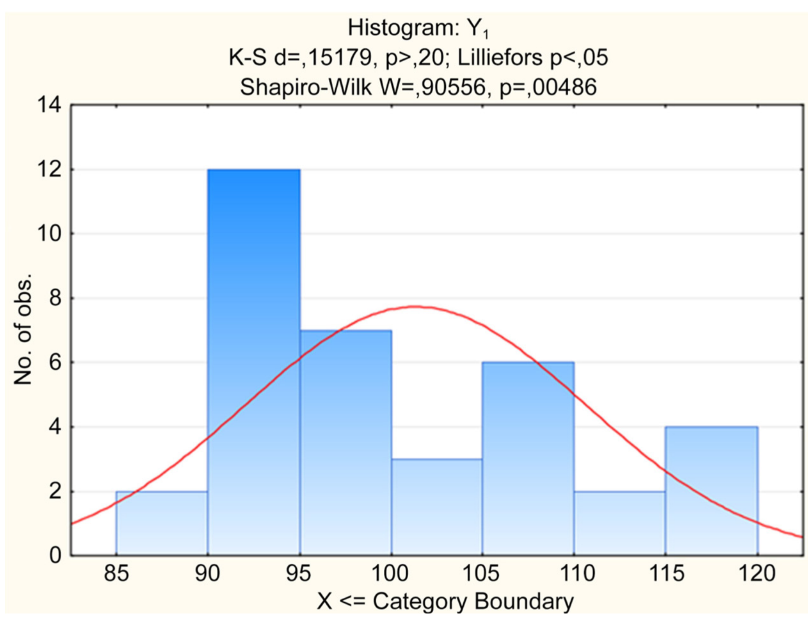


Fig. 2. Empirical distribution of adhesive properties, MDG, instrument unit, quality indicators

Kolmogorov-Smirnov (K-S) – *D*, Lilliefors and Shapiro-Wilk – *W* criteria were used to check the uniformity of the data distributions. These strict and useful criteria were calculated using the STATISTICA package. Where Kolmogorov-Smirnov $-D=0.15$ is equal to the confidence interval $p=0.2$, and Shapiro-Wilk $-W=0.98$ is equal to the confidence interval $p=0.9$.

Correlation analysis of the quality indicators of pasta with the addition of 20 % corn flour (ionized water) by weight of pasta flour, composition of impurities, %, ion concentration, units/cm^3, density and type between random variables was carried out.

To do this, the relationship of the resultant sign to one factor by pair correlation was analyzed. Table 4 shows that the relationship between *X* and *Y* is often not weakly linear.

In conclusion, according to the regression equation determined by the results of the experiment, we need to work with the factors in the next experiment. The value of the coefficients of the progression equation is formed by the optimal values associated with the positive or negative. And its absolute value determines how much the value of *Y* increases or decreases.

Thus, the coefficients of the progression equations determined by adding or subtracting factors are, of course, subject to change. As a result, it is possible to determine the optimal solutions.

If we look at the influence of several factors on the process, as a result of processing the experimental data obtained by implementing the second-order plan, the following regression equation of the mathematical model of the process in the form of a second-order polynomial can be created.

$$Y = b_0 + \sum\nolimits_{i=1}^{n} b_{ii}x_i^2 + \sum\nolimits_{i,j}^{n} b_{ij}x_i x_j + \sum\nolimits_{i=1}^{n} b_i x_i, \quad (5)$$

where b_0 is the empty term of the equation, which is equal to the average value of the parameter when the factors under consideration are at the "zero" level;

x – value of the factors that determine and differentiate the parameters of the function;

i, *j* – index of factors;

bi – coefficient of linear terms;

bij – two-factor coefficient of action, which indicates how much the degree of change of the second factor changes when the magnitude of the change;

bii – coefficient of the quadratic calculation, which determines the nonlinearity of the solver parameter, which does not depend on the factors involved [23].

In the case of secondary terms *XiXj*, $i\neq j$, the equation (5) is the value of *Y*, which complements the interaction of factors in the equation, i.e. the linear effects of *Xi* and *Xj*, and for *XiXj* $i=j$ (i.e. Xi^2) is the argument. The linearity of the change changes.

In general, the estimates of the quadratic regression coefficients in equation (5) are interrelated, although the arguments X*i* and X*j* are not actually correlated. The correlation between the values is due to the correlation of the values *Xi* and Xi^2, *Xi* and *XiXj*.

Now we will study how to choose it, taking into account that the process is influenced by several factors at once.

Selection of the optimal set of components of the model (5) is carried out by stepwise regression methods. The most common and effective methods are Forward, Backward and Stepwise.

Table 4

Pair correlation coefficients of the relationship between the quality of pasta with the addition of 20 % corn flour (ionized water) to pasta flour

Factors	X_1	X_2	Y_1	Y_2	Y_3	Y_4
X_1	1.000	–	–	–	–	–
X_2	0.000	1.000	–	–	–	–
Y_1	0.874	–0.288	1.000	–	–	–
Y_2	–0.995	0.000	–0.868	1.000	–	–
Y_3	0.072	0.226	0.037	–0.046	1.000	–
Y_4	0.894	–0.167	0.930	–0.901	0.064	1.000

In the Forward method, the procedure begins with a regression model that does not contain independent variables. In the initial stage, the variable with the largest partial correlation coefficient is selected from the full argument.

As a result, the values of the variables with the largest partial correlation coefficients with the dependent variable are gradually related to the final regression equation.

The Backward method (exception method or "reverse method") allows you to remove variables from the sample. The procedure begins with a regression model that includes all independent variables. To avoid insignificant evidence, use the specific F-Remove criterion.

The Stepwise method is to sequentially add and (or) remove a variable in regression. The Stepwise method is the same as the Forward method, but after each step, the variables are now studied using the reverse method.

With the above parameters, the standard β-coefficients, coefficients of regression, as a result of a step-by-step procedure on a natural scale, the Student's t-criterion is calculated to check their significance and the degree of reliability of the probability.

The inclusion of the squares of the variables, as well as the interaction of their centralized values, in the model was carried out by a dash after the name of the method of the corresponding steps of the regression procedure, given in Table 5.

At each stage of the procedure, the parameters were recalculated and analyzed with all the statistical characteristics of flour quality assessment. The standard β-coefficients of Table 5 show the importance of independent variables.

Thus, Table 5 shows the parameters of regression models for assessing the quality of pasta made from macaroni flour.

Fig. 3 shows the contour lines of equal levels of spatial surfaces, described by equation (5) for quality indicators of pasta.

These tables allowed estimating the latent structure of the spatial surface of each indicator, as well as identifying complex nonlinear relationships between the studied variables. The contours of the levels represent the undivided horizontal sections of the three-dimensional functions of the response surfaces obtained by approximating the experimental data.

According to Fig. 3, the color markings are displayed according to the intensity of the indicator. They can determine the range of variables for which the quality index of pasta is most important.

Table 5

Parameters of regression models for assessing the quality of pasta made from pasta flour

Arguments of the regression model	Regression coefficients and their values					
20 % corn flour is added to pasta flour (with ionized water)						
	Y_1 – adhesive properties, MDG, instrument unit (Forward) Y_1=88.622+1.240X_1–0.002X_2; R=0.920.					
	Beta	Std.Err.	b	Std.Err.	t(33)	p-level
Intercept	–	–	88.62222	2.109899	42.00307	0.000000
X_1	0.873904	0.068227	1.24000	0.096809	12.80875	0.000000
X_2	–0.287539	0.068227	–0.00236	0.000559	–4.21443	0.000182
	Y_2 – amount of gluten, % (Forward) Y_2=38.481–0.271X_1–0.000X_2; R=0.995.					
Intercept	–	–	38.48111	0.103804	370.7106	0.000000
X_1	–0.994954	0.017465	–0.27133	0.004763	–56.9688	0.000000
X_2	–0.000000	0.017465	–0.00000	0.000027	–0.0000	1.000000
	Y_3 – amount of dry matter transferred to the boiled water, % (Forward) Y_3=–48.637–1.229X_1+0.022X_2; R=0.237.					
Intercept	–	–	–48.6378	62.71312	–0.775561	0.443531
X_1	0.072209	0.169115	1.2286	2.87748	0.426983	0.672165
X_2	0.225812	0.169115	0.0222	0.01661	1.335257	0.190930
	Y_4 – product weight gain (Forward) Y_4=1.813+0.005X_1–0.000X_2; R=0.910.					
Intercept	–	–	1.813111	0.007990	226.9136	0.000000
X_1	0.894169	0.072313	0.004533	0.000367	12.3652	0.000000
X_2	–0.167022	0.072313	–0.000005	0.000002	–2.3097	0.027303
17.5 % amaranth flour is added to pasta flour (with ionized water))						
	Y_1 – adhesive properties, MDG, instrument unit (Forward) Y_1=87.439+1.497X_1–0.002X_2; R=0.967.					
Intercept	–	–	87.43889	1.547163	56.51564	0.000000
X_1	0.937508	0.044467	1.49667	0.070989	21.08317	0.000000
X_2	–0.236278	0.044467	–0.00218	0.000410	–5.31355	0.000007
	Y_2 – amount of gluten, % (Forward) Y_2=38.481–0.271X_1–0.000X_2; R=0.995.					
Intercept	–	–	38.48111	0.103804	370.7106	0.000000
X_1	–0.994954	0.017465	–0.27133	0.004763	–56.9688	0.000000
X_2	–0.000000	0.017465	–0.00000	0.000027	–0.0000	1.000000
	Y_3 – amount of dry matter released into the water during cooking, % (Forward) Y_3=5.532+0.102X_1–0.000X_2; R=0.966.					
Intercept	–	–	5.531833	0.104595	52.88828	0.000000
X_1	0.956705	0.044823	0.102433	0.004799	21.34413	0.000000
X_2	–0.135707	0.044823	–0.000084	0.000028	–3.02763	0.004756
	Y_4 – product weight gain (Forward) Y_4=1.770+0.006X_1–0.000X_2; R=0.900.					
Intercept	–	–	1.769500	0.011145	158.7652	0.000000
X_1	0.896596	0.075996	0.006033	0.000511	11.7980	0.000000
X_2	0.074359	0.075996	0.000003	0.000003	0.9785	0.334966

Volume diagrams are shown to get a clear idea of how the quality indicators of pasta relate to the composition of the ground mixture. Pasta quality indicators are distinguished by the same “wire” grid, different shades of shadows and 3D drawings made of shadows. If these elements of the ground diagrams are the same, the levels have the same values.

The created surface scheme allows you to find the best combination of mixture components, which is difficult to find in other ways than the available values.

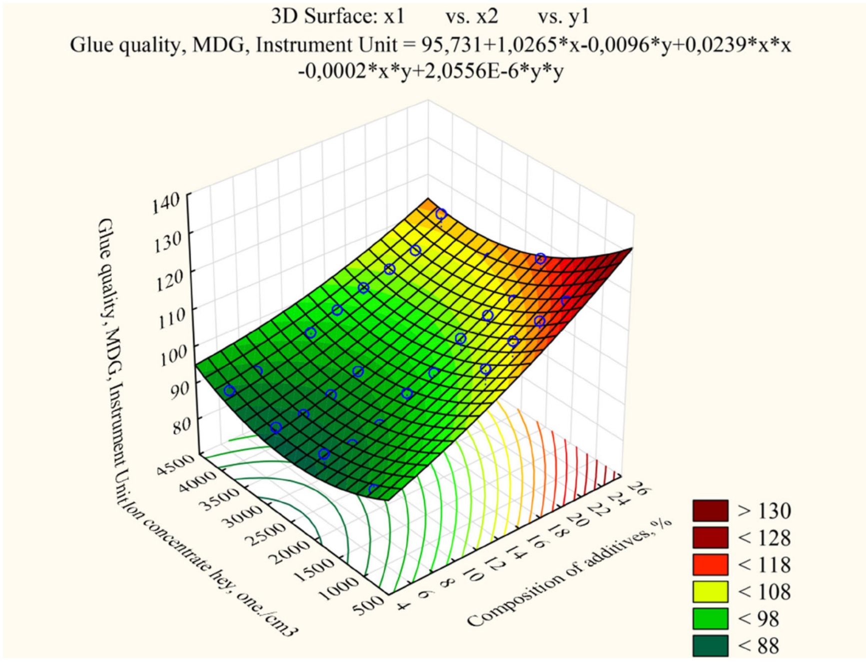
From this graph, we know how many of the next tests of the experiment will be made. To do this, add 20 % corn flour (ionized water) to the pasta flour, put the values of factor x1 on the abscissa, put the values of factor x2 on the ordinate, and add the points of the optimal criteria in space, add the points of the optimal criteria and get a map of the surface.

In Fig. 3, we determine the relationship between the 3 factors using the spatial criterion. This approach helps to identify the real situation in the most rational and visual way.

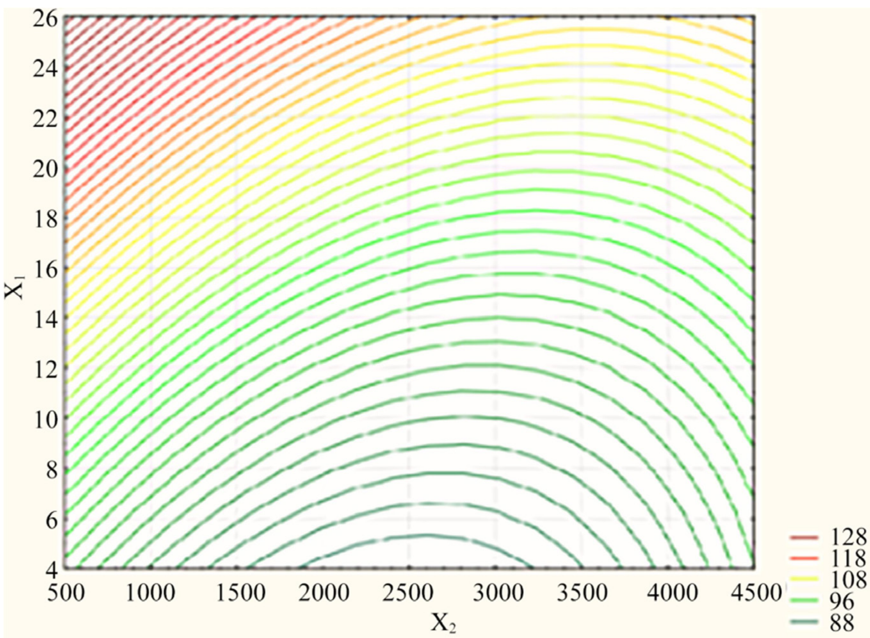
Spatial form of the product equation with the addition of 20 % corn flour (ionized water) to pasta flour.

$$Y_1=95.731-0.0096*X_2+1.0265*X_1+2.0556E-6*X_2*X_2-0.0002*X_2*X_1+0.0239*X_1*X_1.$$

$$Y_3=6.1045+0.0006*X_1-0.0004*X_2+0.003*X_1*X_1-1.3133E-6*X_1*X_2+7.25E-8*X_2*X_2.$$



a



b

Fig. 3. Graph of pasta products with 20 % corn flour (ionized water) in pasta flour: *a* – building a surface in space; *b* – plotting on a plane

Table 8

Parameters of regression models for assessing the quality of pasta made from a mixture of pasta and corn flour

Arguments of the regression model	Regression coefficients and their values					
	Y_1 – adhesive properties, MDG, instrument unit (Forward) Y_1=77.357+2.200X_1; R=0.958					
	Beta	Std.Err.	*b*	Std.Err.	$t(33)$	*p*-level
Intercept	–	–	77.35714	3.963996	19.51494	0.000007
X_1	0.958020	0.128217	2.20000	0.294438	7.47186	0.000678
Y_1=77.3571+2.2*X_1						
	Y_2 – amount of gluten, % (Forward) Y_2=38.343–0.257X_1; R=0.996.					
Intercept	–	–	38.34286	0.131009	292.6742	0.000000
X_1	–0.996439	0.037708	–0.25714	0.009731	–26.4249	0.000001
Y_2=38.3429–0.2571*X_1						

5. 4. Justification of the use of additives in the production of pasta

Extensive research is being conducted on the use of ionized, ozonated water and other agents of ionizing technology in food production, in particular in bread, bakery products and pasta. The bactericidal and redox properties of ionized water in this study contribute to the hardening and safety of the adhesive.

The increase in the strength characteristics of the adhesive with ionized water is primarily due to the oxidizing properties of ozone. Oxidation of sulfhydryl groups and the formation of disulfide bonds in the adhesive protein strengthen the spatial structure of adhesive proteins [24].

6. Discussion of experimental results

Based on the results of an experimental study to determine the effect of selected additives on the properties of pasta flour in order to increase the nutritional value of the finished product, corn flour and amaranth flour were analyzed 5; 7.5; 10; 12.5; 15; 17.5; 20 %. When determining the quantity and quality of the adhesive of the samples added in the dosage per the total flour mass in the recipe, the amount of raw gluten decreased as the amount of additive flour increased. And if the indicator of the IDK–1 device is 90 units for the control sample, then 92 to 120 units of the device, respectively, with the addition of corn and amaranth flour from 5 to 20 % to the weight of pasta flour., From 93 to 123 instrument units., changed to. Therefore, the results of the study confirm that when using corn flour, amaranth flour, the properties of gluten deteriorate. But it should be noted that when adding corn flour to pasta flour up to 12.5 %, amaranth flour up to 10 %, the quality of gluten will be similar to the indicators of the control sample.

And when using ionozone water, it was shown that the quality of gluten does not deteriorate greatly as the amount of added flour increases compared to ionized anhydrous samples. Thus, when using ionozone water, the concentration of ions is 3000 units, increasing the amount of corn flour from 5 to 20 % in the presence of cm^3, it varies from 80 to 102 instrument units, in amaranth flour – from 83 to 108 instrument units, respectively (Table 1). Therefore, the results obtained change in the direction of increasing the elasticity and quality of the adhesive when using ionozone water.

The increase in the strength characteristics of the adhesive with the addition of ionized water is primarily due to the oxidizing properties of ozone. The oxidation of sulfhydryl groups in the gel protein and the formation of disulfide bonds strengthen the spatial structure of gluten proteins [20]. The ion concentration is 3000 units. A very good result can be achieved when using ionized/cm^3, and water with an ozone concentration of 2 mg/l. It was found that the quality indicators of gluten, including corn flour up to 20 % by weight of pasta flour, amaranth flour 17.5 %, are better compared to samples without ionized water.

When using corn flour up to 12.5 % by weight and amaranth flour up to 10 % by weight, no significant changes in organoleptic and physico-chemical indicators were observed compared to the control sample (Table 2). Pasta products have become smooth, the shape corresponds to a given type of product, the color of the product does not deteriorate. After cooking, the products have the same elasticity compared to the control sample. One of the most noticeable indicators is that the weight gain of the product with corn flour increases from 0 to 12.04 % compared to the control sample. These indicators are closely related to the amount of dry matter transferred to the boiled water – the main indicator of the cooking properties of pasta. The increase in dry matter content in the cooked environment is caused by protein-containing additives. Thus, as the amount of ground additives increases, the amount of dry matter transferred to the cooking water of pasta with corn flour increases to 0–45.28 %. In the course of the study, the use of ionozone water made it possible to reduce the transfer of dry substances to boiled water. The ion concentration found to be an effective option is 3,000 units/cm^3 in a sample using corn flour. varies from 5.62 to 7.83 %, respectively, at this time in ionized anhydrous samples, the given indicator changed from 6.20 to 9.1 %, respectively. The values of the result obtained from the determination of samples with the addition of amaranth flour are similar to these values. For this reason, the results of the studies obtained from the use of ionozone water when kneading pasta dough made from macaroni flour with the addition of powdered additives showed that the organoleptic, physico-chemical, baking properties of macaroni products improved compared to anhydrous samples without ionozone. The ion concentration is 3,000 units/cm^3 when using ionized water with an ozone concentration of 2 mg/l, the quality of macaroni products obtained from ground mixtures is improved, when adding corn flour to macaroni flour up to 20 %, amaranth flour up to 17.5 %, the quality indicators of macaroni products do not deviate from the control sample.

It is always necessary to conduct research for obtaining high-quality pasta with additives that increase the nutritional and biological value to the recipe of pasta products made from bakery flour obtained in the pasta industry.

7. Conclusions

1. The influence of low-grade cheese on the content of gluten and corn flour on the total mass of flour was close to the control sample, including 12.5 %, amaranth flour –10 %. Excellent results can be achieved when using ionized water with an ion concentration of 3,000 units/cm^3, with the addition of up to 20 % by weight of pasta flour, corn flour, 17.5 % amaranth flour, the quality of gluten was better than ionic anhydrous samples.

2. The use of ionizing water in the kneading of pasta dough from ground amaranth, corn flour improved the organoleptic, physicochemical, cooking properties of pasta, while the ion concentration was higher when using ionized water with 3,000 units/cm^3.

3. The ion concentration is 3,000 units/cm^3, the optimal amount of vegetable raw material mixture added to the recipe when using ionized water was 20 % in corn flour and 17.5 % in amaranth flour.

4. By the analysis of the results of the study of pasta products made with ground additives and ionized water, the mixture used in the recipe allows obtaining high-quality pasta with high nutritional value, depending on the chemical composition of corn and amaranth flour.

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