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DEVELOPMENT OF RECIPE COMPOSITION OF BREAD WITH THE INCLUSION OF JUNIPER USING MATHEMATICAL MODELING AND ASSESSMENT OF ITS QUALITY

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In order to determine the influence of juniper fruits (Juniperus communis L) on the formation of bread quality, the optimization of the component composition of a new product with increased nutritional value was carried out. To optimize the recipe composition, the response surface methodology was used. The maximum value of the complex indicator of the quality of new bread is noted when the mass fraction of sodium chloride is 1.45 % and the mass fraction of crushed juniper fruits is 3.17 %. According to the developed recipe, prototypes of the product were developed and the main quality indicators were determined. Based on the analysis of the chemical composition, it was found that bread with the inclusion of 3 % crushed juniper fruits is characterized by an increased content of protein, fiber, vitamins, micro- and macroelements compared to the control sample.

The influence of juniper on microbiological parameters and shelf life of the finished product was established. The new type of fortified bread with the addition of 3 % crushed juniper fruits can be stored without changing the quality indicators for up to 72 hours, which exceeds the same indicator of the control bread sample.

In the course of the study, the influence of juniper on the antioxidant activity and safety indicators of bread was determined. The inclusion of crushed juniper fruits in the bread made it possible to double the antioxidant activity compared to the control sample, which is 15.5 and 7.5 mg/100 g, respectively. In terms of safety indicators, the developed bread fully meets the requirements of regulatory documents.

The results obtained make it possible to recommend for production a new type of fortified bread with increased nutritional value with the inclusion of crushed juniper fruits in its recipe, which will expand the range of health products

Keywords: quality assessment, bakery products, optimization, juniper, antioxidant activity, safety, recipe

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1. Introduction

The modern stage of human development is characterized, on the one hand, by the outstanding achievements of science and technology, and on the other, by the deterioration of the ecological situation, changes in lifestyle, decreased physical activity, increased neuro-emotional stress, and decreased nutritional quality. Due to changes in lifestyle, urbanization of the population, the quality of food consumption has changed, namely, their food and biological value has significantly decreased [1]. As is known [2], the health of a particular person and the nation as a whole depends on the quantitative and qualitative composition of food. Food products exhibit protective, neutralizing, prophylactic, therapeutic, pharmacological and other properties to varying degrees. Therefore, one of the ways to solve the problem of balanced diet is to introduce into its composition products that can improve human health [3].

Bread historically has a special value for many peoples, is one of the most ancient sources of energy and nutrients, respect and love for it are preserved at the level of genetic memory. Taking into account national traditions, socio-economic state of the population, consumer properties, bread is one of the most promising products for enriching and improving the quality of food rations and, accordingly, human health [4]. As a result, the development of bread and bakery products for health-improving purposes is relevant due to the inclusion of enriching additives in their composition. The inclusion of additives helps to increase the nutritional and biological value of the product, stabilizes the technological process, saves resources while maintaining traditional consumer properties [3]. In recent years, new types of enriching natural additives have appeared that are of interest to the bakery industry, such as herbs, fruits, berries, etc. They differ in chemical composition and organoleptic properties, which directly affects the consumer and technological properties of bakery products. Juniper (*Juniperus communis L*) is an interesting crop for food fortification. This culture is characterized by an increased content of biologically active substances (BAS) [5]. Juniper is rich in aromatic oils, resins, catechins, organic acids, terpenic acids, alkaloids, flavonoids, tannins, gums, lignins, wax, etc. Essential oils and extracts of juniper have antioxidant, antibacterial, antiviral and antifungal properties promising use of juniper in food, pharmaceutical and cosmetic industries [5, 6].

It is important to take into account that when developing the recipe composition of an enriched product, it is necessary to pay attention to the mass fraction of the added additives, taking into account their effect on consumer quality indicators of finished products. In this regard, it is relevant to conduct research on the formation of the quality of new bread with specified consumer properties in order to substantiate the feasibility of producing a health product.

2. Literature review and problem statement

The target principles of using various enriching additives in bakery, including in the production of bakery products for health purposes, are aimed at improving the quality of finished products (Fig. 1).

The use of natural unconventional herbal nutritional supplements for bread fortification is considered one of the effective means of combating global nutritional deficiencies in the human diet. Vegetable products (rice bran, wheat bran, corn bran, grape pomace extract, tomato seeds and peels, artichoke stems and leaves) are widely used for bread enrichment. These byproducts contain high concentrations of BAS, including phenolic compounds, bioactive peptides, and arabinoxylan. Bread made with the inclusion of flour from plant by-products is characterized by a high content of fiber and biologically active compounds. Also, bread has acceptable sensory properties [7].

Research is being carried out to include watermelon seed flour in bread recipes. Protein content and levels of trace elements such as phosphorus, potassium, iron and calcium increase as the proportion of this additive in bread increases. Researchers found that bread containing 25 % skim flour from watermelon seeds contains iron – 0.056 mg/100 g of the product, while the control sample (not fortified) bread contains 0.001 mg/100 g [8].

A recipe for bread enriched with freeze-dried vegetables (carrots, tomatoes, beets and broccoli) has been developed. Studies have found that the addition of vegetables resulted in increased nutritional value and improved antioxidant properties of bread. At the same time, supplements of beets and broccoli significantly extended the shelf life of the finished product [9].

Scientists from different countries are conducting research on the enrichment of bakery products with herbal ingredients, however, the range of health products that are presented on the consumer market is minimal and needs to be expanded and optimized in the component composition. It is advisable to use as enrichment additives plant components authentic for the area. Juniper is one of the traditional cultures growing in Kazakhstan [10]. Juniper fruits contain essential oils (0.5 % in fresh and 2.5 % in dry fruits), invert sugars (15–30 %), resins (10 %), catechins (3–5 %), organic acids, terpenic acids , leuko-anthocyanidin, tannins, gums, lignins, waxes, vitamins, etc. Flavonoids such as biflavonoids (amentoflavone), flavones (apigenin), flavonols (quercetin, isoquercetin) are also found in juniper berries [5]. Due to the presence of phenolic and aromatic substances, juniper has high antioxidant and antimicrobial activity [5, 6, 11].

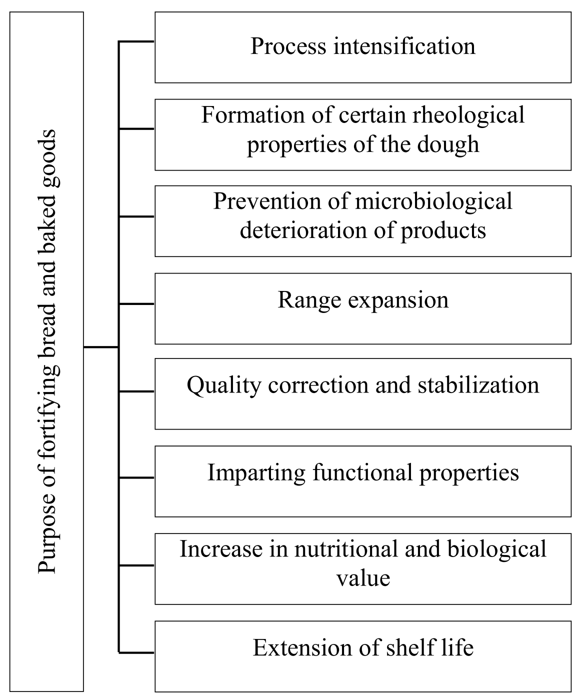


Fig. 1. The purpose of adding enrichment additives to bread and bakery products [3, 4]

Juniper berries are widely used in the production of blended teas, herbal medicines, as spices in the production of alcoholic beverages, etc. Pineal juniper berries are traditionally used to treat cystitis, digestive disorders, in the treatment of chronic arthritis and other indications. They contain an essential oil with a characteristic coniferous aroma and a bitter taste [12].

The main chemical components of juniper oil are α-pinene, camphene, β-pinene, sabinene, α-phellandrene, α-terpinene, γ-terpinene, 1,4-cineole, and traces of limonene, camphor, linalool, linalyl acetate, borneol, and nerol are also present [13] In pharmacy, oil has been used for centuries due to its diuretic and antiseptic properties, it is widely used in aromatherapy, as well as in the production of alcoholic beverages [5, 14].

For many centuries, juniper berries (*Juniperus communis L*) have been used in folk medicine to treat various infectious diseases. They are used as spices for the preparation of meat products, flavorings in the production of gin, liqueurs and other alcoholic beverages.

Essential oils of juniper berries (*Juniperus communis L*), which are characterized by high antioxidant activity, are widely used in the food industry. It is this property that determines the potential of juniper for the production of food additives, and also expands the field of application in pharmaceuticals, medicine, and food production [5, 6, 15].

Scientists have carried out studies to study the antioxidant properties of the common juniper needles for the purpose of their further use in the production of medicinal and preventive drinks. The choice of raw materials was due to the fact that juniper needles have anti-inflammatory, antibacterial and tonic properties, and also contain a complex of trace elements necessary for the normal functioning of the human body [16].

It has been found that essential oils of juniper slow down lipid peroxidation in canned meat due to its high antioxidant effect, which not only improves the quality of the meat product, but also increases its shelf life. A natural antioxidant such as juniper is used in place of a synthetic antioxidant to maintain and improve the vitality of meat products [5].

The research results showed a significant antioxidant activity of *Juniperus communis L* essential oil as an alternative to sodium nitrite in dry fermented sausages [17].

Along with its high biological value, juniper has a number of contraindications, as a result of which it should be used with caution in diseases of the kidneys, gastrointestinal tract, high blood pressure, and a number of other diseases [18–21].

The above information indicates that numerous studies are being carried out both on the development of bakery products with improved consumer properties, and on the use of juniper for the fortification of various types of food. However, studies on the inclusion of this additive in the composition of bakery products are practically not conducted. In this regard, it is relevant to study the issue of including juniper, which has antioxidant properties and is characterized by a high content of biologically active substances, in bread. At the same time, it is important to determine the optimal percentage of the addition of this additive in the composition of bread, since juniper is characterized by an increased content of organic acids, essential oils and other components that affect the taste and aroma characteristics of the product.

3. The aim and objectives of research

The aim of research is to optimize the recipe composition of a new type of bread of improved quality with juniper (*Juniperus communis L*).

To achieve this aim, the following objectives are identified and solved:

– based on the calculation of a complex quality indicator, determine the optimal ratio of prescription components;

– determine the chemical composition and quality indicators of a new type of fortified bread, produced using raw materials in an optimal ratio;

– determine the crushed juniper fruits (CJF) influence on microbiological indicators and shelf life of bread.

4. Materials and methods for optimization of recipe composition and research of quality indicators of a new product

4. 1. Investigated materials

The object of research was bread containing CJF (*Juniperus communis L*). To obtain it, let's use wheat flour of the 1st grade, drinking water, pressed yeast, sodium chloride and the fruits of ordinary juniper. In the course of experimental studies, juniper fruits were preliminarily crushed to a particle size of 1–2 mm.

To determine the optimal recipe for the new bread, all prepared initial components were sent to the kneading machine. At the same time, the CJF mass fraction was varied in the range of 1.0–5.0 %, the mass fraction of sodium chloride (PS) – in the range of 1.0–2.0 %. Next, the dough was prepared (kneaded), fermented, cut, finished, steamed and baked according to a standard method for the baking industry [22]. In the obtained bread samples, the antioxidant activity (AOA, mg/100 g) was determined and an organoleptic assessment was carried out (OA, points). The substantiation of the optimal ratio of components in a new type of fortified bread was carried out using a complex quality indicator (CQI), which takes into account the combined effect of AOA and OA, as well as the coefficients of significance of the indicated unit indicators.

In a new type of fortified bread, produced from raw materials in optimal proportions, the chemical composition and safety indicators were determined. Based on the research results, conclusions were drawn about the possibility of producing a new type of bread enriched with CJF, as well as about the impact of the latter on the safety and quality of the finished product.

4. 2. Methods of research of quality indicators of a new type of bread

To optimize the recipe composition of the new fortified bread, the response surface methodology was used [23]. The modeling and processing of experimental data was carried out using the Statistica 10 package (StatSoft, Inc.).

The nutritional value of bread was assessed according to standard research methods:

– mass fraction of fat was determined by the Soxhlet method;

– mass fraction of carbohydrates – by iodometric titration;

– mass fraction of protein – according to the Kjeldahl method, using an automated incinerator and a distillation apparatus;

– mass fraction of water-soluble vitamins was determined by the method of capillary zone electrophoresis "Kapel 105 M" [24, 25].

AOA of bread with the addition of juniper was determined by the amperometric method using a TsvetYauza-01-AA device.

The content of heavy metals and minerals was determined by the method of atomic sorption spectroscopy (ASC) on a spectrometer with electric atomization "KVANT-Z.ETA-T" [26].

The content of pesticides in finished products was determined by an analytical stationary gas chromatograph "Crystallux-4000M" (Russia) with an electron capture detector and software "NetChrom" (Russia) [27].

When studying the microflora of bread with the addition of juniper, let's use classical methods of microbiological analysis: methods of sampling and preparation of samples for microbiological analyzes [28, 29], methods of cultivating microorganisms [30, 31].

The organoleptic assessment was carried out on the basis of the scoring of the organoleptic quality indicators developed by the authors [32].

5. Results of the study of optimization of the recipe composition and quality indicators of the new product

5. 1. Results of optimization of the recipe composition of a new type of bread based on a complex quality indicator

At the first stage of research, in accordance with the tasks set, work was carried out to optimize the recipe composition of bread with the addition of juniper.

The response surface methodology is a combination of mathematical and statistical techniques aimed at modeling processes and finding combinations of experimental series in order to optimize the response function $\hat{y}$ (x, b), which is generally described by the following polynomial:

$$\hat{y}(x,b) = b_0 + \sum_{l=1}^{n} b_l x_l + \sum_{k=1}^{n} b_k x_k^{\,2} + \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} b_{ij} x_i x_j, \quad (1)$$

where $x \epsilon R^n$ – a vector of variables, b – a vector of parameters.

In the process under study, the response function was chosen, which has the form of a polynomial of the second degree:

$$OA = b_0 + b_1 \cdot C_{SC} + b_{11} \cdot C_{Sc}^2 + b_2 \cdot C_{CJ} + b_{22} \cdot C_{CJ}^2 + b_{12} \cdot C_{SC} \cdot C_{CJ}, \quad (2)$$

$$AOA = b_0 + b_1 \cdot C_{SC} + b_{11} \cdot C_{SC}^2 + b_2 \cdot C_{CJ} + b_{22} \cdot C_{CJ}^2 + b_{12} \cdot C_{SC} \cdot C_{CJ}, \quad (3)$$

$$CQI = b_0 + b_1 \cdot C_{SC} + b_{11} \cdot C_{SC}^2 + b_2 \cdot C_{CJ} + b_{22} \cdot C_{CJ}^2 + b_{12} \cdot C_{SC} \cdot C_{CJ}, \quad (4)$$

where OA – an organoleptic assessment, points; AOA – antioxidant activity, mg/100 g; CQI – a comprehensive quality indicator; b_0 – a constant; C_{SC} – mass fraction of sodium chloride, %; C_{CJF} – mass fraction of crushed juniper fruits, %; b_1, b_{11}, b_2, b_{22}, b_{12} – the coefficients for each element of the polynomial.

The experiment planning matrix and response functions are given in Table 1.

To check the significance of the regression coefficients (2) and (3), Pareto charts were constructed, shown in Fig. 2, 3, respectively (L – linear effect, K – quadratic effect). The specified Pareto charts (Fig. 2, 3) show the standardized coefficients, which are sorted by absolute values.

Table 1

Experiment planning matrix and response functions

Experiment No.	SC mass fraction (C_{SC})		CJF mass fraction (C_{CJF})		Antioxidant activity, AOA, mg/100 g	Organoleptic assessment OA, points
	coded level	%	coded level	%		
1	–1	1.15	–1	1.59	13.89	4.52
2	0	1.50	–√2	1.00	12.60	4.40
3	+1	1.85	–1	1.59	13.77	4.45
4	+√2	2.00	0	3.00	15.37	4.48
5	+1	1.85	+1	4.41	15.70	4.19
6	0	1.50	+√2	5.00	16.00	4.10
7	–1	1.15	+1	4.41	15.84	4.28
8	–√2	1.00	0	3.00	15.66	4.56
9	0	1.50	0	3.00	15.50	4.86
10	0	1.50	0	3.00	15.60	4.84
11	0	1.50	0	3.00	15.50	4.84
12	0	1.50	0	3.00	15.60	4.86

Data analysis in Fig. 2 shows that for the sensory evaluation of a new type of bread, the effect of the interaction of the parameters is insignificant, since the column for evaluating the specified effect does not cross the vertical line, which is the 95 % confidence level. Therefore, the effect of interaction of parameters from regressions (2) was eliminated. The resulting equation for determining the organoleptic evaluation of a new type of bread with the calculated coefficients has the form

$$OA = 0.754 + 4.040 \cdot C_{SC} - 1.379 \cdot C_{SC}^2 + 0.841 \cdot C_{CJ} - 0.154 \cdot C_{CJ}^2. \quad (5)$$

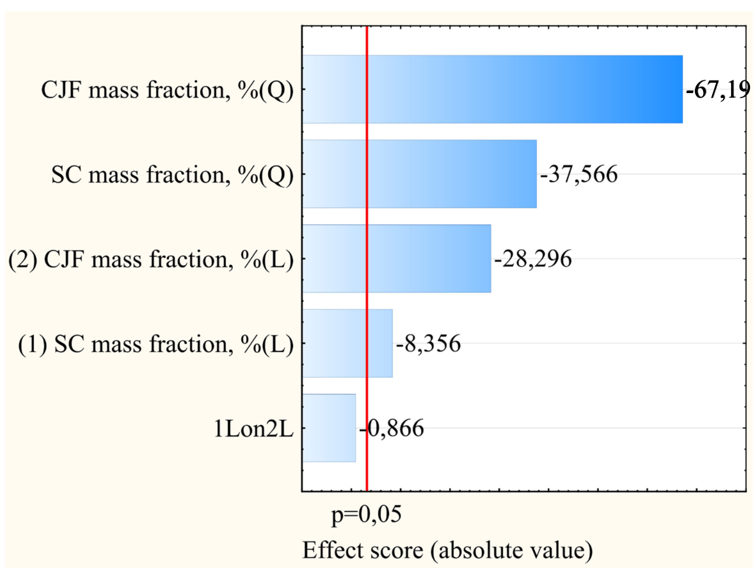


Fig. 2. Pareto chart for checking the significance of the regression coefficients (2)

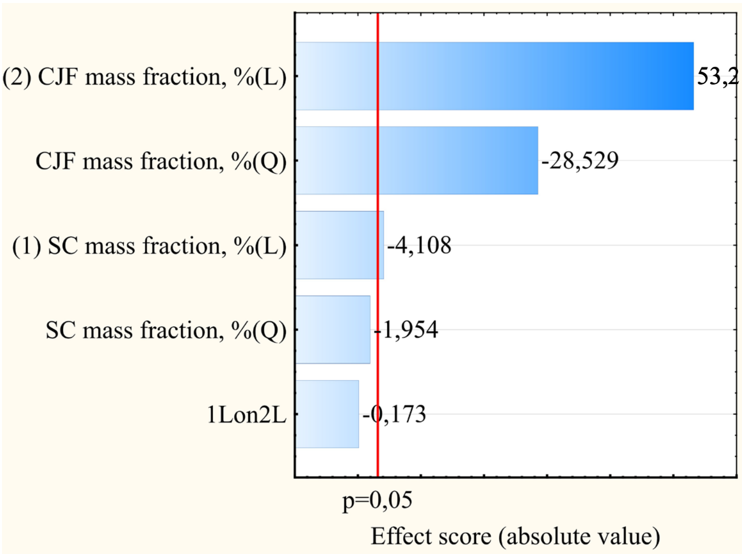


Fig. 3. Pareto chart for checking the significance of the regression coefficients (3)

Analysis of the data shown in Fig. 3 indicates that for the antioxidant activity of a new type of bread, the mass fraction of sodium chloride and the effect of interaction of parameters are insignificant. This is due to the fact that the columns of estimates of these effects do not cross the vertical line, which is the 95 % confidence level. Therefore, the effect of the interaction of parameters and the mass fraction of sodium chloride were eliminated from the regression (3). The resulting equation for determining the antioxidant activity of a new type of bread with the calculated coefficients has the form

$$AOA = 10.668 - 0.238 \cdot C_{SC} + 2.670 \cdot C_{CJ} - 0.322 \cdot C_{CJ}^2. \qquad (6)$$

The adequacy of the developed models (5) and (6) was checked by the method of analysis of variance, its results are presented in Tables 2 and 3 respectively.

Table 2

Dispersion analysis of the model (5)

Factor	Sum of squares, SS	Degree of freedom, df	Mean square value, MS	F-test	Significance level, p
(1) SC mass fraction, % (*L*)	0.009309	1	0.009309	69.818	0.003594
SC mass fraction, % (*K*)	0.188162	1	0.188162	1,411.215	0.000041
(2) CJF mass fraction, %(*L*)	0.106757	1	0.106757	800.675	0.000097
CJF mass fraction, % (*K*)	0.602046	1	0.602046	4,515.342	0.000007
Loss of consent	0.002968	4	0.000742	5.565	0.095035
Pure error	0.000400	3	0.000133		
General SS	0.799767	11			
Determination coefficient R^2=0.99579; $R^2_{adj} = 0.99338$					

The results are shown in Tables 2, 3, in particular, the values of the determination coefficients (for model (5) R^2=0.99579 and $R^2_{adj} = 0.99338$, for model (6) R^2=0.98747 and $R^2_{adj} = 0.98277$) and no loss of consistency (for both models, the level of significance of this indicator is $p>0.05$) indicate that the models adequately describe the experiment.

The combined effect of the mass fraction of sodium chloride and crushed juniper fruits described by polynomials (5) and (6) on the organoleptic assessment and antioxidant activity of a new type of bread is graphically presented in Fig. 4 and 5 respectively.

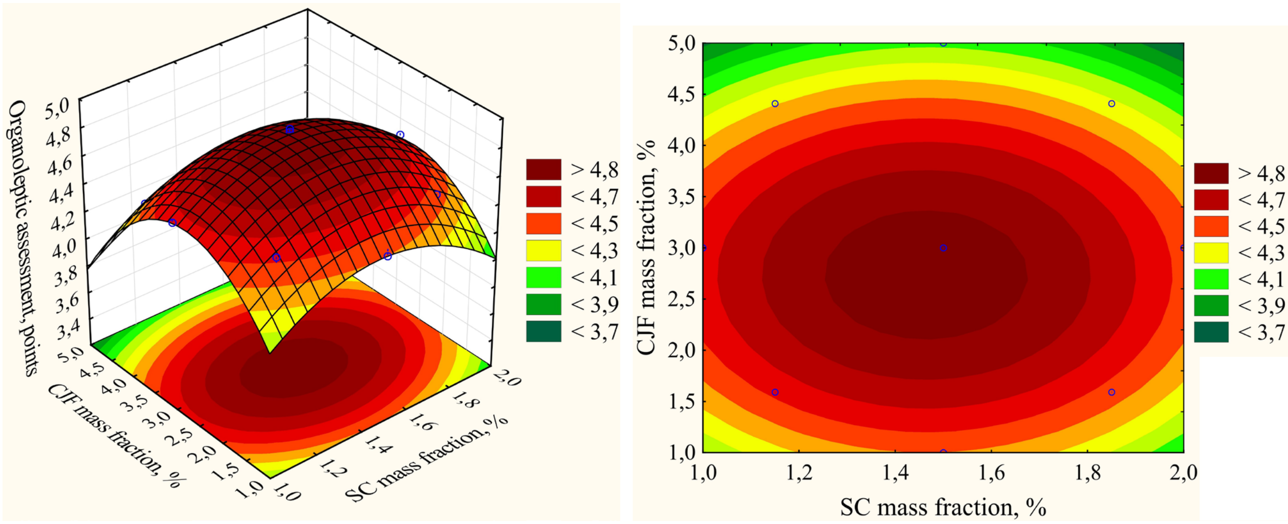
An increase in the bread recipe of the mass fraction of sodium chloride from 1.00 to 1.46 % and the mass fraction of crushed juniper fruits from 1.00 to 2.73 % leads to an improvement in the taste of a new type of bread (Fig. 4, *a*, *b*). The maximum organoleptic score – 4.861 points, has a bread containing 1.46 % sodium chloride and 2.73 % crushed juniper fruits. The bread is characterized by a pleasant taste and aroma with a light juniper aftertaste, the surface without large cracks, the color of the crust is slightly brownish, the crumb is elastic, well-developed and uniform, the pores are small and thin-walled. A further increase in the mass fraction of sodium chloride to 2.00 % and crushed juniper fruits to 5 % leads to a deterioration in organoleptic properties. An unpleasant and slightly sour aftertaste appears, the surface is slightly bubbly and rough, the color of the crust is dark brown, the crumb is noticeably compacted, crumbling, the smell is not expressed and slightly foreign.

Table 3

Dispersion analysis of the model (6)

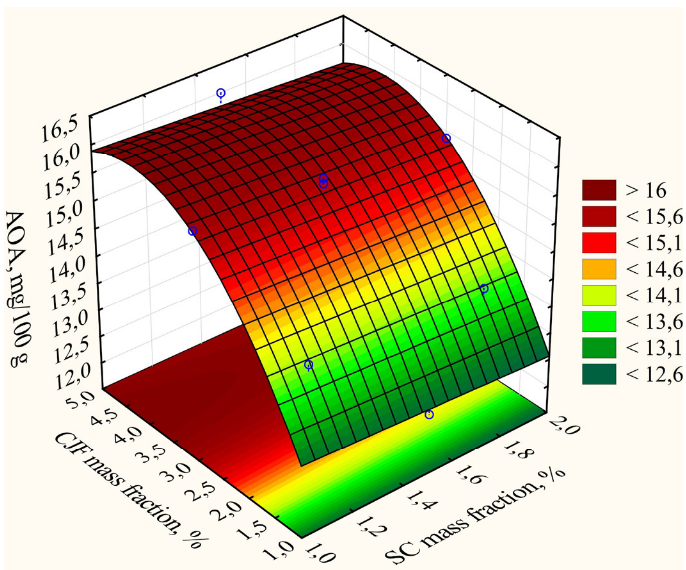
Factor	Sum of squares, SS	Degree of free-dom, df	Mean square value, MS	F-test	Significance level, p
(1) SC mass fraction, % (*L*)	0.05626	1	0.056259	16.878	0.026112
SC mass fraction, % (*K*)	9.43886	1	9.438864	2831.659	0.000015
(2) CJF mass fraction, %(*L*)	2.75410	1	2.754101	826.230	0.000092
CJF mass fraction, % (*K*)	0.14547	5	0.029094	8.728	0.052219
Loss of consent	0.01000	3	0.003333		
Pure error	12.40469	11			
Determination coefficient R^2=0.98747; $R^2_{adj} = 0.98277$					

An increase in the mass fraction of crushed juniper fruits in the formulation of a new type of bread contributes to an increase in antioxidant activity (Fig. 5, *a*, *b*), which is due to an increase in the product composition of powerful antioxidants, which are introduced with juniper. Sodium chloride has practically no effect on the investigated indicator. It should be noted that the maximum antioxidant activity (15.84 mg/100 g) has a bread containing 4.18 % crushed juniper fruits and 1.51 % sodium chloride (Fig. 5, *a*, *b*).

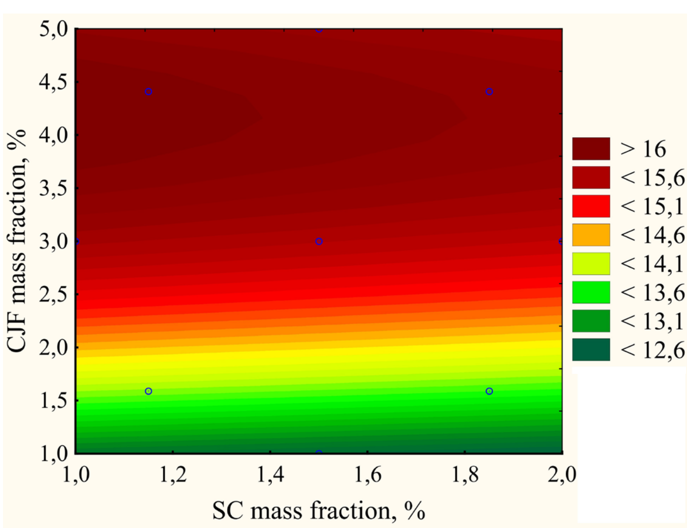


a *b*

Fig. 4. OA dependence (points) of bread on the mass fraction of CJF (%) and SC (%): *a* — response surface; *b* — contour graph



a



b

Fig. 5. AOA dependence (mg/100 g) of bread on the mass fraction of CJ (%) and SC (%): *a* — response surface; *b* — contour graph

The results obtained do not allow determining the optimal mass fractions of raw materials, therefore, to optimize the recipe composition of a new type of bread, a complex quality index (CQI) was used. CQI was determined as a function of assessments of single quality indicators – AOA (mg/100 g) and OA (points) (Table 1), converted to scaled values, taking into account the weight coefficients of individual indicators (Mi) [33]:

$$CQI = M_1 \cdot AOA_{om} + M_2 \cdot OA_{om}, \quad (7)$$

where AOA_{om}, OA_{om} – antioxidant activity and organoleptic assessment of a new type of bread, converted to scaled values; M_1, M_2 – weighting factors of single indicators – AOA and OA, respectively. Wherein:

$$\sum_{i=1}^{n} M_i = 1.0. \quad (8)$$

To transfer single indicators into the range [1, 10], the initial data given in Table 1, scaled by expression (9) [33]:

$$y = \frac{(y_{\max} - y_{\min}) \cdot (x - x_{\min})}{x_{\max} - x_{\min}} + y_{\min}, \quad (9)$$

where y – scaled data; x – initial data, given in Table 1, $x_{\min}$ and $x_{\max}$ – the minimum and maximum values of the initial data (for AOA, $x_{\min}$ and $x_{\max}$ were calculated according to the model (6); for OA – according to the model (5); $y_{\min}$ and $y_{\max}$ – the minimum and maximum values of the new range (1 and 10, respectively).

The scaled values of the unit indicators, calculated by expression (9), and the values of the complex quality indicator, calculated by the formula (7), are given in Table 4 (when calculating the complex quality indicator, the following values of the weight factors were taken (according to the recommendations of the expert commission) – M_1=0.15; M_2=0.85).

Table 4

Scaled values of unit indicators and calculated values of complex quality indicator

Experiment No.	Scaled antioxidant activity scaled (AOA_{om})	Scaled organoleptic assessment (OA_{om})	Complex quality indicator (CQI)
1	4.415	5.961	8.24
2	1.000	4.543	7.50
3	4.097	5.134	8.06
4	8.332	5.488	8.76
5	9.206	2.063	8.33
6	10.000	1.000	8.28
7	9.576	3.126	8.56
8	9.100	6.433	9.02
9	8.676	9.976	9.53
10	8.941	9.740	9.54
11	8.676	9.740	9.50
12	8.941	9.976	9.57

Modeling and processing of the obtained values of the complex quality index of a new type of bread was carried out using the Statistica 10 package (StatSoft, Inc.). To check the significance of the regression coefficients (4), a Pareto chart was constructed, shown in Fig. 6 (*L* – linear effect, *K* – quadratic effect).

The specified Pareto chart (Fig. 6) shows the standardized coefficients, which are sorted by absolute values. Analysis of the data shows that for the complex indicator of the quality of bread, the effect of interaction between the parameters is insignificant (Fig. 5), since the column for evaluating this effect does not cross the vertical line, which is the 95 % confidence level. Therefore, this regression term was eliminated from equation (4). The resulting equation for determining the complex quality indicator of a new type of bread with calculated coefficients is:

$$CQI = -0.560 + 8.059 \cdot C_{SC} - -2.780 \cdot C_{SC}^2 + 2.691 \cdot C_{CJ} - 0.424 \cdot C_{CJ}^2. \quad (10)$$

The adequacy of the developed model (10) was checked by the method of analysis of variance, the results of which are presented in Table 5. The values of the coefficients of determination (R^2=0.98909 and $R^2_{adj} = 0.98285$) and the absence of loss of agreement (p>0.05) indicate that the model adequately describes the experiment.

Table 5

Dispersion analysis of the model (10)

Factor	Sum of squares, SS	Degree of freedom, df	Mean square value, MS	F-test	Significance level, p
(1) SC mass fraction, % (*L*)	0.077675	1	0.077675	76.663	0.003137
SC mass fraction, % (*K*)	0.764549	1	0.764549	754.583	0.000106
(2) CJF mass fraction, %(*L*)	0.354013	1	0.354013	349.399	0.000334
CJF mass fraction, % (*K*)	4.570841	1	4.570841	4511.263	0.000007
Loss of consent	0.054320	4	0.013580	13.403	0.055677
Pure error	0.003040	3	0.001013		
General SS	5.256200	11			
Determination coefficient R^2=0.98909; $R^2_{adj} = 0.98285$					

The combined effect of the mass fraction of sodium chloride and crushed juniper fruits described by polynomial (10) on the complex quality indicator of a new type of bread is graphically presented in Fig. 7.

These data indicate that an increase in the mass fraction of sodium chloride from 1.00 to 1.45 % and the mass fraction of crushed juniper fruits from 1.00 to 3.17 % causes an increase in the value of the complex indicator of the quality of bread (Fig. 7, *a*, *b*). A further increase in the specified ingredients in the bread recipe reduces the value of the complex quality indicator, which is due to the deterioration of the organoleptic characteristics of bread, which have a significant weight in the value of this indicator according to (7) and the recommendations of the expert commission.

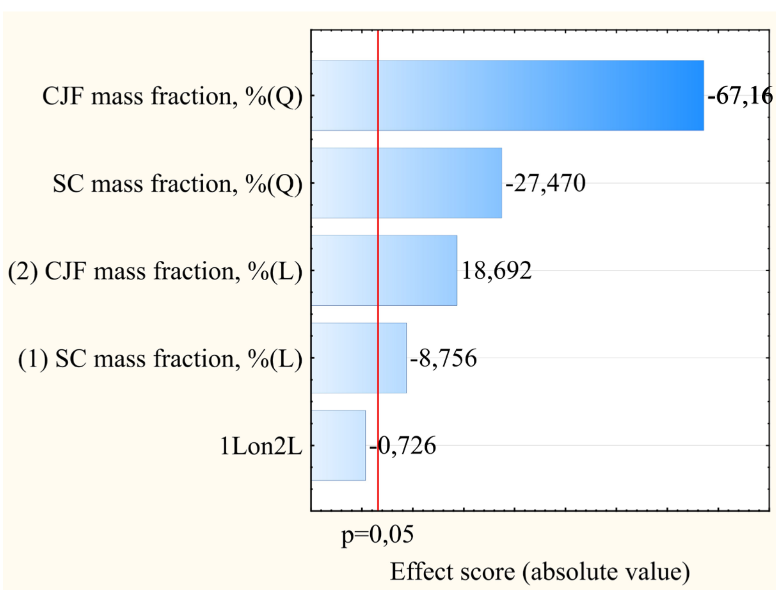


Fig. 6. Pareto chart for checking the significance of the regression coefficients (4)

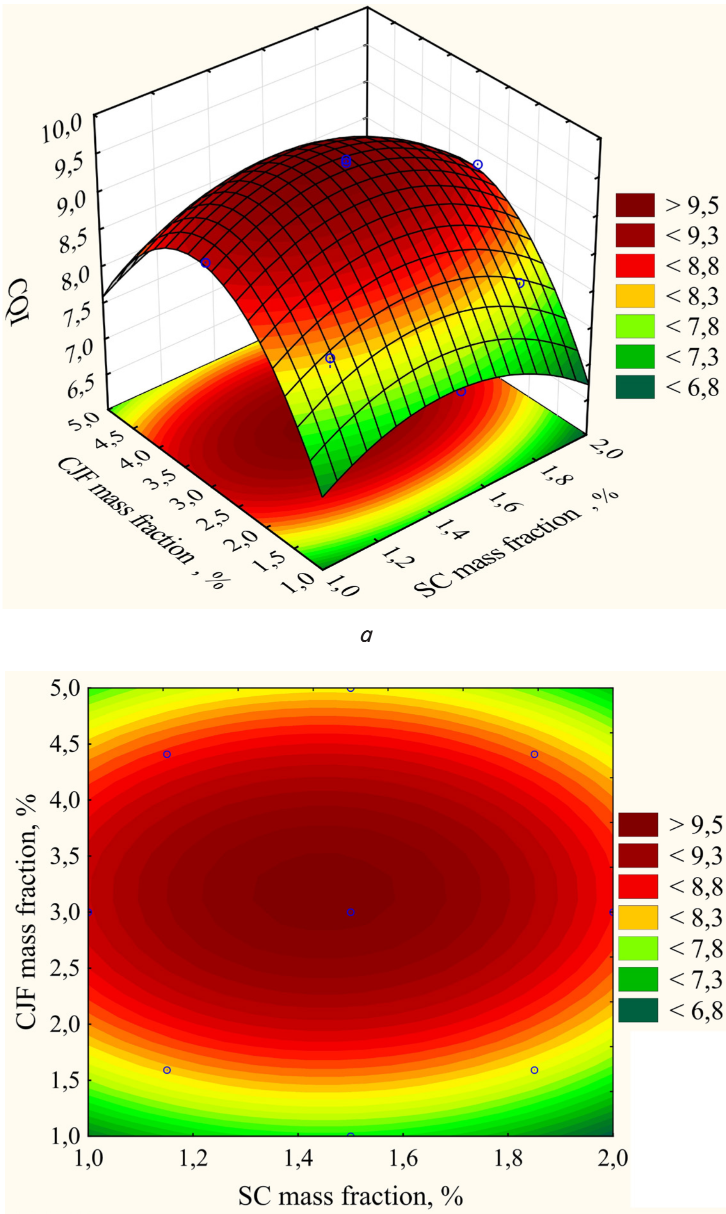


Fig. 7. Dependence of the complex indicator of bread quality on the mass fraction of SC (%) and CJ (%): *a* – response surface; *b* – contour graph

The maximum value of the complex indicator of the quality of a new type of bread, enriched with crushed juniper fruits, is observed at C_{SC}=1.45 % and C_{CJ}=3.17 % (Fig. 7, *a*, *b*). Therefore, the indicated mass fractions of sodium chloride and crushed juniper fruits are optimal in the formulation of a new type of fortified bread.

5. 2. Results of the study of the chemical composition and quality indicators of a new type of bread

The chemical composition and main indicators of the quality of bread with the inclusion of crushed juniper fruits, obtained on the basis of the optimal ratio of recipe components, are given in Table 6. For this, in laboratory conditions, prototypes of a new type of bread were developed, for the convenience of obtaining from a technological point of view, crushed juniper fruits were introduced into the recipe in an amount of 3 %, sodium chloride in an amount of 1.5 %. The developed bread samples were packed in paper bags (leaky containers), and the chemical composition, safety indicators and microbiological indicators were determined in them.

Table 6

Chemical composition and nutritional value of the test samples, g (mg) per 100 g of bread $P \geq 0.95$, $n=3$

Indicators	Control bread sample	Bread with the inclusion of 3 % CJ
Proteins, g	7.1±0.12	7.5±0.26
Fat, g	0.60±0.02	0.80±0.03
Carbohydrates, g incl.:	49.5±0.68	48.7±0.73
– cellulose	1.98±0.04	2.05±0.03
Crumb moisture, %	42.1±0.01	42.3±0.01
Vitamins, mg:		
Ascorbic acid (C)	0	0.0039±0.01
Retinol (A)	0.003±0.01	0.18±0.02
Tocopherol (E)	1.3±0.03	1.7±0.05
Minerals, mg:		
Iron (Fe)	0.95±0.08	2.463±0.05
Cuprum (Cu)	0.032±0.003	0.106±0.005
Potassium (K)	94.84±1.60	120.28±1.80
Phosphorus (P)	67.48±1.53	90.74±1.36
Calcium (Ca)	17.35±0.25	25.79±0.39
Energy value, kcal	231.8	232.0

On the basis of chemical analysis, it was found that bread with the inclusion of 3 % crushed juniper fruits in comparison with the control sample is characterized by an increased content of proteins, fiber, as well as vitamins, micro- and macroelements.

The results of antioxidant activity shown in Fig. 5 indicate that an increase in the amount of crushed juniper fruits in the bread leads to an increase in the studied indicator in comparison with the control sample. Thus, the value of the antioxidant activity of bread with the addition of 3 % juniper is 2 times higher in comparison with the control sample, which is 15.5 and 7.5 mg/100 g, respectively. The results obtained correlate with the literature data [34], which indicate that juniper fruits have high antioxidant activity.

5. 3. Results of studies of microbiological indicators of the quality of new bread and determination of the optimal shelf life

The high antioxidant activity of bread with the inclusion of 3 % juniper directly affects the storage process. The prototypes were stored at a temperature of 20–25 °C and a relative humidity of no more than 75 % for 96 hours. The results of changes in microbiological parameters during storage of the test samples and their compliance with regulatory documents are presented in Table 7.

Table 7

Results of changes in microbiological parameters of the test samples during storage $P \geq 0.95$, $n=3$

Microbiological indicators		Bread sample		According to requirements of CU TR 021/2011
		Control	Bread with the inclusion of 3 % CJ	
QMAFAnM, CFU/g	24 h	Not found	Not found	5.0×10^3
	48 h	$(5.0 \pm 0.5) \times 10^2$	Not found	
	72 h	$(2.5 \pm 1.5) \times 10^4$	Not found	
	96 h	$(8.5 \pm 1.5) \times 10^4$	$(5.3 \pm 0.4) \times 10^2$	
Mold, CFU/g	24 h	Not found	Not found	50
	48 h	<10	Not found	
	72 h	(80±7)	Not found	
	96 h	(135±15)	<30	
Coliform, g	24 h	Not found	Not found	1.0
	48 h	0.01	Not found	
	72 h	0.1	Not found	
	96 h	1.0	0.01	

As a result of the studies carried out, it was established (Table 7) that in a sample of bread with the inclusion of 3 % of crushed juniper fruits, MAFAnM was not detected after 48 hours. In turn, in the control sample, an increase in the amount of MAFAnM was observed after 24 hours of storage. In the samples with the addition of 3 % crushed juniper fruits, mold appeared on the fourth day, in contrast to the control sample. Coliform in the control sample of bread meets the requirements after 72 hours of storage, while in the studied sample of bread with the inclusion of juniper, coliform is less than the standard value after 96 hours of storage. The results obtained indicate that the inclusion of juniper in bread not only increases the nutritional value of finished products, but also prolongs the shelf life of finished products. Thus, a prototype can be stored for up to 72 hours, in contrast to a control sample, which has a guaranteed shelf life of 24 hours.

The results of safety indicators of the samples under study are given in table 8. Prototypes of bread with the addition of crushed juniper fruits meet the safety requirements established by CU TR 021/2011 in all respects. This indicates that the test sample of bread with the addition of 3 % crushed juniper fruits is safe for consumption.

Table 8

Results of safety indicators of the test samples $P \geq 0.95$, $n=3$

Indicator name	Permissible level according to CU TR 021/2011	Control bread sample	Bread with the inclusion of 3 % CJ
Toxic elements, mg/kg:			
Lead	Not more than 0.35	0.01	Not found
Arsenic	Not more than 0.15	Not found	Not found
Cadmium	Not more than 0.07	0.01	Not found
Mercury	Not more than 0.015	Not found	Not found
Pesticides, mg/kg:			
Hexachlorocyclohexane (a-, p-, y-isomers)	Not more than 0.5	0.003	0.001
DDT and its metabolites	Not more than 0.02	0.001	0.001
2,4-D acid, its salts and esters	Not allowed	Not found	Not found
hexachlorobenzene	Not more than 0.01	0.002	0.002
Mycotoxins, mg/kg:			
aflatoxin B1	Not more than 0.005	0.002	0.001
deoxynivalenol	Not more than 0.7	0.3	0.2
T-2 toxin	Not more than 0.1	0.01	0.01
zearalenone	Not more than 0.2	0.1	0.1
Radionuclides, Bq/kg:			
cesium-137	Not more than 40	4.1	4.1
strontium-90	Not more than 20	1.5	1.5

The results obtained indicate the feasibility of producing a new type of bread with the inclusion of crushed juniper fruits. This will expand the range of health products and significantly diversify the traditional nutrition of consumers striving for a healthy lifestyle.

6. Discussion of the results of optimization of the recipe composition and quality indicators of the new product

Based on the optimization of the recipe composition, it was determined that the maximum value of the complex indicator of the quality of a new type of bread, enriched with juniper, is noted at C_{SC}=1.45 % and C_{CJ}=3.17 % (Fig. 7, *a*, *b*). A further increase in the specified components in the bread recipe leads to a decrease in the integrated quality indicator.

First of all, this concerns organoleptic quality indicators, which have a significant weight in the value of a complex quality indicator, and are also one of the main factors influencing the choice of the consumer. The deterioration of organoleptic characteristics is due to the chemical composition of juniper, which is characterized by an increased content of essential oils, organic acids, phenolic compounds and other components that directly affect the change in taste and aromatic characteristics. This is confirmed by the research of scientists in the field of sensory analysis, on the influence of chemical compounds on the organoleptic properties of the product [35, 36].

Due to the inclusion of juniper in the bread, the nutritional value and antioxidant activity of the finished product increases. This is confirmed by the comparative chemical analysis of the developed product with the control sample (Table 6). Due to its chemical composition, namely, the presence of phenolic and aromatic substances [5, 6, 34], juniper has a high antioxidant activity, which is manifested in the finished product (Fig. 5). Also, the inclusion of crushed juniper fruits in an amount of 3 % leads to an improvement in the vitamin and mineral composition of the finished product. This testifies to the prospects for the development and launch of new bread with increased nutritional value on the consumer market.

The results of studies on changes in microbiological quality indicators (Table 7) and determination of the optimal shelf life of the developed product are confirmed by studies on antioxidant activity (Fig. 5). It was found that the experimental sample has a longer shelf life compared to the control sample. This is due to the high value of the antioxidant activity of bread with the inclusion of 3 % juniper.

The research results can be recommended for use in the development of multicomponent products with specified consumer properties, namely yeast bread made from wheat flour of the 1st grade. This will improve the range of products and significantly diversify the traditional diet of consumers striving for a healthy lifestyle.

Prospects for further research are: conducting a comprehensive assessment of the quality of new bread with the inclusion of juniper; drawing up HACCP – a plan for an enterprise for the production of new types of bakery products of increased nutritional value; development of marketing activities for product distribution to the consumer market.

7. Conclusions

1. The optimal ratio of the input of sodium chloride C_{SC}=1.45 % and crushed juniper fruits C_{CJ}=3.17 % is established, corresponding to the maximum value of the complex quality index of the new species.

2. On the basis of chemical analysis, it was found that the prototype bread is characterized by a high content of protein (7.5 g/100 g), fiber (2.05 g/100 g), vitamins, micro- and macroelements. The results of antioxidant activity indicate that the value of the studied indicator for bread with the addition of 3 % juniper is 2 times higher compared to the control sample, which is 15.5 and 7.5 mg/100 g, respectively.

3. The influence of juniper on microbiological parameters and shelf life of bread was determined. A new type of fortified bread with the addition of 3 % crushed juniper fruits can be stored without changing quality indicators for up to 72 hours, which exceeds the same indicator of the control sample. The results of determining safety indicators indicate the sanitary and hygienic safety of the developed product.

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