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Effect of juniper fruit (*Juniperus communis* L.) on bread quality characteristics

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ABSTRACT

The study investigated the effect of chopped juniper fruit in bread formulations on organoleptic, physicochemical and nutritional value. The results showed that juniper fruit added for 3% significantly improved bread's taste, aroma, texture and appearance. According to the results of the tasting evaluation, bread with 3% juniper fruit had high organoleptic parameters and exceptional taste qualities. The protein, fat and fibre content in bread with juniper fruit addition increased significantly compared to the control sample, increasing by 4.0-11.8%, 18.5-14.8% and 322.2-222.2%, respectively. There was also a 2-fold increase in the antioxidant activity of bread with the addition of 3% juniper fruit (15.5 mg/100 g), which has a positive effect on extending the shelf life of bread and preserving its freshness. The loss of bread freshness during storage was slow in the sample with the addition of juniper fruit, which was 20% lower than in the control sample. Physico-chemical analyses showed that juniper fruit increased the nutritional value and enriched the nutrient content. The study's results confirmed that the bread's safety parameters also met the requirements, making it safe for consumption. Thus, chopped juniper fruit in bread production is an effective way to improve the nutritional and organoleptic properties of the product, extending shelf life.

Keywords: bread, juniper fruit, antioxidant, safety, point scale

INTRODUCTION

Today, bread is considered a source of life the basis of nutrition for many nations. The bakery industry is a strategic and socially important branch of the country's economy. In modern conditions of ecological crisis, great attention is paid to the human diet. The diet must contain biologically active natural substances that increase the body's resistance to unfavourable environmental conditions in a mandatory form **[1]**. Bread and bakery products occupy a high share of the consumer basket of the population of our country, so the research in the development of recipe compositions and technologies of new types of bakery products enriched with functional food ingredients is relevant. Phyto powders used as food additives with a high content of biologically active substances are of practical interest in producing food products **[2]**. To expand the range of phytopowders, the food supplements market is constantly searching for new raw materials for their production **[3]**.

Juniper fruits (*Juniperus communis L*) are a rich source of biologically active substances and essential oils, which makes them valuable in medicine and pharmacology. There are four primary terpenes in their composition: bicyclic monoterpenes, monocyclic monoterpenes, monocyclic monoterpene alcohols, and bicyclic sesquiterpenes. The bicyclic monoterpenes, including α- and β-pinene and camphene, represent the highest content. The content of α-pinene in essential oil varies from 30 to 60 %, depending on the place of growth **[4]**.

Juniper fruit oil also includes minor components such as o-cymene, α-limonene, and caryophyllene, emphasising its diverse chemical composition. The fruit contains up to 40% inverted sugar, 2.6% organic acids

(such as malic and ascorbic acids), pectin substances, and up to 2% essential oil, which includes camphor, cadinene, and terpineol **[5]**.

When used in folk medicine, juniper fruits have many properties: they are diuretic, choleretic, antirheumatic, and antiseptic. They are recommended for liver diseases and intestinal disorders and to improve blood quality. In addition, they help to strengthen the immune system, reduce blood sugar levels, and have a rejuvenating effect **[6]**.

Juniper fruit essential oil comprises about 105 components, whereas monoterpenes account for about 57% of all components. The main element remains α-pinene, indicating the pronounced therapeutic potential of this plant **[7]**. The chemical composition of juniper fruit is summarised in Table 1.

Table 1 Chemical composition of common juniper (*Juniperus communis* L.).

Dietary supplement	Composition, %	Components
Essential oil	0.5–2.4	α-pinene, β-pinene, sabinene, limonene, myrcene, terpinen-4-ol,
Monoterpenes		α-terpineol, borneol, geraneol, camphene, camphor, α-eudesmol
Sesquiterpenes		β-caryophyllene, Δ-cadinene, α-cadinene, β-cadinene, farnesol, γ-muurolene, humulene, epi-sesquifelandrene, and others.
Diterpenes	-	sugiol, xanthoperol, 4-epi-abietinic acid
Flavonoids	2.40% - 3.43%	acid, 4-epi-hydrobietinic acid, 4-epi-abietinal, labdane diterpenes, and others.
Tannins		Isoscutelarein, hypoletin, kaempferol 3-O-alpha-rhamnopyranoside, quercetin, nicotiflorin, naringenin-7-o-beta-glucopyranoside, amentoflavone, isoquercetrin, apigenin
Sugar	up to 40	gallocatechin, proanthocyanidin, epigallocatechin
Organic acids		invert sugar (glucose, fructose)
Resins	up to 10	malic, acetic, formic, ascorbic, glucuronic acids
Non-olignan glycosides		
Pigments		unipercomnoside a and b, icarizide

Scientific Hypothesis

Adding 3% juniper to the bread dough composition is expected to improve its organoleptic characteristics, such as flavour and aroma, and positively affect its biological value due to its antioxidant and antimicrobial properties. This ingredient will also positively affect the texture and shelf life of the bread, ensuring an improvement in the quality and safety of the product.

Objectives

Primary objectives: To study the effect of juniper berries on bread quality characteristics and shelf life.

MATERIAL AND METHODS

Samples

Samples description: The following raw materials were used to produce experimental bread samples: Juniper fruits growing in the Almaty region and flour of 1 grade.

Samples collection: Juniper berries (*Juniperus communis* L.) were collected by hand in an ecologically clean area at full ripeness (September-October). The collection site was located away from industrial facilities and motorways, which guaranteed the ecological purity of the raw material. To ensure the homogeneity of the samples, only ripe berries with a characteristic dark blue colour and dense structure were selected. Immediately after collection, the fruits were cleaned of impurities (branches, leaves, dust) and washed in running water. They were then air dried at room temperature in the shade to prevent degradation of the bioactive compounds. The dried fruits were stored in airtight containers in a dark, cool place until they were chopped and used in the experiment.

Samples preparation: To obtain bread, 1st-grade wheat flour, drinking water, pressed yeast, table salt and ordinary juniper fruits were used. In experimental studies, juniper fruits were pre-crushed to 1-2 mm. Crushed juniper fruits were added in 1, 2, 3, 4 and 5%.

Number of samples analysed: 30.

Chemicals

Nitric acid (HNO_3), Sulphuric acid (H_2SO_4), and Ammonia (NH_3) were purchased from Sigma-Aldrich, Inc. (Merck KGaA, Darmstadt, Germany), which guarantees high-quality and reliability of the chemicals used in the experiments.

Animals, Plants and Biological Materials

Juniper berries were provided by NGO "Zerde" LLP, Republic of Kazakhstan, Almaty.

Instruments

pH meter: pH-150 MI (Measuring Technologies LLC, Russia).
Gas chromatograph: «Crystalux 4000M» (Meta-Chrome, Russia)
Mass spectrometer: Agilent 7900 (Agilent Technologies, Japan).

Laboratory Methods

The organoleptic evaluation was conducted using a five-point scale [8]. Each point on this scale represents a specific level of quality in numerical terms: 5 points - excellent, 4 - good, 3 - satisfactory, 2 - insufficiently satisfactory, 1 - unsatisfactory. To express the quality of the bread numerically, it was evaluated as the sum of the points, using the formula (1):

$$K_0 = \sum_{i=1}^{i=n} m_i x_i \quad (1)$$

Where:

K_o – comprehensive evaluation of bread quality, in points;
m_i – weight coefficient of each indicator;
x_i – evaluation of each indicator on a five-point scale;
n – number of indicators.

Ash content is determined by the combustion method by regulatory documents. Fat content is determined by the Soxhlet method, carbohydrates-iodometric titration. The classical method of protein determination in raw and cooked form is the Kjeldahl method, an arbitration method of protein determination. Nutritional and energy value was calculated using generally accepted methods and coefficients: for proteins and carbohydrates - 4 kcal/g; fats - 9 kcal/g.

Determination of physical and chemical parameters is carried out 3 hours after receiving from the oven bakery products from wheat flour weighing more than 200 g.

Determination of sawdust moisture content according to GOST 21094-75.

Determination of sawdust acidity-according to GOST 5670-96.

Determination of porosity-according to GOST 5669-96.

Presence of foreign inclusions and cracks from mineral impurities is determined according to GOST 5667-65.

The vitamins contained in the products are determined by the capillary electrophoresis method in the Kapel 105 K device.

Pesticide content in finished products was determined using an analytical stationary gas chromatograph Crystalux-4000M with an electronic capture detector and NetChrom software. **[9]**.

The content of heavy metals was determined by atomic absorption spectroscopy AAS. Control of the modern instrument and data processing is carried out using a personal computer, software (KVANT) **[10]**.

The determination of antioxidative activity in raw materials and products was carried out using the device TsvetYauza-01-AA, based on the amperometric method of measurement **[11]**.

A Crystallux 4000M gas chromatograph (Meta-Chrome, Russia) equipped with a flame ionisation detector (FID) was used for the analysis. The analytical conditions and instrument parameters are in the column. Type: capillary column with polar stationary phase coating. Length: 30 m. Internal diameter: 0.25 mm. The thickness of the stationary phase layer 0.25 µm. Temperature behaviour: Initial temperature: 60 °C, hold time 2 min. Temperature rise rate: 10 °C/min. Final temperature: 280 °C. Dwell 10 minutes. Injector temperature: 250°C. Detector temperature (PID): 300 °C. Carrier Gas: High purity helium (99.99%). Carrier gas flow rate: 1.0 ml/min. Sample injection volume: 1 µl (split injection with a 1:10 split).

Description of the Experiment

Study flow: At the first stage, all necessary ingredients, including flour, salt, yeast, water, and juniper powder, are received according to the recipe. For the experiment, bread samples were taken with chopped juniper fruits and added in quantities of 1, 2, 3, 4, and 5%. Firstly, all the ingredients are mixed in a carefully dosed manner. After dosing, the dough is kneaded. At this stage, the ingredients are thoroughly mixed to a homogeneous mass. The kneaded dough is allowed to ferment at 32–35 °C for 20–25 minutes. During this process, the yeast activates, releasing carbon dioxide and forming a porous dough structure. This stage is critical to ensuring the desired airy texture. Once fermentation is complete, the dough is cut into portions (disassembly) and placed in moulds or baking trays. This operation takes 15–20 minutes and is essential for forming the future bread's final

structure. After stacking, the dough is left to cool at 18–25 °C. This gives the dough a chance to rest and improves its texture. The humidity at this stage should be 65-70%. The bread is prepared for baking and placed in the oven, where the final rising and crusting occur at high temperatures. After baking, the bread is cooled and stored at a temperature of 20–25 °C and a relative humidity of no more than 75%. This allows the freshness and quality of the product to be preserved for as long as possible.

Quality Assurance

Number of repeated analyses: 5

Number of experiment replications: 5

Reference materials: Buffer solutions with known pH values such as pH 4.00 (KCl), pH 7.00 (phosphate buffer), pH 10.00 (NaOH) were used as standard samples for pH meter calibration. These solutions were used to check the accuracy and correctness of the instrument readings during the calibration process.

Standard mixtures of organic substances including alkanes (e.g., hexane, octane), organic acids, esters, and alcohols, were used to calibrate the gas chromatograph. These mixtures were used to determine the accuracy of the gas chromatograph and its detector in analysing individual components in the samples.

Standard mixtures of organic and inorganic substances were used to calibrate the mass spectrometer such as: perfluorocalene (C5HF11) for mass spectrometric calibration, standard calibration mixtures to determine the accuracy of mass spectrometric measurements, individual compounds of known molecular weight to check mass and peak detection accuracy. These standard samples were used to ensure the accuracy, reproducibility and correctness of laboratory equipment and analytical methods.

Calibration: pH-150 MI (Measuring Technologies LLC, Russia). The pH meter was calibrated before each measurement using standard buffer solutions of known pH (pH 4.00, 7.00 and 10.00). Calibration was performed according to the manufacturer's instructions to ensure accuracy and reproducibility of results. After calibration, the stability of the readings was checked using additional standard solutions. Gas chromatograph: Crystallux 4000M (Meta-Chrome, Russia) - the gas chromatograph was calibrated using standard mixtures of components corresponding to the substances under investigation. Calibration was performed using known concentrations of standard samples to determine the accuracy and linearity of the measurements. The sensitivity and repeatability of the system were checked by analysing control samples of known concentrations to confirm the correct operation of the detector and columns. Mass spectrometer: Agilent 7900 (Agilent Technologies, Japan) - The mass spectrometer was calibrated using standard calibration mixtures to ensure accuracy in determining the mass and structure of molecules. The calibration process checked the sensitivity and accuracy of the system operation for the selected mass ranges. Calibration solutions of known concentrations were used to determine if the detector and spectrometer were operating correctly according to established standards. Each instrument was calibrated before each experiment, and calibration checks were performed regularly to maintain measurement accuracy.

Laboratory accreditation: The experiments were conducted in the laboratory “Food Safety” accredited in the accreditation system of the Republic of Kazakhstan for compliance with the requirements of GOST ISO/IEC 17025-2019 (General requirements for the competence of testing and calibration laboratories), (Accreditation Certificate No. KZ.T.02. E 1158).

Data Access

The data supporting the findings of this study are not publicly available.

Statistical Analysis

The results of the experimental studies were processed using mathematical statistics. The experimental data was analysed using the Data Analysis in Microsoft Excel and Statistica. Each experiment was performed with a minimum of three to seven repetitions. The acquired results were subjected to standard processing methods and are presented as average values and standard errors of the mean (± SEM). Statistical results were assessed using the student’s t-test, with differences considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

The Almaty market has a limited supply of bread with functional additives enriched with natural ingredients. When developing the product, the consumer characteristics of bread and its cost were considered the primary motivation for purchase. Therefore, special attention was paid to the appearance of bread and organoleptic characteristics. In this regard, an assessment of consumer preferences for bread and the feasibility of introducing powders made from vegetable raw materials into the recipe was carried out **[12]**.

Based on the developed point scale, the tasting commission of Odesa National Technological University (Ukraine) conducted a tasting of a new type of bread with juniper fruit powder.

The following bread samples were offered for tasting:

№ 1 - control sample,

№ 2 - bread with the addition of 1.0% juniper fruit powder,

№ 3 - bread with 2.0% juniper added,
№ 4 - bread with 3.0% juniper added,
№. 5 - bread with 4.0% juniper added,
№ 6 - bread with the addition of 5.0 per cent juniper.

The tasting samples of bread were evaluated according to organoleptic quality indicators using a 5-point scale. The results of the tasting panel are given in Table 2.

Table 2 Results of the tasting.

Indicator	**Samples (bread with addition of juniper fruit)**					
	1%	**2%**	**3%**	**4%**	**5%**	**control sample**
	Estimation of indicators taking into account coefficients X_iK_i					
Shape	4.2±0.02	4.2±0.02	4.2±0.02	4.0±0.02	4.0±0.02	4.2±0.02
Outer surface	4.2±0.04	4.2±0.02	4.3±0.02	4.0±0.02	3.9±0.02	4.3±0.02
Colour	4.8±0.03	4.8±0.03	4.8±0.03	4.0±0.02	3.8±0.02	4.8±0.03
Bread crumb	4.8±0.01	4.8±0.01	4.8±0.01	4.3±0.01	4.0±0.01	4.8±0.01
Porosity	4.0±0.04	4.0±0.04	4.0±0.04	3.5±0.05	3.5±0.05	4.0±0.04
Odour	5.0±0.01	5.0±0.01	5.0±0.01	4.3±0.18	4.0±0.18	5.0±0.01
Flavour	4.9±0.25	4.9±0.1	4.9±0.1	4.2±0.25	3.5±0.25	4.9±0.1
Assessment of summary indicators $\sum_{i=1}^{n}$ **XiKi**						
Total score	4.40	4.78	4.86	4.20	4.10	4.86
Quality category	(well)	(perfectly)	(perfectly)	(well)	(well)	(perfectly)

In the course of tasting, in the opinion of experts, bread with 1.0% juniper fruit powder has insufficient flavour and odour. Bread with 3.0% juniper fruit powder has a regular shape, surface without large cracks and breaks, and external colour from light yellow to slightly brown; the crumb is not moist, elastic, well-developed and uniform; the taste is slightly sweetish, and the smell is characteristic. Bread with 5.0% juniper fruit powder has a bubbly, rough surface with large cracks, matt colour, dark brown, sour, unpleasant smell with a slight foreign taste. According to the tasting results, the experts gave a very good assessment of the organoleptic parameters of bread with a 3% addition of juniper fruit powder.

Based on the quality analysis of the tested samples, an organoleptic evaluation was made in the form of a profilogram (Figure 1).

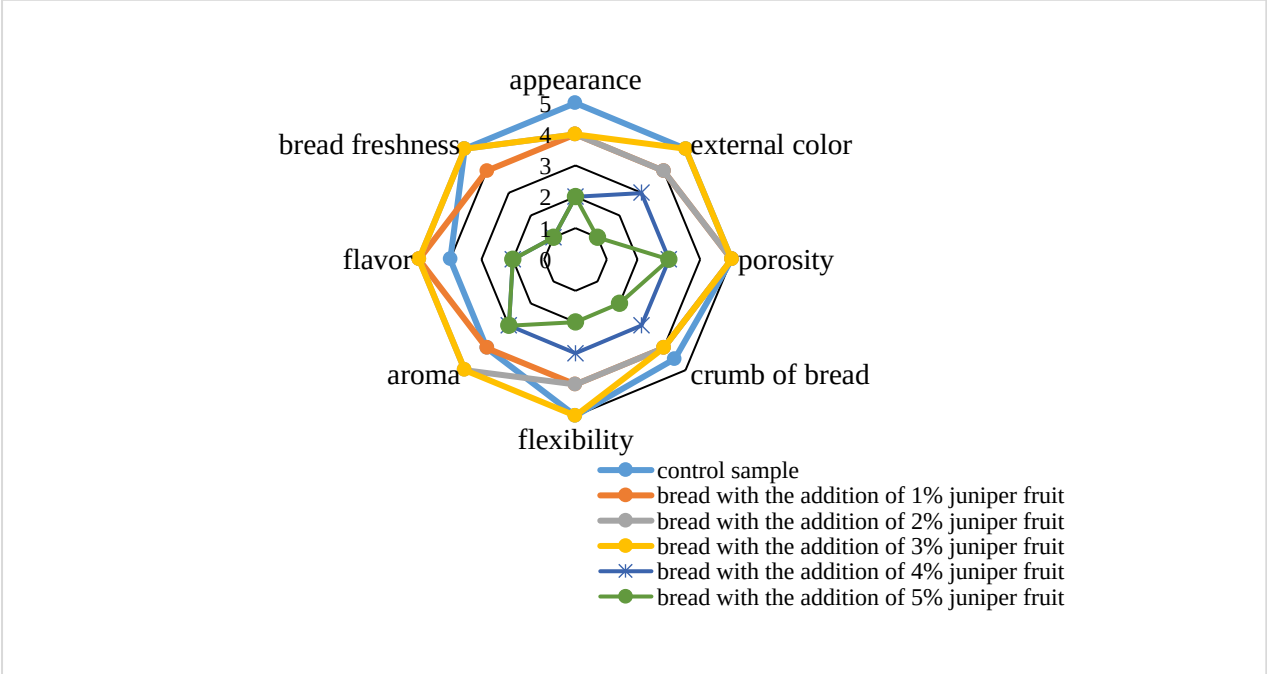

Figure 1 Profilogram of organoleptic quality indicators of bread with juniper fruit addition.

A profilogram of organoleptic quality indicators of bread with the addition of juniper fruit powder showed that bread with the addition of 3% juniper fruit powder has high-quality indicators.

Organoleptic evaluation of bread prepared with the addition of juniper fruit powder confirmed its bright crust colour shades, taste and aroma, which depend not only on the features of the raw materials used but also on the depth of biochemical and microbiological processes in the dough.

In addition, using juniper fruit powder, which is characterised by a high content of sugars, dietary fibres and pectin substances, helps preserve the freshness of the bread crumb.

Physico-chemical quality parameters of the finished product with juniper fruit powder were obtained based on six bread baking series and their effect on the quality of bread prepared from wheat flour.

Juniper fruit powder was added in 1, 2, 3, 4 and 5%.

The results of the study's effect of juniper fruit powder on physicochemical parameters of bread quality are shown in Table 3.

Table 3 Effect of juniper fruit powder on physicochemical parameters of bread.

Physico-chemical parameters	**Bread samples (addition of juniper fruit)**					
	control sample	**1%**	**2%**	**3%**	**4%**	**5%**
Bread humidity, %, not more	42.1±0.01	42.1±0.01	42.4±0.01	42.3±0.01	42.3±0.01	42.5±0.01
Bread acidity, deg., not more	2.3±0.05	2.5±0.01	2.5±0.01	2.6±0.03	2.8±0.03	3±0.04
Bread porosity, %, not less	65±1.15	65±1.24	65±1.24	66±1.10	66.5±1.10	67±1.0

Adding 3% powdered juniper berries to the dough was determined to improve bread quality based on the leading physico-chemical indicators. Using 4% or higher powdered juniper berries makes the breadcrumb darker.

Thus, it can be concluded that adding 3% powdered juniper berries is optimal. Considering unconventional raw materials, the composition of nutrients in 100 g of bread with powdered juniper berries was determined. The obtained results are presented in Table 3. The protein content in bread with powdered juniper berries increased by 4.0% and 11.8% compared to the control sample; the fat content increased by 18.5% and 14.8%; the fiber content increased by 322.2% and 222.2%, respectively. Nutritional values of tested bread samples are present in Table 4.

Table 4 Nutritional value of tested samples, per 100 g of bread.

Indicator	**Bread samples (addition of juniper fruit)**					
	control sample	**1%**	**2%**	**3%**	**4%**	**5%**
Protein, g	7.1±0.12	7.1±0.26	7.1±0.26	7.98±0.26	7.5±0.26	7.5±0.26
Oil, g	0.60±0.02	0.62±0.03	0.62±0.03	0.20±0.03	0.80±0.03	0.80±0.03
Carbohydrates, including: g	49.5±0.68	49.2±0.73	49.2±0.73	48.7±0.73	48.7±0.73	48.7±0.73
- fibre	1.98±0.04	1.98±0.03	1.98±0.03	2.11±0.03	2.05±0.03	2.05±0.03
Vitamins, mg						
Ascorbic acid (C)	0	0.0001±0.01	0.0001±0.01	0.0039±0.01	0.0040±0.01	0.0042±0.01
Retinol (A)	0.003±0.01	0.003±0.01	0.003±0.01	0.18±0.02	0.18±0.02	0.18±0.02
Tocopherol (E)	1.3±0.03	1.3±0.03	1.3±0.03	1.7±0.05	1.7±0.05	1.7±0.05
Mineral substances, mg						
Iron (Fe)	0.95±0.08	0.98±0.08	0.98±0.08	2.463±0.05	2.463±0.05	2.463±0.05
Cape (Cu)	0.032±0.003	0.035±0.003	0.035±0.003	0.106±0.005	0.106±0.005	0.106±0.005
Potassium (K)	94.84±1.60	98.84±1.60	98.84±1.60	120.28±1.80	120.28±1.80	120.28±1.80
Phosphorus (P)	67.48±1.53	69.48±1.53	69.48±1.53	90.74±1.36	90.74±1.36	90.74±1.36
Calcium (Ca)	17.35±0.25	19.35±0.25	19.35±0.25	25.79±0.39	25.79±0.39	25.79±0.39
Energy value, kcal	231.8	231.9	231.9	232	232	232

The energy value of bread with powdered juniper berries slightly decreased and amounted to 232 kcal, compared to the control sample with an energy value of 231.8 kcal.

In the bread with powdered juniper berries, safety indicators such as toxic elements, mycotoxins, pesticides, radionuclides, and microbiological parameters were determined. The results of the conducted research are presented in Table 5 and Figure 2.

Table 5 presents the results of the safety indicators of the studied samples. The analysis of the conducted studies proves that the experimental samples of bread with powdered juniper berries meet all the safety requirements established by the technical regulation TR 021/2011.

Table 5 Results of safety indicators of the tested samples.

		Bread samples (addition of juniper fruit)					
Indicator	**Permissible level according to TR TS 021/2011**	**control sample**	**1%**	**2%**	**3%**	**4%**	**5%**
Pesticides, mg/kg:							
hexachlorocyclohexane (α-, β-, γ-isomers)	no more than 0.5	0.003	0.002	0.002	0.001	0.001	0.001
DDT and its metabolites	no more than 0.02	0.001	0.001	0.001	0.001	0.001	0.001
2,4-D acid, its salts and ester	is not allowed	Not found	Not found	Not found	Not found	Not found	Not found
hexachlorobenzene	no more than 0.01	0.002	0.002	0.002	0.002	0.002	0.002
Mycotoxins, mg/kg:							
aflatoxin B1	no more than 0.005	0.02	0.001	0.001	0.001	0.001	0.001
deoxynivalenol	no more than 0.7	0.3	0.2	0.2	0.2	0.2	0.2
T-2 toxin	no more than 0.1	0.01	0.01	0.01	0.01	0.01	0.01
zearalenone	no more than 0.2	0.1	0.1	0.1	0.1	0.1	0.1
Radionuclides, Bq/kg:							
caesium-137	no more than 40	4.1	4.1	4.1	4.1	4.1	4.1
strontium-90	no more than 20	1.5	1.5	1.5	1.5	1.4	1.3

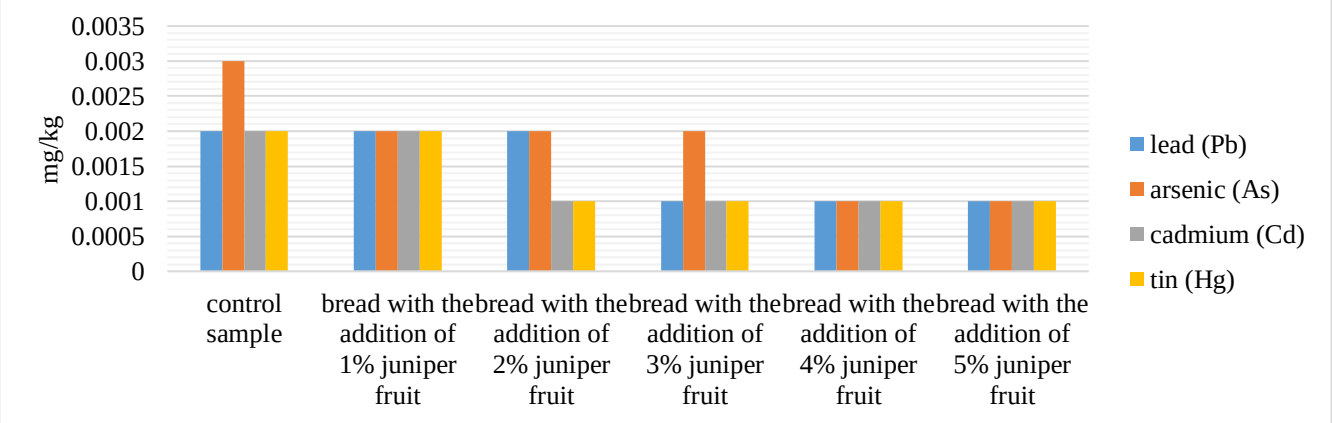

Figure 2 Indicators of toxic elements in bread with the addition of juniper powder.

The tested bread sample with 3% ground juniper berries did not exceed the permissible limits set by theTechnical Regulation 021/2011 for food safety.

As a result of processing the research data, a histogram of the overall antioxidant activity of the bread with ground juniper berries was created (Figure 3).

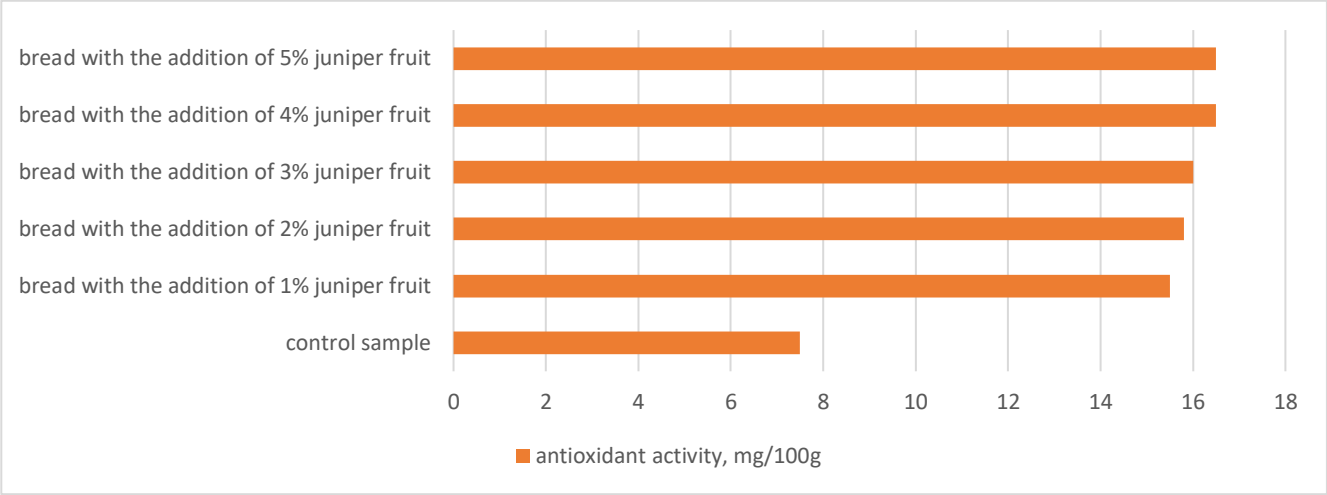

Figure 3 Effect of antioxidant activity of chopped juniper fruit on bread.

Antioxidant parameters of the control sample and bread with 3% chopped juniper fruit were determined. Compared to the control sample, bread with 3% chopped juniper fruit showed higher antioxidant activity. Thus, the antioxidant activity of bread with adding 3% chopped juniper fruit was 2 times higher than the control sample, amounting to 15.5 and 7.5 mg/100 g, respectively. These results follow literature data indicating the high antioxidant activity of crushed juniper fruits. The high level of antioxidant activity of bread with 3% juniper addition directly affects its storage process.

Thus, using crushed juniper fruit (*Juniperus communis* L.) in food products positively affects quality parameters.

To determine the influence of crushed juniper fruit on the quality indicators of bread from wheat flour and its shelf life, organoleptic parameters were analysed 16 hours after baking and during storage. The control sample was bread baked without herbal ingredients.

The study results of freshness and stale indices of samples of different storage durations are presented as a diagram (Figure 4).

In 16 hours after baking, the bread sample enriched with chopped juniper fruit had a regular shape, smooth, golden, uniformly coloured crust, light pleasant fruit aroma with a pronounced taste, and developed thin-walled homogeneous porosity.

During storage, the organoleptic parameters of bread changed: hard and brittle crust became soft and shrivelled, intensity of taste and aroma decreased, crumb elasticity and chewability deteriorated, and the number of crumbs increased.

In the course of storage, it was found that the degree of loss of freshness of bread in the control sample was more intense than in the sample with the addition of crushed juniper fruit. For the control sample, the average score for all indicators of freshness and stiffness of bread decreased by 51.8% after 72 hours of storage, while for the sample with the addition of crushed juniper fruit, the decrease amounted to 31.3%.

The results of the study showed that the addition of crushed juniper fruit to bread improved its organoleptic characteristics such as flavour, aroma, texture and appearance, as well as physicochemical parameters. These results are supported by similar studies where adding natural additives also improved bread quality. For example, the effect of post-distillation solid waste aromatic plants, oregano, rosemary, melissa and mint in wheat bread at concentrations of 1% and 2% on their physicochemical and sensory properties, as well as antioxidant and volatile matter profile has been investigated **[13]**, and that bread made with flour derived from vegetable waste contains more fiber and bioactive substances **[14]**. In some studies, for example, adding grape seed powder to bread also improved composition, including increased fiber and antioxidant components **[15]**.

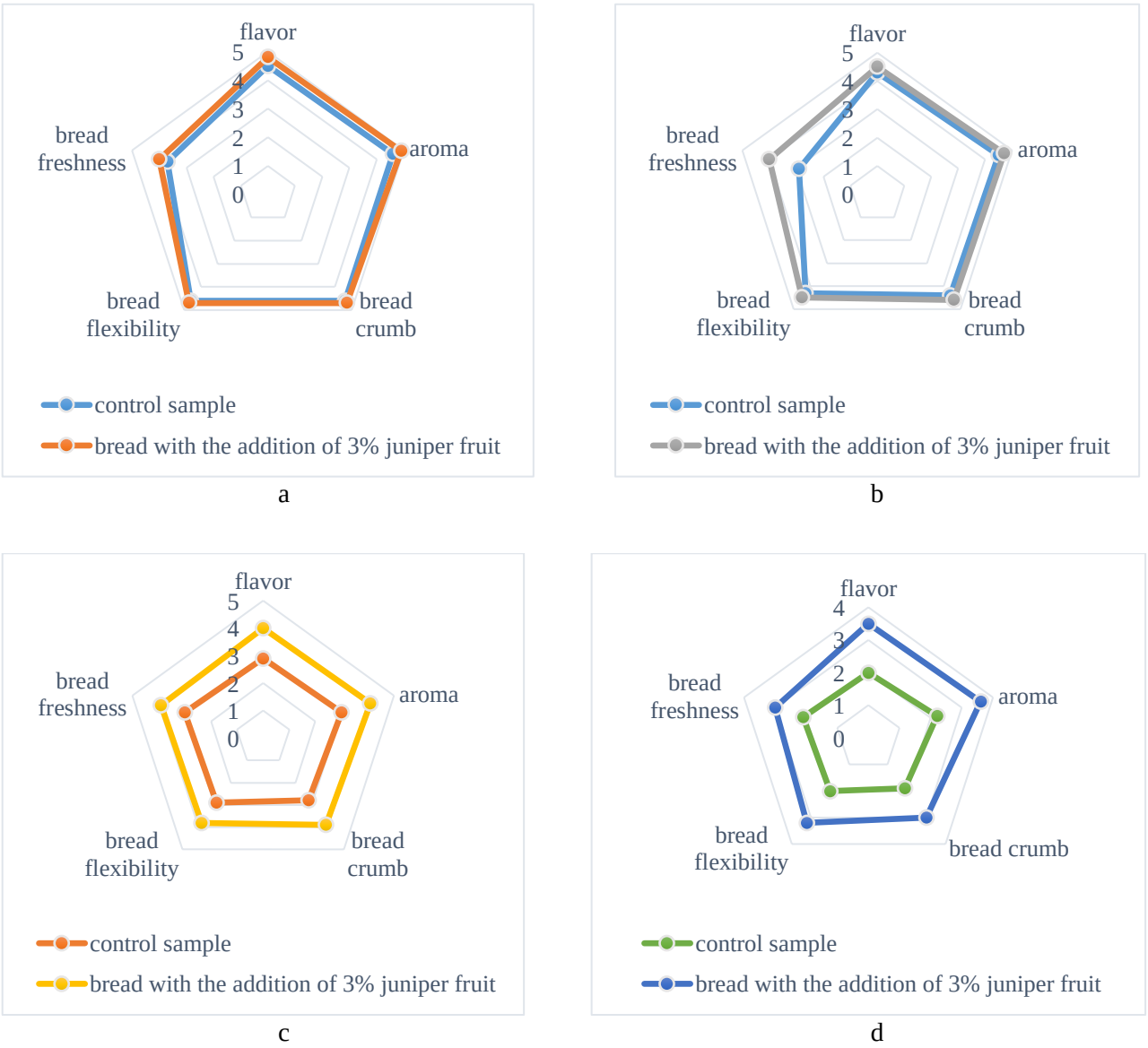

Figure 4 Diagram of bread freshness assessment (a – storage after 16 hours, b – storage after 24 hours, c –storage after 48 hours, d – storage after 72 hours).

The effects of different plant materials such as defatted *Cephalaria syriaca* flour (0.5%), rosehip (2.5%), native gluten (2.5%) and malt flour (2%) and their combinations on the quality of whole wheat bread were investigated **[16]**. Adding 4% fermented wheat germ to bread improves nutritional properties, flavour, quality and structural characteristics and increases shelf life **[17]**. Adding flaxseed cake and lupin flour to wheat bread increases its nutritional value while maintaining its physicochemical properties and sensory acceptability **[18]**. Apple pomace has been experimentally found to improve bread's iron and phosphorus content. Apple pomace powder and frozen apple pomace improved the organoleptic properties of wheat bread, while apple pomace powder improved the physicochemical parameters **[19]**. The addition of white mulberry extract to chilled bread improves its phenolic compounds sensory properties **[20]**, and the use of 10% dough flour and sourdough starter in wheat bread improves its quality and nutritional value by maintaining the elasticity and extensibility of the dough **[21]**. Replacing wheat flour with 1% chia seeds significantly increases the nutritional value and volume of the loaf, making this option more economically and technologically feasible for bakers **[22]**. Adding 15% fermented oat beverage byproduct to wheat bread increases the nutritional value **[23]**. Adding spices, herbs and green plant parts to wheat bread can increase its antioxidant capacity and nutritional value, making it a functional food with potential health benefits **[24]**.

One of the key results of our study is a significant increase in the antioxidant activity of bread with the addition of 3% juniper fruit, which was twice as high as that of the control sample. In addition, the increase in antioxidant

activity may contribute to the shelf life of bread. In our study, the bread with juniper added retained its freshness 31.3% longer than the control sample, indicating its potential as a natural preservative.

This observation is consistent with numerous studies in which plant extracts such as juniper have been confirmed as effective antioxidants. Juniper berries have natural antioxidant and antimicrobial properties, suggesting they could be a potential natural food additive **[25]**. For example, in one study, Juniperus Siberia Burgs Dorf exhibit potent antioxidant and anti-inflammatory properties, making them a promising new source of bioactive natural compounds for food additives and therapeutic agents **[26]**. Also, extracts of Juniperus fruits exhibit strong antioxidant properties, potentially contributing to the inhibition of lipid peroxidation **[27]**. The alcoholic extract of Juniperus communis L. berries has the most potent antioxidant activity, with a higher total phenols and flavonoids content, suggesting potential use as significant antioxidants **[28]**. Methanolic extract of juniper fruit shows potent inhibition of Gram-positive bacteria, with high phenolic content and antioxidant potential **[29]**.

Due to their high antioxidant activity, *Juniperus excelsa*, *Juniperus oxycedrus* subsp. *oxycedrus*, *Juniperus sabina* and *Juniperus phoenicia* can be used in the food industry as preservatives or to extend the shelf life of raw and processed foods **[30]**.

The results of analysing scientific studies of methanolic extracts of juniper (Juniperus communis) showed fairly good activity against both sensitive and antibiotic-resistant strains of Staphylococcus aureus. They suggested an essential role of soluble phenolic fraction **[31]**, and some researchers have also demonstrated the antitumor effects of these plant extracts on some cancer cells. Unique therapeutic properties such as antidiabetic, antiparkinsonian, antioxidant and antimicrobial effects have also been reported **[32]**.

Juniperus essential oil has antioxidant properties and antifungal activity against *Penicillium citrinum* and *Aspergillus niger* **[33]**. This was investigated and confirmed in vitro for its antioxidant and antiradical activity **[34]**. The effect of adding *Juniperus communis* L. essential oil (JEO) at concentrations of 0.01, 0.05 and 0.10 µl/g on pH was evaluated. The reduced level of sodium nitrite (75 mg/kg) combined with all three JEO concentrations (0.01-0.10 µl/g) resulted in satisfactory physicochemical properties and improved oxidative stability (TBARS < 0.3 mg MDA/kg) of dry fermented sausages produced with 25% fat **[35]**. Essential oils from *Juniperus thurifera* L. have significant antioxidant, antibacterial and antifungal properties, potentially offering an alternative to antibiotics in the fight against microbial resistance **[36]**. As well as, aromatic water from juniper fruit has antibacterial and antioxidant properties, with the essential oil inhibiting the growth of some bacteria and the aromatic water having no significant effect **[37]**.

Adding juniper fruit also increased the protein, fat and fiber content of bread, confirming the effectiveness of this ingredient in improving the nutritional value. This demonstrates the prospects of using juniper and other herbal additives to improve the nutritional properties of baked goods.

CONCLUSION

The study showed that chopped juniper fruit in bread formulations significantly improved the product's organoleptic, physicochemical and nutritional value. Juniper fruit added in 3% optimised the bread's taste, aroma, texture and appearance. According to the results of the tasting evaluation, the bread with 3% juniper fruit had high organoleptic parameters and was characterised by special taste qualities.

In addition, the protein content of bread with added chopped juniper fruits increased by 4.0 and 11.8% compared to the control sample; the fat content increased by 18.5 and 14.8%; and the fibre content increased by 322.2 and 222.2%, respectively.

The value of the antioxidant activity of bread with the addition of 3% chopped juniper fruit was 2 times higher compared to the control model, which was 15.5 and 7.5 mg/100 g, respectively. The high antioxidant activity of juniper fruit showed that it had a positive effect on preserving the freshness of bread, extending its shelf life.

It was found that the loss of the degree of freshness of the control bread sample during storage was more intensive than that of the sample with the addition of chopped juniper fruit. The average score of all freshness-blackness indicators for the control sample decreased by 51.8% after 72 hours of storage and by 31.3% for the bread sample with crushed juniper fruit.

Physicochemical analyses also showed promising results in the bread by adding 3% juniper fruit, which increased the product's nutritional value and enriched the nutrient content. In addition, the safety performance of the bread also met the requirements during the study, which ensured the product was safe for consumption.

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