Scifood
vol. 20, 2026, p. 265-279
https://doi.org/10.5219/scifood.93
ISSN: 2989-4034 online
https://scifood.eu

Received: 2.2.2026
Revised: 17.3.2026
Accepted: 19.3.2026
Published: 2.4.2026

Quality assessment of canned vegetable snacks with added grains

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ABSTRACT
This study investigated the effect of adding different cereal grains (rice, buckwheat, and bulgur) to canned vegetable snacks on their organoleptic, nutritional, and safety characteristics. Experimental samples containing 10%, 20%, and 30% cereal components were prepared and evaluated using physicochemical, amino acid, and sensory analyses. The results demonstrated that the addition of 20% buckwheat or bulgur significantly improved sensory characteristics, including taste, aroma, colour, consistency, and component balance. According to the organoleptic evaluation, samples containing 20% cereals received the highest total sensory scores, indicating optimal harmony between vegetable and grain components. Protein content increased from 1.52% in the rice control sample to 2.11–2.44% in cereal-enriched formulations (approximately 39–60%, $p < 0.05$). The enrichment also led to higher levels of vitamins B and E (25–55%) and minerals such as magnesium, potassium, and iron (25–70%), depending on the type of cereal added. Amino acid analysis revealed elevated levels of several essential amino acids, thereby improving the products' nutritional profile. Safety analysis showed that toxic elements (Pb, Cd) and pesticide residues (HCH isomers and DDT metabolites) were not detected in the analysed samples, indicating compliance with current food safety requirements. The results demonstrate that incorporating buckwheat and bulgur into canned vegetable snacks is a promising approach to enhance nutritional value and sensory quality while maintaining compliance with established food safety standards.

Keywords: bulgur, buckwheat, canned vegetable snacks, nutritional value, safety

INTRODUCTION
Ensuring a rational and balanced diet for the population is a priority for the modern food industry and the agro-industrial complex as a whole. Canned products play an important role in achieving this goal, as they preserve the nutritional value of raw materials and ensure a year-round, stable supply of high-quality, safe products to consumers. Among the various types of processed products, canned vegetable snacks occupy a special place, distinguished by their high nutritional value, variety of recipes, and ease of use **[1]**, **[2]**.

In recent decades, there has been a growing interest in ready-to-eat canned vegetables. These products are ready-made dishes prepared from various vegetables, suitable for both cold and hot consumption. They may include whole or chopped vegetables, stuffed or unstuffed, covered with tomato sauce, vegetable oil, or other liquid ingredients. Canned vegetable snacks retain the main nutrients of the original raw materials — vitamins, minerals, and dietary fibre — while providing convenient storage and a long shelf life **[3]**.

The preservation process is characterised by minimal processing, thereby maintaining the nutritional value of vegetables at a level comparable to that of fresh or frozen products. Heat treatment ensures microbiological safety and increases the bioavailability of several biologically active compounds, such as lycopene and β-carotene, despite the partial loss of water-soluble vitamins (C and B group). As a result, canned vegetables are an important part of a healthy diet, providing essential nutrients and vitamins year-round.

Current trends in the canned vegetable market focus on expanding product ranges, enhancing nutritional and functional value, and improving organoleptic characteristics. One promising direction is incorporating cereals such as rice, buckwheat, millet, bulgur, and wheat groats into recipes, thereby increasing the protein, fibre, vitamin, and mineral content. The inclusion of cereals improves the texture, taste, and nutritional value of the finished product, as well as creating new types of functional canned foods adapted to the needs of different population groups **[4]**, and **[5]**.

Of particular interest are cereal crops such as buckwheat and bulgur, which are high in protein, dietary fibre, and biologically active substances. Buckwheat (Fagopyrum esculentum) is a source of complete vegetable protein containing all essential amino acids, as well as being rich in B vitamins, rutin, iron, magnesium, potassium, zinc, and manganese. It has a low glycaemic index and is recommended for inclusion in diets for individuals with diabetes and cardiovascular disease. Buckwheat proteins are highly digestible, and the presence of rutin gives them antioxidant properties and helps strengthen blood vessel walls **[6]**, and **[7]**.

Bulgur, in turn, is a cereal product obtained from wheat by steaming, drying, and crushing, a process that preserves most of the original grain's nutritional components. It is a valuable source of plant protein, dietary fiber, B vitamins, and essential minerals, including magnesium, phosphorus, potassium, and zinc. Compared with rice, bulgur contains approximately 1.5 times more dietary fiber and a significantly higher protein content, which may improve digestion, reduce blood cholesterol levels, and normalize metabolic processes. Its low glycemic index makes bulgur a valuable component of dietary and functional nutrition **[8]**, and **[9]**.

The use of bulgur in vegetable canning technology also offers technological advantages: a preliminary heat treatment ensures long-term storage and stability of the grain without loss of its nutritional properties, thereby increasing the stability and safety of the finished product **[10]**.

Thus, the development of new types of canned vegetable snacks using various cereal crops is a relevant area of focus in the food industry. This study aims to develop and comparatively evaluate recipes for canned vegetables incorporating buckwheat and bulgur, and to determine their effects on the organoleptic, physicochemical, and nutritional characteristics of the finished product. The results obtained may help expand the range of canned foods, enhance their functional value, and meet the growing demand for high-quality, balanced ready-made foods **[11]**.

Scientific Hypothesis

The addition of various grains (buckwheat, bulgur, and rice) to canned vegetable snacks enhances their nutritional, biological, and organoleptic value by increasing protein, vitamin, mineral, and essential amino acid content while maintaining product safety and organoleptic qualities. The optimal proportion of grain additives ensures a balance between the product's nutritional value and consumer characteristics.

Objectives

Primary objectives: Determine the effect of adding various grain crops on the quality and consumer properties of canned vegetable snacks.

MATERIAL AND METHODS

Samples

Samples description: Fresh vegetables (carrots, onions, sweet peppers, and tomatoes), vegetable oil, table salt, and three types of grains — buckwheat, bulgur, and rice (control sample) — were used to prepare experimental samples of canned vegetable snacks.

Selection and preparation of raw materials: The vegetables were purchased from local farmers in the Almaty region during the harvest season (August–September), which ensured the freshness and uniformity of the raw materials. All vegetables were sorted by hand, damaged and unripe specimens were removed, thoroughly washed with running water, cleaned, and cut into uniform pieces.

Cereals (buckwheat, bulgur, rice) were obtained from the local producer KazGrain LLP. Before use, the cereals were visually inspected to exclude impurities and foreign particles, washed, and dried at 40 ± 2 °C in a drying oven (Binder FD 115, Germany) to constant weight.

Samples preparation: The vegetable mixture was blanched at 90–95 °C for 3–5 minutes, after which it was mixed with various grains at 10%, 20%, and 30% of the vegetable mass. The control sample contained rice. The resulting mixtures were packed into 0.5-litre glass jars, sealed tightly, and sterilised in an autoclave (type AVK-30, Russia) at 115 °C for 60 minutes. After sterilisation, the jars were cooled to room temperature and stored at 20–22 °C.

Number of samples analysed: A total of 35 experimental units were evaluated: 6 grain-enriched formulations (2 grain types × 3 concentrations) plus one rice-based control formulation. Each formulation was prepared in five independent replicates. Two-way ANOVA was applied only to buckwheat and bulgur formulations (grain type × concentration), while the rice sample was used as a reference control.

Chemicals

Nitric acid (HNO_3, ≥65%, ACS reagent grade), sulphuric acid (H_2SO_4, ≥95–98%, ACS reagent grade), ammonia solution (NH_3, 25%, analytical grade), and petroleum ether (boiling range 40–60 °C, ≥99%, HPLC grade) were purchased from Sigma-Aldrich (Merck KGaA, Darmstadt, Germany).

Animals, Plants and Biological Material

Not applicable. The present study did not involve the use of experimental animals, biological strains, cell cultures, or human biological materials. The research was conducted using commercially available raw materials for food production (vegetables and cereal grains).

Instruments

pH meter – pH-150 MI (Measuring Technologies LLC, Russia);
Gas chromatograph – Crystallux 4000M (Meta-Chrome, Russia);
Spectrophotometer – UV-1800 (Shimadzu, Japan);
Amino acid analyser – L-8900 (Hitachi, Japan);
Atomic absorption spectrometer – Agilent 7900 (Agilent Technologies, Japan).

Laboratory Methods

Determination of chemical composition

The chemical composition of the samples was determined using standard methods:
Protein content — using the Kjeldahl method (GOST 10846-91);
Fat content — using the Soxhlet method (GOST 29033-91);
Carbohydrates — using a calculation method (based on the difference);
Vitamins A, E, B, and C — using high-performance liquid chromatography (HPLC, Agilent 1260).

Determination of vitamins by HPLC. Vitamins A, E, C, and the B group were determined by high-performance liquid chromatography (HPLC) using an Agilent 1260 system (Agilent Technologies, USA) equipped with a diode-array detector. Separation was performed on a Zorbax Eclipse Plus C18 column (4.6 × 150 mm, 5 µm particle size). The mobile phase consisted of acetonitrile and water in gradient mode at a flow rate of 1.0 mL/min. The column temperature was maintained at 30 °C. Injection volume was 20 µL. Detection wavelengths were set according to the specific vitamin analyzed. Calibration curves were constructed using external standard solutions in the range of 0.1–50 mg/L ($R^2 \geq 0.995$). The limits of detection (LOD) ranged from 0.01 to 0.05 mg/kg, and limits of quantification (LOQ) ranged from 0.05 to 0.1 mg/kg. Recovery values ranged from 92% to 105%. Quantification was performed using external calibration standards; internal standards were not used, which may affect analytical precision but remains acceptable for comparative analysis.

Mineral elements (Ca, Mg, K, Fe, Zn) and toxic elements (Pb, Cd, As, Hg) — by atomic absorption spectroscopy (AAS, Agilent 7900). Determination of mineral and toxic elements. Mineral elements (Ca, Mg, K, Fe, Zn) and toxic elements (Pb, Cd, As, Hg) were determined by atomic absorption spectroscopy (AAS) using a flame and graphite furnace system. Samples were digested with concentrated nitric acid (HNO_3) by wet mineralization prior to analysis. Flame AAS was used for Ca, Mg, K, Fe, and Zn, while graphite furnace AAS was applied for Pb, Cd, As, and Hg determination. Calibration curves were prepared using certified standard solutions in the range of 0.01–5.0 mg/L ($R^2 \geq 0.995$). LOD values ranged from 0.001 to 0.01 mg/kg depending on the element. LOQ values were calculated as 3×LOD. Recovery values ranged from 90% to 110%.

Residual pesticide content — by gas chromatography (Crystallux 4000M, Russia). Determination of pesticide residues by gas chromatography (GC). Residual pesticides (HCH isomers and DDT with metabolites) were determined using gas chromatography (Crystallux 4000M, Russia) equipped with an electron capture detector (ECD). Separation was carried out on a capillary column (30 m × 0.25 mm × 0.25 µm film thickness). Nitrogen was used as carrier gas at a constant flow rate of 1.2 mL/min. Injector and detector temperatures were 250 °C and 300 °C, respectively. Calibration was performed using certified standard solutions in the concentration range of 0.001–0.1 mg/kg ($R^2 \geq 0.995$). LOD and LOQ values were 0.001 mg/kg and 0.003 mg/kg, respectively. Recovery ranged from 85% to 110%.

Amino acid composition was determined by ion-exchange chromatography using a Hitachi L-8900 amino acid analyzer (Hitachi, Japan). Samples were hydrolyzed with 6N HCl at 110 °C for 24 h prior to analysis. Separation was performed on a cation-exchange column with post-column derivatization using ninhydrin, and detection was carried out photometrically at 570 and 440 nm. Quantification was performed using external amino acid standards (calibration range 0.01–2.0 mg/mL, $R^2 \geq 0.995$). LOD values ranged from 0.005 to 0.02 g/100 g, with recovery between 90% and 108%. It should be noted that tryptophan was not determined due to its degradation during acid hydrolysis. In addition, sulfur-containing amino acids (cysteine and methionine) were not specifically quantified using oxidation procedures, which may affect the completeness of the amino acid profile.

Organoleptic assessment: Organoleptic evaluation of the canned vegetable snacks was performed by a panel of 10 trained experts using a five-point scoring system evaluating appearance, colour, smell, taste and component ratio. All panelists voluntarily participated in the evaluation and provided informed consent prior to the assessment.

Description of the experiment

In the first stage, all ingredients were prepared and measured according to the recipe. Vegetables were chopped, blanched, and mixed with pre-cooked grains (buckwheat, bulgur, rice). The mixtures were packed into jars, sealed, and sterilised. After cooling, the samples were subjected to organoleptic and physicochemical tests, and safety indicators were determined.

The control sample was canned vegetables with rice, and the experimental samples were with buckwheat and bulgur to assess the effect of replacing grains on the nutritional value and quality of the finished product.

Quality Assurance

Number of repeat analyses: 5.

Calibration of instruments: The pH meter was calibrated using standard buffer solutions (pH 4.00; 7.00; 10.00). The gas chromatograph and AAS were calibrated using certified standard mixtures.

Laboratory accreditation: All tests were conducted in an accredited Food Safety laboratory in accordance with the requirements of GOST ISO/IEC 17025-2019 (Accreditation Certificate No. KZ.T.02.E.1158).

Data Access

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Statistical Analysis

Statistical analysis was performed using Statistica 10.0 and Microsoft Excel 2019. Prior to analysis, data distribution normality was assessed using the Shapiro–Wilk test, and homogeneity of variances was evaluated using Levene's test. For physicochemical and nutritional parameters, a two-way analysis of variance (two-way ANOVA) was applied to evaluate the effects of grain type and grain concentration, as well as their interaction. When significant differences were detected ($p < 0.05$), Tukey's post-hoc test was used for multiple comparisons. For organoleptic evaluation (ordinal data), nonparametric statistical methods were applied. Differences between groups were assessed using the Kruskal–Wallis test followed by Dunn's post-hoc test with Bonferroni correction. Results are presented as mean ± standard error (SEM). Effect sizes (η^2 for ANOVA) and 95% confidence intervals (CI) were calculated to estimate the magnitude of differences. Each experimental condition was analyzed in five independent replicates. The significance level of $p < 0.05$ was considered statistically significant.

Reporting and transparency statement

The authors confirm that the study was conducted in accordance with relevant methodological standards. All experimental procedures, analytical methods, and statistical analyses are described in sufficient detail to allow reproducibility of the results.

RESULTS AND DISCUSSION

To assess the impact of various cereal crops on canned vegetable snacks, their nutritional value, vitamin and mineral content, amino acid profile, safety indicators, and organoleptic properties were analysed and discussed.

Table 1 provides a comparative assessment of the nutritional value of canned vegetable snacks enriched with rice, buckwheat, and bulgur wheat.

Table 1 Nutritional value of canned vegetable snacks with added cultures.

No	Indicator, %	Vegetable snack can with rice	Vegetable snack can with buckwheat	Vegetable snack can with bulgur wheat
1	Mass fraction of protein	1.52 ± 0.02^{a}	2.44 ± 0.03^{c}	2.11 ± 0.03^{b}
2	Mass fraction of fat	3.32 ± 0.01^{b}	2.77 ± 0.02^{a}	3.41 ± 0.03^{c}
3	Mass fraction of carbohydrate	10.23 ± 0.12^{b}	10.58 ± 0.13^{a}	9.20 ± 0.11^{a}

Note: Values are presented as mean ± standard error (SEM), n = 5. Different superscript letters within the same row indicate statistically significant differences between samples according to Tukey's post-hoc test ($p < 0.05$).

Table 1 presents the nutritional values of canned vegetable snacks containing different grains: rice, buckwheat, and bulgur. The mass fraction of protein ranged from 1.52% in the rice sample to 2.44% in the buckwheat sample, indicating a higher protein contribution from buckwheat. Considering the protein content of 2.11–2.44 g per 100 g of product, a standard 200 g serving could provide approximately 4.2–4.9 g of protein, corresponding to about 8–10% of the recommended daily intake for adults. This observation is consistent with previous studies reporting that buckwheat grains contain relatively high levels of plant protein and a more balanced amino acid composition compared with many other cereals. In addition, the incorporation of cereal components into vegetable matrices has been shown to increase the overall protein content of processed foods due to the complementary composition of plant proteins **[2]**.

The fat content of the studied samples ranged from 2.77% to 3.41%, with the lowest value observed in canned products with buckwheat and the highest in the bulgur formulation. Differences in fat content may be associated with the intrinsic lipid composition of cereal grains, as well as with technological factors, such as interactions between grain components and vegetable oil during thermal processing and sterilization. Similar effects of processing conditions on lipid distribution in cereal-based food systems have been reported in previous studies **[8]**.

The mass fraction of carbohydrates ranged from 9.20% to 10.58%, with the highest value observed in the sample containing buckwheat and the lowest in the bulgur formulation. These differences can be explained by variations in starch composition and dietary fibre content among cereal grains. Buckwheat, for example, contains significant amounts of complex carbohydrates and structural polysaccharides that may contribute to higher carbohydrate values in composite food systems **[2]**. In addition, thermal processing during sterilization may influence carbohydrate redistribution and water binding within the vegetable–grain matrix, thereby affecting the measured composition of the final product. It should be noted that carbohydrate content was calculated by difference, which may introduce cumulative analytical error due to propagation from other measured components, and this limitation should be considered when interpreting the results.

Figure 1 shows the differences in vitamin content in canned vegetable snacks depending on the type of grain added, which reflects the influence of the choice of grain on nutritional value.

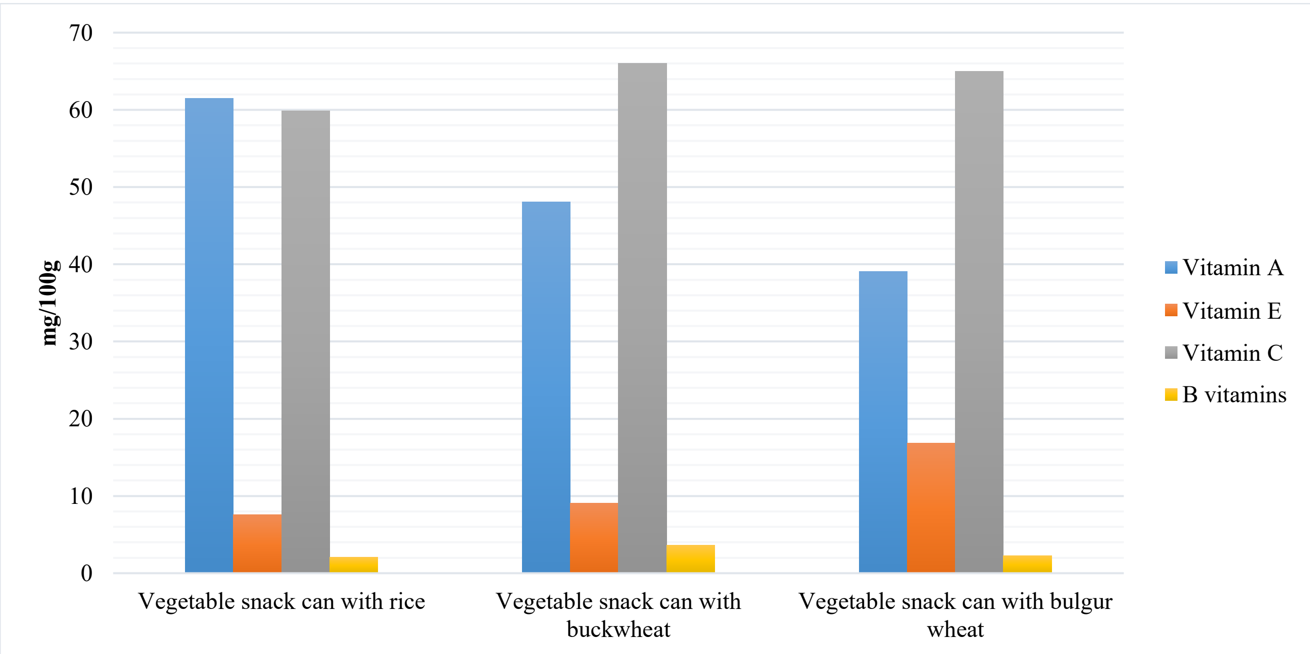
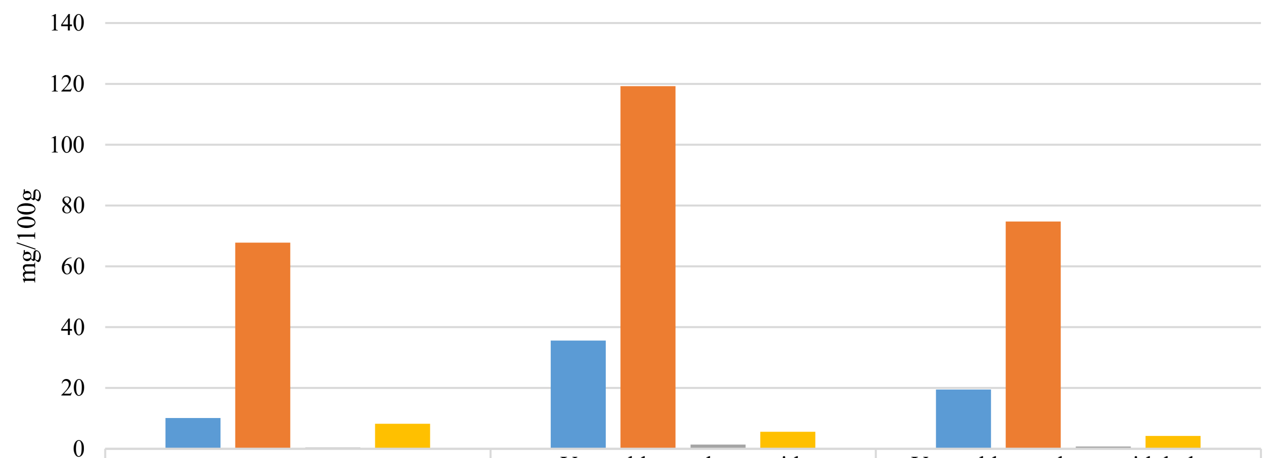


Figure 1 Vitamin content of canned vegetable snacks with added cultures.

Figure 1 shows data on the vitamin content in canned vegetable snacks with added rice, buckwheat and bulgur. The highest vitamin A content was observed in the rice sample (61.47), while the lowest was in canned bulgur (39.1). The vitamin E content ranges from 7.57 to 16.83, with the highest value recorded in the bulgur sample, likely due to its specific biochemical composition. Vitamin C is present in all samples at comparable levels, with the highest value in the buckwheat product (66.04). The total B vitamin content ranges from 2.1 to 3.6, with the highest value observed in canned vegetable snacks with buckwheat. The results indicate that the type of grain used influences the vitamin composition of canned vegetable snacks.

Figure 2 shows the differences in the mineral content of canned vegetable snacks depending on the type of grain added, which reflects the influence of the grain on the nutritional value of the product.



	Vegetable snack can with rice	Vegetable snack can with buckwheat	Vegetable snack can with bulgur wheat
Mg	10.08	35.6	19.5
K	67.77	119.23	74.75
Fe	0.48	1.4	0.79
Ca	8.26	5.57	4.24

Figure 2 Mineral elements in canned vegetable snacks with added cultures.

Figure 2 shows data on the mineral content (Mg, K, Fe, Ca) in canned vegetable snacks with added rice, buckwheat, and bulgur. Analysis of the results showed that the highest magnesium content was observed in the buckwheat sample (35.6), attributable to the high natural magnesium content of buckwheat grains, confirming its value as a mineral source. A similar trend was observed for potassium, with the highest content recorded in canned buckwheat (119.23), which may be due to both the mineral composition of the grain itself and its ability to retain potassium during heat treatment. The iron content varies from 0.48 to 1.4, with the highest value characteristic of the sample with buckwheat, which is explained by the known ability of buckwheat to accumulate iron and increase the biological value of products based on it. The calcium content across all samples is relatively low (4.24–8.26), with higher values observed in the rice-containing product, likely due to the recipe's composition and the contribution of vegetable components. In general, the use of buckwheat and bulgur improves the amino acid composition and increases the nutritional value of canned vegetable snacks. These observed effects can be further interpreted from a mechanistic perspective. The observed improvements in nutritional and sensory characteristics can be explained by interactions within the vegetable–grain matrix during thermal processing. Proteins from cereal grains contribute to enhanced water-binding capacity, thereby improving product texture and structural stability. In addition, the starch in buckwheat and bulgur undergoes gelatinization during sterilization, increasing viscosity and promoting a more homogeneous consistency. Mineral retention may also be influenced by matrix interactions, as the presence of cereal components can reduce leaching losses during heat treatment by binding ions within the food structure. These combined effects contribute to the improved physicochemical and organoleptic properties observed in cereal-enriched formulations.

The results of the analysis of the amino acid composition (% by mass) of canned vegetable snacks with the addition of rice, buckwheat, and bulgur are presented in Table 2.

Table 2 shows the amino acid composition of canned vegetable snacks with added rice, buckwheat, and bulgur. The data indicate significant differences in the content of both essential and non-essential amino acids across grain types. Vegetable canned snacks with buckwheat have the highest content of arginine (0.528%), valine (0.236%), proline (0.333%), glycine (0.231%), and the total fraction of leucine and isoleucine (0.167%), which reflects a more balanced amino acid profile and an improved nutritional composition of buckwheat proteins. The bulgur sample showed an increased content of lysine (0.198%), tyrosine (0.186%), phenylalanine (0.169%), histidine (0.158%), threonine (0.189%), and alanine (0.236%), which may be due to the specific amino acid composition of wheat proteins and the preservation of protein fractions with minimal grain processing. Canned rice products are characterised by a lower content of most amino acids, which corresponds to the comparatively lower biological value of rice protein. Essential amino acids, including lysine, methionine, valine, and threonine, are present in all samples studied, but their total content is higher in products with added buckwheat and bulgur. In general, the use of buckwheat and bulgur improves the amino acid composition and increases the nutritional and biological value of canned vegetable snacks.

Table 2 Amino acid composition of canned vegetable snacks with the addition of various cultures.

No	Indicator, %	Vegetable snack can with rice	Vegetable snack can with buckwheat	Vegetable snack can with bulgur wheat
1	arginine	0.260 ± 0.104^{b}	0.528 ± 0.211^{c}	0.236 ± 0.018^{a}
2	lysine	0.095 ± 0.032^{a}	0.139 ± 0.047^{b}	0.198 ± 0.030^{c}
3	tyrosine	0.055 ± 0.017^{a}	0.069 ± 0.021^{a}	0.186 ± 0.039^{b}
4	phenylalanine	0.080 ± 0.024^{a}	0.114 ± 0.034^{b}	0.169 ± 0.031^{c}
5	histidine	0.041 ± 0.020^{a}	0.058 ± 0.029^{a}	0.158 ± 0.037^{b}
6	leucine + isoleucine	0.120 ± 0.031^{a}	0.167 ± 0.043^{b}	0.136 ± 0.054^{ab}
7	methionine	0.055 ± 0.019^{a}	0.100 ± 0.034^{b}	0.108 ± 0.026^{b}
8	valine	0.130 ± 0.052^{a}	0.236 ± 0.094^{b}	0.109 ± 0.047^{a}
9	proline	0.175 ± 0.046^{a}	0.333 ± 0.087^{c}	0.108 ± 0.054^{a}
10	threonine	0.065 ± 0.026^{a}	0.139 ± 0.056^{b}	0.189 ± 0.036^{c}
11	serine	0.080 ± 0.021^{a}	0.089 ± 0.023^{a}	0.124 ± 0.042^{b}
12	alanine	0.100 ± 0.026^{a}	0.156 ± 0.040^{b}	0.236 ± 0.018^{c}
13	glycine	0.095 ± 0.032^{b}	0.231 ± 0.078^{c}	0.198 ± 0.030^{b}

Note: Values are presented as mean ± standard error (SEM), n = 5. Different superscript letters within the same row indicate statistically significant differences between samples according to Tukey's post-hoc test ($p < 0.05$).

Table 3 presents the safety indicator results for the samples studied. Analysis of studies indicates that experimental samples of canned vegetable snacks containing different crops meet all safety requirements established by the technical regulation TR 021/2011.

Table 3 shows the content of toxic elements and pesticides in canned vegetable snacks containing rice, buckwheat, and bulgur, enabling assessment of their safety for consumers.

Table 3 Safety indicators for canned vegetable snacks with added cultures.

No	Indicator, mg/kg	Vegetable snack can with rice	Vegetable snack can with buckwheat	Vegetable snack can with bulgur wheat
	Toxic elements			
1	Pb, mg/kg, not more than	Not found	Not found	Not found
2	Cd, mg/kg, not more than	Not found	Not found	Not found
	Pesticides			
1	HCH (α-, β-, γ-isomers), mg/kg, not more than	Not found	Not found	Not found
2	DDT and its metabolites, mg/kg, not more than	Not found	Not found	Not found

Table 3 shows the safety indicators for canned vegetable snacks containing added rice, buckwheat, and bulgur, including toxic elements and pesticides. The studies found that lead (Pb) and cadmium (Cd) were not detected in any of the samples analysed, indicating that the products comply with current regulatory requirements for toxic element content. Similarly, no residual amounts of pesticides, including hexachlorocyclohexane (α-, β-, γ-isomers) and DDT with its metabolites, were detected in any of the samples. The results indicate the environmental safety of the plant raw materials used and the effectiveness of the technological processes employed in the production of canned vegetable snacks. Thus, the analysed samples comply with the tested safety parameters for toxic elements and pesticide residues according to the requirements of TR CU 021/2011.

The following samples of canned vegetable snacks with the addition of different crops were offered for tasting:

No. 1 - control sample (canned vegetable snack with rice)

No. 2 - Vegetable snack canned food with 10% buckwheat

No. 3 - Vegetable snack canned food with 20% buckwheat

No. 4 - Vegetable snack canned food with 30% buckwheat

No. 5 - Vegetable snack canned food with 10% bulgur

No. 6 - Vegetable snack canned food with 20% bulgur

No. 7 - Vegetable snack canned food with 30% bulgur.

The canned food samples were evaluated for organoleptic quality using a 5-point scale. The results of the tasting commission are presented in Table 4.

Table 4 Results of the tasting.

Parameter	Buckwheat 10%	Buckwheat 20%	Buckwheat 30%	Bulgur 10%	Bulgur 20%	Bulgur 30%	Rice control
Appearance	4.0 ± 0.02	4.4 ± 0.02	4.0 ± 0.02	4.0 ± 0.02	4.2 ± 0.02	4.2 ± 0.02	4.3 ± 0.02
Colour	3.9 ± 0.02	4.3 ± 0.02	3.9 ± 0.02	4.0 ± 0.02	4.5 ± 0.02	4.2 ± 0.04	4.4 ± 0.02
Smell	3.8 ± 0.02	4.7 ± 0.03	3.8 ± 0.02	4.0 ± 0.02	4.7 ± 0.03	4.8 ± 0.03	4.7 ± 0.03
Taste	4.0 ± 0.01	4.8 ± 0.01	4.0 ± 0.01	4.3 ± 0.01	4.8 ± 0.01	4.8 ± 0.01	4.7 ± 0.01
Component ratio	3.9 ± 0.05	4.1 ± 0.04	3.5 ± 0.05	3.5 ± 0.05	4.0 ± 0.04	4.0 ± 0.04	4.0 ± 0.04
Total score	4.20	4.86	4.10	4.20	4.86	4.40	4.40

Note: Values are presented as mean ± standard error (SEM). Sensory evaluation was carried out by a panel of 10 trained experts using a five-point scale. The total score was calculated as the weighted sum of sensory parameters using the coefficient method (∑XiKi).

The results of the organoleptic evaluation demonstrated that the sensory characteristics of the canned vegetable snacks depended on the type and concentration of cereal components. Among the bulgur-containing samples, the formulation with 20% bulgur obtained the highest sensory scores. This sample was characterised by a uniform distribution of vegetables and grains, stable consistency without sedimentation or separation, and preservation of the structural integrity of the ingredients. The product exhibited a bright natural colour typical of vegetable snacks and a balanced flavour profile combining vegetable and cereal notes. The aroma was clean and characteristic of vegetable-based products with a moderately pronounced grain component.

The sample containing 10% bulgur showed a less pronounced cereal flavour and aroma, which was reflected in slightly lower scores for taste intensity and component balance. Increasing the bulgur content to 30% resulted in a slight deterioration of several organoleptic indicators, particularly appearance and consistency, which may be explained by excessive cereal content and partial overcooking of the grains during thermal processing.

A similar tendency was observed for samples containing buckwheat. The formulation with 20% buckwheat received the highest scores for most evaluated parameters. This sample demonstrated harmonious taste characteristics with a mild nutty flavour typical of buckwheat, pleasant aroma, and optimal balance between vegetable and cereal components. The colour and appearance remained attractive, and the consistency was uniform without visible separation.

The sample containing 10% buckwheat had a less pronounced cereal flavour and aroma, while the sample with 30% buckwheat showed a slight decline in sensory scores due to increased density of the product and partial softening of the grains during sterilisation.

The control sample prepared with rice was characterised by more neutral sensory properties and a less pronounced flavour and aroma profile. Overall, the formulations containing 20% buckwheat and 20% bulgur demonstrated the most favourable sensory characteristics and achieved the highest total sensory scores.

Based on the quality analysis of the tested samples, an organoleptic assessment was conducted using a profilogram (Figures 3 and 4).

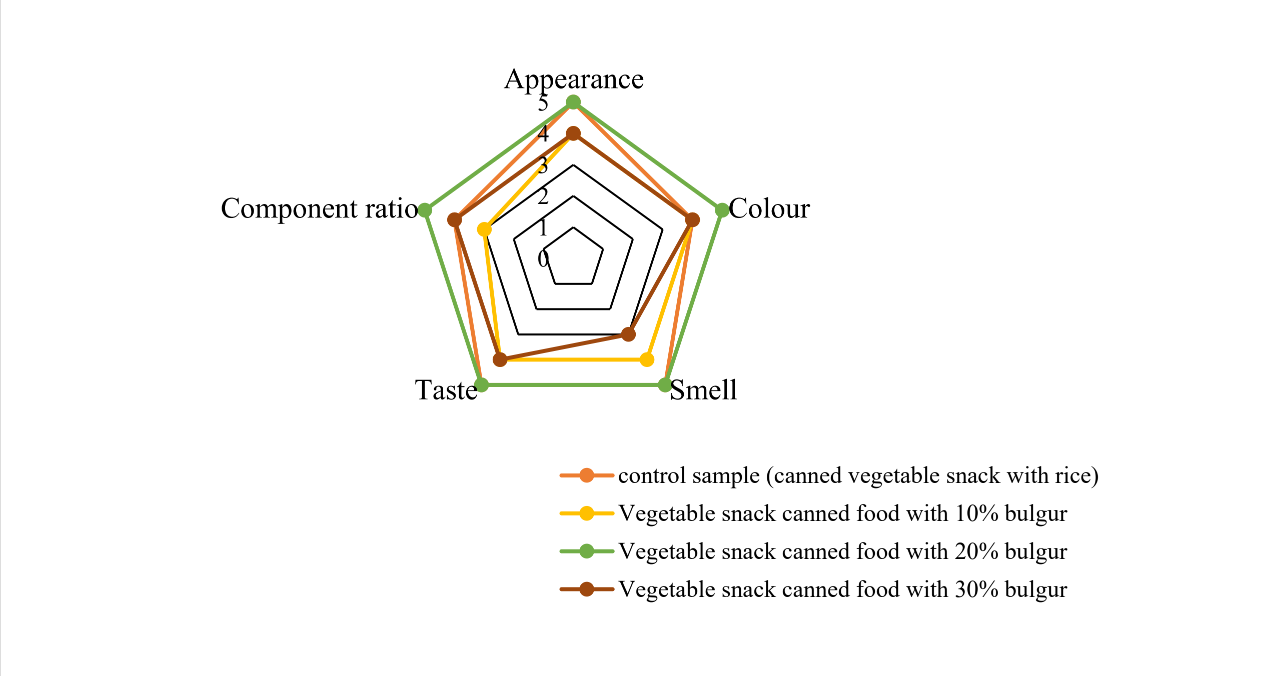


Figure 3 Profile diagram of organoleptic quality indicators of vegetable snack canned products with the addition of bulgur.

The profile of organoleptic indicators of canned vegetable snacks with bulgur wheat (Figure 3), assessed on a five-point scale for 'appearance,' 'colour', 'taste', 'smell', and 'component ratio', showed differences in product quality depending on the amount of grain added. Based on the results of the profile and organoleptic assessments, it was established that the optimal bulgur content for producing canned vegetable snacks is 20%, which provides the best combination of appearance, taste, smell, colour, and a balanced product composition.

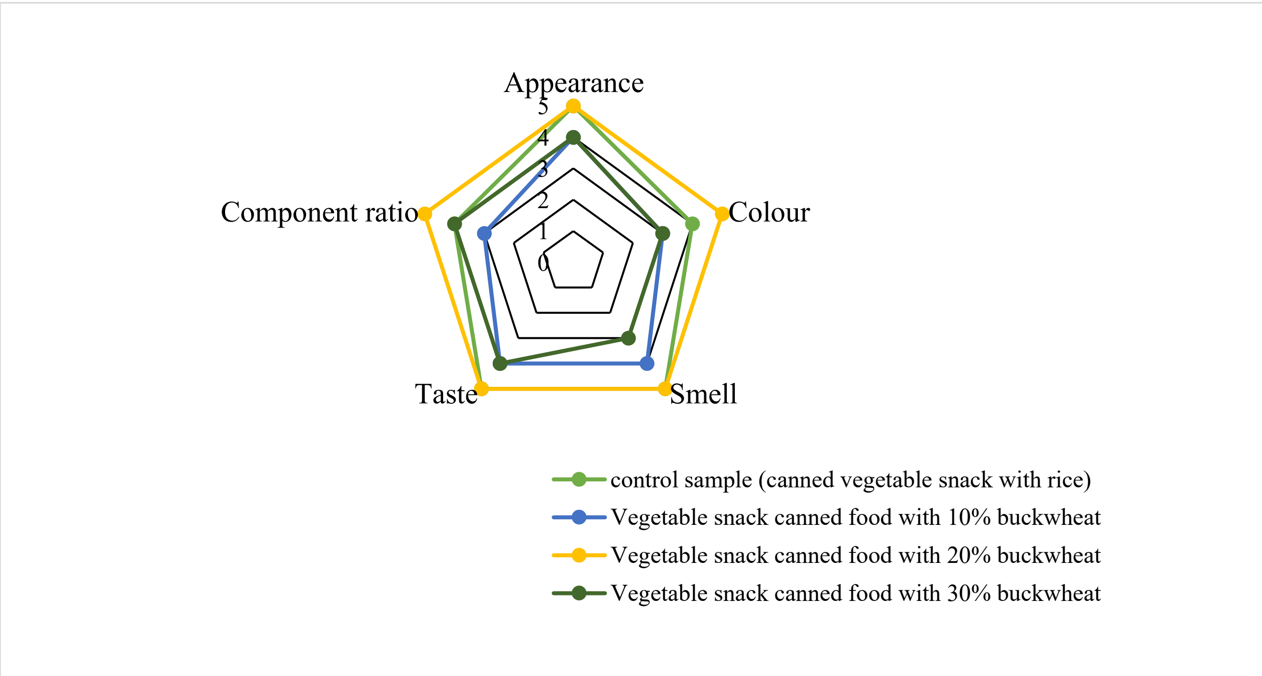


Figure 4 Profile diagram of organoleptic quality indicators of vegetable snack canned products with the addition of buckwheat.

The profile of organoleptic indicators of canned vegetable snacks with buckwheat added (Figure 4), evaluated on a five-point scale for 'appearance,' 'colour,' 'taste,' 'smell,' and 'component ratio,' showed that the quality of the finished product depends on the amount of grain added.

Thus, the results of the organoleptic assessment indicate that the optimal buckwheat content for producing canned vegetable snacks is 20%, which yields the best quality indicators for the finished product.

Figure 5 Appearance of ready-made canned vegetable snacks with buckwheat and bulgur.

Figure 5 shows the finished products of canned vegetable snacks containing various cereals.

Recent studies confirm that canned vegetables and products based on them are an important component of the diet due to their long shelf life, ease of use, and preservation of nutritional value **[12]**. Widely available types of canned vegetables, including corn, green beans, carrots, mushrooms, beetroot, and asparagus, are characterised by consistent quality and versatility, making them staple ingredients in both home and industrial cooking. Vegetable purees and processed tomato and pumpkin products are widely used in sauces, soups, and dishes worldwide, ensuring reliable retention of nutrients during processing **[13]**.

Canned legumes such as peas, chickpeas, and lentils, although botanically members of the legume family, are often treated as vegetables in culinary practice. They are a valuable source of plant protein and dietary fibre and are widely used in vegetarian and vegan diets **[14]**. Similar benefits have been noted for beans, pinto beans, baked beans, and chickpeas, which are considered alternatives to animal sources of protein **[15]**. Replacing traditional protein sources with canned beans improves nutritional quality and reduces nutrient deficiencies in the adult population **[16]**.

Experimental data show that adding lentils, peas, chickpeas or beans to chicken-based meat and vegetable canned food recipes can cover up to 16.91–17.55% of the daily protein requirement and significantly increase the vitamin and mineral content **[17]**. Another promising raw material is edamame, which can be consumed both fresh and canned, ensuring year-round availability **[18]**, and **[19]**.

Along with nutritional value, the microbiological safety of canned foods is an important aspect. Studies show that the presence of grain and legume components may be associated with increased bacterial load, including *Enterobacteriaceae*, *Salmonella* spp. and *Listeria* spp., which highlights the need for strict quality control at all stages of production **[20]**, and **[21]**. This is particularly relevant for combined products containing both plant and animal ingredients.

The scientific literature contains numerous studies on the development of extruded cereal-based snacks incorporating vegetables and animal products to enhance their functional and antioxidant properties **[22]**, and **[23]**. Replacing part of the grain raw materials with alternative ingredients, such as turmeric powder, enables the production of gluten-free products with high organoleptic and antioxidant properties **[24]**. Similarly, the addition of buckwheat increases nutritional value and manifests antioxidant and cardiovascular-protective effects **[25]**.

The use of bulgur is considered a promising way to increase nutritional value and production sustainability. Its use in bakery and flour products helps to improve consumer properties, reduce dependence on wheat imports, and strengthen food security **[26]**, as well as increasing the dietary fibre content in biscuits with an addition level of less than 10% **[27]**.

Combined meat and vegetable preserves deserve special attention. The use of frozen corn kernels in combination with carrageenan enables the production of low-calorie products with high yield and improved organoleptic properties **[28]**. Adding carrots to canned goat meat increases its nutritional value and improves its sensory properties, with 30% as the optimal addition level **[29]**. The use of sprouted grains and malt extract enables the formation of a favourable taste and aroma profile and supports high consumer preferences **[30]**.

From a chemical safety perspective, it has been established that canned foods may contain endocrine-active compounds and heavy metals **[31]**, and **[32]**, but in most cases their concentrations do not exceed acceptable limits when technological requirements are met **[33]**, and **[34]**. In particular, the addition of zinc to FDA standards does not negatively affect the physicochemical and microbiological indicators of canned soybean vegetables **[35]**.

Epidemiological data indicate that consumption of canned fruits and vegetables is associated with higher nutrient intake and improved nutritional quality, without increasing the risk of obesity or hypertension in children and adults **[36]**. Thus, canned vegetables and products derived from them can be considered an important component of a healthy and balanced diet.

Overall, the studies presented confirm the high potential of using canned vegetables, cereals and legumes for the development of functional and safe food products. However, effective realisation of this potential requires an integrated approach to quality and safety management, including control of raw materials, recipe optimisation, selection of appropriate preservation methods, and monitoring of chemical and microbiological risks.

Limitations

Despite the comprehensive evaluation of canned vegetable snacks with added grains, several limitations should be considered. First, the raw materials were sourced from a single region, which may limit the generalizability of the results, and seasonal variability was not fully addressed. Second, the number of production batches was limited, which may affect the reproducibility of findings. Third, the sensory panel consisted of 10 trained evaluators, providing insight into organoleptic properties but not necessarily reflecting broader consumer preferences. Additionally, microbiological analysis was not performed, and the products' shelf life was not evaluated. These limitations should be taken into account when interpreting the results, and future studies could expand raw material sourcing, include larger sensory panels, and incorporate microbiological and shelf-life assessments to strengthen the findings.

CONCLUSION

The study demonstrated that incorporating different cereal grains significantly affects the nutritional value, micronutrient composition, amino acid profile, safety, and organoleptic characteristics of canned vegetable snacks. The addition of buckwheat resulted in the highest protein content (2.44%), compared with bulgur (2.11%) and rice (1.52%), confirming its greater contribution to the product's biological value. Buckwheat-enriched samples also showed elevated levels of magnesium (35.6), potassium (119.23), and iron (1.4), as well as the highest vitamin C content (66.04) and total B vitamins (3.6). Bulgur-containing products were characterized by the highest vitamin E content (16.83) and increased levels of several essential amino acids, including lysine (0.198%) and threonine (0.189%). In contrast, rice-based samples demonstrated comparatively lower concentrations of protein and essential amino acids. The amino acid analysis confirmed a more balanced profile in buckwheat and bulgur formulations, indicating improved biological value compared to rice-containing products. Safety assessment showed that toxic elements (Pb, Cd) and pesticide residues (HCH, DDT) were not detected in any sample, confirming compliance with regulatory requirements and the effectiveness of the technological process. Organoleptic evaluation established that a 20% grain inclusion level (for both buckwheat and bulgur) provides optimal sensory characteristics, including taste balance, texture, and appearance. Overall, the results confirm that the inclusion of buckwheat and bulgur at an optimal level of 20% enhances the nutritional and biological value of canned vegetable snacks while maintaining safety and high sensory quality. These findings can be applied in the development of functional canned vegetable products and in dietary planning for various consumer groups, including vegetarians and individuals seeking balanced nutrition.

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Funds:
This work was not supported by external grants.
Acknowledgments:
-
Competing Interests:
No potential conflict of interest was reported by the author(s).
Ethical Statement:
This article does not contain any studies that would require an ethical statement.

AI Statement:
Artificial intelligence was not used in the article

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