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DEVELOPMENT OF A PRODUCTION TECHNOLOGY FOR COOKED SAUSAGES USING BUCKWHEAT EXTRACTS AND THEIR IMPACT ON QUALITY AND STORAGE LIFE

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The paper examines the production of meat sausages using buckwheat extracts, which possess antioxidant activity and are of great interest to the food industry. Adding buckwheat extract to cooked sausages has shown significant advantages in preserving quality and nutritional value. Products containing the extract retained their organoleptic properties longer and exhibited lower oxidation rates, confirming buckwheat's high antioxidant activity. The use of natural additives to enhance the quality and extend the shelf life of finished products is a relevant issue. The paper provides a detailed description of experimental results on different fat varieties, confirming the positive impact of buckwheat extracts on their oxidation stability. Research has revealed significant improvements in the moisture-binding capacity, as well as increased biological value of meat sausages. A recipe and production technology for cooked sausages using a meat additive containing buckwheat extract have been developed. The inclusion of this extract significantly slows down the accumulation of primary and secondary oxidation products and reduces the concentration of carbonyl compounds in the finished product. Adding buckwheat extract at 0.025 % by weight of fat to the sausage recipe proved particularly effective. The obtained results highlight the potential of buckwheat extracts as effective antioxidants that enhance the oxidation stability of meat sausages, improve their nutritional properties, and extend shelf life without synthetic preservatives. This provides a basis for implementation in real industrial production

Keywords: buckwheat extracts, bioflavonoids, cooked sausages, meat sausages, antioxidant activity, peroxide value, acid value, natural preservatives

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1. Introduction

The current stage of development of human society is characterized, on the one hand, by outstanding achievements in science and technology and, on the other, by a sharp deterioration in the global environmental situation, lifestyle changes, increased neuro-emotional stress, a constant lack of time, an overload of information, and shifts in the nature and rhythm of life [1]. Nutrients supplied with food provide the human body with energy, influence health, physical activity, life expectancy, and reproductive ability [2]. Animal products are significantly richer in amino acids compared to plant-based foods. Animal-derived proteins are not only well absorbed but also enhance the digestibility of plant proteins, allowing for a balanced amino acid composition of food. To meet the body's amino acid requirements, it is advisable to consume a varied combination of products [3]. The relevance of functional food production is growing immeasurably, particularly due to the rise in toxic-allergic diseases, weakened immunity caused by increased consumption of pharmaceutical agents, and adverse environmental conditions [4, 5]. The range of preventive products that meet consumer needs is limited. In Azerbaijan, the vast majority of food ingredients, additives, and premixes are imported, making their local production a pressing social task. Food premixes are widely used by manufacturers because they not only enrich food products with biologically active substances and vitamins but also improve technological properties, extend shelf life, and enhance food safety. Consumers seeking healthier meat products prefer options without artificial additives or with natural substitutes that improve both commercial stability and safety [6]. When consuming such products, food additive components activate fat oxidation, and the energy released in this process contributes to the synthesis of glycogen and high-energy phosphorus compounds, thereby increasing physical performance and endurance [7].

The effectiveness of addressing this issue largely depends on a well-defined scientific approach to the rational and pathogenetically justified use of functional ingredients from natural raw materials. This approach must also consider technological aspects of production when developing new food products, vitamin supplementation, and healthy nutrition [8, 9].

Common buckwheat is an important grain crop. Buckwheat grain is a source of valuable proteins, low glycemic index starch, and high content of unsaturated fatty acids [10, 11]. The high antioxidant capacity of buckwheat bioflavonoids makes them useful in the food industry as fat antioxidants [12]. Buckwheat is rich in vitamins B1 and B2 and contains minimal fat, with total lipid content in the seeds ranging from 1.5 to 3.7 % [13]. The rate and type of fat oxidation depend on the composition and properties of fatty acids involved, as well as production and storage conditions [14].

Based on the above, it can be noted that comparing the quality of fats of different origins under the influence of bioflavonoids in buckwheat extracts and using these extracts in sausage production is a relevant and practically valuable research direction.

2. Literature review and problem statement

The paper [15] presents the results of research on the intensification of technological parameters in sausage production. It has been shown that replacing table salt in minced meat with sea salt enriched with kelp extract reduces peroxide levels in the fat-meat mixture over 10 days of storage and slows down the growth rate of fatty acids in minced meat. However, unresolved issues remain regarding economic feasibility, making related studies impractical. This suggests the need for more in-depth research in this area. The paper [16] presents the results of research on experimental and control samples of cooked sausages, showing that the inclusion of 1 % purslane powder has an antioxidant effect, extending the shelf life of cooked sausage. However, issues remain regarding mass production and economic viability, likely due to experimental limitations, making such studies impractical, etc. The paper [17] presents the results of research on using Psyllium in cooked sausage production. It has been shown that incorporating Psyllium as a biologically active additive at a 2 % concentration inhibits antibiotic activity. However, unresolved issues remain regarding the availability of this drug. The paper [18] presents the results of research on using starter cultures as a factor in sausage quality formation. It is shown that bacterial starters can reduce nitrite dosage to 40 % of conventional levels, accelerate sedimentation, and enhance the organoleptic properties of the finished product. In [19], the author presents the results of research on using buckwheat flour in semi-smoked sausage production, focusing on physicochemical, functional-technological, structural-mechanical, and organoleptic properties. It has been shown that adding a small amount of buckwheat flour (up to 10.0 % by weight of unsalted raw materials) to semi-smoked sausages increases the moisture-binding capacity of the control sample by 1.1–1.8 %. However, the impact of this additive on sausage shelf life remains unexplored, possibly due to the broad scope of research. Addressing this gap may require targeted studies on using buckwheat in sausage production to extend shelf life.

The paper [20] presents the results of buckwheat research. It is shown that buckwheat husks can be used as a non-meat additive to improve the nutritional value of sausages while maintaining technological quality. However, uncertainties persist regarding the impact of buckwheat on microbial quality and shelf life. Further research is needed to assess the potential of buckwheat grains as a phytoadditive for developing new functional meat products. The paper [21] presents the results of research on the effect of buckwheat husk extracts on the quality of chicken meatballs during refrigeration storage. The additive was shown to have antioxidant activity in chicken meatballs over 14 days of refrigeration storage. However, increasing the product's nutritional value remains a challenge, likely due to experimental limitations. The papers [22, 23] present the results of research on using buckwheat flour in semi-smoked sausage production. It is shown that incorporating up to 6 % buckwheat flour (by weight of meat raw materials) in minced meat enhances the physicochemical, functional-technological, structural-mechanical and organoleptic characteristics of semi-smoked sausage.

However, these studies still do not address the impact of phytoadditives on sausage shelf life.

3. The aim and objectives of the study

The aim of the study is to develop a production technology for meat sausages using buckwheat extracts with antioxidant properties to extend the shelf life of the finished product. Specifically, it is planned to create new sausage varieties enriched with buckwheat extracts, thereby improving the quality and expanding the range of food products.

To achieve this aim, the following objectives are accomplished:

– to study changes in the acid and peroxide values of animal fats (duck, lamb, and beef) under the influence of buckwheat extracts;

– to examine the nutritional value and quality indicators of experimental samples with buckwheat extract during storage;

– to develop a recipe and production technology for sausages using buckwheat extracts.

4. Materials and methods

The object of the study is the production of cooked sausages using buckwheat extracts. The hypothesis of the study suggests that buckwheat extracts, as a rich source of bioflavonoids, can be used in the production of functional sausages. For this purpose, buckwheat grains were soaked (for 2.5–3 hours) and germinated (for 6–7 days) at a temperature of 25–26 °C.

The Soxhlet extraction method was employed. This is the simplest and most accessible technique for laboratory analysis based on cold extraction. The method involves washing out fats with a solvent, followed by determining the weight difference between the dry flask and the flask after extraction, containing fat [10]. To assess the quality indicators and shelf life of finished products, GOSTs were used. Fats – GOST 32905-2014; Toxic elements (cadmium and lead) – GOST 30178-96; Arsenic – GOST R 51766-2001; Organochlorine pesticides (Hexachlorocyclohexane) – GOST 2013; Mycotoxins (Aflatoxin M1) – GOST 30711-01. Organoleptic properties were evaluated through sensory analysis using a five-point scale. The dependencies of color, aroma, and taste on the applied extract are presented as a functional food diagram.

5. Results of sausage production using buckwheat bioflavonoids

5. 1. Determining the acid and peroxide values of duck, lamb, and beef fat under the influence of buckwheat extracts

The high antioxidant capacity of buckwheat bioflavonoids makes them valuable for use in the food industry as fat antioxidants. The organoleptic and physicochemical properties of the studied fats are presented in Table 1.

Table 1

Quality indicators of fats of various origins

Type of fat	Color at 20 °C	Smell and taste	Transparency	Moisture content, %	Acid value, Mg KOH
Duck	White, light yellow	Characteristic	Transparent	0.2	1.1
Lamb	Yellowish	Characteristic	Transparent	0.2	1.24
Beef	Yellow	Characteristic	Transparent	0.1	1.38

Introducing buckwheat extracts as antioxidants at 0.02–0.03 % by weight of fat is effective and does not have a negative impact on fat properties or human health upon consumption.

5. 2. Determining the influence of buckwheat extracts on the nutritional value and quality indicators of experimental samples during storage

During the experiment, the active acidity in homemade sausages during storage was investigated (Fig. 1). This parameter affects quality parameters such as color, tenderness, moisture-binding capacity, and shelf life.

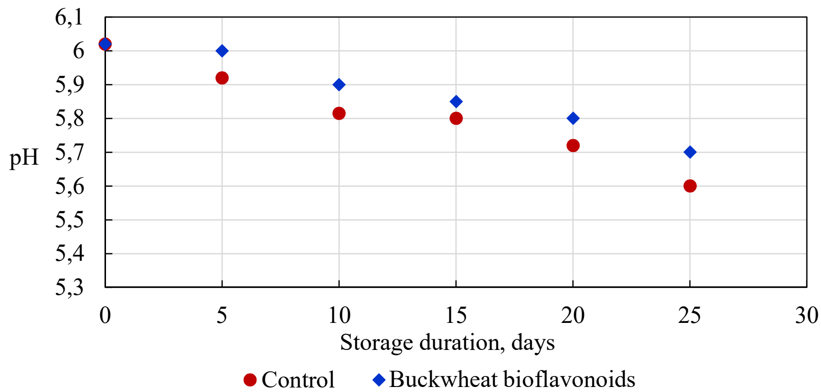

Fig. 1. Changes in active acidity in cooked sausage samples during storage: control and buckwheat extracts

A comparative analysis was carried out to examine the relationship between physico-chemical and organoleptic indicators (Fig. 2).

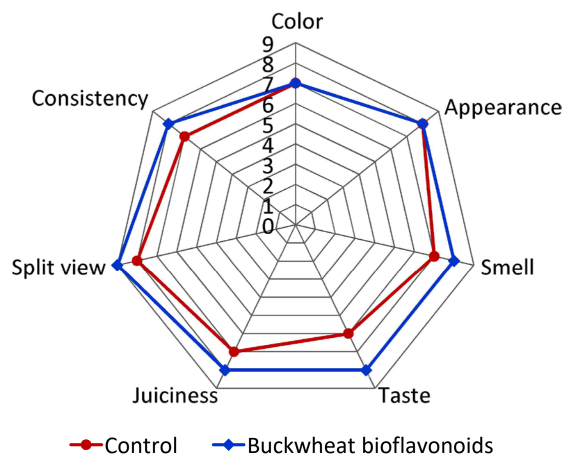

Fig. 2. Quality assessment of the experimental product sample at the end of shelf life: 1 – control; 2 – with buckwheat extracts

Regarding safety indicators, all tested samples met the standards (Table 2).

Organoleptic evaluation of the samples was carried out by sensory analysis using a five-point scale. The dependence of organoleptic indicators such as color, smell, and taste on the extract used is presented in Fig. 3.

The acid value dynamics in experimental samples are shown in the diagram (Fig. 4).

Table 2

Safety indicators at the end of shelf life

No.	Determined indicators	Test results, units	Permissible level, units
1	Toxic elements	mg/kg	No more than, mg/kg
	Cadmium	0.0020±0.0002	0.05
	Lead	0.030±0.003	0.5
	Arsenic	0.0010±0.0004	0.1
2	Organochlorines	mg/kg	No more than, mg/kg
	Pesticides	<0.005	0.1
3	Hexachlorocyclohexane	mg/kg	No more than mg/kg
	Mycotoxins	<0.0005	0.0005 Mycotoxins

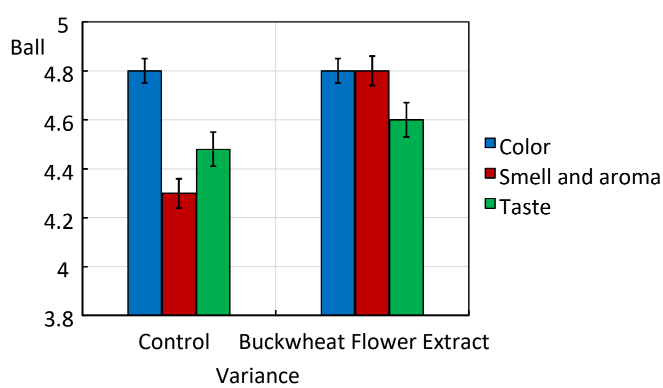

Fig. 3. Effect of buckwheat extracts on the organoleptic characteristics of cooked sausage: control and buckwheat extract

The results of peroxide value measurements are shown in comparative diagrams (Fig. 5).

The addition of buckwheat extracts showed positive results, slowing down peroxide accumulation by 1.61 and 1.49 times, respectively. As seen in the diagrams, the inhibition of oxidative fat spoilage is influenced more by the type of extract rather than the method of application.

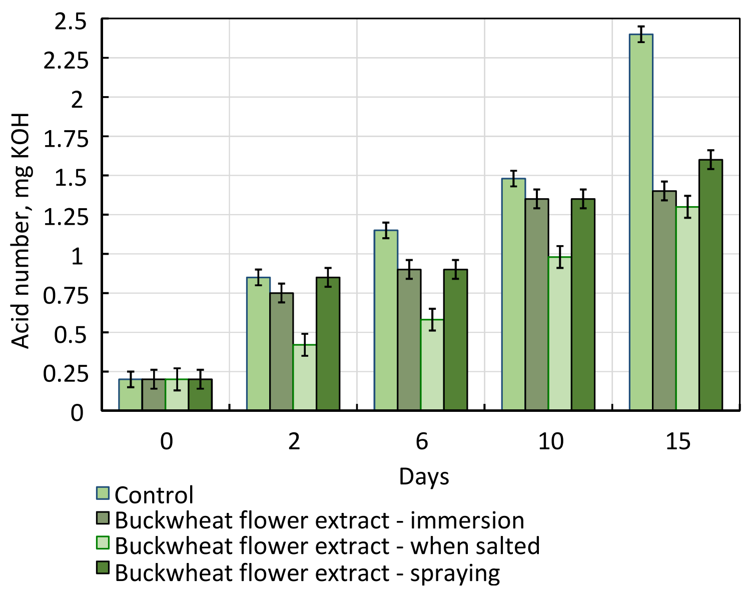

Fig. 4. Changes in acid values during product storage using different methods of buckwheat extract application

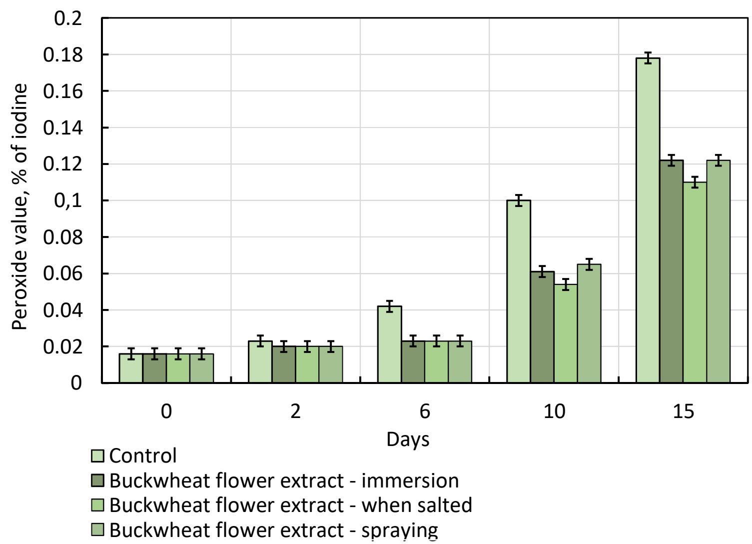

Fig. 5. Changes in peroxide values during product storage using different methods of buckwheat extract application

5. 3. Development of a recipe and production technology for cooked sausages using buckwheat extracts

To study the antioxidant activity of the proposed additives, an experimental batch of cooked sausages was prepared using a meat additive with buckwheat extract (Table 3, Fig. 6).

Table 3

Recipe for cooked sausage

Raw materials	Quantity
Pork shoulder	750 g
Beef tenderloin	250 g
Salt	10 g
Ground black pepper	1 g
Sugar	2 g
Dry milk	20 g
Ice water	200 ml
Nitrite salt (0.5–0.6 %)	10 g
Seasoning for cooked sausage (meat additive with buckwheat extract)	3 g
Protein casing	40 cm

Fig. 7, 8 show the dynamics of accumulation of primary and secondary oxidation products in test samples containing buckwheat extract.

The total content of carbonyl compounds by appropriate doses of buckwheat extracts is presented in Table 4.

Table 4

Total amount of carbonyl compounds in experimental samples

No.	Name of phytoadditive	Total content of carbonyl compounds (ppm) during storage, days					
		3	6	9	12	18	24
1	Control	8±1	19±1	54±2	82±2	118±4	155±2
2	Buckwheat bioflavonoids	0	6±1	14±1	19±2	24±2	42±4

It was found that the accumulation of peroxide compounds over time follows an individual pattern.

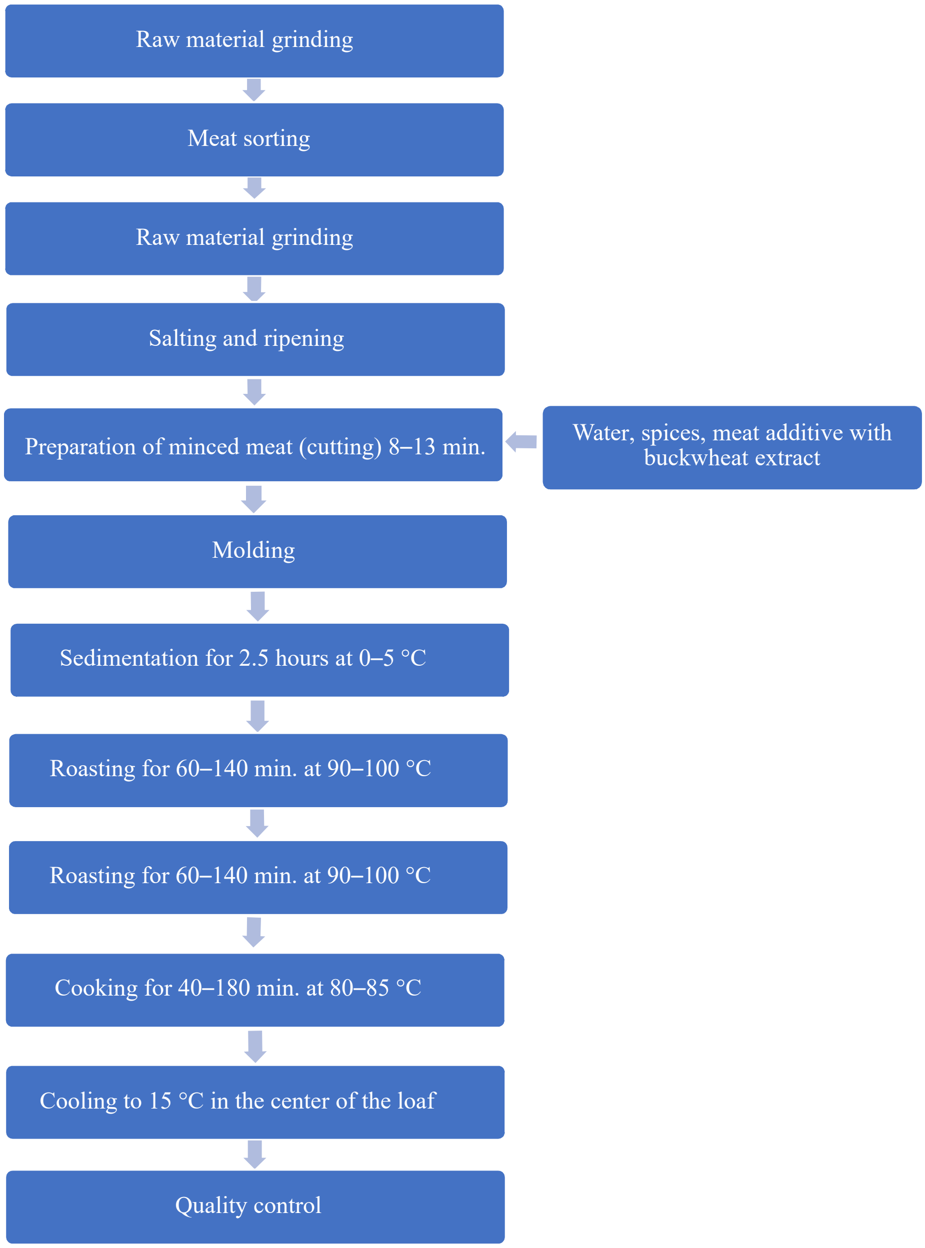

Fig. 6. Production technology for cooked sausages using a meat additive with buckwheat extract

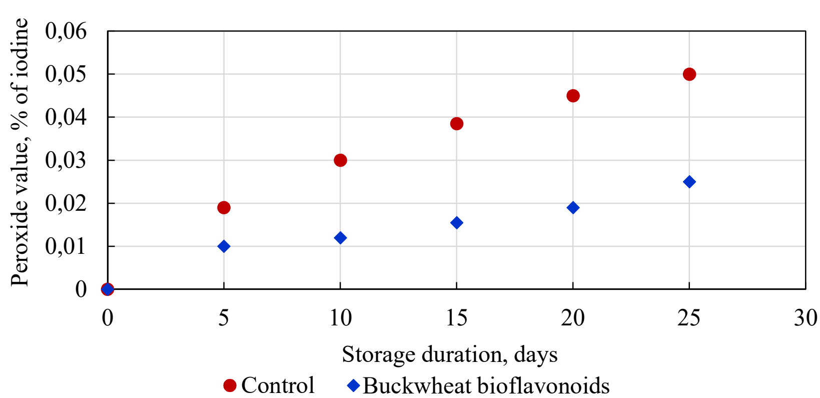

Fig. 7. Dynamics of accumulation of primary oxidation products in experimental samples with buckwheat extracts during storage: 1 — control; 2 — buckwheat bioflavonoids

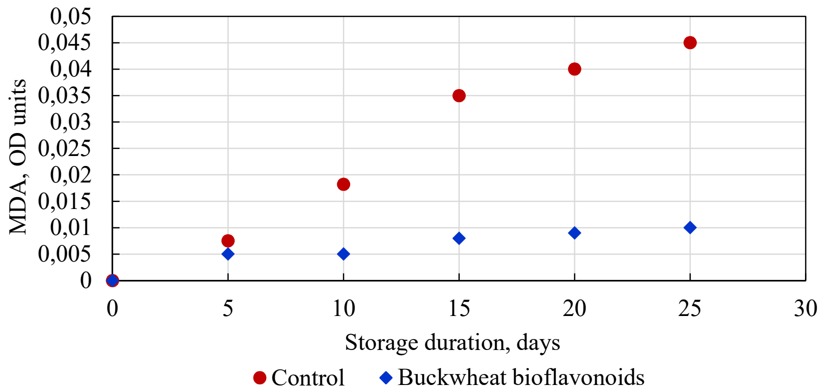

Fig. 8. Dynamics of accumulation of secondary oxidation products in experimental samples with buckwheat extracts during storage: 1 – control; 2 – buckwheat extracts

6. Discussion of the results of developing a sausage production technology using buckwheat extracts and their impact on quality and storage life

Research has shown that antioxidants help the body reduce tissue damage, accelerate healing processes, and improve tolerance [24]. The rate and type of fat oxidation depend on the composition and properties of fatty acids involved, as well as production and storage conditions. Therefore, comparing the quality of fats of different origins under the influence of bioflavonoids in buckwheat extracts has practical significance. The organoleptic and physicochemical properties of the studied fats are presented in Table 1.

Analysis of the data showed that changes in the acid value of fats during storage at any temperature and without antioxidants for more than 3 days lead to changes in their properties, except for lamb fat. The first signs of lamb fat spoilage appear after 10 days of storage, when the acid value exceeds 2.2 mg KOH. Temperature was found to influence fat transformation differently. For instance, mutton fat stored over 1 month at 40 °C and 200 °C showed only a 5 % difference in acid value, making it suitable for use and storage in hot climates. Duck and beef fats, however, exhibit a strong dependence on storage temperature, with a maximum difference of 15 %, indicating strict temperature control during storage. The changes occurring during lipid oxidation are reflected in the peroxide values. After 10 days of storage without antioxidants, the ~~of~~ formation of peroxides and hydroperoxides accelerates sharply, as confirmed by the peroxide value growth curve for these fats.

At lower temperatures, the peroxide value increased by 4–25 times over 1 month, depending on fat variety, while at higher temperatures, it changes by 5–35 times.

The induction period can be extended by adding natural or artificial antioxidants.

Analysis of Fig. 1 shows that adding buckwheat extracts in amounts of 10–12 g per 100 kg of fat ensures complete preservation of all fat types under any storage conditions. According to the regulatory documentation, products with an acid value exceeding 3.5 mg KOH/1 g are not suitable for storage. As seen in the graphs, none of the samples exceeded the permissible level of 1 month, confirming the effectiveness of using buckwheat extracts in fat production for food purposes.

Analysis of Fig. 2 revealed that buckwheat bioflavonoids exhibit strong antioxidant activity, making them suitable as additives in fat production. Organoleptic studies of fat samples showed no signs of spoilage, such as discoloration, rancid odor, sliming, or grayish tint, in any sample with buckwheat extracts over one month of storage. Thus, the studies demonstrated that introducing buckwheat extracts as antioxidants at 0.02–0.03 % by weight of fat is effective and does not have a negative impact on fat properties or human health upon consumption. During storage, all samples showed a pH decrease of 0.3–0.5 units.

According to Fig. 3, adding buckwheat extract at 0.2–0.3 % by weight of fat to minced meat positively affects the quality and biological value of the finished product.

The data analysis revealed that adding buckwheat extract to raw meat does not have a significant effect on product yield. As a result of the experiment and product figure construction, a comparative analysis was conducted to examine the relationships between physico-chemical and organoleptic indicators (Fig. 4).

Fig. 4 illustrates that adding buckwheat extract improves the quality of the experimental samples.

Table 2 shows that all tested samples meet safety standards.

The extracts were applied in three ways: directly to minced meat when salted in an amount of 0.2–0.3 %; on the casing by immersing sausages in water-alcohol extracts containing 40–45 % ethyl alcohol for 2–3 minutes before heat treatment; onto the casing after heat treatment of sausages as aerosols of extracts with the same concentration as in the previous methods. All samples were stored under identical conditions in a refrigerator at 4–5 °C and 80–85 % relative humidity. The organoleptic evaluation of the finished product is influenced by multiple factors. Food additives, including antioxidants, can alter product properties such as taste, color, smell, and consistency. Therefore, a sensory evaluation of sausages containing buckwheat extracts was carried out.

Fig. 5 illustrates the relationship between organoleptic indicators and buckwheat extract applied. Samples subjected to external treatment (immersion and spraying) showed no changes compared to the control sample. The organoleptic assessment confirmed that adding buckwheat extract improved the finished product indicators such as color, smell, and taste. Oxidative changes were tracked by the dynamics of acid and peroxide values. At the same time, acid value changes in the control sample without buckwheat extract were recorded.

The diagram (Fig. 7) illustrates acid value dynamics when aqueous-alcohol buckwheat extracts are added via different methods. The smallest amount of primary lipid breakdown products is observed in samples where aqueous-alcohol extracts were added directly to minced meat when salted. Applying buckwheat extracts to the casing, either by complete immersion or aerosol treatment, yielded similar acid values, which were 50–55 % lower than in the control sample. The same samples were used to determine the peroxide values at identical time intervals (Fig. 8). Adding 0.2–0.3 % buckwheat extracts to the recipe or treating sausage surfaces with them inhibits peroxide accumulation. Thus, buckwheat extract administration slowed peroxide formation by 1.60 and 1.50 times, respectively. As can be seen from the diagrams, the method of extract application does not affect the inhibition of oxidative fat spoilage. To assess the impact of buckwheat extract bioflavonoids on lipid oxidation rates, a meat additive with a 25 % fat fraction was used. Changes in peroxide values, reflecting the accumulation of primary lipid breakdown products, were recorded. When determining the peroxide value, all additive samples with buckwheat extracts were added to the experimental samples at 0.1 % per 100 g. The results confirmed that buckwheat extract effectively slows the accumulation of primary oxidation products in the experimental samples. The studied buckwheat extracts demonstrated antioxidant properties, with peroxide values being 2–3 times lower than in the control samples. The optimal dose for maximum antioxidant activity was determined: for bioflavonoids isolated from buckwheat, it is 0.025 % per 100 g of the product by weight of fat.

According to Table 4, measuring the total carbonyl compound concentration in control and experimental samples during storage revealed the highest levels in the control samples. Experimental meat products with buckwheat extract had a 1.5–2.5 times lower content of carbonyl compounds, proving the effectiveness of these additives.

The proposed method and obtained results differ from existing studies [16, 19] by evaluating not only the organoleptic, physicochemical, and nutritional properties of the new functional product but also the effect of the natural meat additive on shelf life. Thus, adding buckwheat extract to cooked sausages showed significant advantages in preserving quality and nutritional value. Products containing the extract retained their organoleptic properties longer and exhibited lower oxidation rates, confirming buckwheat's high antioxidant activity. Sausages treated with buckwheat extracts met all safety standards.

Unlike [20, 22, 23], where buckwheat groats and husks were used as non-meat additives to enhance the nutritional, physicochemical, functional-technological, structural-mechanical, and organoleptic properties of sausage products, our study utilized a meat additive combined with buckwheat extracts containing bioflavonoids. This approach leveraged the antioxidant properties of buckwheat extract to extend the shelf life of the finished product.

Despite the significance and positive outcomes of the conducted research, some limitations may affect the accuracy and applicability of the conclusions. These include factors such as humidity and packaging type, as even minor variations in packaging or storage conditions can significantly affect oxidation processes. Another drawback is the short-term nature of the experiment, with the storage period restricted to one month.

Although the research identifies an optimal buckwheat extract dosage, testing of different dosages for various products has not been conducted. Therefore, dosage recommendations may not be universally applicable to all product types.

These limitations highlight the need for additional research to gain a more comprehensive understanding of buckwheat extracts' antioxidant properties and their applicability in various conditions.

7. Conclusions

1. The addition of buckwheat extracts as antioxidants significantly slowed down oxidation processes in all three fat varieties. In the presence of buckwheat extracts, the acid value, which according to regulatory documentation should not exceed 3.5 mg KOH/1 g, increased at a much lower rate. This indicates that antioxidants contributed to maintaining fat stability during storage. None of the samples exceeded the maximum permissible level of 30 days, confirming the effectiveness of buckwheat bioflavonoids in fat production for food purposes.

2. The addition of buckwheat extract to cooked sausages demonstrated significant advantages in preserving quality and nutritional value. Organoleptic studies of fat samples showed ~~that~~ no signs of spoilage (slime formation, rancid odor, color change, darkening, or grayish tint) in any sample with buckwheat extracts over 1 month of storage. Products treated with buckwheat extracts met all safety standards. The studies confirmed that introducing buckwheat extracts as antioxidants at 0.01 % by weight of fat is effective and does not have a negative impact on fat properties or human health upon consumption.

3. A recipe and production technology for cooked sausages using a meat additive containing buckwheat extract have been developed. The inclusion this extract significantly slows down the accumulation of primary and secondary oxidation products and reduces the concentration of carbonyl compounds in the finished product. Adding buckwheat extract at 0.025 % by weight of fat to the sausage recipe proved particularly effective, positively influencing the quality and biological value of homemade sausage samples.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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