CHAPTER 15

Technology improvement of cooked sausage products with the addition of non-traditional raw materials

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Abstract

The growing interest in functional meat and fish-based foods has driven the development of novel formulations enriched with biologically active and nutritionally beneficial ingredients. This research explores the impact of incorporating unconventional components – such as chicken meat, spelt flour, dried vegetables, cuttlefish ink, and red caviar – into the composition of cooked fish sausages made primarily from hake. Three experimental formulations were created by substituting 10% of the fish meat with chicken and adding 6% spelt flour. Additionally, each variant included one of the following: bell pepper, olives, or garlic.

The study evaluated various parameters, including proximate composition (moisture, protein, fat, ash), water-holding and moisture-binding capacities, texture-related properties (shear stress), oxidative stability (acid and peroxide values), and sensory characteristics. Protein content in the modified products increased by 8–10% relative to the control (17.2 vs. 15.1 g/100 g). Among the samples, the first exhibited the highest water-holding capacity (86.3%), while the second and third demonstrated a notable 18–20% enhancement in structural density.

Over a 10-day refrigerated storage period, the third sample maintained superior oxidative stability, as its acid value increased only slightly (from 1.7 to 2.3 mg KOH/g fat). Sensory evaluation revealed improved acceptability: Sample 1 achieved a score of 4.6, and Sample 3 received 4.5, both outperforming the control 3.8.

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Overall, the integration of chicken meat, spelt flour, and dried vegetable inclusions into fish sausage formulations resulted in improved nutritional quality, functional-technological performance, and organoleptic appeal. These findings support the potential use of alternative raw materials in the production of value-added, health-oriented fish sausages. Further research is recommended to assess microbial stability over extended storage periods and to determine consumer preferences for potential market introduction.

Keywords

Hake, vegetable raw materials, cuttlefish ink, red caviar, sausage products.

15.1 Introduction

In recent years, a new direction in the food industry has been widely recognized all over the world – the so-called functional nutrition, which refers to the use of such products of natural origin, which, when used systematically, have a regulatory effect on the human body.

At the same time, the analysis of domestic and foreign literature shows that today little attention is paid to the development of technologies for specialized food products with targeted physiological and biochemical properties, increased nutritional and biological value. Therefore, the development of technologies for combined fish products (cooked sausage products) for functional nutrition is an important and relevant direction of scientific research.

The production of fish sausages has been successfully developed in many countries over the past few years. This started in Japan. The expansion of this production is stimulated by an increase in the catch of small fish and fish with low palatability, which can be successfully used to produce fish sausage products [1, 2].

Moreover, as experts note, fish sausage is more useful for human health than its meat and chicken counterparts due to the saturation of easily digestible protein and essential amino acids, such as lysine and tryptophan. Another advantage of fish sausage is that, with the initial raw materials, it is possible to establish its production at a specialized fish factory and a regular meat processing plant.

The technology for producing sausage products has been developed and implemented in many countries, but production in Ukraine remains limited.

Fish and fish processing products have traditionally been essential in the human diet due to their high nutritional value and remarkably complete animal protein, vitamins, and macro and microelements [3]. In modern conditions, there is an increasing interest in developing new types of fish products, including those with functional purposes, which contribute to maintaining public health and ensuring high-quality nutrition.

A separate niche in the food market is occupied by fish sausages – an innovative product that can serve as an alternative to traditional meat. The technology of their production involves the use of minced fish combined with components that improve structural-mechanical and organoleptic properties: lard, eggs, dry milk, starch, spices, salt, stabilizers, and food additives (such as phosphates, nitrites, etc.) [4].

Among the current directions in improving meat product technologies, special attention is given to using mineral components to enhance their nutritional value. In the study by I. Shurduk et al. [5], the feasibility of using a protein-mineral supplement (PMS) as a source of calcium in the formulations of emulsion-type meat products was substantiated. According to the study results, adding 7–8% PMS has a positive effect on the water-binding, fat-retention, and emulsifying properties, as well as the structure of the meat system. Improved microbiological stability and sensory characteristics of the final product were also observed, without negatively affecting its taste. The authors particularly emphasize that more than 60% of the calcium in the final product is present in the form of organically bound compounds, ensuring a high degree of absorption. The proposed technology enables the creation of functional meat products with enhanced biological value and health-promoting effects.

O. Shtonda [6] developed recipes of combined meat-vegetable and fish-vegetable cooked sausage products with the taste and smoke aroma using CO_2 extract of the smoke liquid. In this work, the effect of added plant components (carrots, eggplants, onions and peas in meat-vegetable sausages, carrots, eggplants, onions and peas, in fish-vegetable sausages – carrots, potatoes, onions and rice) on the nutritional properties of the product, the yield of the finished product and determination of the sanitary and hygienic properties of the finished product due to the use of CO_2 smoke extract.

X. Zhao et al. [7] investigated the possibility of using such non-traditional additives as a structuring agent from fish skin, lotus seeds, water, and water-alcohol infusions from Sargentodoxa cuneata (Sargentodoxa cuneata Rend. et Wils) in the technology of making fish sausages, which made it possible to obtain sausages with high organoleptic indicators.

N. Bozhko et al. [8] investigated the possibility of using squid and shrimp to produce cooked sausages. The study demonstrated that incorporating these seafood ingredients enhances the nutritional value and taste of the final product. Along with other authors, he investigated using protein-containing raw materials, such as soy protein, to produce boiled-smoked sausages. The use of such additives allows for reducing the production cost and improving the nutritional value of the product [9].

O. Fursik [10], in her dissertation, substantiated the feasibility of using protein-containing functional compositions that include both plant and animal proteins to improve cooked sausage technology. Using such compositions makes it possible to enhanceenables the enhancement of the amino acid profile and the functional and technological properties of the product.

I. Martyniuk [11] investigated the possibility of using amaranth as an unconventional plant-based raw material to produce cooked sausages. The results showed that the addition of amaranth improves the organoleptic, physicochemical, and microbiological properties of the product.

Other authors, M. Paska and I. Markovych, investigated the use of lentil plant material and lentil flour in the technology of cooked sausages. They found that the addition of lentil flour improves the structure and consistency of sausage, as well as reduces production costs [12].

Other studies have been conducted using protein compositions that include both plant and animal proteins to improve cooked sausage technology. These compositions allow for the enhancement of the amino acid profile and the functional and technological properties of the product [13].

One of the promising raw materials for producing such products is African catfish (*Clarias gariepinus*), which is characterized by rapid growth rates, efficient feed conversion, low maintenance requirements, and high nutritional value of its meat. According to literature sources, African catfish meat contains, on average, 75% moisture, 16.9% protein, and 6.7% fat. In comparison, 100 g of the product provides over 40% of the daily selenium requirement and more than 20% of the phosphorus requirement. Studies on the water-holding capacity of the raw material indicate that African catfish meat can ensure a stable sausage mince structure, juiciness, and a tender texture in the final products [14].

The article by V. Tyshchenko et al. [15] discusses using fish mince as a raw material for sausage production. The study demonstrated that fish mince exhibits high functional and technological properties, enabling the production of high-quality and nutritious products.

The study by A. Tayeva et al. [16] investigates the potential for enhancing the functional and technological properties of cooked sausages by incorporating camel fat and chicken fillet. The effect of pumpkin shell powder on lipid oxidation and the functional and technological properties of sausages made from mixed meat was investigated. It was found that adding pumpkin shell powder enhances the taste and organoleptic characteristics of the product.

K. Elavarasan et al. explore the possibility of using millet and coconut flour to formulate fish sausages in their research. It was found that adding millet flour is an ideal healthy substitute for traditional wheat flour [17–19].

Critical studies have been conducted on incorporating textured soy protein (TSP) into surimi products, particularly fish sausages. It was found that adding 15% TSP improves gel strength, water-holding capacity, and organoleptic properties of the product while maintaining its quality for up to 120 days when stored at −18°C [19–21].

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The analysis of scientific research suggests a high potential for enhancing the technology of cooked fish sausages using unconventional raw materials. Including components such as pumpkin shell powder, millet flour, textured soy protein, camel fat, and fish milt enhances the products' functional and technological properties. In particular, improvements have been observed in texture, gel strength, water-holding capacity, and the organoleptic characteristics of the sausages.

Moreover, using unconventional raw materials increases the biological value of the products by boosting the content of high-quality protein and beneficial fats, while also extending shelf life through the reduction of lipid oxidation. A significant advantage is the economic feasibility and environmental sustainability of these innovations, aligning with current trends in the development of the food industry.

Therefore, integrating unconventional raw materials into the production of cooked fish sausages effectively improves product quality and competitiveness while meeting the demands of healthy nutrition and sustainable development.

At the same time, the nutritional and biological value. Therefore, developing technologies for combined fish products (cooked sausage products) for functional nutrition is an essential and relevant direction of scientific research.

15.2 Characteristics of the nutritional and biological value of fish and meat raw materials

The primary raw materials for the production of cooked sausage products are minced hake (in a frozen state) and chicken fillet (in a chilled state). According to organoleptic indicators, frozen fillet must meet the requirements and standards specified in **Table 15.1**.

Table 15.1 Organoleptic characteristics of frozen fish fillets

Indicator name	Characteristic and standard
Appearance: blocks individually frozen fillets	Clean, dense, with a flat surface without significant differences in block height. Clean, even, whole, without significant deformation. May exhibit: slight loosening of the muscle tissue along the edge of the fillet block; presence of scale residues on the surface of the fillet with skin without scales; skin damage in horse mackerel and sturgeon fillets at the sites where scutes have been removed
Placement procedure	The fillets are placed into molds in uniform layers: in the bottom layer with the skin or subcutaneous side facing downward, and in the top layer with the skin or subcutaneous side facing upward
Flesh consistency: after defrosting	Firm, typical of this type of fish
After boiling	Tender, juicy, brittle, typical of this type of fish. It may be slightly dry, fibrous, but not hard, rubbery, jelly-like
Flesh color	Typical of this type of fish
Odor (after defrosting)	Typical of fresh fish, without any foreign odor
Taste and smell after cooking	Typical for this type of fish, without any foreign taste or smell

The primary raw materials for cooking sausage products are minced hake (in a frozen state) and chicken fillet (in a cooled state).

The size and mass characteristics of fish are an important criterion for assessing its biological condition, marketable quality and technological suitability.

The aim of the study was to establish the average indicators of length, body weight, carcass weight, head, viscera, skin and scales, which allows for a reasonable assessment of the yield of finished products and the efficiency of raw material use.

The dimensional composition of the fish is given in the **Table 15.2**.

Table 15.2 Dimensional composition of hake

L_a, cm	L_i, cm	L_h, cm	L_t, cm	L_m, cm	h, cm	b, cm
–	–	–	–	25.2	6	4

Note: initial weight of gutted carcass – 356 g

The length of the carcass is 25.2 cm, the height of the fish body is 6 cm, and the width of the fish body is 4 cm (average size of the fish). The mass composition of hake is presented in **Table 15.3**.

Table 15.3 Mass composition of hake, %

Weight, kg	Content to the total weight of fish, %				
	fillet	skin	bones	fins	scales
0.356	82 ± 1.9	5.3 ± 0.3	7.57 ± 0.9	0.76 ± 0.3	0.03 ± 0.01

Note: initial weight of gutted carcass – 356 g; $n = 5$, $p \leq 0.05$

The data obtained are the starting point for further physicochemical, technological and organoleptic studies, as well as for comparative analysis between different types of fish raw materials.

The output of fish meat is 301.3 g, waste – 48.4 g, losses – 6.3 g. The chemical composition of fish raw materials was determined during the study, as shown in **Table 15.4**.

Chicken provides moderate energy and contains highly digestible proteins with low collagen, offering good nutritional quality. It is also a source of unsaturated fats, primarily in the skin, which can be easily removed, and B vitamins such as pantothenic acid and thiamine. Consumption of chicken is associated with a lower risk of overweight and obesity, as well as cardiovascular diseases and type 2 diabetes. The chemical composition of chicken is given in **Table 15.5**.

Table 15.4 Chemical composition of hake, %

Indicator	Content
Protein content	18.31 ± 0.6
Fat content	1.31 ± 0.22
Moisture content	78.9 ± 2.83
Mineral content	1.48 ± 0.15

Note: $n = 5$, $p \leq 0.05$

Table 15.5 Chemical composition of chicken, %

Indicator	Content
Calories, kcal	202 ± 4.0
Protein content	18.5 ± 0.17
Fat content	14.3 ± 0.21
Moisture content	3.7 ± 1.26
Mineral content	70.9 ± 2.25

Note: $n = 5$, $p \leq 0.05$

The combination of fish and meat raw materials enables the production of a new, fully developed product, specifically a cooked sausage, utilizing various types of raw materials.

The nutritional value of salmon roe used for the production of cooked sausage products is given in **Table 15.6** [17].

Table 15.6 Nutritional value of salmon roe

Indicator	Content per 100 g of product
Calories, kcal	249
Protein, g	26.0
Fat, g	13.2
Water, g	62.0
Carbohydrate, g	1
B_1, μg%	1800
B_2, μg%	2100
Folic Acid, μg%	1300
PP, μg%	2.1
Pantothenic Acid, μg%	1.3
Vitamin C, μg%	93

Salmon caviar is a highly nutritious product with a significant biological value. 100 g of the product contains 249 kcal, which indicates its energy saturation. Caviar is rich in proteins (26.0 g), which makes it a valuable source of easily digestible amino acids necessary for maintaining muscle mass and cellular metabolism. The fat component (13.2 g) provides the body with beneficial fatty acids that play a key role in the functioning of the nervous and cardiovascular systems.

The high content of B vitamins (in particular B_1 – 1800 mcg%, B_2 – 2100 mcg%, folic acid – 1300 mcg%) contributes to the normalization of metabolism, maintenance of nervous system functions and hematopoiesis processes. Caviar also contains vitamin C (93 mcg%), which is an antioxidant and supports immunity.

Given these indicators, salmon caviar can be considered a functional product that combines high nutritional value, vitamin richness, and health benefits when consumed in moderation.

Given the limited data on the chemical composition of spelled flour grown in Ukraine, it is possible to investigate the composition of this flour (**Table 15.7**).

Spelt is notable for its high protein content. Research has shown that spelt contains 28% more protein, 1.6 times more fat, and 22% more minerals (ash) than common wheat. Additionally, it has 7.6% fewer carbohydrates overall, including 20% less starch. While the total dietary fiber content in spelt is higher than in wheat, it contains less crude fiber.

Table 15.7 Chemical composition of spelled flour, % on dry matter

Indicator	Spelled flour
Protein, g	17.46
Fat, g	3.17
Carbohydrate, g	75.92
Includes Starch, g	52.49
Total Sugars, g	3.62
Dietary Fiber, g	14.34
Includes Roughage, g	2.1

The advantages of adding spelt flour to sausages: increased protein value, enrichment with dietary fiber, improved structure and water-binding properties, reduced starch content, improved mineral composition.

Therefore, adding spelt flour to sausage recipes allows to create functional products with improved nutritional properties, increase their dietary appeal and meet the needs of consumers focused on healthy eating.

Cuttlefish ink is a natural coloring agent that provides a deep black hue and comes in a convenient single-use package containing two 4 g sachets. Its composition includes: cuttlefish ink (40%), water, salt, and sodium carboxymethylcellulose stabilizer. It is gluten-free but may contain shellfish and traces of crustaceans, celery, and milk.

Cuttlefish ink is increasingly valued in the food industry not only for its natural pigmentation but also for its content of bioactive substances that may offer health-promoting effects. M. Gómez-Guillén et al. [22] noted that this ingredient contains melanin, peptides, and amino acids that contribute antioxidant, antimicrobial, and anti-inflammatory activities. These properties position cuttlefish ink as a multifunctional additive that supports visual enhancement and improved functional attributes of food products.

Incorporating natural colorants, such as cuttlefish ink, aligns with the modern trend toward clean-label ingredients and the increasing consumer preference for natural alternatives to synthetic additives [23]. In contrast to artificial colorants, it is considered a safer and more consumer-friendly option.

In addition, the intense black color and distinct flavor profile of cuttlefish ink make it a novel and appealing component in formulating premium and health-oriented foods, including fish-based sausages and alternative meat products [24]. Its use in cooked sausages made from unconventional raw materials is justified from a technological standpoint, as it improves product appearance, enriches flavor, and supports innovation in food development.

15.3 Recipes for cooked sausage products with the addition of non-traditional raw materials

Samples from the manufacturer Savin Product were used to produce cooked sausage products made from non-traditional raw materials. The recipe of the control sample is presented in **Table 15.8**.

Table 15.8 Sausage recipe Squid ink & Red roe and meat turkey, from the manufacturer Savin product

Components name	Prescription composition of the control sample, g/100 g of product
Turkey meat	48.3
Refined sunflower oil	28
Red caviar	6.5
Cow's powdered milk	6
Kitchen salt	1.3
Sugar	0.4
Spice extracts (nutmeg, black pepper, allspice)	0.5
Color fixative: sodium nitrite	0.008
Drinking water	8.492
Cuttlefish ink	0.5

In the formulated recipes for cooked sausage products, various vegetable ingredients were incorporated to enhance flavor characteristics, while the inclusion of natural color sources aimed to achieve a more visually appealing final product. Additionally, fish-based raw materials and modifications to animal-based components were incorporated to enhance taste and better align with daily nutritional needs. A novel water-binding agent was also introduced to enhance product stability and maintain shape. The finalized cooked sausage formulations are detailed in **Table 15.9**.

Table 15.9 Sausage recipes Squid ink & Red caviar and bell pepper, Squid ink & Red caviar and olives, Ink Cuttlefish & Red Caviar & Garlic

The name of the components	Recipe composition, g/100 g of products		
	Sample 1	Sample 2	Sample 3
Hake meat	42	47	45
Chicken meat	10	10	10
Refined sunflower oil	20.5	20.5	20.5
Red caviar	6.5	6.5	6.5
Potato starch	2	2	2
Spelled flour	6	6	6
Kitchen salt	1	1	1
Sugar	0.4	0.4	0.4
Spices (basil, oregano, thyme)	5.55	3.55	5.55
Cuttlefish ink	1.05	1.05	1.05
Dried Bulgarian red pepper	5	–	–
Dried olives	–	2	–
Dried garlic (granulated)	–	–	2

The development of formulations for cooked sausages incorporating plant-based raw materials, natural colorants, unconventional types of meat, and water-retaining components aligns with current trends in the food industry, which aim to improve product quality, safety, and functional properties.

According to I. Markovych research [24], the use of plant components, particularly lentil flour, contributes to the improved structure and consistency of sausage products while also helping to reduce production costs. The addition of natural colorants, such as cuttlefish ink, not only provides a rich color but also imparts antioxidant properties, as noted by M. Gómez-Guillén et al. [21], which positively affect product stability during storage.

Including fish raw materials in the formulations of cooked sausages enhances the nutritional value of the product due to its high content of complete proteins, polyunsaturated fatty acids, and minerals, as confirmed by the research of N. Bozhko et al. [8]. Replacing traditional meat ingredients with more easily digestible protein sources (e.g., African catfish or poultry meat) allows products to be better adapted to the needs of modern consumers, particularly those who follow healthy eating habits [26–28].

Additionally, incorporating water-retaining components, such as dietary fiber or stabilizers, enhances the texture, juiciness, and shape of the finished product. This is consistent with the findings of I. Shurduk et al. [5], who highlight the effectiveness of protein-mineral additives in enhancing the technological properties of emulsion-type meat systems.

Thus, comprehensive improvement of formulations by incorporating unconventional ingredients and enhanced structural components is a justified step toward developing cooked sausages with increased nutritional and functional value.

The obtained samples of cooked sausage products are shown in **Fig. 15.1–15.3**.

Fig. 15.1 Squid ink & red caviar & bell pepper (Sample 1)

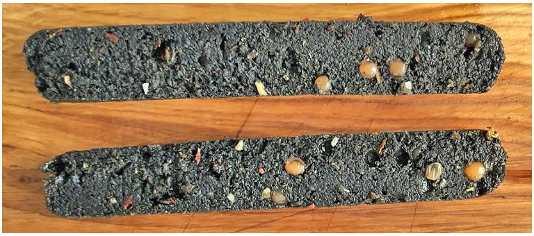

Fig. 15.2 Cutball ink & red caviar & olives (Sample 2)

Fig. 15.3 Squid ink & red caviar & garlic (Sample 3)

Thus, by developing the aforementioned recipes, it is possible to obtain a cooked sausage product enriched with B-group vitamins, vitamin PP, vitamin A, and vitamin E, as well as mineral elements such as iron, iodine, phosphorus, calcium, and essential Omega-3 fatty acids. This product is easily digestible and aligns with the principles of healthy nutrition.

15.4 Properties of mince for the production of cooked sausage products

To assess the use of dried plant raw materials and to determine the optimal amount of additives in the production of cooked sausage products containing non-traditional raw materials, a study was conducted on the properties of the added components within a multi-component system, as the structure, composition, and production conditions of the final product directly depend on the properties of the mince. Indicators such as water-retaining capacity (WRC) and water-binding capacity (WBC) of the experimental mince affect the juiciness, density of the products, and the yield of the finished product. Results of the study of the WRC (**Fig. 15.4**) and WBC (**Fig. 15.5**) of the mince.

The influence of functional food additives on the technological characteristics of cooked sausage products is given in **Table 15.10**.

According to the data obtained, an increase in the mass of the sausage is observed after cooking. This is due to the swelling of dried plant components as a result of moisture release during the boiling-down process of the combined meat and fish raw materials, which constitute the main part of the product – the mince.

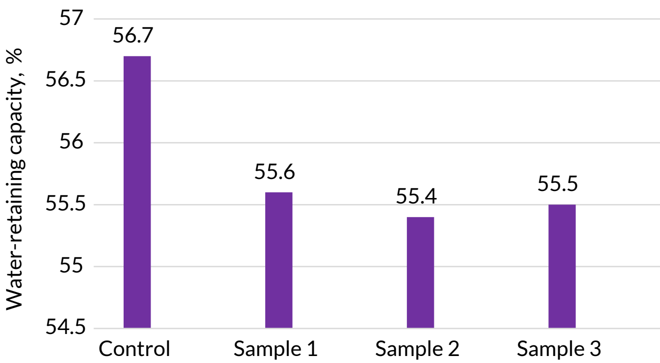

Fig. 15.4 Changes in the water-retaining capacity of mince

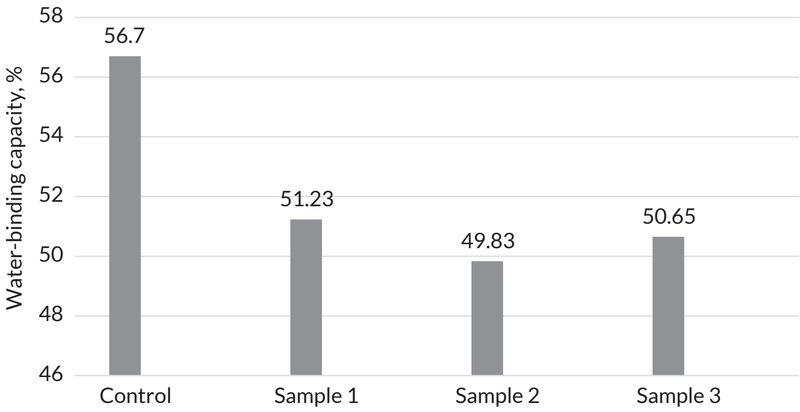

Fig. 15.5 Changes in the water-binding capacity of mince

Table 15.10 The influence of functional food additives on the technological characteristics of cooked sausage products

Sample	Mass of sausage prior to boiling, g	Mass of sausage after boiling, g
Sample 1	57.0942	59.7426
Sample 2	61.2023	62.8742
Sample 3	55.3214	56.1327

Based on the data presented in **Table 15.10**, it can be concluded that functional food additives have a positive effect on the technological characteristics of cooked sausage products, in particular, on the preservation or even increase in mass after heat treatment.

All three samples demonstrate an increase in the mass of sausages after boiling, which is an important indicator of technological efficiency and economic feasibility of using functional ingredients. In particular:

– Sample 1: the mass before boiling was 57.09 g, after boiling – 59.74 g, which indicates an increase of 2.65 g, or about 4.64%;

– Sample 2: mass before boiling – 61.20 g, after – 62.87 g, the increase was 1.67 g (≈ 2.73%);

– Sample 3: the mass increased from 55.32 g to 56.13 g, i.e. by 0.81 g (≈ 1.46%).

The greatest increase in mass after boiling is observed in Sample 1, the smallest in Sample 3, which may be due to both differences in the recipe and the properties of the functional additives used.

The increase in mass after boiling is attributed to the swelling of functional food components, including dried plant components that actively bind moisture. This is also partly due to the reduction of losses during heat treatment, resulting from the formation of a stable gel-like matrix that retains moisture within the product. In addition, the combination of meat and fish raw materials provides a balanced protein-fat structure of the mince, which enhances moisture retention during cooking.

Thus, the presented data confirm that the use of functional additives allows not only to increase the nutritional value of sausage products, but also to improve their technological properties, in particular, water-holding capacity water-retaining capacity and mass stability after heat treatment, which is an important factor in the production of quality products.

15.5 Research on the organoleptic evaluation of cooked sausage products

The tasting evaluation of vegetarian ice cream was carried out with the involvement of specialists with experience in the field of food technology. 5 people aged 25 to 45 years were selected as tasters, who had higher education in the field of food technology and experience in evaluating the organoleptic properties of food products for at least 3 years.

Before the start of the study, the tasters underwent a brief briefing, which included familiarization with the method of organoleptic evaluation on a five-point scale according to ISO 11036:1994, as well as a repetition of the criteria for evaluating appearance, taste, consistency, color and aroma.

In order to ensure the objectivity of the results, the tasting was carried out by blind evaluation, without prior informing the tasters about the composition or origin of the samples.

A quantitative evaluation of the cooked sausage products was conducted using a set of organoleptic indicators, comparing them to the control sample. Based on the overall organoleptic assessment, experimental formulations No. 1 and No. 3 demonstrated superiority over the control, which exhibited a very dense texture and an unpleasant taste with no distinct sausage flavor.

In formulation No. 1, the taste, aroma, and juiciness were enhanced by adding red bell pepper, which increases juiciness and imparts a pleasant sweet flavor due to its high moisture content. In formulation No. 3, the flavor profile was enhanced by incorporating dried garlic, resulting in a subtle and mild taste. Although formulation No. 2 scored lower overall compared to No. 1 and No. 3, it still outperformed the control sample due to the inclusion of dried olives and herbs, which enhanced the texture and added a distinctive aroma.

To determine the qualitative differences in the organoleptic evaluation of the developed product, the construction of profilograms was added, allowing for the visual demonstration of the complete picture of the comparative assessment of the samples. The graphically obtained indicators are presented in **Fig. 15.6–15.8**.

Summarizing the results of the comparative evaluation of organoleptic properties, it can be concluded that adding plant-based raw materials enhances these sensory attributes. All developed formulations received higher overall scores than the control sample, although each showed improvements in specific indicators depending on the type of plant material used.

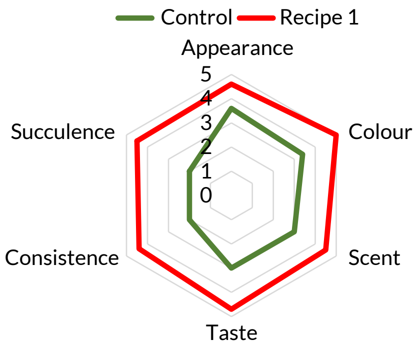

Fig. 15.6 Comparative analysis of Sample 1 with the control sample

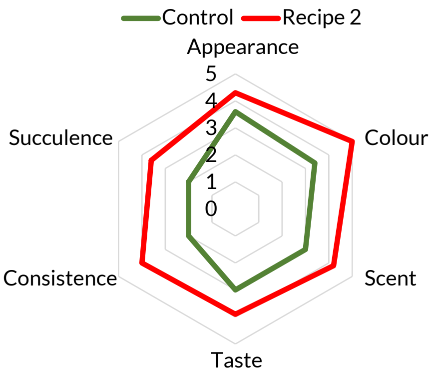

Fig. 15.7 Comparative analysis of Sample 2 with the control sample

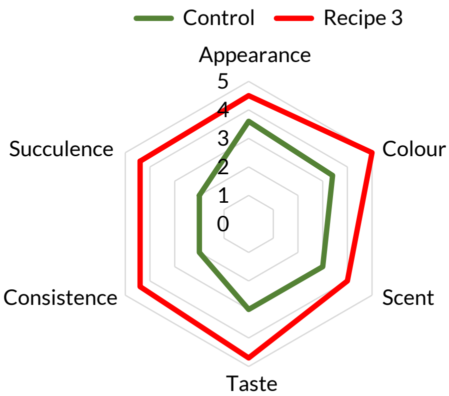

Fig. 15.8 Comparative analysis of Sample 3 with the control sample

The addition of plant-based raw materials to meat and fish products is an effective way to enhance the organoleptic properties of these products. According to the research by I. Markovych [24], soy protein in sausage formulations contributes to enhanced texture, taste, and overall consumer perception of the product. Similarly, the findings of showed that the inclusion of amaranth in cooked sausages increases their organoleptic appeal, as evidenced by higher ratings for flavor, aroma, and consistency [29–35]. Furthermore, the study by I. Bayram et al. [36–39] demonstrates that using pumpkin peel powder in sausage products significantly improves taste and textural characteristics, positively influencing the end consumer's perception of the product.

15.6 Research on structural and mechanical properties and chemical composition of cooked sausage products

Due to the incorporation of fish and additional plant raw materials in dried form (in particular, in the form of pieces, granulated spice particles) into the recipes of boiled sausages, a study was carried out on the influence of new ingredients on the consistency characteristics of the finished product. In order to quantitatively determine changes in the structure of the studied samples, the penetration method was used, which enables the evaluation of the density and elasticity of the product.

Spot samples were taken from one batch of mince at three different points, with a total mass of at least 250 g. A composite sample was used for measurement.

The sample was placed in a container after removing air by tapping the bottom and sealing with a spatula. After that, the container with the sample was kept in a water bath at a temperature of 20°C until the temperature equilibrium within 20 ± 5°C was reached. Temperature control was provided using a thermometer.

The indenter penetration depth was determined for ready-made boiled sausages, which are characterized by a firm-elastic consistency. For this purpose, a needle indenter weighing 2 g was used. Measurements were performed on the open surface of the sample, no closer than 10 mm to the edge and at the maximum distance from the places of previous punctures. In this case, zones with air inclusions, visible defects or inhomogeneous structure were avoided, which could affect the objectivity of the results.

When using a needle indenter, measurements were made at five points along the length of the product for each sample. In **Fig. 15.9**, the results of the ultimate shear stress for cooked sausage products are given.

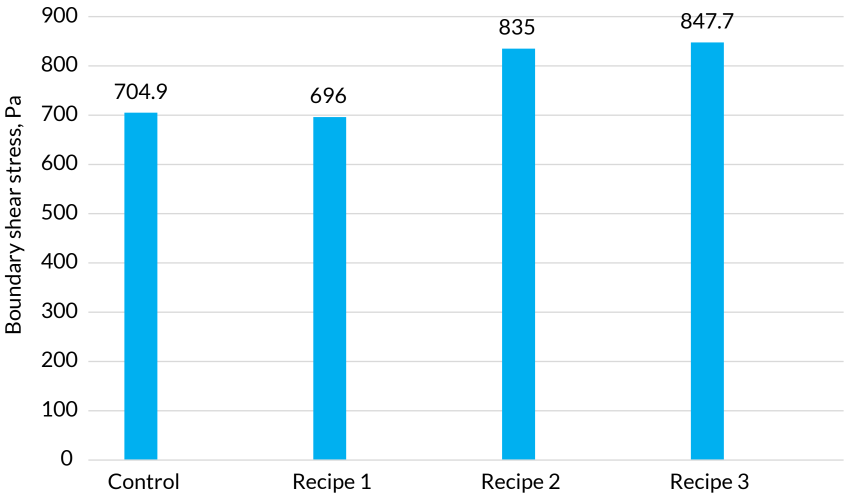

Fig. 15.9 Boundary shear stress of cooked sausage products

According to the diagram, Samples 2 and 3 exhibited statistically significant improvements in structural and mechanical properties ($p < 0.05$), with shear force values increased by 18–20% compared to the control, which can be attributed to the increased content of fish raw materials (an increase of 5 g in Sample 2 and 3 g in Sample 3) and variations in the ratio of spices to dried vegetable raw materials.

Although the amount of dried vegetable raw materials was the same in both samples (2 g each), Sample 2 contained a reduced quantity of spices compared to Sample 3.

Relative to the control sample, the density of Samples 2 and 3 increased by 18–20%. This improvement was due to the substitution of the binding agent, replacing powdered milk with a mixture of potato starch and spelled flour in a 2:6 ratio, and the incorporation of smaller pieces of plant material compared to Sample 1.

The study of the plasticity of the product was conducted using a method based on the separation of moisture from the sample during pressing by a load weighing 1 kg, sorption of the separated water by filter paper and determination of the released moisture by the size of the spot area formed on the paper. The results obtained are presented in **Fig. 15.10**.

Based on the data presented in the diagram, it can be concluded that the plasticity of the test samples differs significantly from that of the control. The plasticity of Samples 1 and 2 remains almost unchanged, but the plasticity of Sample 3 is 2 times less than the previous samples. This is due to the different types and sizes of plant raw materials introduced (Sample 1 – dried sweet pepper in pieces 6 × 6 mm; Sample 2 – dried olives in pieces 3 × 3 mm; Sample 3 – granulated garlic 8 × 16 mm).

In laboratory conditions, chemical composition studies were conducted to evaluate the quality of ready-made cooked sausage products from non-traditional raw materials. The comparative characteristics of the chemical composition depending on the introduced auxiliary raw materials are presented in **Fig. 15.11–15.13**.

The obtained results indicate that the developed formulations contain a lower protein level due to the partial substitution of fish raw materials with plant-based ingredients, a reduced fat content across all samples, and a higher mineral content compared to the control sample.

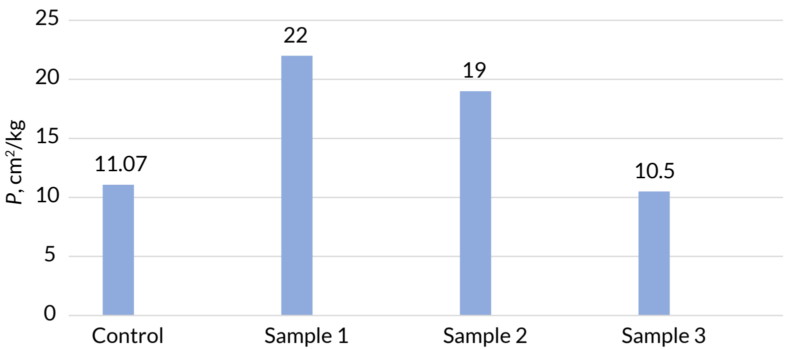

Fig. 15.10 Plasticity of cooked sausage products

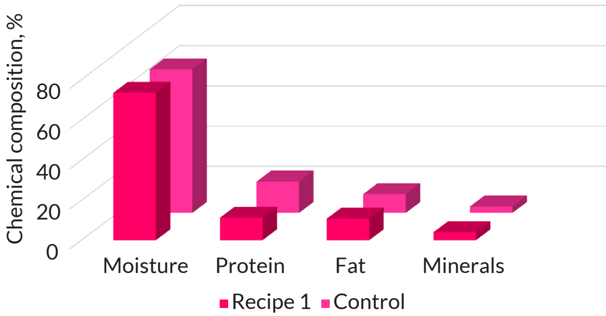

Fig. 15.11 Comparative analysis of the chemical composition of cooked sausage products (Sample 1)

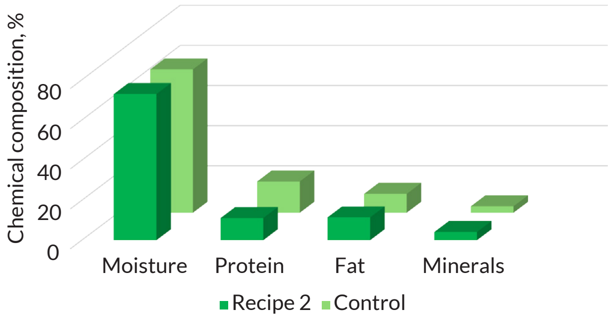

Fig. 15.12 Comparative analysis of the chemical composition of cooked sausage products (Sample 2)

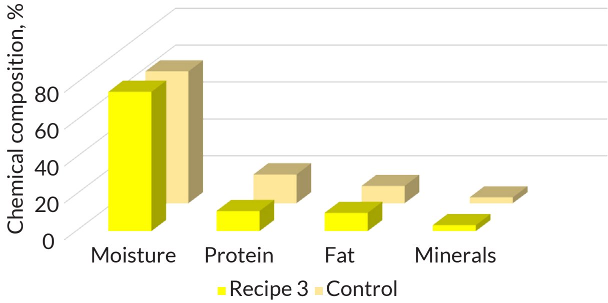

Fig. 15.13 Comparative analysis of the chemical composition of cooked sausage products (Sample 3)

The energy value of the product was calculated according to MU 4287-86. The obtained data are presented in the **Table 15.11**.

Table 15.11 Energy value of cooked sausage products, %

Indicator	Boiled sausage products from non-traditional raw materials			
	Control	Sample 1	Sample 2	Sample 3
Energy value, kcal	148.3 ± 0.54	143.7 ± 0.67	149.5 ± 0.63	134 ± 0.71

Note: $n = 5$, $p \leq 0.05$

An analysis of the obtained data shows that the energy value of the experimental samples is generally comparable to that of the control sample. This similarity is attributed to only minor differences in their chemical composition.

The acid number serves as a key quality indicator reflecting the freshness of fats, as it measures the content of free fatty acids, including those produced through the oxidation of fish fat during storage.

Determining the acid number is one of the primary methods for assessing the quality and freshness of fat, particularly in meat and fish-based products. It reflects the accumulation of free fatty acids (FFA) formed due to lipid hydrolysis caused by tissue or microbial lipases. An increase in the acid number in fish raw materials during storage is a reliable indicator of lipid hydrolytic spoilage [37]. It is established that FFA accumulation indicates not only hydrolysis but may also serve as a secondary marker of fat oxidation, which negatively affects the organoleptic properties of the product [38].

15.7 Research on the fatty acid composition of cooked sausage products

The fatty acid spectrum was determined according to DSTU ISO 5508-2001 [39] by gas chromatography of fatty acid methyl esters. Sample preparation was carried out according to DSTU ISO 5509-2002 [40]. Chromatographic analysis of fatty acids was performed on a Trace Ultra gas chromatograph with a flame ionization detector, on a capillary column SP-2560 (Supelco). The method limit is < 0.01%. The results of the studied samples are presented in **Tables 15.12–15.14**, and the total amount of fatty acids is presented in **Fig. 15.14–15.16**.

The comparative characteristics of the amount of fatty acids of the studied samples are presented in **Table 15.15** and **Fig. 15.17**.

Table 15.12 Fatty acid composition in cooked sausage product (Sample 1)

Fatty acids	Content, g/100 g of fat
Caproic acid (C6:0)	0.11
Capric acid (C10:0)	0.26
Myristic acid (C14:0)	0.42
Pentadecanoic acid (C15:0)	0.11
Palmitic acid (C16:0)	10.00
Palmitoleic acid (C16:1)	1.07
Stearic acid (C18:0)	3.37
Oleic acid (C18:1n9c)	23.93
Linoleic acid (C18:2n6c)	54.19
Arachidic acid (C20:0)	0.13
Cis-11-eicosenoic acid (C20:1n9)	0.56
Linolenic acid (C18:3n3)	0.52
Geneicosanoic acid (C21:0)	0.17
Behenic acid (C22:0)	0.16
Cis-8,11,14-eicosatrienoic acid (C20:3n6)	0.41
Erucic acid (C22:1n9)	0.32
Lignoceric acid (C24:0)	1.58
Cis-4,7,10,13,16,19-docosahexaenoic acid (C22:6n3)	2.69
Σ saturated fatty acids	16.31
Σ unsaturated fatty acids	83.69
Σ monounsaturated fatty acids	25.88
Σ polyunsaturated fatty acids	57.81
ω 6 fatty acids	54.60
ω 3 fatty acids	3.21

Table 15.13 Fatty acid composition in cooked sausage product (Sample 2)

Fatty acids	Content, g/100 g of fat
Caproic acid (C6:0)	0.03
Capric acid (C10:0)	0.05
Undecanoic acid (C11:0)	0.03
Lauric acid (C12:0)	0.09
Myristic acid (C14:0)	0.45
Pentadecanoic acid (C15:0)	0.06
Palmitic acid (C16:0)	10.17
Palmitoleic acid (C16:1)	1.12
Stearic acid (C18:0)	3.52
Oleic acid (C18:1n9c)	27.99
Linoleic acid (C18:2n6c)	48.17
Arachidic acid (C20:0)	0.16
Cis-11-eicosenoic acid (C20:1n9)	0.75
Linolenic acid (C18:3n3)	0.59
Geneicosanoic acid (C21:0)	0.16
Cis-11,14-eicosadienoic acid (C20:2n6)	0.24
Behenic acid (C22:0)	0.23
Cis-8,11,14-eicosatrienoic acid (C20:3n6)	0.36
Cis-11,14,17-eicosatrienoic acid (C20:3n3)	0.33
Lignoceric acid (C24:0)	1.90
Cis-4,7,10,13,16,19-docosahexaenoic acid (C22:6n3)	3.60
Σ saturated fatty acids	16.85
Σ unsaturated fatty acids	83.15
Σ monounsaturated fatty acids	29.86
Σ polyunsaturated fatty acids	53.29
ω 6 fatty acids	48.77
ω 3 fatty acids	4.52

Table 15.14 Fatty acid composition in cooked sausage product (Sample 3)

Fatty acids	Content, g/100 g of fat
Caproic acid (C6:0)	0.04
Caprylic acid (C8:0)	0.04
Capric acid (C10:0)	0.17
Myristic acid (C14:0)	0.42
Pentadecanoic acid (C15:0)	0.07
Palmitic acid (C16:0)	9.23
Palmitoleic acid (C16:1)	1.06
Stearic acid (C18:0)	3.68
Oleic acid (C18:1n9c)	24.16
Linoleic acid (C18:2n6c)	55.75
Arachidic acid (C20:0)	0.13
Cis-11-eicosenoic acid (C20:1n9)	0.41
Linolenic acid (C18:3n3)	0.53
Geneicosanoic acid (C21:0)	0.18
Cis-11,14-eicosadienoic acid (C20:2n6)	0.08
Behenic acid (C22:0)	0.10
Cis-8,11,14-eicosatrienoic acid (C20:3n6)	0.49
Cis-11,14,17-eicosatrienoic acid (C20:3n3)	0.20
Lignoceric acid (C24:0)	1.31
Cis-4,7,10,13,16,19-docosahexaenoic acid (C22:6n3)	1.95
Σ saturated fatty acids	15.37
Σ unsaturated fatty acids	84.63
Σ monounsaturated fatty acids	25.63
Σ polyunsaturated fatty acids	59.00
ω 6 fatty acids	56.32
ω 3 fatty acids	2.68

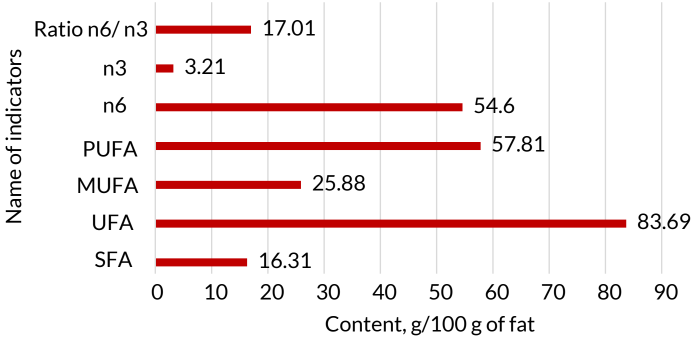

Fig. 15.14 Total fatty acid content in Sample 1

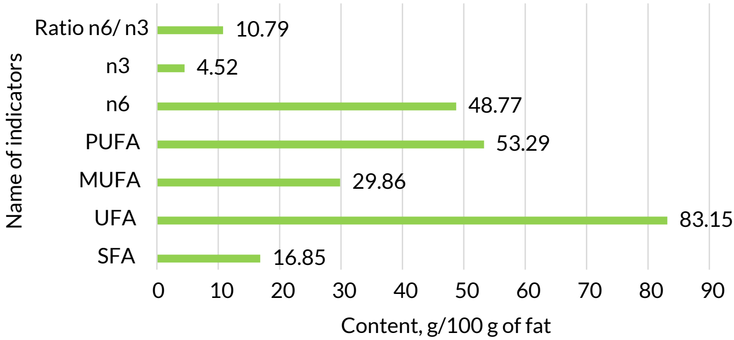

Fig. 15.15 Total fatty acid content in Sample 2

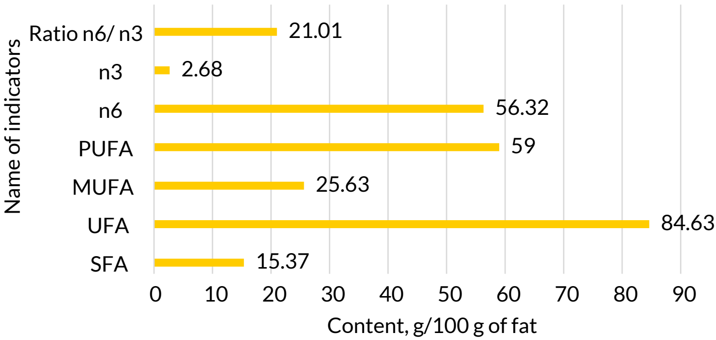

Fig. 15.16 Total fatty acid content in Sample 3

Table 15.15 Comparative characteristics of the amount of fatty acids in the studied samples

Indicator	Sample 1	Sample 2	Sample 3
SFA	16.31	16.85	15.37
UFA	83.69	83.15	84.63
MUFA	25.88	29.86	25.63
PUFA	57.81	53.29	59.00
n6	54.6	48.77	56.32
n3	3.21	4.52	2.68
Ratio n6/ n3	17.01	10.79	21.01

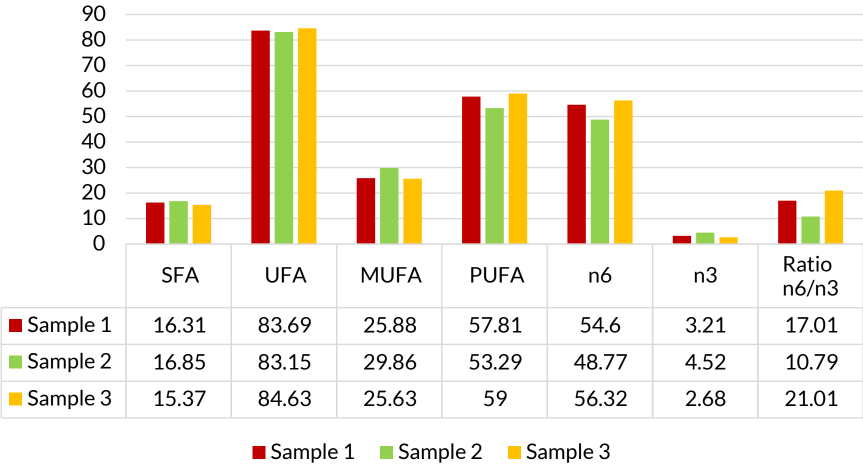

Fig. 15.17 Comparative characteristics of fatty acid content

The total amount of SFA remains almost unchanged. The content of SFA in the obtained samples does not exceed the daily intake. The total amount of UFA does not change significantly in the studied samples. The total amount of MUFA remains almost unchanged. A high indicator is observed in Sample 2. The total amount of PUFA remains almost unchanged. A high indicator is observed in Sample 3. The indicator of the quantity of Omega-6 prevails in Sample 3 over Samples 1 and 2. The indicator of the quantity of Omega-3 prevails in Sample 2. The result obtained in Sample 3 is twice as low as in Samples 1 and 2.

15.8 Dynamics of physicochemical quality indicators of cooked sausage products during storage

The evaluation of organoleptic indicators for cooked sausage products was conducted over 6 days at temperatures ranging from 0°C to 5°C using a five-point scale. The results of changes in organoleptic indicators of cooked sausage products during storage over 6 days are presented in **Fig. 15.18**.

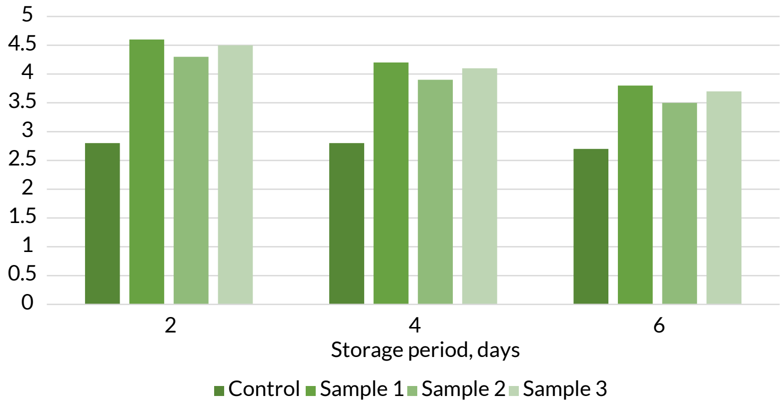

Fig. 15.18 Dynamics of organoleptic evaluation indicators during storage

When conducting an organoleptic assessment, it was found that the most optimal storage period for cooked sausage products is 3 days. During this period, cooked sausage products correspond to high taste properties. When storing cooked sausage products (tested samples) for more than 4 days, a decrease in organoleptic properties (loss of saturated color, appearance of a strong fishy odor, deterioration of taste) is observed due to the absence of a color fixative (sodium nitrite and quality indicators due to deterioration of the muscle tissue of the raw material compared to the control sample.

The physicochemical properties of cooked sausage products were studied over 6 days at temperatures ranging from 0°C to 5°C. The results of changes in moisture content in cooked sausage products over 6 days during storage are presented in **Fig. 15.19**.

From the data presented in **Fig. 15.19**, it can be observed that the moisture content of cooked sausage products decreases during storage. The greatest dynamics of changes in moisture content is observed in Sample 3 due to the high moisture content in the product compared to the control. In Samples 1 and 2, less pronounced dynamics of changes in moisture during storage are observed.

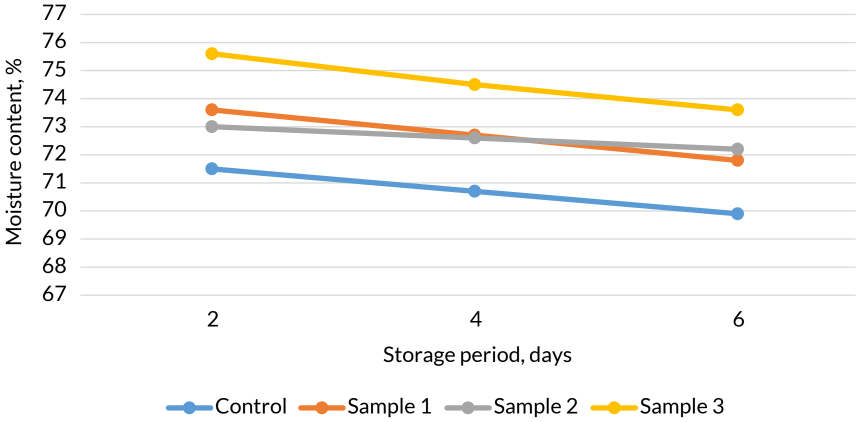

Fig. 15.19 Dynamics of changes in the moisture content of cooked sausage products during storage

Acid value is one of the main quality indicators that characterize the degree of freshness of fat, as it determines the amount of free fatty acids, including those formed during the oxidation of fish fat during its storage.

During storage, free fatty acids accumulate as a result of lipid hydrolysis in muscle tissues, catalyzed by tissue lipases. The extent and direction of this hydrolytic process were assessed based on the buildup of free fatty acids in the lipids of fish muscle tissue. Changes in the acid number of lipids during cold storage of both experimental and control cooked sausage samples are illustrated in **Fig. 15.20**.

The content of peroxide compounds in fat was judged by the value of the peroxide number, which is a reasonably sensitive indicator that characterizes the beginning and depth of oxidative deterioration of fat.

The change in the peroxide number of lipids during the storage of experimental and control samples of cooked sausage products is presented in **Fig. 15.21**.

Measuring the peroxide value enables the early detection of oxidation processes and the formation of spoilage products, well before they can be identified through organoleptic assessment. As illustrated in **Fig. 15.21,** the peroxide value, like the acid value, increases throughout storage, though it remains within acceptable limits by the end of the storage period.

As noted by F. Shahidi and Y. Zhong [33], the early stage of lipid oxidation is a highly sensitive indicator of the initial phases of autoxidation. It is widely used to assess the oxidative stability of food products.

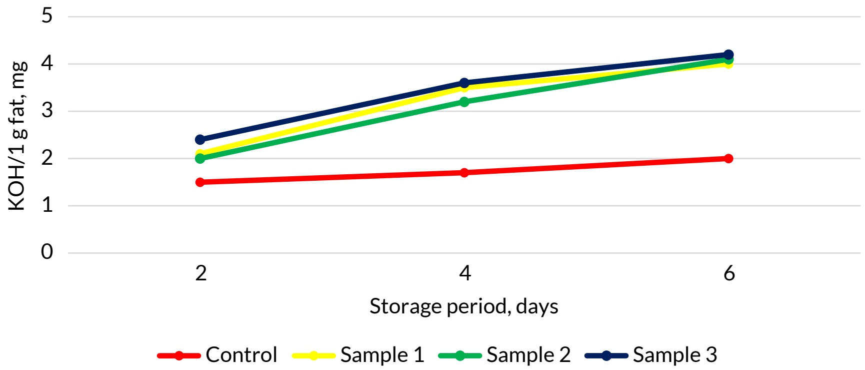

Fig. 15.20 Dynamics of changes in the acid number of cooked sausage products during storage

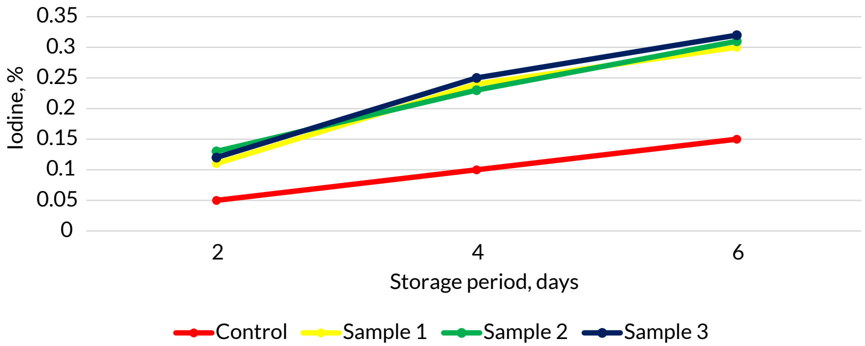

Fig. 15.21 Dynamics of changes in the peroxide value of cooked sausage products during storage

Research by R. Domínguez et al. [31] indicates that the peroxide value is closely related to storage duration, the quality of the lipid raw material, and the presence of antioxidant compounds in the product. A gradual increase in this indicator signals the activation of oxidation processes. In contrast, slower growth in specific samples (such as Sample 3) may result from the inclusion of components with pronounced antioxidant properties or a more stable fatty acid composition.

Determination of peroxide value is one of the key methods for assessing the initial stages of lipid oxidation in meat and fish products. This indicator allows to quickly detect the development of oxidative processes long before the appearance of characteristic changes that can be recorded by organoleptic methods [35–38]. Since peroxide compounds are the primary products of the autocatalytic oxidation of fats, their content directly indicates the stability of the lipid fraction under storage conditions.

The increase in peroxide value during product storage is an expected phenomenon, which confirms the activation of oxidation processes, especially in the presence of unsaturated fatty acids inherent in fish raw materials. However, in cases where natural antioxidants or more stable fat components are used, as in Sample 3, the rate of peroxide accumulation is significantly reduced ($p < 0.05$ compared to control), as confirmed by the Tukey test results. This indicates the effectiveness of functional ingredients that act as oxidation inhibitors [36].

As S. Lee notes, the peroxide value is an extremely sensitive indicator of the initial stages of autooxidation, making its monitoring a reliable tool for predicting the shelf life and quality control of products. In addition, according to R. Domínguez et al., this indicator is closely correlated with the duration of storage, the quality of the fatty raw material and the presence of antioxidant substances. Thus, the gradual increase in the peroxide value in the tested samples, which remains within the regulatory values, confirms the proper technological stability of the product and the effectiveness of the developed formulation [37].

15.9 Microbiological indicators of cooked sausage products

For food safety, cooked sausage products must comply with microbiological control. The regulated compliance indicators are presented in **Table 15.16**.

Table 15.16 Microbiological quality indicators of cooked sausage products

Product group	Number of mesophilic aerobic and facultative anaerobic microorganisms, CFU per 1 g/cm³, not exceeding	Acceptable levels, 1 g/cm³
Control	2.4×10^3	Not more than 1×10^5
Sample 1	1.5×10^3	
Sample 2	0.7×10^3	
Sample 3	0.9×10^3	

According to **Table 15.16**, it can be concluded that the number of mesophilic aerobic and facultative anaerobic microorganisms CFU in 1 g/cm^3 should not exceed 2.5×10^3, bacteria of the coliform group – 1.0, S.aureus – 1.0, bacteria of the genus Proteus – 0.1, pathogenic microorganisms, including bacteria (Salmonella), viruses – 25.

Based on the results obtained, it can be concluded that the microbiological indicators of the sausages remained within acceptable limits over a period of four days.

Based on the results of the research and the developed recipe, a new type of boiled sausage was introduced into production under the "Savin Product" trademark. The recipe was adapted to the conditions of industrial production, taking into account modern requirements for quality, nutritional value and product safety.

After the launch of production, the sausage product aroused interest among consumers who prefer more natural and functional meat products. The addition of spelt flour contributed to the enrichment of the sausage with protein, dietary fiber and microelements, which had a positive effect on its perception by buyers. Consumers noted the improved texture, pleasant taste and health benefits. Today, the product demonstrates stable demand and is actively sold through retail chains, which indicates its successful positioning in the market of functional meat products.

15.10 Conclusion

The conducted research confirmed that the incorporation of 10% chicken meat, 6% spelt flour, and selected dried vegetables significantly improved the quality characteristics of cooked fish sausages based on hake. Experimental samples demonstrated an increase in protein content to 16.4–17.2 g/100 g, representing an 8–10% improvement compared to the control (15.1 g/100 g). The moisture-holding capacity increased to 86.3% (in the bell pepper sample), enhancing juiciness and texture. Structural and mechanical tests revealed that the shear force in Samples 2 and 3 increased by 18–20%, indicating an improvement in the density and cohesiveness of the product matrix. During 10 days of refrigerated storage, Sample 3 exhibited the lowest increase in acid value (from 1.7 to 2.3 mg KOH/g fat) and peroxide value (from 1.6 to 2.1% Iodine), suggesting enhanced oxidative stability due to the presence of natural antioxidants.

The results support the initial hypothesis that the proposed formulation has a positive impact on the physicochemical, structural, and sensory properties of cooked fish sausages. These findings suggest the potential for scaling up the developed formulation in pilot-scale production and integrating it into functional food product lines within the fish and meat processing industry.

Nonetheless, the current study is subject to certain limitations, including the lack of extended microbiological stability data and a limited assessment of shelf life under variable temperature conditions. Future work should focus on broader screening of plant-based functional ingredients, long-term storage evaluation, and consumer preference testing to further optimize the formulation and ensure commercial viability.

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