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EVALUATION OF QUALITY INDICATORS AND COMPOSITION OF SEMI-SMOKED SAUSAGE FROM PLANT-BASED MEAT SUBSTITUTE ENRICHED WITH BLOOD OF SLAUGHTERED ANIMALS

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Object of the study is semi-smoked sausage from a plant-based meat substitute, enriched with blood of slaughtered animals in various proportions.

The problem to be solved is that the blood of farm animals, being a valuable source of protein, is thrown away by the tons as waste, and is aggravated by the emerging serious problems of environmental pollution. But in many countries, most of the blood proteins are used as binders, natural color enhancers, emulsifiers, fat substitutes and agents for salting meat.

The article presents the results of the study of organoleptic evaluation, mineral and physicochemical composition of semi-smoked sausage from plant-based meat substitute enriched with blood of slaughtered animals. Soybeans and chickpeas were selected as plant raw materials in a ratio of 70:30. According to the results of the organoleptic evaluation, it was found that the addition of blood of slaughtered animals into the recipe of investigational product in the amount of 2%, improves the taste and color of the finished product. In the course of the study it was proved that when 2% dry blood of slaughtered animals was added to a semi-smoked sausage from plant-based meat substitute, the amount of protein increased by 2.26% compared with the control sample. Also, the increased fat content in the investigational samples of semi-smoked sausage showed that the blood of slaughtered animals can be used as a fat substitute. Based on studies of the mineral composition of semi-smoked sausage from plant-based meat substitutes, it has been proven that adding 2–6% blood of slaughtered animal increases the content of mineral substances compared to the control sample. Studies have shown that adding 2%, 4%, 6% blood of slaughtered animals to a semi-smoked sausage from plant-based meat substitute increases the content of essential and non-essential amino acids compared to the control sample. It was found that in experimental samples with the addition of 2%, 4%, 6% blood of slaughtered animals, the content of saturated and polyunsaturated fatty acids increases compared with the control sample. Thereby enriching and increasing the biological and nutritional value of the finished product

Keywords: semi-smoked sausage, meat substitute, blood of slaughtered animals, physicochemical composition

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1. Introduction

Nowadays, the meat market is one of the highest priorities and largest food markets. Meat producers around the world are facing the need to meet the growing demand from consumers of meat products [1]. Meat is a healthy food product for humans, rich in zinc, iron, vitamins, protein, etc., but it contains a lot of saturated fatty acids and cholesterol, so the constant consumption of large amounts of meat causes chronic diseases such as diabetes, colorectal cancer and cardiovascular diseases [2].

Also, with the increase in population growth around the world, the need for meat products is correspondingly increasing, but due to the increase in prices for these products, not everyone has the opportunity to purchase them. Therefore, there has been an increased interest in plant-based meat-like substitutes based on dietary proteins that replace animal-derived proteins. The results of the conducted research allowed, taking into account the current trends, to structure the meat market in terms of traditional and vegetable substitutes.

To meet the needs of the country's population in meat products, one of the priorities is the use of vegetable raw materials in the production of sausages, which are one of the most popular food products. In modern conditions, the optimal choice of plant-based raw materials for semi-smoked sausage is determined not only by the compliance of biological and nutritional characteristics, but also to saturate it with high-grade protein and the competitiveness of the products produced. Vegetable proteins can replace meat products, while being an economical, functional and high-protein food ingredient, or they can be consumed directly as a meat substitute. Meat substitutes are popular due to their healthy appearance (they do not contain cholesterol), meaty texture and low cost [3, 4]. They can also contain important nutrients such as fiber and vegetable protein, which makes them more preferable for consumers.

Proteins from legumes are becoming increasingly important in the production of various functional foods due to their high protein content. Legumes provide a balanced level of amino acids. More than 19,000 species make up the botanical family of legumes, of which chickpeas, peas, lentils, beans and soybeans are widely grown and popular crops. The nutritional properties of these crops are following [5] (g/100g): proteins-soya bean36.9, bean 21.3, lentil 20.6, pea 21.9, chickpea 23.6; lipids-soya bean18, bean 1.7, lentil 2.15, pea 2.3, chickpea 6.4.

From the data given above, it can be concluded that the highest content of protein and fat is found in products such as soy and chickpeas. And their use in the development of semi-smoked sausage, as a plant-based meat substitute, will make the product with increased nutritional and biological value.

Soybean and chickpea proteins are successfully used to prepare meat additives. Many proteins are used in meat products as ingredients because of their properties to function as a water binding agent. Soy protein, which consists of fractions of albumin and globulin, is the most common substitute for whole meat protein [6]. Soy is the main ingredient in structured vegetable proteins due to its prevalence, low cost, texture that resembles meat after hydration, and high-quality amino acid composition. Soy-based meat substitutes not only have high protein and nutritional value equivalent to meat, but also contain little or no cholesterol and fat due to the addition of plant ingredients [7].

In addition to soy protein, chickpea protein is also common. Chickpeas (*Cicer arietinum* L.) are one of the most cultivated and consumed legumes, characterized by high protein content (17–22%), fiber and fat, but lower carbohydrate content compared to wheat. In addition, chickpeas contain many biologically active compounds, including isoflavones and phenolic acid. Chickpeas are recognized as a valuable dietary protein source due to their sufficient biological value and bioavailability. Chickpeas contain fewer sulfur-containing amino acids such as cystine and methionine. In addition, the functional properties of chickpea proteins, including foaming, soluble, gelling and emulsifying properties, are favorable for the development of new food products. Chickpea seeds contain a large amount of protein, usually from 20 to 25%. Prolamin, albumin, glutelin, and globulin are the main proteins in chickpeas and account for approximately 3–7%, 8–12%, 19–25%, and 53–60% of the total protein, respectively [8].

The technology of extracting pure protein from soybeans, chickpeas and various green parts of plants has long been mastered by mankind. But this protein is not complete, as it does not contain some essential amino acids, and for a normal diet, a person needs complete animal protein in sufficient quantities. With the help of animal blood, it is possible to get a complete protein with all the essential amino acids. The blood of slaughtered animals, which is considered waste during the slaughter of cattle, can be added to semi-smoked sausage from plant-based meat substitute to give the meat product juiciness, taste and enrichment with essential amino acids.

Blood is a rich source of iron and proteins of high nutritional and functional quality. Due to the high protein content in the blood, usually about 18%, it is sometimes referred to as «liquid protein». Thus, a valuable protein source is lost if animal blood is disposed of as waste, and this is compounded by the serious environmental pollution problems that arise [9].

In sausage production are used a wide range of blood and its components. Whole blood can be used as a flavoring agent where it provides a rich, savory, and distinctive flavor profile to sausage products. In addition, whole blood as well as blood plasma (i.e., the liquid portion of blood after blood cells have been removed) provide excellent binding properties [10].

Dry blood (black food albumin) was chosen to enrich the composition of semi-smoked sausages from plant-based meat substitutes, as it will enrich the products with high-grade protein, as well as easily digestible iron.

Therefore, studies that are devoted at developing semi-smoked sausages from plant-based meat substitutes enriched with complete animal proteins such as dry blood (food grade black albumin) are scientific relevance. Such studies contribute to the development of food technologies, as they solve urgent problems related to ensuring nutritional value, accessibility and sustainability in the production of meat products. A rational combination of plant and animal protein sources makes it possible to create functional meat analogues with improved amino acid composition, increased iron content and attractive organoleptic properties. In addition, the use of animal slaughter by-products helps to reduce waste and improve environmental sustainability, which underscores the importance of an integrated approach in modern food science.

2. Literature review and problem statement

The paper [11] studied the inclusion of bovine plasma proteins and the polysaccharide inulin as fat substitutes in meat batters. Their results showed that the corresponding levels of bovine plasma proteins (2.5% by weight) and inulin (2.0% by weight) provided effective fat replacement of 20–30% in meat batters based on textural profile and sensory properties. Although the paper touches on the theme of nutritional modification (fat reduction, protein addition), the deep biochemical composition, such as fatty acids and amino acids, was not the subject of this study.

The study in the paper [12] was conducted to explore the changes in quality attributes of mutton sausage incorporated with sheep plasma protein hydrolysates (SPPH) stored at refrigeration temperature under aerobic packaging. The plasma protein hydrolyzed by *in vitro* gastrointestinal digestion was incorporated into mutton sausages at 5(T1), 7.5(T2) and 10% (T3)(w/w) levels and compared with control (C: 0% SPPH) for fatty acids, physic-chemical properties, color, texture profile and oxidative stability at 7 days intervals for 21 days. The authors concluded from their research that SPPH (10%) can serve as a potential ingredient for improving the physico-chemical properties and oxidative stability of emulsion-based products. The work did not analyze the amino acid composition of sausages with the addition of SPPH, which limits the understanding of their nutritional value.

There is also no data on consumers' perception of the taste, aroma, and texture of sausages with SPPH. Perhaps this is due to the fact that the main aim of the study was to evaluate physico-chemical changes.

The paper [13] studied the inclusion of blood protein in chicken sausages as a substitute for soy proteins and synthetic dyes. They concluded that there were no significant differences in physicochemical, microbiological, or sensory profiles between standard formulations of chicken sausages and those formulated with liquid plasma or freeze-dried plasma. This paper does not specify quantitative and qualitative analysis of macro- or microelements. Studies of the amino acid and fatty acid composition of sausages, which is an important aspect for assessing nutritional value and health effects, are also not described. In this article, it was important to describe the formulation development and the initial technological assessment.

The paper [14] evaluated the potential of seven different protein-based ingredients (peas, blood plasma, gelatin, soy, whey, egg, and potato) to serve as replacements for phosphate in emulsified meat products. The authors reported that blood plasma and soy were superior in the phosphate-free cooked sausages when compared with the other ingredients, as no significant differences in hardness, cooking yield, or stability were found in relation to phosphate-formulated sausages. This paper did not analyze the content of minerals (for example, sodium, potassium, phosphorus) in new formulations, although this is important when excluding phosphates. They also did not determine how protein substitutes affect the nutritional value (fatty acid and amino acid composition) of the finished product. The article provides valuable data on the technological quality of phosphate-free products, but there is no data on nutritional value, such as mineral, amino acid and fatty acid composition, which makes this a promising area for extended analysis.

The paper [15] investigated the effect of protein content in blood plasma and soy fibers on the properties of Bologna sausage depending on the fat level. The authors concluded that plasma protein could be a promising fat replacement in low-fat meat emulsion. Plasma protein had more influence on binding and textural properties than soy fiber and was, therefore, thought best to limit the effect of fat reduction. The modification of composition had some influence on technological properties of both nonmeat ingredients. No synergistic or antagonistic effects were observed between plasma protein and soy protein, which suggested that there were no limits to the combinations of these that can be used. The paper does not investigate the effect of plasma proteins on the content of minerals and amino acids, as the article focuses on the textural and functional characteristics of the product when changing the amount of fat.

The paper [16] studied the functional and physical properties of bovine plasma proteins depending on processing and pH, application in food formulation. Bovine plasma proteins can be an alternative to other proteins such as soy and milk proteins in the production of emulsions and foams. For the preparation of minced meat, RM (raw material) and PBP (the processed bovine plasma) were used which showed higher moisture content, improved stability and consistency, while no changes in aroma, taste and color were observed. Thus, these results indicate that PBP had a beneficial effect on the quality of minced meat suggesting that it can be used as a stabilizer and emulsifier. The paper is important as a basic study of the functional properties of using cattle blood plasma. However, the assessment of the nutritional value of the finished product, as well as the effect of proteins on its properties, is not indicated. Data on the sensory characteristics of the final product with the addition of plasma are not described. The main aim of this paper was to describe research on the basic functional properties of plasma proteins and its possible use in food products.

The paper [17] investigated the performance of cold-set binding agents in re-formed beef steaks. The study showed that three of the four cold-set binding agents tested provided satisfactory binding in re-formed beef steaks made from the muscles of the forequarter of the beef carcass (shoulder and brisket). Although the binders varied in color, texture, and yield of the finished product, the tasting committees rated them all as generally acceptable. Taking into account the combination of binding results, appearance, yield of the finished product and organoleptic qualities, it was concluded that the binding agents Activa, containing the enzyme transglutaminase, and Fibrimex, containing the blood plasma fractions fibrinogen and thrombin showed the best results. However, this paper did not evaluate changes in the amino acid, fatty acid and mineral composition of products when using various binding agents.

Papers [18, 19] studied the composition and biological activity of the slaughter blood of red deer, sheep, pigs and cattle. Since animal blood is used as fertilizer for blood meal and as a food additive, a minimal comparative study of animal blood fractions in slaughterhouses was conducted. This study compared blood counts of deer, sheep, pigs, and cattle slaughtered in slaughterhouses. The iron content in the blood serum ranged from 35.3 ± 0.6 mmol/l in cattle to 16.3 ± 3.1 mmol/l in deer. In cattle, the total protein content in blood plasma was the highest (81.7 ± 1.5 g/l). As a result of the study, they came to the conclusion that fractionated animal blood obtained at local slaughterhouses contains native proteins with antioxidant activity and antimicrobial activity. However, this paper does not study the use of agricultural blood in specific products, although it talks about potential use in the food industry.

As a result of the critical analysis of the cited sources, the insufficiently described studies were identified. This gives the opportunity in our work to describe the results of a study conducted to evaluate the quality and composition of semi-smoked sausage made from a vegetable meat substitute with the addition of blood from slaughtered animals.

From the presented materials, it can be concluded that the rational use of blood from slaughtered animals and its processed products (plasma, serum, formed elements) allows increasing animal protein resources. And also improves the quality and increases the nutritional value of non-meat products, diversifies the range of manufactured products and provides additional profit to the enterprise.

However, the use of soybeans, chickpeas, and blood of slaughtered animals as the main food ingredients is still in the early stages of research. Since their use as a meat substitute in sausage production has practically not been studied.

3. The aim and objectives of the study

The aim of the study is to evaluation of the quality and composition of semi-smoked sausage from plant-based meat substitute with the addition of blood from slaughtered animals. This will improve not only the organoleptic parameters, but also the mineral, physico-chemical composition of the final product.

In accordance with the stated aim, the following objectives were solved:

– to investigate the effect of blood of slaughtered animals on the organoleptic properties of semi-smoked sausage from plant-based meat substitute;

– to investigate the content of mineral substances in semi-smoked sausage from plant-based meat substitute enriched with blood of slaughtered animals;

– to determine the amount of protein in semi-smoked sausage from plant-based meat substitute;

– to determine the content of essential and non-essential amino acids in semi-smoked sausage from plant-based meat substitute;

– to study the content of fatty acid composition of semi-smoked sausage from plant-based meat substitute.

4. Materials and methods

The object of the study is semi-smoked sausage from a plant-based meat substitute, enriched with blood of slaughtered animals in various proportions.

The main hypothesis of the study is the possibility of the enrichment of semi-smoked sausages from plant-based meat substitutes with the blood of slaughtered animals, which improves their organoleptic properties, increases mineral value and improves physicochemical indicators.

The assumptions of the study are that the plant-based meat substitute is compatible with animal components in structure and taste, and will have a good effect on the final product. As well as the assessment methods used (organoleptic assessment, physico-chemical parameters, mineral composition) are accurate and reproducible.

Simplifications adopted in the study: the conditions of long-term storage, packaging and expiration dates are not considered.

Soy isolate and chickpeas in a ratio of 70:30 were chosen as the objects of the main raw material research. Dry beef blood (Yerubá S.A., Argentina) was used to enrich the semi-smoked sausage from plant-based meat substitute in the amount of 2%, 4%, 6% by weight of the raw material.

Research materials:

1) No. 1 – control sample, semi-smoked sausage from plant-based meat substitute;

2) No. 2 – experimental sample, semi-smoked sausage from plant-based meat substitute with the addition of 2% blood of slaughtered animals;

3) No. 3 – experimental sample, semi-smoked sausage from plant-based meat substitute with the addition of 4% blood of slaughtered animals;

4) No. 4 – experimental sample, semi-smoked sausage from plant-based meat substitute with the addition of 6% blood of slaughtered animals.

The mineral composition of semi-smoked sausage from plant-based meat substitute was studied using a scanning electron microscope (JSM-6490LV, JEOL (Japan)). SEM experiment procedure. Samples of thin sheet material are fixed in special clips. Several samples are collected in a package and placed between plates that are tightened with bolts. Then pour a fusible sulfur substance. Next, the sample is placed on paper with a flattened surface and ground with light pressure. A test sample of the product is applied to a special, double-sided adhesive tape. After blowing the product under study with a jet of clean air, it must be installed in the working chamber of the microscope. Pump out the electron microscope to a high vacuum, checking the operation of the vacuum system components. After obtaining an image of the object under study in secondary electrons, it is possible to select a pre-accelerating voltage of 20 kV, an electron probe diameter of 40 nm, and an eccentric table tilt of 0 degrees. To obtain an electronic image of the microstructure of the sample. X-ray microanalysis is performed using the INCA ENERGY Analyser Navigator program. After obtaining the X-ray spectrum of the selected area, the peaks in the spectrum are identified. The results of the analysis of inorganic initial and final products are obtained in the form of micro and macro photographs with magnification of 50–3000 times.

The fatty acid composition was determined by gas chromatography according to ISO 12966-1. The method is intended for determining the fatty acid composition in animal and vegetable fats and oils following their conversion to fatty acid methyl esters [20].

The determination of the mass fraction of amino acids was carried out by high-performance liquid chromatography according to AOAC Official Method 994.12. Method is a validated procedure for determining the amino acid content in feeds and other biological samples like food and dietary supplements. It uses performic acid oxidation followed by acid hydrolysis to break down proteins into individual amino acids, which are then separated and quantified using high-performance liquid chromatography (HPLC). This method requires special treatment for sulfur-containing amino acids (cysteine and methionine) and is a key analytical standard in the animal feed industry for nutritional analysis [21].

The determination of the mass fraction of protein was carried out according to ISO 1871:2009 using the classical Kjeldahl method, using modern DK6, UDK159 devices with the use of an automated combustion furnace and a distillation apparatus. The determination of the mass fraction of fat was carried out according to ISO 1443:1973 by the Soxlet method. The method is based on repeated extraction of fat with a solvent from a dried sample of the product, followed by removal of the solvent. Then drying of fat in a drying cabinet at a temperature of (103 ± 2) °C to constant mass.

The technological process. The technology of preparing semi-smoked sausage from a plant-based meat substitute is similar to preparing semi-smoked meat sausage, with minor changes. The technological stages of preparing sausage samples from a plant-based meat substitute include: primary processing of plant-based raw materials (soybeans, chickpeas); preparation of plant-based minced meat in a cutter (TalsaK15S) with the addition of blood of slaughtered animals, salt, spices (8–10 min.); filling of shells and binding of loaves; precipitation (4–8°C; 2–4 hours); heat treatment: drying (45°C, 10 min), frying (75°C; 30 min); cooking (85°C, 40–80 min), cooling (20°C and below, 2–3 hours), smoking (43 ± 7°C, 12–24 hours), drying (10–12°C, humidity 76.5 ± 1.5%, 1–2 days); storage.

The formulation for the production of experimental samples of semi-smoked sausage from a plant-based meat substitute with the addition of blood of slaughtered animals is shown in Table 1.

All control and experimental samples were prepared according to this formulation. During the preparation of the experimental sample, 2%, 4%, 6% of the dry blood of slaughtered animals was added to the mass of plant-based raw materials.

Table 1

Formulation for the production of experimental samples of semi-smoked sausage from a plant-based meat substitute with the addition of blood of slaughtered animals

The name of raw materials, spices and materials	Semi-smoked sausage from plant-based meat substitute			
	Semi-smoked sausage made from plant-based meat substitute (control)	Semi-smoked sausage from plant-based meat substitute with the addition of 2% blood of slaughtered animals	Semi-smoked sausage from plant-based meat substitute with the addition of 4% blood of slaughtered animals	Semi-smoked sausage from plant-based meat substitute with the addition of 6% blood of slaughtered animals
Raw materials are not salted, kg per 100 kg				
Chickpeas	30	30	30	30
Soy isolate	70	68	66	64
Dry blood of slaughtered animals	–	2	4	6
Total	100	100	100	100
Spices and materials, g per 100 kg of unsalted raw materials				
Table salt	2000	2000	2000	2000
Fermented rice	50	–	–	–
Sunflower oil	5000	5000	5000	5000
Coconut oil	5000	5000	5000	5000
Ground black pepper	100	100	100	100
Ground allspice	90	90	90	90
Ground coriander	50	50	50	50

5. Results of the study of semi-smoked sausage from plant-based meat substitute

5. 1. Determination of organoleptic characteristics of semi-smoked sausage from plant-based raw materials

The organoleptic characteristics of semi-smoked sausage from plant-based raw materials with the addition of various amounts of dry food blood were determined. Three samples were developed with the addition of dry food blood in the amount of 2%, 4%, 6%. The results of the organoleptic evaluation are shown in Table 2.

Table 2

Organoleptic characteristics of semi-smoked sausages from plant-based raw materials

Name of indicators	Characteristics of semi-smoked sausage from plant-based raw materials with added blood		
	Semi-smoked sausage from plant-based meat substitute with the addition of 2% blood of slaughtered animals	Semi-smoked sausage from plant-based meat substitute with the addition of 4% blood of slaughtered animals	Semi-smoked sausage from plant-based meat substitute with the addition of 6% blood of slaughtered animals
Appearance	Clean, dry surface, free of stains and slips		
Color	Light brown	Dark red	Dark red
Smell	Characteristic of this kind of product, no extraneous odor, slight smell of spices	Characteristic of this kind of product, without extraneous odor, pleasant aroma of spices	Characteristic of this kind of product, without extraneous odor, pleasant aroma of spices
Consistency	Dense, homogeneous		
Taste	Characteristic of this type of product, without extraneous taste, pleasant taste of spices	Characteristic of this type of product, slightly ferrous flavor	felt a pronounced taste of iron

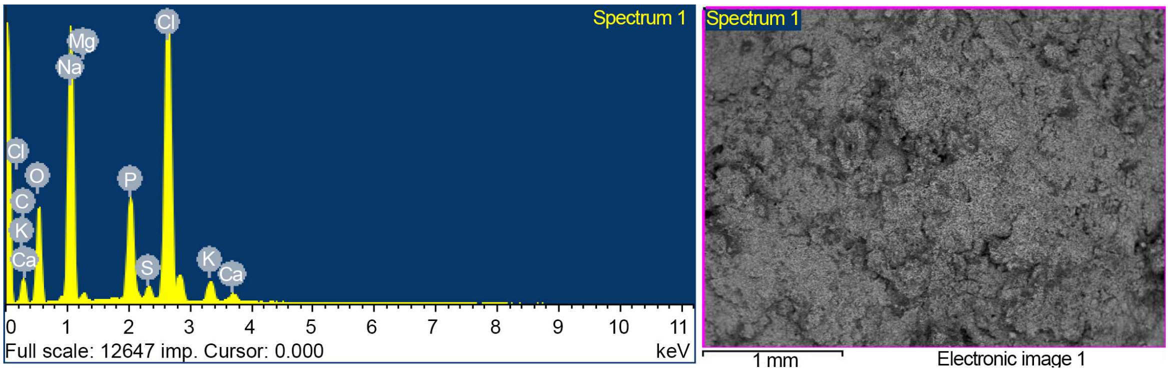
According to the results of organoleptic parameters studies, it was determined that when dry blood is added to semi-smoked sausage in the amount of 2%, 4% and 6%, it affects the color and taste of the finished product. When 2% of dry blood was added to a semi-smoked sausage from plant-based raw materials, the color became light brown. The smell and taste of the investigational sample were characteristic of this type of product, and the consistency was dense and homogeneous. When 4% of dry blood is added to semi-smoked sausage from plant-based raw materials, the consistency, appearance and smell are characteristic of this type of product, characterized by a slightly ferrous flavor and dark red color. Also, when adding dry blood in an amount of 6% to semi-smoked sausage from plant-based raw materials, felt a pronounced taste of iron, and the color became dark red, which is unacceptable in the manufacture of semi-smoked sausages.

5. 2. Study of the mineral composition of semi-smoked sausage from plant-based meat substitute

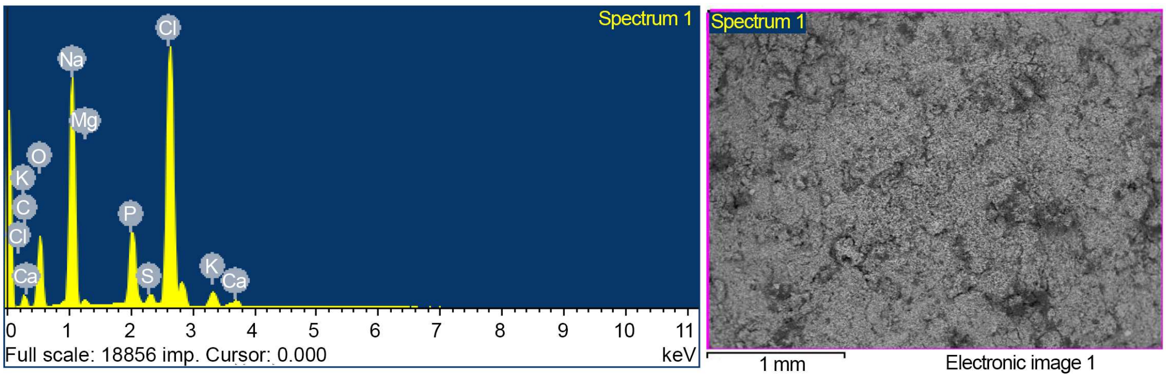
The results of the study of the mineral composition of semi-smoked sausages from plant-based meat substitute with the addition of blood from slaughtered animals are shown in Fig. 1.

The results of the chromatogram processing are shown in Fig. 2, 3.

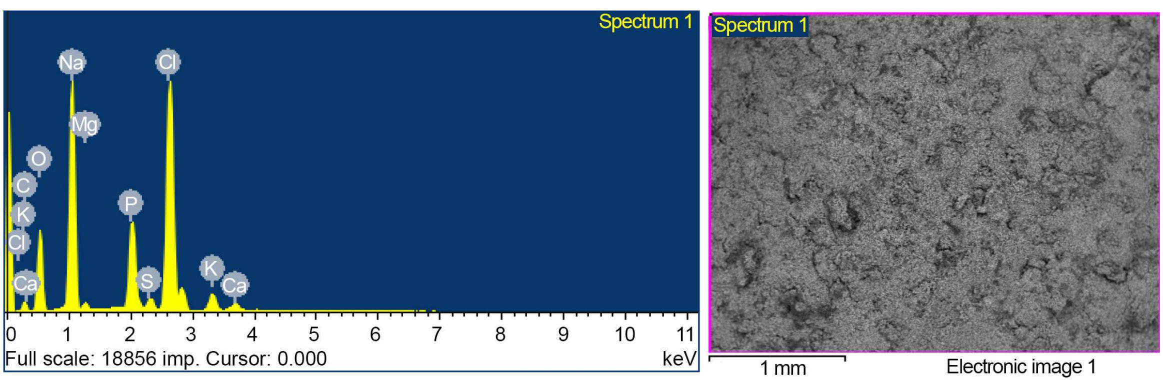
According to the results of the studies of the mineral composition of semi-smoked sausage made from plant-based meat substitute, it was found that in experimental sample No. 2 the content of sulfur (by 0.02%), magnesium (by 0.04%), sodium (by 2.24%), phosphorus (by 0.12%), potassium (by 0.08%), chlorine (by 4.24%), calcium (by 0.02%) increased compared to the control sample. An increase the blood content by 4% in the composition of semi-smoked sausage made from plant-based meat substitute shows that sulfur (by 0.05%), magnesium (by 0.13%), sodium (by 3.07%), phosphorus (by 1.28%), potassium (by 0.25%), chlorine (by 2.46%), calcium (by 0.07%) increases compared to the control sample.



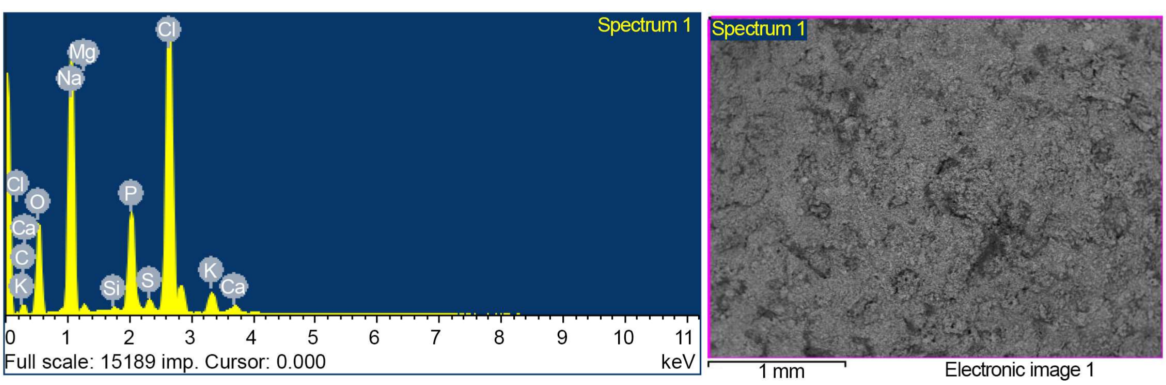
a



b



c



d

Fig. 1. Chromatograms of semi-smoked sausage made from plant-based meat substitute with the addition of blood from slaughtered animals: *a* – control sample, without blood addition; *b* – experimental sample with 2% blood addition; *c* – experimental sample with 4% blood addition; *d* – experimental sample with 6% blood addition

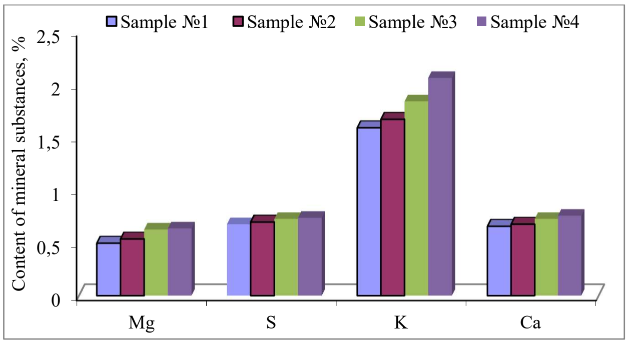


Fig. 2. Content of mineral substances in semi-smoked sausage with the addition of blood of slaughtered animals: sample No. 1 – control sample, without the addition of blood; sample No. 2 – experimental sample with the addition of 2% blood; sample No. 3 – experimental sample with the addition of 4% blood; sample No. 4 – experimental sample with the addition of 6% blood

Also, when adding 6% of the blood of slaughtered animals to semi-smoked sausage from plant-based meat substitute, the mineral composition such as sulfur (by 0.06%), magnesium (by 0.14%), sodium (by 3.21%), phosphorus (by 1.07%), potassium (by 0.47%), chlorine (by 4.09%), calcium (by 0.1%) increases compared to the control sample.

Based on the above, it can be concluded that when the dry blood of slaughtered animals is added to a semi-smoked sausage from plant-based meat substitute, it increases the mineral composition of the investigational product.

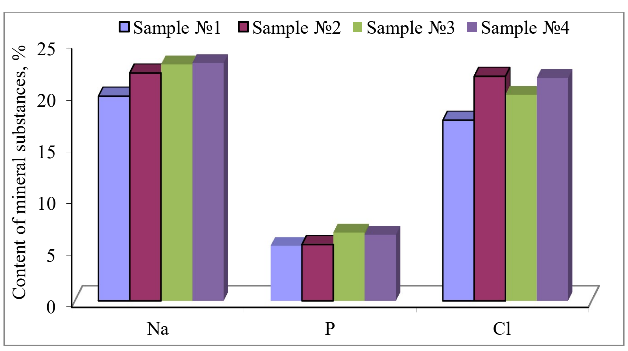


Fig. 3. Content of mineral substances in semi-smoked sausage with the addition of blood of slaughtered animals: sample No. 1 – control sample, without the addition of blood; sample No. 2 – experimental sample with the addition of 2% blood; sample No. 3 – experimental sample with the addition of 4% blood; sample No. 4 – experimental sample with the addition of 6% blood

5. 3. Investigation of the mass fraction content of protein and fat

As is known, the quality indicators of sausage products are characterized by the mass fraction of protein and fat.

Fats are important components of our diet because they serve as a vital source of energy and carrier of vital nutrients, including vitamins and bioactive chemicals. The desired taste, texture and functionality of food products are provided by fats.

The results of the study of the mass fraction of protein and fat of semi-smoked sausage from a plant-based meat substitute with the addition of blood of slaughtered animals with a control sample are presented in Table 3.

As the analysis of the table data shows, the mass fraction of protein in semi-smoked sausage with the addition of 2% dry blood of slaughtered animals increases by 2.26%, and with the addition of 4% dry blood increases by 1.27%, and with the addition of 6% dry blood increases by 3.07%, compared with the control sample. Table 2 also shows, that the fat content in semi-smoked sausage enriched with 2% blood of slaughter animals increases by 53.85%, and with the addition of 4% dry blood increases by 2.25 times, and with the enrichment of the investigational product with 6% blood of slaughter animals, the mass fraction of fat increases by 1.84 times, compared with the control sample.

Table 3

Mass fraction of protein and fat of semi-smoked sausage from plant-based meat substitute with the addition of blood of slaughtered animals with a control sample

Name of indicators, units of measurement	Semi-smoked sausage made from plant-based meat substitute (control)	Semi-smoked sausage from plant-based meat substitute with the addition of 2% blood of slaughtered animals	Semi-smoked sausage from plant-based meat substitute with the addition of 4% blood of slaughtered animals	Semi-smoked sausage from plant-based meat substitute with the addition of 6% blood of slaughtered animals
Mass fraction of protein, %	26.44±1.77	28.7±1.72	27.71±1.66	29.51±1.77
Mass fraction of fat, g/100g	2.86±0.17	4.40±0.26	6.44±0.39	5.27±0.32

5. 4. Investigation of the amino acid composition of semi-smoked sausage from plant-based meat substitute

The biological value of food products is determined by the presence, quantity and degree of balance of essential and non-essential amino acids in proteins.

The results of the study of the amino acid composition of control sample and semi-smoked sausage from plant-based meat substitute with the addition of blood from slaughtered animals are presented in Table 4.

The results of comparison of the amino acid composition of semi-smoked sausage from plant-based meat substitute of the experimental and control samples are presented in Fig. 4, 5.

The study of the amino acid composition of semi-smoked sausage from plant-based meat substitute with the addition of blood from slaughtered animals showed that in experimental sample No. 2 with 2% of the blood of slaughtered animals, the content of tyrosine was 20.42 times, cysteine 11.5 times, valine 14.93 times, alanine 2.94 times, methionine 1.67 times, tryptophan 1.43 times, isoleucine 7.22 times, proline by 22.05%, hydroxyproline by 2.23 times more than in the control sample. Also, in experimental sample No. 3 with the addition of 4% of the blood of slaughtered animals, the content of tyrosine was 40.58 times, cysteine 6.46 times, valine 22.07 times, alanine 4.44 times, methionine 1.70 times, tryptophan 2.04 times, isoleucine 5.04 times, proline 72.63%, hydroxyproline 1.81 times more than in the control sample.

Table 4

Amino acid composition of semi-smoked sausage from plant-based meat substitute with the addition of blood from slaughtered animals and a control sample

Amino acid composition	Semi-smoked sausage made from plant-based meat substitute (control), mg/100g	Semi-smoked sausage from plant-based meat substitute with the addition of 2% blood of slaughtered animals, mg/100g	Semi-smoked sausage from plant-based meat substitute with the addition of 4% blood of slaughtered animals, mg/100g
Aspartic acid	4160 ± 416	273.8 ± 13.69	591.92 ± 29.6
Glutamic acid	2560 ± 265	1745.14 ± 87.25	1434.94 ± 71.7
Serine	140 ± 14	183.87 ± 4.2	1345.28 ± 67.26
Histidine	–	958.23 ± 47.9	564.68 ± 28.23
Glycine	–	111.13 ± 5.6	88.01 ± 4.40
Threonine	–	210.23 ± 10.5	73.31 ± 3.7
Arginine	2510 ± 251	67.27 ± 3.36	1193.83 ± 59.7
Alanine	140 ± 14	411.36 ± 20.6	622 ± 0.31
Tyrosine	63 ± 6.3	1286.55 ± 64.3	2556.8 ± 127.84
Cysteine	170 ± 17	1955.4 ± 97.7	1097.84 ± 54.9
Valine	40 ± 4.0	597.25 ± 29.9	882.88 ± 44.14
Methionine	610 ± 61	1023.37 ± 51.2	1041.70 ± 52.1
Tryptophan	360 ± 36	513.48 ± 25.7	733 ± 3.7
Phenylalanine	3120 ± 310	2256.94 ± 112.8	339.73 ± 17.0
Isoleucine	20 ± 2.0	144.35 ± 7.2	100.85 ± 5.04
Leucine	4630 ± 463	485.99 ± 24.3	3933.3 ± 196.7
Lysine	6900 ± 690	1237.08 ± 61.9	3649 ± 182.5
Proline	510 ± 51	622.5 ± 31.12	880.39 ± 44.02
Hydroxyproline	630 ± 63	1401.8 ± 70.1	1139.68 ± 57.0
Asparagine	–	1794.0 ± 89.7	10.69 ± 0.53
Glutamine	–	1209.92 ± 60.5	8440.92 ± 422.04

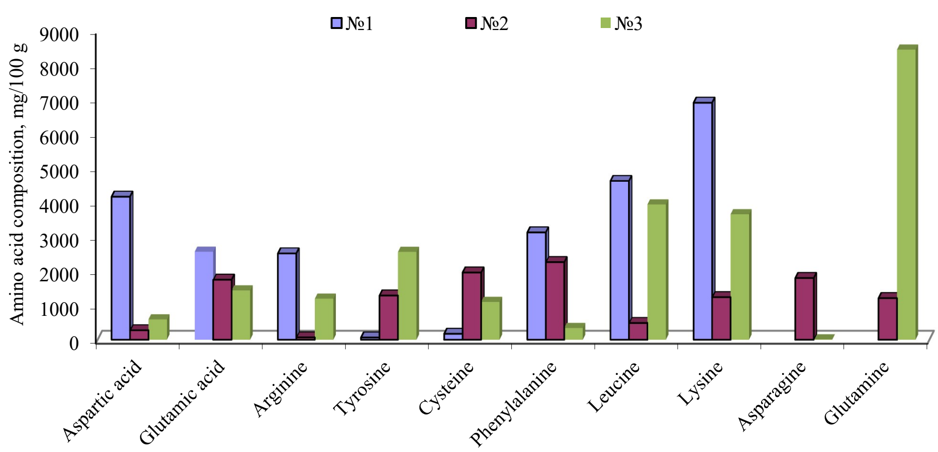


Fig. 4. Amino acid composition of semi-smoked sausage from plant-based meat substitute: No. 1 – control sample without blood addition; No. 2 – experimental sample with 2% of blood addition; No. 3 – experimental sample with 4% of blood addition

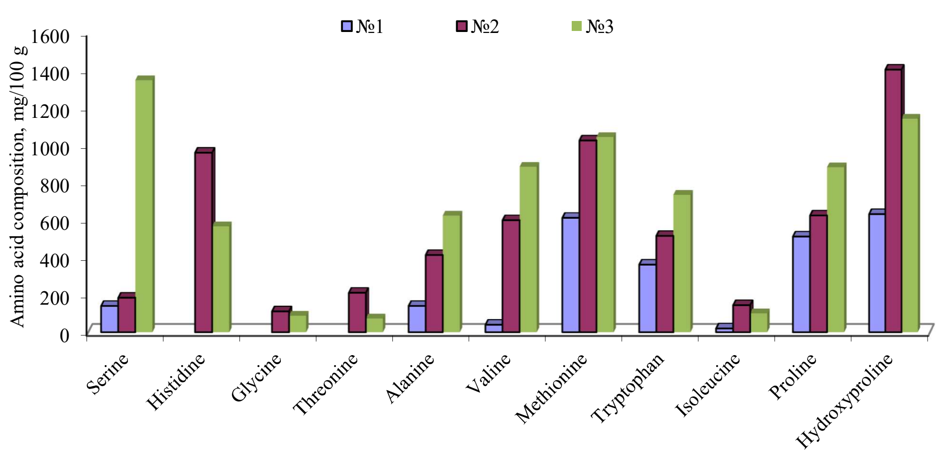


Fig. 5. Amino acid composition of semi-smoked sausage from plant-based meat substitute: No. 1 – control sample without blood addition; No. 2 – experimental sample with 2% of blood addition; No. 3 – experimental sample with 4% of blood addition

5. 5. Investigation of the fatty acid composition of semi-smoked sausage from plant-based meat substitute

The results of comparison of the fatty acid composition of semi-smoked sausage from plant-based meat substitute of the experimental sample with the control sample are presented in Table 5.

The contents of saturated and monounsaturated fatty acids in semi-smoked sausage from plant-based meat substitute are shown in Fig. 6–8.

During the study of saturated fatty acids, it was established, that in the investigational products the highest content of fatty acid composition was found in semi-smoked sausage from plant-based meat substitute with the addition of 2% blood of slaughtered animals. The content of caproic acid was 0.127% higher, caprylic acid was 2.186% higher, capric acid was 1.317% higher, lauric acid was 10.947% higher, and myristic acid was 3.827% higher compared to the control sample. It was also revealed that the experimental sample No. 2 contains palmitic, stearic, and arachidic acids (their content was 9.782%, 3.338%, and 0.016%, respectively), which were not contained in the control sample (Fig. 7, 8).

Table 5

Content of fatty acid composition of semi-smoked sausages from plant-based meat substitute

Fatty acid composition	Semi-smoked sausage made from plant-based meat substitute (control), %	Semi-smoked sausage from plant-based meat substitute with the addition of 2% blood of slaughtered animals, %	Semi-smoked sausage from plant-based meat substitute with the addition of 4% blood of slaughtered animals, %	Semi-smoked sausage from plant-based meat substitute with the addition of 6% blood of slaughtered animals, %
Saturated fatty acids:				
C6:0caproic	0.087 ± 0.008	0.214 ± 0.02	0.136 ± 0.01	0.089 ± 0.009
C8:0caprylic	0.626 ± 0.06	2.812 ± 0.3	1.849 ± 0.2	1.677 ± 0.2
C10:0capric	0.894 ± 0.09	2.211 ± 0.2	1.484 ± 0.1	1.493 ± 0.1
C12:0lauric	6.930 ± 0.7	17.877 ± 1.8	12.139 ± 1.2	13.242 ± 1.3
C14:0myristic	3.088 ± 0.3	6.915 ± 0.7	4.789 ± 0.5	5.469 ± 0.5
C15:0pentadecanoic	0.064 ± 0.006	–	–	–
C16:0palmitic	–	9.782 ± 0.9	9.084 ± 0.9	9.715 ± 0.9
C17:0margaric	0.082 ± 0.008	0.05 ± 0.005	0.063 ± 0.006	0.058 ± 0.006
C18:0stearic	–	3.338 ± 0.3	3.280 ± 0.3	3.324 ± 0.3
C20:0arachidic	–	0.016 ± 0.002	–	0.02 ± 0.002
C22:0behenic	0.245 ± 0.02	0.015 ± 0.002	0.016 ± 0.002	0.008 ± 0.0008
C24:0lignoceric	0.149 ± 0.1	–	0.208 ± 0.02	0.187 ± 0.02
Monounsaturated fatty acids:				
C14:1(cis-9) myristoleic	0.042 ± 0.004	0.031 ± 0.003	0.031 ± 0.003	0.033 ± 0.003
C15:1(cis-10) pentadecenoic	11.262 ± 1.1	–	–	–
C16:1(cis-9) palmitoleic	0.308 ± 0.03	0.149 ± 0.01	0.099 ± 0.009	0.099 ± 0.009
C17:1(cis-10) margarinoleic	6.919 ± 0.7	0.019 ± 0.002	0.029 ± 0.003	0.034 ± 0.003
C18:1(cis-9) oleic	24.505 ± 2.5	18.025 ± 1.8	21.426 ± 2.1	20.596 ± 2.0
C20:1(cis-11)eicosenoic	0.152 ± 0.02	0.235 ± 0.02	0.192 ± 0.02	0.165 ± 0.02
Polyunsaturated fatty acids:				
C18:2n6t linoleidic	0.180 ± 0.02	0.028 ± 0.003	0.039 ± 0.004	0.031 ± 0.003
C18:2n6c linoleic	39.030 ± 3.9	–	–	–
C18:3n3linolenic	0.334 ± 0.03	35.395 ± 3.5	43.056 ± 4.3	41.391 ± 4.1
C20:2eicosadienoic	0.680 ± 0.07	0.841 ± 0.08	0.691 ± 0.07	0.878 ± 0.09
C20:5n3eicosapentaenoic	–	0.043 ± 004	0.042 ± 0.004	0.044 ± 0.004

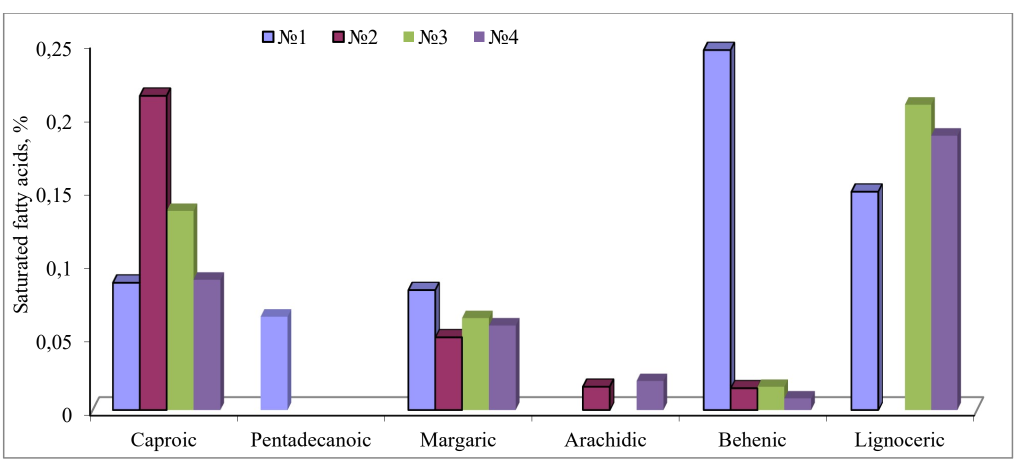


Fig. 6. Saturated fatty acids content in semi-smoked sausage from plant-based meat substitute: No. 1 – control sample without blood addition; No. 2 – experimental sample with 2% of blood addition; No. 3 – experimental sample with 4% of blood addition; No. 4 – experimental sample with 6% of blood addition

The results of the study of monounsaturated fatty acids in semi-smoked sausage from a vegetable meat substitute showed that in experimental samples No. 2, No. 3, No. 4 eicosenic acid increased by 0.083%, 0.04%, 0.013%, respectively, compared with the control sample (Fig. 8).

The contents of polyunsaturated fatty acids in semi-smoked sausage from plant-based meat substitute are shown in Fig. 9.

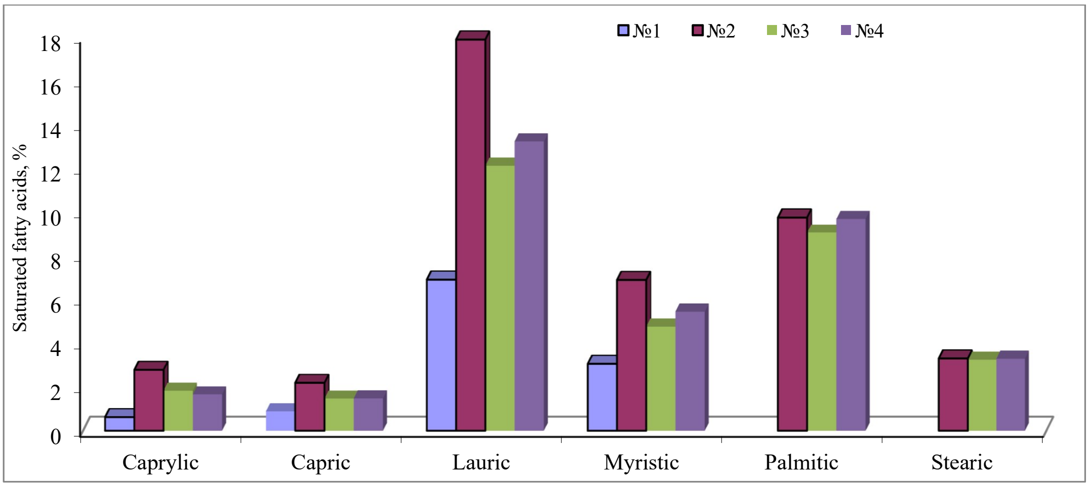
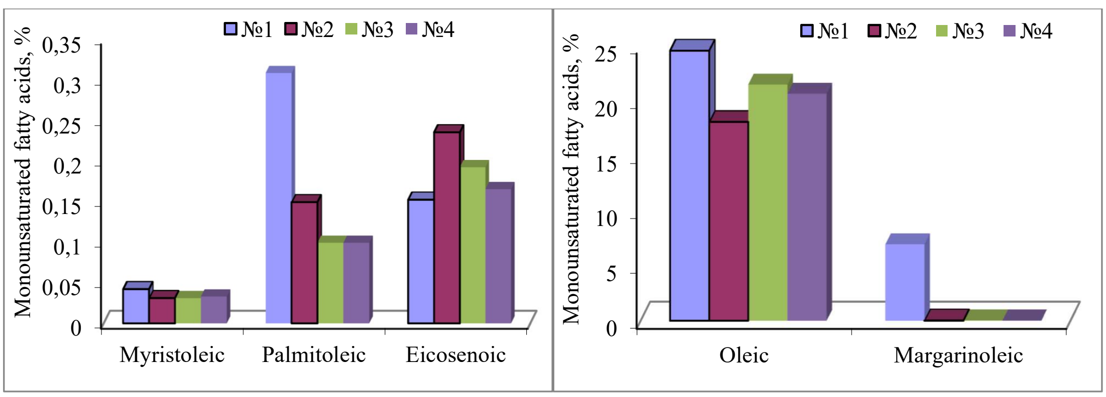
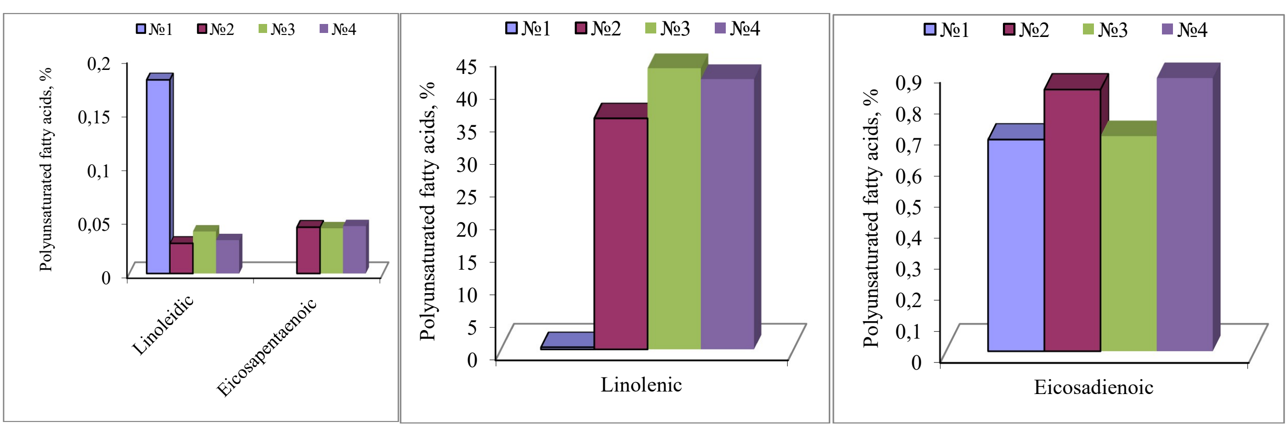


Fig. 7. Saturated fatty acids content in semi-smoked sausage from plant-based meat substitute: No. 1 – control sample without blood addition; No. 2 – experimental sample with 2% of blood addition; No. 3 – experimental sample with 4% of blood addition; No. 4 – experimental sample with 6% of blood addition



a *b*

Fig. 8. Monounsaturated fatty acids content in semi-smoked sausage from plant-based meat substitute: *a* – myristoleic, palmitoleic and eicosenoic acids; *b* – oleic and margarinoleic acids



a *b* *c*

Fig. 9. Polyunsaturated fatty acids content in semi-smoked sausage from plant-based meat substitute: *a* – linoleidic and eicosapentaenoic acids; *b* – linolenic acid; *c* – eicosadienoic acid

The results of the study of polyunsaturated fatty acids show that in experimental samples No. 2–4 the content of linolenic acid is higher by 35.061%, 42.722%, 41.057%, respectively, than in the control sample. Also, in experimental samples with the addition of 2%, 4%, 6% blood of slaughtered animals, the content of eicosadienoic acid increases by 0.161%, 0.011%, 0.198%, respectively, compared to the control sample (Fig. 9).

6. Discussion of the results of the study of organoleptic evaluation, mineral and physicochemical composition of semi-smoked sausage from plant-based meat substitute enriched with blood of slaughtered animals

The organoleptic characteristics of a product influence consumer choice much more than its chemical composition and nutritional value and, ultimately, shape their demand. Therefore, when studying the effect of slaughtered animal blood on the quality of semi-smoked sausage made from plant-based meat substitute, special attention was paid to the organoleptic characteristics. From the analysis of the obtained results (Table 2) of organoleptic characteristics, the optimal amount of food blood (2%) was selected for adding to the semi-smoked sausage from plant-based meat substitute.

According to the results of the studies of the mineral composition of semi-smoked sausage from plant-based meat substitute, it was found that the mineral composition of the experimental samples increases with the increase in the blood content of slaughtered animals. Thus, enriching and increasing the biological value of the finished product. Comparative analyses of four samples are shown in Fig. 1–3.

When dry blood of slaughtered animals is added to the composition of semi-smoked sausage, the content of the mass fraction of protein is increased. This made it possible to obtain a full-fledged source of protein. Also, the increased fat content in the investigational samples of semi-smoked sausage showed that the blood of slaughtered animals can be used as a fat substitute (Table 3). The paper [22] provide data on the use of blood as a partial substitute for fat in sausage up to 10%. The above research results prove this information.

According to the data presented, the addition of blood from slaughtered animals to semi-smoked sausage from plant-based meat substitute leads to an increase in the balance of the amino acid composition compared with the control product (Table 4). The indicators of the amino acid composition indicate that a product containing 2–4% of the blood of slaughtered animals increases the content of essential and non-essential amino acids compared to the control sample (Fig. 4, 5). Thereby increase the biological and nutritional value of the investigational product.

The ratio of saturated and unsaturated fatty acids is an important indicator that can indicate the overall quality of the fat in the sausage. In semi-smoked sausage made from a vegetable meat substitute with the addition of blood from slaughtered animals, the amount of saturated and polyunsaturated fatty acids increases significantly compared to the control sample (Table 5). Comparative analyses of saturated, monounsaturated and polyunsaturated fatty acids in semi-smoked sausage from plant-based meat substitute are shown in Fig. 7–10. The ratio of saturated and unsaturated fatty acids in the experimental samples is 1:1.

The limitations of this study include the lack of regulatory and technological documentation for the production of semi-smoked sausage from a vegetable meat substitute. The disadvantages of this study include the fact that there are consumers who do not consume the blood of farm animals in accordance with religious dictates. This issue can be resolved through accurate and concise labeling of the presence of blood from slaughtered animals to help consumers make the right food choices. Better labeling is vital to ensure the protection of interests and increase consumer confidence in such products, thus promoting efforts to ensure the full-scale utilization of blood proteins.

In the future, it is planned to study the microbiological safety of semi-smoked sausage from plant-based meat substitute with added blood, as well as assessing shelf life, heat resistance and changes in storage indicators for further sale of the product.

7. Conclusion

1. The results of organoleptic evaluation studies of semi-smoked sausage from plant-based meat substitute have shown that the addition of 2% dried blood improves the taste and color of the finished product.

2. An increase in the mineral content of the finished product was established with the addition of 2% blood of slaughtered animals: the content of sulfur (by 0.02%), magnesium (by 0.04%), sodium (by 2.24%), phosphorus (by 0.12%), potassium (by 0.08%), chlorine (by 4.24%), and calcium (by 0.02%) increased compared to the control sample.

3. It is proved that when 2% of the dry blood of slaughtered animals was added to a semi-smoked sausage from plant-based meat substitute, the amount of protein increased by 2.26% compared to the control sample.

4. Studies have shown that the addition of 2% blood of slaughtered animals to a semi-smoked sausage from plant-based meat substitute, increases the content of tyrosine by 20.42 times, cysteine by11.5 times, valine by 14.93 times, alanine by 2.94 times, methionine by 1.67 times, tryptophan by 1.43 times, isoleucine by 7.22 times, proline by 22.05%, hydroxyproline by 2.23 times more than in the control the sample. Thereby enriching and increasing the biological and nutritional value of the finished product.

5. During the study of samples for determination of saturated fatty acids, it was proved that in the investigational products the highest content of fatty acid composition was found in control sample with the addition of 2% blood of slaughtered animals. The content of caproic acid is higher y 0.127%, caprylic acid is higher by 2.186%, capric acid is higher by 1.317%, lauric acid is higher by 10.947%, myristic acid is higher by 3.827% compared to the control sample. It was also determined that in experimental sample No. 2 the content of palmitic, stearic, arachidic acids is 9.782%, 3.338% and 0.016% respectively, although they were not found in the control sample.

When studying monounsaturated fatty acids in samples of semi-smoked sausages from plant-based meat substitute, it was found that in experimental samples No. 2, No. 3, No. 4, the content of eicosenoic acid was higher by 0.083%, 0.04%, 0.013%, respectively, compared with the control.

The results of the study of polyunsaturated fatty acids show that in experimental samples No. 2, No. 3, No. 4, the content of linolenic acid is 35.061%, 42.722%, 41.057% higher, respectively, than in the control. It was found that in experimental samples with the addition of 2%, 4%, and 6% blood of slaughtered animals, the content of eicosadienoic acid increased by 0.161%, 0.011%, and 0.198%, respectively, compared with the control.

Conflict of interest

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

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

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

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