The object of the study is sausage products based on finely ground beef meat with the addition of soy isolate and chopped chickpeas. A technology for the preparation of semi-smoked sausages using plant-based raw materials as a functional component has been developed. Soy isolate and coarsely ground chickpea flour were used as additional functional components for comparison with the control sample, with ratios of 60:40, 70:30, 80:20, and 90:10.

Comparative analyses of the physico-chemical parameters, amino acid and fatty acid composition of the samples were carried out, which showed that, compared with the control samples, proteins increased by 2 times and the situation improved in terms of the content of amino acid groups, including aspartic acid by 4160 mg/100 g. and arginine by 2,510 mg/100 g. All samples were tasted and their organoleptic characteristics (taste, smell, color) were shown, which influenced the choice of the optimal option. Therefore, after the research, it is possible to study a new formulation with the addition of soy isolate and chickpeas, which corresponded and followed the processes for the entire technology of semi-smoked sausages.

The optimal variant of the sample, which positively influences the qualitative indicators and texture of the sausage product, was identified. The physicochemical attributes of the samples derived from plant raw materials exhibited significant differences from the control, with increases in the mass fractions of protein and fat. The results obtained can be used in the production of functional meat products for preventive purposes, especially for the creation of products with increased antioxidant potential and improved organoleptic characteristics. Such amino acid group contents may be in demand in the production of products for the prevention of the human body

Keywords: soy isolate, chickpeas, amino acids, fatty acids, food, semi-smoked sausage

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DEVELOPING A SAUSAGE PRODUCT WHICH HAVE INCREASED NUTRITIONAL VALUE AND IMPROVED AMINO ACID PROPERTIES

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1. Introduction

Diet constitutes a significant determinant of health and well-being among the elderly population, necessitating that their dietary intake supplies all requisite nutrients, vitamins, and macro- and microelements. The daily nutritional requirements for proteins, fats, carbohydrates, and numerous minerals and vitamins among older adults exhibit minimal divergence from those of younger adults. The most important distinction is that elderly people primarily need energy due to reduced physical activity. Therefore, the diet for older people should include more nutrient-dense foods. The idea is to provide the necessary nutrients in a lower-calorie portion. It is advisable for older adults to consume smaller meal portions, ensuring that these portions are rich in nutrients [1]. The marked increase in the global consumption of functional foods signifies their emerging role in contemporary dietary practices. Functional foods serve as a potential alternative to pharmacological therapies, intended to minimize reliance on medications. While functional foods are not classified as drugs, their primary objective is disease prevention [2].

To achieve high-quality sausage products, manufacturers use only quality only premium raw materials. To mitigate costs, they incorporate protein ingredients derived from both plant and animal sources. Furthermore, to enhance shelf life and improve aesthetic appeal, non-meat components such as preservatives, flavoring additives, and emulsifiers are integrated into the formulations [3]. The findings of conducted experiments indicate that the application of a protein-fat composition comprising carrageenan, soy protein isolate, soybean oil, water, and an infusion of Icelandic cetraria enhances the nutritional and biological value of boiled sausage. It has been established that the dry thalli of Icelandic cetraria are abundant in biologically active polysaccharides, primarily lichenin and usnic acid, which impart a bitter taste to the infusion. To mitigate the bitterness, it is essential to soak the thalli in a one-percent solution of baking soda for 120 minutes prior to infusion preparation. The infusion of cetraria contributes to stability in a false system due to its polysaccharide content [4]. Presently, the array of biologically active additives available for product enrichment is extensive and varied, characterized by distinct physicochemical and functional-technological properties as well as diverse physiological effects [5, 6].

The introduction of chickpeas and soy isolate into sausage products allows them to be enriched with vitamins, antioxidants and dietary fiber. Such as soy isolate and chickpeas, not only improve the taste and organoleptic characteristics of products, but also add useful biologically active substances to their composition, increasing antioxidant activity. It is important to explore the possibilities of increasing the nutritional value of

sausage products using soy isolate and chickpeas. This makes it possible to create products that not only have improved taste characteristics, but also promote human health through antioxidant activity.

2. Literature review and problem statement

The article [7] presents an analysis of consumer demand for meat products that align with the principles of healthy eating and highlights the relevance of developing innovative technologies for functional sausage production. However, the question remains unresolved regarding the comprehensive assessment of the effectiveness of plant-based ingredients (e.g., chickpeas, buckwheat, peas) as substitutes for animal-derived components, taking into account both nutritional value and sensory characteristics. Furthermore, the technological compatibility of such ingredients in the production of cooked or smoked sausages has not been sufficiently studied.

In paper [8] provides a comparative analysis of the essential amino acid content in various plant proteins. While the levels in isolates such as soy, black rice, pea, and corn meet WHO/FAO/UN standards, they still fall short of those found in milk proteins. This highlights the issue of the limited completeness of plant proteins, especially when developing products aimed at providing balanced protein nutrition. The digestibility and bioavailability of these proteins within meat-based matrices remain unaddressed.

The paper [9] focusing on the fermentation of soybean meal, demonstrates the possibility of increasing protein content through microbial processing. Nevertheless, there is an unresolved issue concerning the thermal stability of the resulting product, particularly under conditions typical for sausage production. Additionally, there is a lack of data regarding the sensory properties and compatibility of fermented proteins with other sausage components.

The paper [10] have demonstrated positive dynamics in protein accumulation in soybean seeds when inoculated with nitragin and worked with active strains. However, these studies are mainly agronomic in nature and do not address the processing implications, nor the impact of technological parameters (temperature, pressure, moisture) on the functional properties of the raw material in food technology applications.

Research [11, 12] on fungal proteins, particularly Pleurotus geesteranus, suggests potential value as an alternative source. However, it remains unclear to what extent these proteins are stable during thermal processing and whether they can provide desirable texture and taste in sausage products. Furthermore, the scalability and economic feasibility of using mushroom proteins in mass production remain insufficiently explored.

In the paper [13] about Pleurotus geesteranus, it has been gaining popularity lately due to its strong umami flavor. In this study, umami taste, energy levels, and the activity of enzymes related to energy metabolism were studied in collected P. geesteranus stored at 20, 10, 5, and 0 °C to assess the relationship between umami taste and energy status. When adding biological plant raw materials, it has not been studied during smoking, i.e. how it will affect high temperature.

Studies [14, 15] on algae proteins indicate relatively low essential amino acid content in Spirulina sp., though higher values are reported in red and green algae. Nevertheless, unresolved issues include the compatibility of these proteins with meat systems, their influence on flavor and color of finished products, and their stability during storage and heating.

The paper [16] consolidates fragmented information on the nutritional and functional value of soy proteins used in food systems. However, it lacks a clear classification of their effects on the structural, mechanical, and sensory properties of meat products. In addition, it does not clarify how various soy protein forms (isolate, concentrate, texturate) can be adapted for low-calorie formulations without compromising consumer acceptance.

The study [17] explores the use of the proteolytic enzyme protepsin in low-calorie sausage production. Although improved water-binding capacity and pH balance were recorded, concerns remain regarding the safety and tolerance of protepsin among sensitive consumer groups. Moreover, the exploration of alternative enzymatic or non-enzymatic structuring methods that could minimize allergy risks is lacking.

These sources [18, 19] describe the activities of soy protein manufacturers (ADM, PTI, Moguntia-Interrus) and their product ranges, including isolates, concentrates, and texturates used in the meat industry.

However, there is a lack of comparative analysis regarding the efficacy of these ingredients within functional nutrition formulations. The interaction of these products with non-conventional components (e.g., chickpeas), as well as their influence on the sensory and textural quality of sausages, has not been sufficiently addressed.

3. The aim and objectives of the study

The aim of the study is to develop a sausage product with the addition of soy isolate and ground chickpeas, which have increased nutritional value and improved amino acid properties and saturated and unsaturated fats, as well as physic-chemical properties. The research is aimed at creating a product that would be more useful and attractive for preventive nutrition compared to traditional sausage products.

To achieve this aim, the following objectives were set:

– to analyze the physic-chemical composition of soy isolate and ground chickpeas used to enrich sausage products;

– to study the effect of the addition of vegetable raw materials on their nutritional value, amino acid and fatty acid groups, features of digestion and digestibility based on soy isolate and ground chickpeas.

4. Materials and methods

4. 1. The object and hypothesis of the study

The object of the study is sausage products based on finely ground beef meat with the addition of soy isolate and chopped chickpeas.

The hypothesis of the study suggests that the addition of soy isolate and ground chickpeas to a sausage product reduces the specific smell and taste of meat, as well as improves protein absorption and increases the nutritional value of the product, making it more attractive for preventive nutrition.

It can be relied upon that chickpeas and soy isolate can be combined as a meat substitute and contain many useful substances.

For this, it is necessary to conduct significant studies that affect the quality of the human body and the sausage product itself.

The following ingredients were used sausage product: the main component is ground beef. Each sample was used to enrich soy isolate and chickpeas.

4. 2. Preparation of curd samples

Number of samples analyzed: let's analyze three samples.

Number of repeated analyses: all measurements of instrument readings were performed two times.

Number of experiment replication: the number of repetitions of each experiment to determine one value was two times.

Design of the experiment.

The research objects at a temperature of 2–24.5 °C and a humidity of 68–71 %:

– semi-smoked sausage No. 1 – control;

– semi-smoked sausage No. 2 – made from a plant-based substitute, chickpea and soy isolate in a ratio of 90:10;

– semi-smoked sausage No. 3 – made from a plant-based substitute, chickpea and soy isolate in a ratio of 80:20;

– semi-smoked sausage No. 4 – made from a plant-based substitute, chickpea and soy isolate in a ratio of 70:30;

– semi-smoked sausage No. 5 – made from a plant-based substitute, chickpea and soy isolate in a ratio of 60:40.

With the variety of existing recipes, the samples taken as controls represent the semi-smoked sausages. This will allow the research results to be applied to a wide range of sausage products produced in the food industry. The technological process of producing semi-smoked sausages was carried out according to the classic technology, which includes preparation of the recipe mixture, grinding, injection, cooking, frying, and smoking.

4. 3. Chemical analysis

The quantitative determination of the amino acid composition and protein content was carried out in the "Nutritest" testing laboratories using the high-performance liquid chromatography method. The method of determination is based on the preliminary determination of the protein concentration in the product (Kjeldahl method or method with using reference data).

The carbohydrate content in sausages was determined by determining the mass fraction of soluble carbohydrates according to Bertrand. The essence of the method lies in the ability of reducing sugars to reduce divalent copper in an alkaline medium to copper (I) oxide, which is oxidized with ferric ammonium alum. Then, the reduced divalent iron is titrated with a potassium permanganate solution. The amino acid content was determined on the device using an AAA-881 automatic amino acid analyzer. The amino acid analyzer is a special compact liquid chromatograph designed to analyze amino acids on an anion exchange column with post-column derivatization with ninhydrin and determine biogenic amines. The difference in electrical potentials between the glass electrode and the reference electrode placed in the sample of meat or meat products is measured. The pH meter is calibrated using a buffer solution with a known pH value close to the pH value of the analyzed solution at the measurement temperature. The electrodes are inserted into the sample and the pH meter temperature controller is set to the sample temperature. pH measurements are carried out depending on the design of the pH meter. After establishing the instrument readings, the pH value is taken directly from the instrument scale with an accuracy of ±0.05 pH units. The final result is the arithmetic mean of three separate measurements, subject to the requirements for the convergence of the results.

5. Results of the study of sausage products with additives

5. 1. Analysis of the physico-chemical composition of sausage products with the addition of soy isolate and crushed chickpeas

Research was conducted to determine the physico-chemical parameters of the sausage products after thermal treatment (frying, cooking, and smoking). The results are presented in Table 1. The study of the protein and fat content showed that it increased in all samples compared to the control values. This is due to the fact that by adding soy, the protein and fat content in soy is significantly higher compared to chickpeas. The protein and fat content in the control sample were 18.36 % and 2.73 %, while in sample No. 2, it showed the highest values, with protein at 34.13 % and fat at 3.31 %. For the other samples, the indicators corresponded to the ratios of adding soy and chickpeas.

Table 1

Composition of control samples of semi-smoked sausages

Indicators	Control	90 chickpea: 10 soy	80 chickpea: 20 soy	70 chickpea: 30 soy	60 chickpea: 40 soy
Protein content, %	18.37±2.76	34.13±2.05	33.14±1.99	29.44±1.77	28.35±1.7
Fat content, %	2.73±0.16	3.31±0.2	3.19±0.19	2.86±0.17	2.73±0.16
pH, the active acidity	18.37±2.76	34.13±2.05	33.14±1.99	29.44±1.77	28.35±1.7

In the production of semi-smoked sausages from plant materials, soy and chickpea grains were added in a ground form, with particle sizes ranging from 450 to 600 μm. These particle sizes are optimal for addition to the recipe, as they blend uniformly with other ingredients when mixed. After heat treatment in the temperature chamber, the pH value increased to 5.9 %. This is due to the soluble protein substances transferring when chickpeas are added.

The pH values after heat treatment correlate with changes in the chemical composition of the sausage product.

5. 2. The results of the study of the effect of soy isolate and ground chickpeas addition on amino acid groups

The main scientific hypothesis of the study is to determine and compare the indicators of the amino acid group and changes in the physicochemical indicators in sausages, taking into account the change in the traditional recipe for plant origin. It is possible to expect that the consumer qualities of sausages (shape retention indicators) during a certain period of storage will affect their quality and, thus, will affect the needs of the consumer.

The results of the quantitative and qualitative determination of the amino acid composition of semi-smoked sausages were taken only from control and sample No. 2 with a ratio of 70:30, while the other samples were similarly derived to sample No. 2, differing only in their physicochemical compositions, and are presented in Table 2.

Analyzing the obtained data, it can be noted that the amino acid composition undergoes significant changes during technological processing. Table 2 presents data on the calculation of the chemical composition of amino acids in control and experimental samples of sausages immediately after heat treatment. The possibility of preserving the biological value of total proteins in the product at a level equivalent to the ideal FAO/WHO protein provides the definition of the chemical composition of sausages.

As is known, amino acids are the basic building blocks of proteins, participating in the regulation of key metabolic pathways and processes that are crucial for the growth and maintenance of organism vitality. Nine essential amino acids, including lysine, histidine, isoleucine, leucine, methionine, phenylalanine, threonine, tryptophan, and valine, cannot be synthesized by the human body and can only be added through food; thus, the content of these essential amino acids is a key indicator in assessing protein quality.

Table 2

Amino acid composition of semi-smoked sausages after heat treatment, mg/100 g of protein

Indicators	Control	70 chickpea:30 soy isolate
Aspartic acid	2,580±258	4,160±416
Glutamic acid	3,320±258	2,650±416
Serine	1,040±104	140±14
Histidine	275±27.5	2,510±14
Glycine	940±94	–
Threonine	2,100±210	–
Arginine	1,960±19.6	2,510±14
Alanine	1,380±138	140±14
Tyrosine	237±23.7	63±6.3
Cysteine	2,280±22.8	170±17
Valine	500±50	40±4.0
Methionine	1,860±186	610±61
Tryptophan	3,710±371	360±36
Phenylalanine	2,500±250	3,120±312
Isoleucine	870±87	20±2.0
Leucine	1,120±112	4,630±463
Lysine	1,280±128	6,900±690
Proline	–	510±51
Hydroxyproline	–	630±63

The presented data shows that semi-smoked sausage No. 2 stands out in terms of amino acid content – made from a vegetable substitute of soy and chickpea in a ratio of 90:10 compared to the control.

In sample No. 2, it can be noted that the lysine content is 19 % higher than the control, and leucine is 24 % higher.

The accumulation of a relatively significant amount of free amino acids in the experimental samples with the addition of vegetable raw materials such as soy isolate and chickpea compared to the control samples indicates the manifestation of sufficient activity of various enzymes, alongside saturated and unsaturated amino acids. The predominant accumulation of glycine, glutamic acid, lysine, phenylalanine, tyrosine, leucine, isoleucine reflects a specific joint effect on the proteins, as well as the biosynthesis of soy and chickpea proteins.

Studies have been conducted to determine the fatty acid indicators of sausage products during thermal processing. The results are presented in Table 3.

Table 3

Fatty acid composition of semi-smoked sausages after heat treatment, mg/100 g of protein

Indicators	Control	70 chickpea:30 soy isolate
Saturated fatty acids		
Caproic	0.087	0.04
Caprylic	0.626	–
Undecylic	–	0.061
Capric	0.894	–
Lauric	6.930	0.08
Myristic	3.088	2.125
Tridecanoic	–	0.033
Pentadecanoic	0.064	0.371
Margaric	0.082	0.947
Behenic	0.245	–
Stearic	–	9.607
Arachidic	–	0.146
Lignoceric	0.149	–
Gadoleic	–	0.11
Monounsaturated fatty acids		
Myristoleic	0.042	0.5
Pentadecenoic	11.262	24.013
Palmitoleic	0.308	5.373
Margaroleic	6.919	0.754
Oleic	24.505	31.295
Eicosenoic	0.152	0.36
Erucic	–	0.18
Polyunsaturated fatty acids		
Linoleic	0.180	0.081
Linoleic	39.030	19.998
Linolenic	0.334	0.111
Eicosadienoic	0.680	1.977

The study of the fatty acid composition of the sausage product showed that compared to the control sample, the sample of soy isolate and chickpea 70:30 increased by 3 units after heat treatment. The loss of some soluble fats leads to the conclusion that their proportions are relatively large, through open pores and capillaries and from cells with damaged membranes. The content of saturated fatty acids in the stearic acid composition is 9.607, and in the 70:30 sample it increased due to the introduction of chickpeas. Significant changes were observed in the content of monounsaturated fatty acids, except for margaroleic acid, as it is predominantly contained in animal fat. The pH in the meat after massaging and salting correlates with changes in the chemical composition of the meat (20–22). The initial moisture content in the meat was 75.6 %. After massaging, the moisture value increased to 77.4 %. Meat hydrolysis in a salt solution showed lower moisture – 76.1 %. The fat values before and after salting or massaging in a cyclical mode changed slightly from 3.44 to 3.3 and 3.2 units, respectively.

Fig. 1 shows the data characterizing the change in the moisture binding capacity of samples with soy isolates and chickpeas.

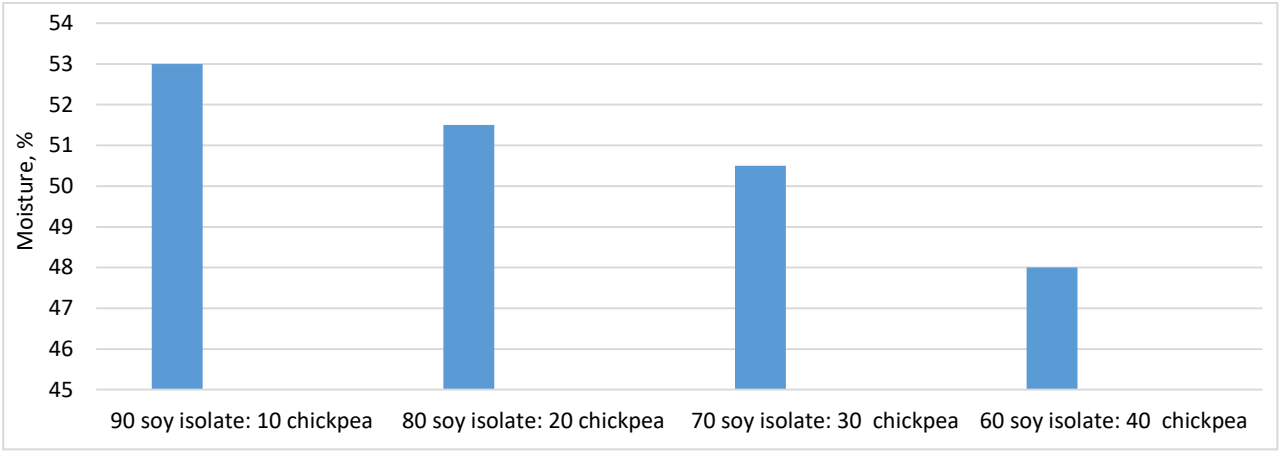

Fig. 1. Moisture retention capacity of the prototypes

Moisture-binding capacity is one of the most important indicators of raw materials, reflecting the nature of the interaction in the protein-water system, which is influenced by factors such as the solubility of protein systems, concentration, type, protein composition, etc. Moisture-retaining capacity characterizes the moisture content in muscle tissue and the amount of moisture released during heat treatment. WUS approximately characterizes changes in the colloidal chemical properties of the texture. This indicator is closely related to the output of finished products. As a result of the physico-chemical, colloidal-chemical changes occurring during heat treatment, part of the water associated with chickpeas is lost in the form of mass losses of the finished product.

A formulation based on Table 4 from vegetable raw materials has been developed.

Table 4

Semi-smoked sausage made from vegetable meat substitute

The name of raw materials, spices and materials	Semi-smoked sausage made from vegetable meat substitute
Unsalted raw materials, kg per 100 kg	
Chickpea	70
Soy isolate	30
Spices and materials, gr. per 100 kg	
Salt	2,000
Fermented rice	50
Sunflower oil	50
Ground black pepper	100
Allspice	90
Ground coriander	50
«Fabios» shell, mm	50

The organoleptic properties of the samples were determined in Table 5.

Based on the data presented in Table 5, it was found that soybeans and chickpeas have their own specific smell and taste, and they can be neutralized by the right combination of plant raw materials. In plant-based semi-smoked sausages with a ratio of soybeans to chickpeas of 90:10 and 80:20, the specific smell and taste of soybeans are especially strongly felt, and in the sample with a ratio of soybeans to chickpeas of 60:40, the taste of chickpeas was clearly felt, and since the consistency when cut was crushed, these sausages were considered unacceptable for consumers. In plant-based semi-smoked sausage with a soy-chickpea ratio of 70:30, only the faint specific smell and taste of chickpeas and soybeans added a special piquancy to the semi-smoked sausage.

Table 5

Organoleptic indicators of semi-smoked sausage made from a plant-based meat substitute

Name of indicators	Description of semi-smoked sausage made from a plant-based meat substitute			
	90:10	80:20	70:30	60:40
Appearance	The surface is dry, clean, without stains and without sticking			
Color	Light brown	Light brown	Light brown	Light brown
Smell	Semi smoked typical for sausage, spices pleasant aroma has a smell, weak chickpea the original smell and soy clear the smell is felt	Characteristic of this type of product is the aroma of spices, the characteristic smell of chickpeas and soybeans	Semi smoked typical for sausage, spices pleasant aroma has a smell, chickpeas the original smell and soy weak the smell is felt	Semi smoked typical for sausage, spices pleasant aroma has a smell, chickpeas pronounced smell, soy weak unusual smell felt
Consistency	Dense, homogeneous		Homogeneous, slightly when cut will be crushed	
Taste	Products to the named type characteristic, spices pleasant taste bar, chickpeas weak self taste and soy clear the taste is felt	Products to the named type characteristic, spices pleasant taste, chickpeas and the origin of soy with a taste	Semi smoked typical for sausage, spices pleasant taste, chickpeas and soy weak has an original taste	Semi smoked typical for sausage, spices pleasant taste, chickpeas pronounced taste, soy weak original taste felt

Summing up the results obtained, it is possible to conclude that semi-smoked sausage the optimal ratio of soybeans and chickpeas as a meat substitute in production (70:30) selected.

According to the texture of the finished product, as can be seen in Fig. 2, from gently soft airy inclusions to elastic and juicy pieces of meat, each sausage has its own unique character.

All sausage products were observed according to traditional technology, the proportions of soy isolate and chickpeas were taken into account.

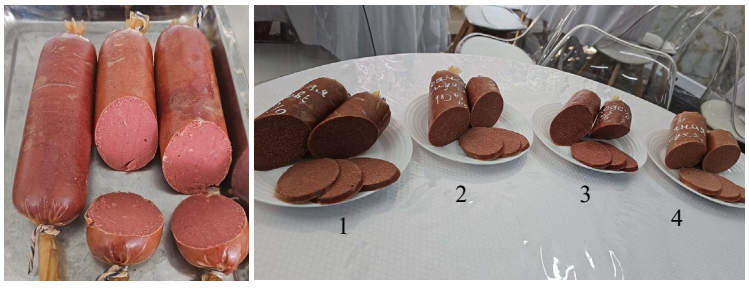

Fig. 2. The texture of the finished product: *a* — control; *b* — experimental samples: 1 — 60 chickpea:40 soy isolate; 2 — 90 chickpea:10 soy isolate; 3 — 70 chickpea:30 soy isolate; 4 — 80 chickpea:20 soy isolate

Chickpea seeds are rich in protein, vitamins and minerals, which gives them great nutritional value for the product. The use of chickpea seeds for sausage products makes it possible to increase the economic performance of production by reducing the cost of raw materials and increasing the profitability of production.

6. Discussion of the results of the study on the physicochemical, amino acid and fatty acid composition of semi-smoked sausages enriched with soy isolate and ground chickpeas

The increase in protein and fat content across all experimental samples (Table 1) compared to the control is explained by the high nutritional value of soy isolate. This is particularly evident in sample No. 2 (soy:chickpea ratio of 90:10), where the protein content reached 34.13 %, more than 15 % higher than the control. This is attributed to the high protein concentration in soy and its good solubility, which ensures uniform distribution within the meat system. The increase in pH to 5.9 can be explained by the transition of soluble proteins from chickpeas into the product structure during thermal processing, which influences water-holding capacity and textural stability.

Changes in the amino acid composition (Table 2) demonstrate a significant increase in the content of essential amino acids such as lysine (5.39 times higher than the control) and leucine (4.13 times higher), which may be due to the combined action of soy and chickpea proteins, as well as enzymatic activity during thermal treatment. The reduction in tryptophan and isoleucine levels may be attributed to their instability at high temperatures or their limited availability in chickpeas.

The fatty acid composition (Table 3) revealed an increase in stearic acid (up to 9.607 mg/100 g protein), as well as higher concentrations of oleic acid and a range of monounsaturated fatty acids, indicating an improvement in the product's lipid profile. The decrease in caproic and capric acids is associated with their high volatility and loss during heat treatment. An increase in linoleic and linolenic acids was also established, indicating the preservation of polyunsaturated fatty acids in the experimental samples.

Fig. 1 shows the moisture-retaining ability of soy isolate and chickpea substitute meat. Such properties as juiciness, tenderness, losses during heat treatment, presentation, and technological advantages depend on this ability of meat to retain or bind water.

In our case, the moisture retention capacity exceeds 50 %, this is explained by the fact that the moisture absorption of soy isolate itself is higher.

Unlike the approaches proposed in [20, 21], where jackfruit-based plant substitutes with a lower proportion of saturated fats were used, the present study achieved a balance between high biological value and acceptable sensory characteristics. In [22], a technology based on pea isolate and potato protein was proposed, but the resulting product exhibited high moisture content (73 %) and low protein levels (2.2 %), limiting its suitability for semi-smoked sausage production. In the present study, the use of soy isolate in combination with chickpeas ensured structural integrity, thermal stability, and an improved amino acid profile.

The results presented in Tables 1–3 clearly demonstrate that the proposed formulation addresses the key limitations outlined in Section 2, namely: the incompleteness of plant proteins, unsatisfactory texture and flavor characteristics, and the high caloric content of traditional meat products. The increase in essential amino acid content and the improved lipid profile indicate that the goal of developing a functional product with enhanced nutritional and biological value has been achieved.

It should be noted that the study included in-depth amino acid and fatty acid analysis for only one formulation (70:30). Although promising results were obtained, a full comparative analysis of all formulation variants is necessary to gain a more complete picture. In addition, no sensory evaluation was carried out, nor was storage stability investigated, which are essential aspects for industrial implementation.

Fig. 2 shows the textures of all the samples with the addition of soy isolate and chickpeas. They are similar in texture, but differ in taste and color.

Despite the high content of most amino acids, a reduction in isoleucine and tryptophan was observed. This may limit the completeness of the protein profile for certain consumer groups. Furthermore, there is a lack of data on the potential allergenicity or tolerance of soy- and chickpea-based products, which warrants further investigation.

Future research should focus on evaluating the stability of the product during long-term storage under various temperature conditions. Consumer perception studies (taste, texture, appearance), determination of shelf life, and the introduction of sensory evaluation panels are also recommended. These steps will help tailor the product to market demands and ensure its competitiveness among analogues.

7. Conclusions

1. The formulation of semi-smoked sausages using soy isolate and ground chickpeas allowed for the optimization of the physicochemical composition of the final products.

In all experimental samples, the protein content increased significantly compared to the control (from 18.36% to 34.13% in the sample with a soy:chickpea ratio of 90:10), and the fat content remained within acceptable limits (up to 3.31 %), indicating a favorable nutritional balance.

2. The inclusion of soy isolate and chickpeas in the sausage recipe improved the amino acid profile, ensuring enrichment with essential amino acids. In the sample with a 70:30 ratio, lysine content increased from

2.00 to 4.68 mg/100 g, proline from 0.76 to 8.6 mg/100 g, leucine and isoleucine from 0.62 to 5.3 mg/100 g. This demonstrates the ability of the new formulation to enhance the biological value of the product by enriching it with amino acids essential for protein synthesis and metabolic regulation.

The fatty acid profile of sausage products was improved through the use of soy isolate and chickpeas, promoting a healthier lipid composition. In particular, the content of stearic acid increased to 9.607 mg/100 g of protein, and oleic acid to 31.295 mg/100 g, while capric and lauric acids decreased significantly. The proportion of polyunsaturated fatty acids, such as linoleic and linolenic acids, also increased, indicating a shift towards more desirable lipid fractions that support cardiovascular health.

As a result of the organoleptic assessment, the plant the optimal ratio (70:30) of soy and chickpeas used for semi-smoked sausage was determined as raw materials.

Conflict of interest

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

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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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