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SUBSTANTIATING THE FEASIBILITY OF USING HEMP SEED PROTEIN IN COOKED SAUSAGE TECHNOLOGY

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The object of this study was the technology of cooked sausages with hemp seed protein. The research considers determining the effectiveness of using protein from hemp seeds in the technology of cooked sausages to increase the nutritional value and improve the functional and technological indicators when replacing part of the meat raw material. The subject of the research was meat model systems, cooked sausage with hemp seed protein.

Three prototypes of cooked sausages based on the analog were developed. In experimental samples of cooked sausages, second-grade beef was replaced with protein from hemp seeds (Cannabis Sativa L.) (ToV "Desnaland", Ukraine) in amounts of 12, 14, and 16 %. The functional and technological indicators of hemp seed protein were previously investigated at hydromodules of 1:1, 1:2, and 1:3. It was found that hydrated hemp seed protein in a ratio of 1:1 had the best parameters for introduction into minced meat systems.

It was determined that the introduction of proteins from hemp seeds (hydromodule 1:1) in the amount of 12–16 % increases the water-binding capacity of minced meat to 97.8 %, plasticity by 16.19–23.85 %, and the content of total moisture in samples of cooked sausages after heat treatment by 5.08–7.08 %, yield of the finished product up to 129.83 %. Replacing second-grade beef in cooked sausage with protein from hemp seeds causes an increase in the mass fraction of protein in finished products by 14.99–19.98 %, and mineral substances by 68.52–97.22 %. The organoleptic indicators of the experimental cooked sausages met the regulatory requirements. The safety of the developed products was established according to microbiological indicators.

It has been proven that the use of hydrated protein from hemp seeds in the technology of cooked sausages in the amount of 12–14 % makes it possible to obtain a meat product with a high level of functional and technological indicators of model meat systems and organoleptic indicators of finished products. The use of protein from hemp seeds in the production of cooked sausages makes it possible to expand the range of products popular among the population

Keywords: hemp seed protein, boiled sausage, functional and technological indicators, energy value

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1. Introduction

The main task of the meat industry is to provide the population with high-quality meat products in a wide range. Products, in accordance with the modern requirements of nutrition science, must be complete in terms of the content of biologically necessary substances, have pronounced taste and aromatic properties, and be safe for the consumer.

Meat and meat products are one of the main products of animal origin in the human diet as they contain irreplaceable sources of complete protein, fat, vitamins, minerals, and other vital nutrients [1, 2].

However, many meat products produced by the industry are not sufficiently balanced in terms of protein and fat composition and are not differentiated according to the needs of different population groups. A decrease in the quality of food products of animal origin, an increase in the deficit of dietary protein encourages the search for new sources of food ingredients [3, 4].

Thus, solving the problem of integrated rational use of raw materials in the production of meat products is a relevant and important factor from the point of view of preserving the original quality of products in the processing process.

2. Literature review and problem statement

When developing new types of meat products, one of the criteria for evaluating their recipes is the normalization of the chemical composition of the product from the standpoint of the optimal ratio of protein and fat [5]. The solution of this task is facilitated by the targeted use of protein preparations to increase the functional and technological indicators of minced meat [6, 7]. At the same time, the lack of muscle protein in minced meat is compensated by the use of protein preparations, which make it possible to increase the moisture-binding capacity (MBC), moisture-retaining capacity (MRC), and fat-retaining capacity (FRC), as well as increasing the stability of meat products during storage [8]. The use of these ingredients makes it possible to increase the volume of production while simultaneously reducing the consumption of meat raw materials [9], to increase the nutritional value and safety of the product [10]. However, due to the shortage of raw meat and its high cost, the problem of finding alternative sources of protein that would meet sanitary and hygienic safety requirements, have a high protein content, and acceptable properties from a technological point of view arises. In addition, protein fillers should increase the functional and technological indicators of existing substandard raw materials and the rationality of their use.

The latest trend in the meat industry is the development of meat-rich products, the consumption of which makes it possible to reduce the deficiency of functional ingredients by combining recipe components [11–14]. Work [11] reports the results of studies on the reduction of nitrite in meat products due to the introduction of plant ingredients that make it possible to increase the biological value of the final product. The authors of work [12] suggest the use of plant antioxidants that increase the safety of meat products and extend their shelf life. It has been shown [13] that the extract of black rowan, blueberry, and blackcurrant can be effectively used in the storage of mechanically deboned poultry meat and thereby ensure its high nutritional value and safety. And work [14] demonstrated that black rowan extract is effective in the technology of semi-smoked sausages of a combined composition. But when making recipes for such products, the problem of effective combination of components arises. At the same time, not only from the point of view of the formation of biological value but also taking into account the functional and technological properties of raw materials and their combination in the composition of meat model systems without reducing technological indicators.

Information on the use of plant antioxidants is given as an example of directions for the use of plant ingredients in modern technologies of combined meat-containing products.

The combination of plant ingredients in the composition of meat-containing products makes it possible to improve the functional and technological properties of emulsified systems, to increase the biological value of products by increasing the content of fiber, unsaturated fatty acids, and some mineral elements [15, 16]. This direction opens up wide opportunities in terms of increasing production volumes of meat products, as well as stabilization of product quality, regulation of its consumer properties, nutritional and biological value. It has been proven that vegetable raw materials are of undeniable interest from the point of view of the production of functional meat products, the features of which technologies impose a number of restrictions on their fortification with isolated functional components [17, 18]. But the issue of modeling the recipes of functional meat products with the help of plant ingredients of regional cultivation is not sufficiently studied.

At the same time, the problem of technological approaches to the inclusion of plant raw materials in meat systems remains relevant, which requires a comprehensive study of the safety and feasibility of combining, in particular, in terms of changing the hydrophilic properties of the meat system. It has been shown that the introduction of plant ingredients effectively simulates the emulsifying properties of meat model systems [19]; but in the study hemp protein was isolated using alkaline extraction and isoelectric precipitation and micellization, which obviously had an impact on the studied parameters. It was shown that the use of chia and quinoa in meat products affects the indicators of the product appearance and nutritional value [20]; however, the effect of adding these ingredients on the functional and technological properties of model minced meat systems has not been sufficiently studied. In [21], the influence of partial and complete replacement of chicken meat on vegetable proteins in the composition of sausages was investigated. Vegetable proteins were shown to minimize cooking losses and shrinkage, and also improved emulsion stability by creating a strong structural matrix, but at the same time degraded structural and mechanical properties. Therefore, the issues of a comprehensive approach to modeling the functional and technological properties of meat systems using vegetable proteins remained unresolved.

The use of protein vegetable raw materials in the production of cooked sausage products makes it possible to increase the output, reduce the risk of the formation of broth-fat swellings, and stabilize the quality of the finished product. Depending on the type of plant raw materials, various goals are achieved: fortification with vitamins, minerals, dietary fibers; improvement of functional and technological properties; reducing the calorie content and cost of meat products. At the same time, the problem of choosing optimal functional characteristics and safe plant ingredients remains unsolved. One of the solutions to this problem can be the use of regionally produced hemp seed protein.

Hemp protein has a unique composition and contains many useful components [22, 23], so the products of processing of technical varieties of this crop can be used in food technology as protein ingredients. Thus, work [24] shows that industrial hemp is one of the agricultural crops that is widely used in various branches of the national economy, and, in particular, in food technology due to its rich nutrient composition. There are also results of research on the content of biologically active substances, which prove that hemp is a valuable raw material from the point of view of pharmacology. The benefits of using hemp processing products for human health have been established [25], which proves its safety and usefulness for use in rational and healthy nutrition. In addition, work [26] describes a comprehensive approach to various areas of hemp application in food technology and health care, which makes it and its processing products a valuable raw resource for the food industry. For example, the authors of [27] note that hemp seeds are rich in beneficial lipids with a high content of polyunsaturated fatty acids, such as linoleic acid (omega-6), alpha-linolenic acid (omega-3), as well as vitamins E, D, and A. In addition, hemp seeds contain polyphenols and terpenoids that provide antimicrobial, antioxidant and anti-inflammatory properties. Research results [28] prove that hemp seeds are a valuable source of essential amino acids, fatty acids, mineral elements, vitamins, and fiber. Due to these characteristics, hemp seeds are a promising ingredient for the production of functional foods. However, questions related to the expediency of the targeted use of this ingredient in various types of food products, including meat products, remain unresolved. It is necessary to develop technological approaches in the application of this ingredient in the meat processing industry, taking into account the effects of heat treatment regimes, the resistance of biologically active substances to changes in pH and other parameters.

From the point of view of the production of meat products, vegetable raw materials must first of all satisfy the demand for protein components of meat and meat-containing products. This is the approach used by the authors of paper [29] who established that hemp protein has a good amino acid profile and digestibility, diverse biological activity and high functionality. According to researchers [30], industrial hemp seeds are an underutilized source of protein. The authors propose a technology for obtaining biologically active peptides for use in functional food products by hydrolysis of hemp protein with proteolytic enzymes. However, this technology is expensive and increases the cost of food products, which makes these studies impractical. Therefore, the priority in hemp protein research today is the development of effective and resource-saving technologies.

One of the advantages of hemp protein compared to other vegetable proteins is its easy digestibility, which is about 88–91 % [31], therefore, studies into the effectiveness of its use in meat products technologies are needed.

In recent years, research has been conducted on hemp seed protein as a multifunctional ingredient for the production of various types of food products. Thus, the authors of work [32] investigated the ability of protein from hemp seeds to act as a technological and functional tool in the technology of gluten-free bread, and in work [33] it was shown that the functional properties of hemp seeds are preserved during the digestion process, which further enhances the beneficial effects of the introduction of this by-product into the human diet.

The authors of paper [34] showed the role of hemp seed protein as an emulsifier and foaming agent, a gelling agent, which makes it possible to offer it as a functional ingredient for the production of meat and meat-containing products.

However, it should be taken into account that the functional properties of the protein products of hemp seeds depend on the structural conformations, as well as on the protein concentration and pH, which is of great importance in the processing of meat raw materials [35]. At the same time, an unsolved problem is the degree of hydration of hemp seed protein and the effect of pH on the nature of hydrodynamic interactions in meat model systems.

From the point of view of the functionality of hemp seed protein in complex multicomponent meat-based systems, the peptidom composition of hemp seeds is of great importance. Work [36] reports the results of the study on the peptidom composition of seeds and other parts of hemp. At the same time, the protein composition of hemp is mostly represented by specific proteins that require additional denaturation for effective use in food technology. This problem is solved by obtaining protein hydrolysates. On the other hand, it was established [37] that protein hydrolysates have antioxidant activity, as well as the ability to inhibit the activity of angiotensin-converting enzyme, which has therapeutic value in the treatment of hypertension. This means that hemp seed proteins can serve not only as nutritional nutrients in food products, but also as nutraceuticals. Thus, it has been proven [38] that biologically active compounds of hemp can be effective nutraceuticals and be used in the technologies of functional products. Therefore, our literature review reveled that hemp seed protein is a valuable, promising functional ingredient for the production of food products. However, the question of the effective and rational use of this ingredient in the technologies of meat and meat-containing products, taking into account the structural features of hemp protein, their functional activity, interaction with water and proteins of vegetable origin, remains unresolved.

It is obvious that hemp processing products have a number of advantages in the production of food products, fortify products with biologically active substances, have a positive effect on human health, and are therapeutic agents. However, the issue of effective combination of protein from hemp seeds with traditional types of meat raw materials and its effect on the functional and technological properties of multicomponent meat model systems remains unresolved. In addition, there is not enough information in the literature about research on the use of protein from hemp seeds in the technology of cooked sausages. This indicates the expediency of conducting a study on the effect of hemp seed protein on the production of cooked sausages through a comprehensive assessment of meat model systems and the quality of ready-made cooked sausages with a combined composition.

3. The aim and objectives of the study

The purpose of our study is to determine the possibility of combining protein from hemp seeds in combination with traditional ingredients in meat model systems of cooked sausages. This will make it possible to expand the range of cooked sausage products, increase the efficiency of production and determine the optimal dosage of this ingredient in the recipe composition of combined cooked sausages from a technological point of view.

To achieve the goal, the following tasks were set:

– to investigate the functional and technological indicators of protein from hemp seeds to determine the technological conditions of use of this ingredient;

– to investigate the influence of the quantitative ratio of protein from hemp seeds in the composition of cooked sausage recipes on the stability of the functional and technological indicators of minced meat and finished products;

– to determine the content of the main nutrients and the energy value of sausages cooked with hydrated protein from hemp seeds according to the developed model recipes;

– to determine the impact of the use of protein from hemp seeds on the possibility of ensuring high sensory indicators and the safety of the developed cooked sausages.

4. The study materials and methods

The object of our study was the technology of cooked sausages from traditional meat raw materials and hemp seed protein. The subject of the study was meat model systems, functional-technological properties of protein from hemp seeds at different hydromodules, functional-technological, structural-mechanical, organoleptic properties of cooked sausage samples; microbiological indicators of finished product samples.

Research hypothesis assumes that the inclusion of a vegetable filler in the technology of cooked sausages affects the functional and technological properties of meat model systems, in particular, their moisture-binding and emulsifying properties, and the quality of the finished cooked sausage. The high functional and technological properties of hemp seed protein lead to the expansion of the range of products using them, in particular cooked sausages with a combined composition of raw materials. It is assumed that the study of the effect of hemp seed protein on the quality and nutritional value of cooked sausages would make it possible to expand the range of meat products with a combined composition and determine the rational amount of this vegetable filler.

Protein from hemp seeds (*Cannabis Sativa L.*) was chosen for the experiments (TU U 10.4-39224310-002:2019, ToV "Desnaland", Ukraine). For experiments, samples were taken in dry and hydrated form in the ratio of 1:1, 1:2, and 1:3. Hydration of protein from hemp seeds was carried out with drinking water at a temperature of 20...25 °C for 10 minutes.

The protein from hemp seeds had a yellow-green color, the smell and taste were clean, impersonal, without extraneous odors and flavors, metallomagnetic inclusions and pest infestation.

Boiled “Chayna” sausage (DSTU 4436:2005) was used as an analog for the study. The recipe consisted of second grade boneless beef – 70 %, semi-fat pork – 20 %, side lard – 10 %, table salt, sodium nitrite, and spices. In experimental samples of cooked sausages, beef of the second grade was replaced with protein from hemp seeds (hydromodule 1:1) in the amount of 12, 14, and 16 %. Recipes of control and experimental samples of cooked sausage are given in Table 1.

Table 1

Recipes of control and experimental samples of cooked sausage, %

Raw materials	Sample recipes for boiled sausages			
	Analog	Sample 1	Sample 2	Sample 3
Deveined beef, 2 grade	70	58	56	54
Semi-fat pork	20	20	20	20
Side lard	10	10	10	10
Hydrated protein from hemp seeds (hydromodule 1:1)	–	12	14	16
Table salt	2.2	2.2	2.2	2.2
Ground black pepper	0.1	0.1	0.1	0.1
Sodium nitrite	0.005	0.005	0.005	0.005

When preparing minced meat, at the beginning, pre-salted beef of the 2nd grade, ice in the amount of 2/3 of the total amount of added moisture was introduced. The duration of beef cutting was 3.5–4.0 minutes. Then table salt, sodium nitrite, hydrated (1:2) protein from hemp seeds and semi-fat pork, the remaining water were added to the cutter and boiled for another 3–4 minutes. Lard and spices were added 1–2 minutes before the end of the cooking process. The temperature of the minced meat during cooking was within 8–10 °C. After preparation, the minced meat was injected into the natural shell using a manual horizontal syringe. After forming the loaves, heat treatment was carried out according to generally accepted technology in a thermal chamber. Sausages were cooked at a temperature of 75–85 °C for 60 min until the temperature in the center of the loaf reached 71±1 °C. Cooling was carried out under water irrigation for 10–15 min, then in the refrigerator until the temperature in the center of the loaf does not exceed 8 °C.

To determine the nutritional value of cooked sausages, moisture content was determined by the gravimetric method [39]. A glass rod was filled with sand in an amount 2–3 times greater than the weight of the product and dried in an oven at a temperature of (150±2) degrees for 30 minutes. Then the mixture was cooled in a desiccator to room temperature and weighed. Next, a sample of 3 g of minced meat was added to the box with sand, weighed again, thoroughly mixed with sand with a glass stick, and dried in a drying cabinet in an open box at a temperature of (150±2) degrees for 1 hour. Then the mixture was cooled in a desiccator to room temperature and weighed. Moisture content was calculated from the difference in weight before and after drying and expressed as a percentage.

The protein content was determined by the Kjeldad method (ISO 937:2005. 2007). 5 g of homogeneous minced meat with 20 ml of concentrated sulfuric acid and 8 g of catalysts were placed in a special container and heated at 350 °C for 30 min. After mineralization, the sample was quantitatively transferred into a NaOH solution with a concentration of 33 %, closed, and boiled with steam. The resulting steam distillate was transferred to a container containing a few drops of Tashiro’s indicator. Titration was carried out with a solution of 0.01 N sulfuric acid.

Fat content was determined by the Soxhlet method (ISO 1443:2005. 2008). 4 g of the dried sample in a paper cartridge was placed in the extraction flask of the Soxhlet apparatus (Simax, Czech Republic). Petroleum ether with a boiling point of 45 °C was used for extraction. After several extractions, the weight of the test cartridge was determined to constant weight. The difference between the initial and final weight shows the percentage of fat.

The mass fraction of mineral substances was determined by the method of dry ashing at a temperature of 520 °C. Porcelain crucibles were calcined in a muffle furnace (MLW, Germany) at a temperature of 520 °C for one hour. Then it was cooled in a desiccator. A 1 g mass of minced meat was weighed, transferred to a crucible, and placed in a muffle furnace and ashed to a constant mass at a temperature of 520 °C. After that, the crucible with ash was cooled, after which it was weighed and according to the difference in weight before ashing, and then the content of mineral substances was determined [39].

The energy value was calculated according to the method from [40]. The energy value was determined by multiplying the number of proteins, fats, and carbohydrates by the corresponding coefficients of the energy value, the value for proteins is 4; for fats – 9; for carbohydrates – 4 kcal/g:

$$EV=P\times 4+F\times 9+C\times 4, \quad (1)$$

where EV is energy value; P – proteins; F – fats; C – carbohydrates.

WBC of minced meat was determined by the pressing method [41]. WBC_a is the ability of minced meat to bind moisture in relation to the total moisture of the sample; WBC_m is the ability of minced meat to bind moisture in relation to the mass of the sample. For research, the samples were weighed with a mass of 0.3 g with an absolute error of 0.001 g. The weight was transferred to a polyethylene circle, then to a circle of filter paper placed on a glass plate so that the weight of minced meat lay on the filter paper. From above, the polyethylene circle was covered with a plate on which a load weighing 1 kg was placed. The duration of pressing is 10 minutes. After pressing, the mass was removed from the filter paper, the area of the wet spot was measured. The moisture-binding capacity of minced meat (WBC), as the mass fraction of moisture (relative to the total moisture content in the sample) remaining in the sample after pressing, was determined from formula (1):

$$WBC=\left[\left(\frac{(W-m)}{100}-8.4S\right)/m\right]\cdot 100, \quad (2)$$

where m is the weight of the batch, mg;

W is the mass fraction of moisture in the sample, %;

S – wet spot area, mg.

WHC of minced meat was defined as the difference between the mass fraction of moisture in the minced meat and the amount of moisture released during heat treatment. Samples of minced meat weighing 4–6 g were evenly applied with a glass rod on the inner surface of the wide part of the milk fat meter. It was tightly closed with a cork and placed with the narrow part downwards in a water bath at boiling temperature for 15 minutes, after which the mass of moisture released was determined by the number of divisions on the scale of the fat meter.

The emulsifying capacity of the model systems was determined according to the methodology from [41]. A weight of minced meat of 7 g was mixed with 100 cm^3 of water in a homogenizer and ground at a rotation frequency of 66.6 s^{-1} for 60 sec. Then 100 cm^3 of oil was added and the mixture was emulsified in a homogenizer at a speed of 1500 s^{-1} for 5 minutes. After that, the emulsion was centrifuged at 500 s^{-1} for 10 minutes. Then the volume of emulsified oil was determined. The emulsifying ability was determined from the formula:

$$EC=V_1/V\times 100, \quad (3)$$

where V_1 is the volume of emulsified oil, cm^3; V is the total volume of oil, cm^3.

The stability of the emulsion was determined according to the methodology from [41]. A weight of minced meat of 7 g was mixed with 100 cm^3 of water in a homogenizer and ground at a rotation frequency of 66.6 s^{-1} for 60 sec. Then 100 cm^3 of oil was added and the mixture was emulsified in a homogenizer at a speed of 1500 s^{-1} for 5 min. The stability of the emulsion was determined by heating at a temperature of 80 °C for 30 min and cooling with water for 15 min. After that, the emulsion was centrifuged at 500 s^{-1} for 10 minutes. Then the volume of emulsified oil was determined. The stability of the emulsion was calculated according to the formula:

$$CE=V_1/V_2\times 100, \%, \quad (4)$$

where V_1 is the volume of emulsified oil, cm^3; V_2 is the total volume of the emulsion, cm^3.

The pH value of the meat was determined using a digital pH-meter pH-150MI according to the methodology from [42]. 10 g of minced meat was mixed in 100 ml of water, followed by exposure for 30 minutes.

The plasticity of minced meat was determined by the area of the spot of minced meat formed under the action of a static load weighing 1 kg for 10 minutes. according to the method [43].

The rheological parameters of the crushed systems were determined using a rotary viscometer. The RV-8m viscometer (Ukraine) was used with a corrugated rotor (corrugation step 2 mm) with an inner cylinder (Rc) of 0.605 cm, the outer radius of the rotor Rn – 1.9 cm, the length of the rotor was equal to 8 cm according to the scale using a stopwatch. Processing of the obtained results was carried out according to the methodology from [43]. Losses during cooking were calculated from the difference in weight before and after cooking, and moisture content was determined by drying samples (4 g) at 150 °C [43]. Color intensity was determined by the spectrophotometric method [44], which is based on the extraction of pigments of meat and meat products with an aqueous solution of acetone followed by measurement of the optical density of the extract (D). The measurement of the color intensity of the solutions was carried out on a prepared spectrophotocolorimeter Spekol-11 (Germany) at a wavelength of 540 nm to the control solution, in which the test solution is replaced by 15 ml of water. The value of the optical density is proportional to the pigment concentration and is an indicator of the color intensity.

When assessing the microbiological safety of sausages, test plates certified by international organizations (AOAC, AFNOR, NordVal) with a nutrient medium on a substrate (petri films) were used [45]. 3M Petrifilm Aerobic Count plates for determination of KMAFAnM, 3M Petrifilm Coliform Count Plate – for determination of total coliforms capable of growing at temperatures (30–37) °C, 3M Petrifilm Series 2000 Rapid Coliform Count Plate – for determination of coliform bacteria. Determination of microbiological indicators was carried out at the end of the storage period of cooked sausages after 72 hours.

The organoleptic evaluation of cooked sausages was carried out on a five-point scale with the participation of 10 tasters [46]. Such indicators as appearance, consistency, taste, juiciness, smell, color were evaluated.

Statistical processing of the results was carried out using the standard package of Microsoft Excel software (USA), using the Student's t-test. A difference was considered probable if the value of $p<0.05$.

5. Results of investigating the consumer, functional, and technological properties and safety of experimental cooked sausages

5. 1. Results of investigating the functional and technological properties of protein from hemp seeds

To confirm the expediency of using protein from hemp seeds, hydrated in various ratios, as well as the correctness of the selected level of its introduction into the composition of the recipe, studies of the functional and technological indicators of this product at different degrees of hydration were conducted. Functional and technological indicators of protein from hemp seeds of different degrees of hydration are given in Table 2.

Table 2

Functional and technological indicators of protein from hemp seeds of different degrees of hydration

Hydration level	WBC_a	WBC_m	EC	pH
1:1	79.63±1.58	69.27±0.54	38.16±2.07	7.01±0.03
1:2	67.81±0.76	61.13±1.13	35.27±1.33	7.01±0.03
1:3	43.16±1.37	49.65±0.97	30.21±1.56	7.00±0.01

As can be seen from from Table 2, $B33_a$ ranged from 79.63±1.58 % in the sample with a hydraulic modulus of 1:1 to 43.16±1.37 % in the sample with a hydraulic modulus of 1:3. A similar trend was noted in relation to WBC_m and emulsifying capacity. Thus, the emulsifying capacity of protein from hemp seeds at a hydromodulus of 1:1 was 38.16±2.07 %, and when the hydromodulus was increased to 1:3, it decreased to 30.21±1.56 %. The pH of protein from hemp seeds with all variants of the hydromodule was practically the same and amounted to 7.00–7.01.

5. 2. Results of investigating the functional and technological properties of model meat systems of cooked sausages

Experimental data on the functional and technological indicators of model minced meat and the finished product of boiled sausages are given in Tables 3, 4.

Table 3 data indicate that the introduction of 12–16 % hydrated hemp seed protein into the minced meat increases the water binding capacity of the test samples to total moisture (almost 100.0 %).

Table 3

Functional and technological indicators of model meat systems of cooked sausages for heat treatment

Samples of raw meat mince	Moisture content, %	WBC_a, %	pH	Stress shear, Pa	Plasticity, cm²/g
Control	68.71±1.57	89.1±2.03	6.09±0.09	713.5	4.57±0.17
Sample 1	67.13±1.89	93.2±1.57	6.31±0.11	692.7	5.31±0.21
Sample 2	67.09±1.34	97.8±1.99	6.31±0.11	687.1	5.62±0.11
Sample 3	67.11±1.07	97.4±1.16	6.57±0.11	681.3	5.66±0.17

The moisture content in the minced sausage samples ranged from 67.09 to 68.71 % and was practically the same. However, the results of WBC_a study showed a difference between the model meat systems with different hemp seed protein content. Thus, in the second and third samples, $B33_a$ was 97.4–97.8 %, which is 9.76 % higher compared to the control. The pH ranged from 6.09 in the control sample to 6.57 in the sample with a hemp protein content of 16 %. Stress shear in the experimental samples was lower compared to the control by an average of 3.65 %. The plasticity of minced meat with the addition of hemp seed protein increased and was from 5.31±0.21 cm²/g in the sample with a 12 % hemp seed protein content to 5.66±0.17 cm²/g in the sample containing 16 % protein from hemp seeds.

All test samples had a moisture content that meets the technological requirements. As we can see from from Table 4, the content of total moisture in the test samples is higher compared to the control sample by 5.08–7.08 % and increases with the increase in the level of replacement of beef with hydrated protein from hemp seeds. At the same time, the output of the finished product increases to 129.83 %. The lower moisture content was in sausage products made according to the traditional recipe and was 62.1±2.31 %.

Table 4

Functional and technological indicators of model minced sausages cooked after heat treatment

Ready-made products	Moisture mass fraction, %	MBC, %	pH	Yield, %	Color intensity (*D*)
Analog	62.17±2.31	91.09±0.79	6.09±0.011	119.33	168.31
Sample 1	65.33±1.73	93.57±1.64	6.27±0.011	124.71	163.71
Sample 2	65.39±2.06	96.78±1.82	6.33±0.014	129.71	163.03
Sample 3	66.57±1.58	96.83±0.93	6.37±0.07	129.83	161.02

There was a slight difference in the color of the control and experimental samples. The optical density of the extract of the control sample was the highest and was 168.31, while the color intensity or optical density of the extracts of the experimental samples was 163.71 for sample 1; for sample 2 – 163.03; and for sample 3 – 161.02.

5. 3. Results of investigating the nutritional and energy value of cooked sausages

In cooked sausages with hemp seed protein, according to the developed model recipes, the content of the main nutrients and energy value were studied. The results of the research are given in Table 5.

Table 5

Nutritional and energy value of cooked sausages

Indicator	Analog	Sample		
		1	2	3
Protein content, g/100 g	20.82±0.95	23.94±0.86	24.46±0.87	24.98±1.02
Fat content, g/100 g	25.17±1.03	24.64±1.12	24.56±1.09	24.50±1.23
The content of mineral substances, g/100 g	1.08±0.09	1.82±0.14	1.98±0.12	2.13±0.09
Energy value, Kcal	309.81	317.52	318.88	320.42

Analysis of data in Table 5 reveals that cooked sausages had a high protein content, which ranged from 20.82 to 24.98 g/100 g of product. At the same time, the amount of protein was higher in the developed products and amounted to 23.94–24.98 g/100 g, which is 14.99–19.98 % higher compared to the analog. In experimental samples of sausages, the proportion of fat ranged from 24.64±1.12 to 24.50±1.23 g/100 g. The highest content of mineral residue in experimental samples was 2.13±0.09 g/100 g, which is 97.22 % higher compared to the analog.

The developed samples of cooked sausages contained a total amount of minerals of 1.82–2.13 g/100 g of product. Compared to the analog, the content of mineral residue in experimental sausage samples was higher by 68.52–97.22 %.

5. 4. Results of organoleptic evaluation and study of microbiological safety of cooked sausages

Important indicators that determine the quality of the product are its organoleptic indicators – appearance, color on the cut, aroma, taste, consistency, and juiciness. The results of the organoleptic evaluation of finished products are shown in Fig. 1.

The organoleptic evaluation was carried out on a 5-point scale, according to the results of which the test samples of sausages had quite high organoleptic indicators. The main indicators of the quality of cooked sausage were within the limits stipulated by the standards. A slight deterioration of sensory properties compared to the control is observed in sample 3 (16 % hydrated hemp seed protein).

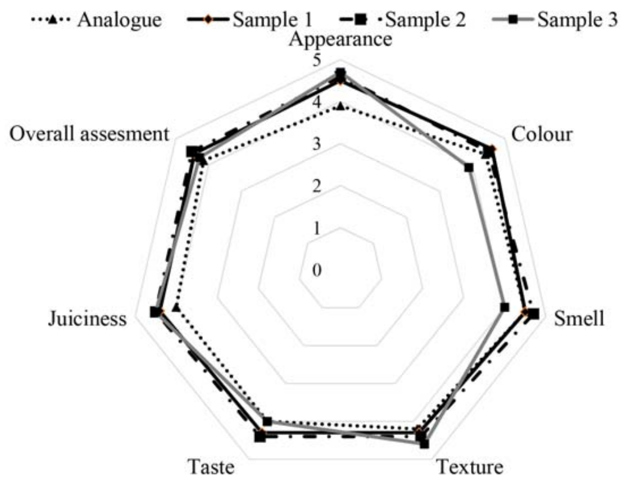

Fig. 1. Results of organoleptic evaluation of finished products

Our results of determining the microbiological indicators of finished products after storage for 72 hours are given in Table 6.

Table 6

Microbiological indicators of cooked sausages

Samples of cooked sausages	QMAFAnM, CFU/g, not exceeding	BGKP, per 1 g
Analog	2.1×10^3	Not detected
Sample 1	2.1×10^3	Not detected
Sample 2	1.9×10^3	Not detected
Sample 3	1.8×10^3	Not detected

Our microbiological studies of the experimental samples and an analog of cooked sausages show that according to the QMAFAnM indicator, all samples meet the standardized requirements according to DCTU 4432:2005.

The number of mesophilic anaerobic and facultative anaerobic microorganisms both in the control sample and in all variants of experimental samples with different content of hydrated protein from hemp seeds did not exceed 1×10^3 CFU/g. Escherichia coli bacteria, pathogenic microorganisms, and sulfite-reducing clostridia were not detected in the control and in all recipes of experimental cooked sausages.

6. Discussion of results based on the research into consumer, functional, and technological properties and safety of cooked sausages

The choice of hemp seed protein as a component of vegetable raw materials in the recipe for sausages is determined by the analysis of its nutritional value, vitamin, mineral, and amino acid composition. A necessary condition for the effective use of a functional ingredient is knowledge of its functional and technological properties. Our results of the study on water-binding and emulsifying capacity (Table 2) indicate high functional and technological indicators of protein from hemp seeds. This is explained by the high concentration of protein substances (more than 50 % according to the manufacturer) and the presence of complex carbohydrates, which have an increased ability to adsorb and retain moisture. However, with an increase in hydration (up to 1:3), the samples lose their technological characteristics. This is due to oversaturation of functional groups of proteins and dietary fibers with water molecules. Our studies on the water-binding capacity of protein from hemp seeds at different hydromodules showed that with an increase in the amount of water taken for hydration, the functional and technological indicators of protein from hemp seeds worsened. This requires finding ways to increase technological and rheological indicators of hydrated protein. In general, hydrated protein from hemp seeds in a ratio of 1:1 had high enough parameters for introduction into minced meat systems. The functional-technological properties of hemp seed protein are consistent with the results of studies reported in [47], which show a high level of moisture-binding, emulsifying, and rheological properties, which makes it possible to recommend it for use in meat systems.

It was established that the pH of protein from hemp seeds at different degrees of hydration is close to neutral (pH=7), so it is not able to have an adverse effect on the functional and technological indicators of finished products.

At the stage of development and optimization of recipes of experimental samples, the functional and technological indicators of the protein-carbohydrate complex of protein from hemp seeds and the general properties of minced meat systems were taken into account.

The results of the study of functional and technological indicators of model meat systems of cooked sausages before heat treatment (Table 3) show that WBC_a in the experimental samples was higher by 4.6–9.76 % compared to the control one. Higher indicators of WBC_a are due to high functional and technological properties of hemp protein, which is confirmed by research results in [48]. An increase in the proportion of vegetable raw materials in experimental samples of cooked sausage led to a slight decrease in the strength characteristics, as evidenced by the results of the ultimate shear stress (USS) study. The decrease in the strength of minced meat is apparently associated with a decrease in the proportion of myofibrillar proteins, which form a denser structure than vegetable proteins. At the same time, plasticity increases, while the value of this indicator increases according to the increase in the proportion of protein from hemp seeds.

The pH studies (Table 3) showed that the introduction of hydrated (1:1) protein from hemp seeds into minced meat leads to a shift in pH towards a neutral environment, which is associated with a neutral pH value in hemp seed protein. The pH indicator of experimental meat systems was in the range of 6.31–6.57, which caused a high moisture-binding capacity. The shift in the pH value of the experimental samples towards higher values had a positive effect on MBC of minced meat and finished products.

The results of investigating the functional and technological indicators of model minced sausages cooked after heat treatment (Table 4) showed that the addition of protein from hemp seeds has a positive effect on the binding of moisture and its retention under the influence of high temperatures, which led to an increase in the yield of the finished product 129.83 %, which is 25 % higher than the control sample. It is obvious that the high content of protein in hemp seeds causes moisture-binding properties due to the binding of moisture by the polar groups of hemp proteins, which are characterized by a high proportion of hydrophilic amino acids, which is also confirmed by research reported in [36].

One of the most important indicators determining the consumer quality of meat products is color. The color of the meat is determined by the concentration of hemoglobin and myoglobin in the muscles, as well as physical and chemical changes that determine the processes of color formation [44]. When developing combined products using non-meat ingredients, there is a risk of losing the color of the finished product due to a decrease in the content of heme chromoproteins. Determining the intensity of color of sausage products is necessary, especially for products containing a significant proportion of raw materials of plant origin. As a result of the study of the color intensity, it was established that when increasing the proportion of protein from hemp seeds instead of beef in the recipe of cooked sausages, the optical density of the solution also decreases, which in turn affects the color intensity of the finished product. A similar trend was noted by the authors of [21, 49] when developing chicken sausages with partial or complete replacement of chicken with vegetable proteins. The decrease in the color intensity of sausage products is explained by the decrease in the proportion of meat as a result of replacing it with vegetable protein.

The results of investigating the nutritional and energy value of cooked sausages (Table 5) show that, compared to the analog, the protein content in the experimental products increased by almost 20 %. This was achieved due to the inclusion of high-protein vegetable protein from hemp seeds in the formulation. The protein concentration in hemp seeds varies from 20 to 25 % [50] depending on the variety and environmental factors. Under the conditions of additional processing of hemp seeds, such as cleaning the seeds and obtaining meal after the extraction of the oil fraction, this indicator can increase to 50–52 % [51].

Despite the use of protein components, the fat content almost did not change. The developed samples of cooked sausages had a fat content of 24.50–24.64 g/100 g of the product, which caused the high calorie content of the obtained products. However, according to research [52, 53], hemp seeds contain a higher proportion of PUFAs compared to beef and pork. The developed samples of cooked sausages contained a total amount of minerals of 1.82–2.13 g/100 g of product. Compared to the analog, the content of mineral residue in experimental sausage samples was higher by 68.52–97.22 %. This is explained by the presence in the recipes of protein from hemp seeds, the content of minerals in which, according to the manufacturer's data, is 8.84 %.

Protein-energy deficiency in the diet is one of the most important problems of health care in many regions of the world and causes half of all cases of child mortality, negatively affects the development of children who do not have compensatory mechanisms [54]. Therefore, the inclusion of high-protein and high-calorie products in the diet can eliminate the protein and energy deficit in the human diet. As a result of the experiment, samples of cooked sausages were modeled and produced, which differ in high protein and fat content and can be included in the diet of various segments of the population.

The general conclusion based on the results of the organoleptic evaluation (Fig. 1) showed that the introduction of hydrated protein from hemp seeds of more than 14 % into the product is not advisable as there is a deterioration of the organoleptic properties of finished sausages, in particular, color and taste. Our microbiological studies of the experimental samples and an analog of cooked sausages show that the microbiological indicators were within the normative values. This confirms the microbiological safety of cooked sausages using hydrated protein from hemp seeds and allows us to recommend this protein-flavored ingredient for use in the technology of the production of cooked sausages.

Thus, the results prove that the use of hemp seed protein in cooked sausages increases the functional and technological indicators of model meat systems, the nutritional value, and makes it possible to obtain finished products with organoleptic indicators that are not inferior to traditional products. Similar results were obtained when using hemp seed products in chicken sausages [53], hemp seed flour and protein in meat loaves [16], combining hemp seed protein with meat and fish raw materials [54]. The addition of vegetable ingredients to the recipes of meat products and their partial replacement of meat raw materials is an effective strategy for reducing meat consumption and improving the quality of meat products.

The main limitations of the study are the use of hemp seed protein grown in the Sumy region. Agricultural cultivation techniques, seed processing technologies may differ depending on geographical and climatic features in different countries. In addition, the research was conducted with only one technological group of sausage products and in a limited range of dosages of hemp seed protein in prescription ratios.

The drawback of the work is the study of the impact of protein from hemp seeds on the quality and nutritional value of cooked sausages made by traditional technology and in combination with traditional types of raw materials. Further research should determine the quality indicators of cooked sausages of a combined composition when they are combined with secondary raw materials and other vegetable proteins. Our research has a practical significance that relates to the combination of raw materials of vegetable and animal origin, which expands the assortment, contributes to the improvement of technological indicators and nutritional value of cooked sausages, as well as the profitability of production. When conducting further research, special attention should be paid to modeling the recipe composition of cooked sausages to obtain high-quality meat-rich products.

7. Conclusions

1. Studies have shown a high level of functional and technological indicators of protein from hemp seeds, which makes it a promising ingredient for use in minced meat systems. Hydrated protein from hemp seeds in a ratio of 1:1 had the best parameters for introduction into minced meat

systems, namely, MBC (79.63±1.58 %) and emulsifying capacity (38.16±2.07 %). When the hydromodule is increased to 1:3, these parameters decrease.

2. As a result of investigating functional technological properties of minced meat, it was established that the introduction of 12–16 % of hydrated hemp seed protein into the composition of cooked sausages in a ratio of 1:1 increases WBC to 97.8 %. It has been proven that the use of protein from hemp seeds in the recipe of cooked sausages leads to an increase in the plasticity of minced meat by 16.19–23.85 %, corresponding to an increase in the proportion of protein from hemp seeds. It is shown that the content of total moisture in the samples of sausages cooked with protein from hemp seeds after heat treatment is higher compared to the analog by 5.08–7.08 % and increases with the increase in the level of replacement of beef meat with hydrated protein from hemp seeds. At the same time, the yield of the finished product increases to 129.83 %.

3. It has been proven that the replacement of second-grade beef in the composition of cooked sausages with protein from hemp seeds leads to an increase in the mass fraction of protein in finished products by 14.99–19.98 %, and mineral substances by 68.52–97.22 %.

4. Our organoleptic evaluation of experimental samples of cooked sausages showed that the organoleptic indicators of cooked sausages met the requirements of the standard for cooked sausages. However, the introduction of protein from hemp seeds of more than 14 % into the product is impractical since there is a deterioration of the organoleptic properties of finished sausage products, in particular, color and taste. Our microbiological studies of the experimental samples and an analog of cooked sausages confirm the microbiological safety of the developed products. It was established that QMAFAnM in cooked sausages with hemp seed protein in the amount of 12–16 % after storage for 72 hours is from $1.8–2.1\times10^3$ CFU/g and met sanitary and hygienic requirements.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

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

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