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RESEARCH OF NUTRITIONAL AND BIOLOGICAL VALUE OF SEMI-SMOKED MEAT-CONTAINING SAUSAGE

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Abstract. This study proves the advantages of combining duck meat of regional origin with other proteinic raw materials in meat-containing semi-smoked sausages. The model for the formulation and the technology of combining duck meat of regional origin with other types of raw materials was a recipe for semi-smoked sausage containing duck meat, semi-fat pork, mid-back pork fat, and spices. The formulations developed contained meat of Peking duck, pork hearts (instead of semi-fat pork), soybean isolate, demineralised whey powder, chicken skin, and soluble dietary fibre. In the model samples of smoked sausage, the parameters studied were the qualitative characteristics, indicators of microbiological safety, nutritional and biological value. The analysis of the results of the sensory evaluation has confirmed that combining Peking duck meat with protein preparations of different origins improves the appearance of the products, their taste and smell, texture and colour. Studying the microbiological parameters of the sausages developed has indicated that the number of mesophilic aerobic and facultative anaerobic microorganisms (MAFAM) in all the samples tested was within the normal limits. The study of the number of bacteria of E. coli group has not detected these microorganisms in any of the samples. The analysis of the nutritional value of the products has allowed proving that the meat-containing semi-smoked sausages developed are high in protein, have low fat concentrations, and are low-calorie food. Combinations of protein ingredients of different origins can increase the protein content in the products developed by 29.98–31.69%, and reduce the mass fraction of fat by 31.18–35.64%. The product's high biological value by the content of essential amino acids has been confirmed, as well as the biological effectiveness by the content of fatty acids of the ω-6 and ω-3 families. It has been determined that when Peking duck meat in meat-containing semi-smoked sausage is combined with non-meat types of protein-containing raw materials (pork hearts, soybean isolate, demineralised whey powder), it allows producing nutritious products with high quality characteristics.

Keywords: Peking duck, meat-containing semi-smoked sausage, nutritional value, biological value.

Introduction. Formulation of the problem

The growing deficiency of high-value protein in the human diet poses the problem of finding its additional sources of both animal and vegetable origin. That is why it is so important to use secondary protein raw materials rationally and as fully as possible. Effective implementation of the biological and technological functionality of unconventional protein resources is possible through the development and introduction of private technologies for combined meat and vegetable products [1]. One of the challenges for the modern meat industry is reducing the production cost while achieving a high biological and nutritional value of the manufactured products. Another challenge is improving and stabilising a product's quality despite the unstable composition and properties of the raw materials processed. Thus, modern manufacturers face the need to refine the traditional approaches to

production in order to achieve the high quality, nutritional and biological value of meat products.

Analysis of recent research and publications

Nowadays, very popular is manufacturing various combined meat and meat-containing products that are enriched with protein and other ingredients and are affordable and available for a lot of consumers.

Combined meat products are meat or meat and vegetable produce in which traditional meat processing products can be used together with by-products of meat processing and with vegetable foods. When making combined products, the task is to create a quality protein-balanced product with good organoleptic properties and to equalise the varying quality of raw meat and other components of the product's recipe.

One of the raw materials that can be used in the preparation of meat-containing systems for combined products is waterfowl meat. The situation in the poultry market is advantageous as compared with that for other types of meat. In this segment, the results of the year 2015 show an increase in the production volume by 1.6 times, up to 1,143.7 thousand tons compared to 708.4 thousand tons in 1990. In particular, production in agricultural enterprises increased by 2.7 times: from 356.8 thousand tons in 1990 to 967.7 thousand tons in 2015. In households, though, production decreased by almost 50%: from 351 thousand tons to 176 thousand tons, respectively [2,3].

Duck meat ranks second in the world's poultry consumption [4,5]. It is also popular in Ukraine. Value-added combined emulsion-type products can be made from duck meat to increase their digestibility. An even more important purpose of duck meat processing is providing consumers with a variety of duck meat products, so as to increase the demand and marketability. Using duck meat in emulsions allows including by-products in the formulations (such as skin, stomach, and heart), which is enough to reduce the cost of a product and improve its yield and quality. The consumer properties of this meat type are as good as those of beef and pork [6,7].

Along with raw meat, emulsified product technologies allow using a variety of non-meat ingredients that reduce the cost of the products obtained without losing their nutritional and biological value. Non-meat supplements used as fat substitutes, fillers, binding agents include soybean flour (in buffalo meat nuggets) [8], eggs and soybean protein (in goat meat patties) [9], surimi proteins from duck meat (in emulsified products such as sausages) [10].

Studies on the development of meat-containing emulsified products based on duck meat [11-13] evidence that in their functional, technological and organoleptic characteristics, they are as good as traditional products based on pork and beef.

Thus, development of new combined foods that contain waterfowl meat is a topical task.

The purpose of the research is to prove the advantages of combining Peking duck meat of regional origin with other raw materials in meat-containing semi-smoked sausages.

To achieve this purpose, the following **tasks** were to be solved:

– to establish whether it is practical to use duck meat in the formulation of meat-containing semi-smoked sausages;

– to study the quality characteristics and indicators of microbiological safety of the meat-containing semi-smoked sausage developed;

– to analyse the nutritional and biological value of the meat-containing semi-smoked sausage developed.

Research materials and methods

To solve the above tasks, the formulation of the semi-smoked sausage *Utinaya* was chosen to be used for the sausage analogue [14].

The study used minced Peking duck meat, obtained after deboning the meat and crushing in a mincer with the diameter of the grid holes 2–3 mm.

To increase the cost efficiency, semi-fat desinewed pork was excluded from the recipe because of the higher production cost of this raw material and its decreasing offer on the market. For the experiments, instead of semi-fat pork, pork hearts were taken. The nutritional value and functional and technological properties of this first category by-product are equal to those of the main meat types.

Also, part of the pork was substituted for a soybean isolate, which is a source of protein and functionally is as good as pork, and for demineralised whey powder.

To improve the functional and technological properties of the products, chicken skin and a preparation of soluble dietary fibre were introduced into the recipe. The quantity of salt, sodium nitrite, and spices were the same in the experimental and the control samples.

The process chart of the semi-smoked sausage technology is presented in Fig. 1. The recipe variants are shown in Table 1.

In the samples of semi-smoked sausages, the sensory parameters, nutritional and biological value were determined by the standard methods. The sensory evaluation of meat-containing semi-smoked sausage was performed on a five-point scale. The following parameters were evaluated: appearance, consistency, taste, juiciness, smell, and colour. The nutritional value was determined by the computational method [15].

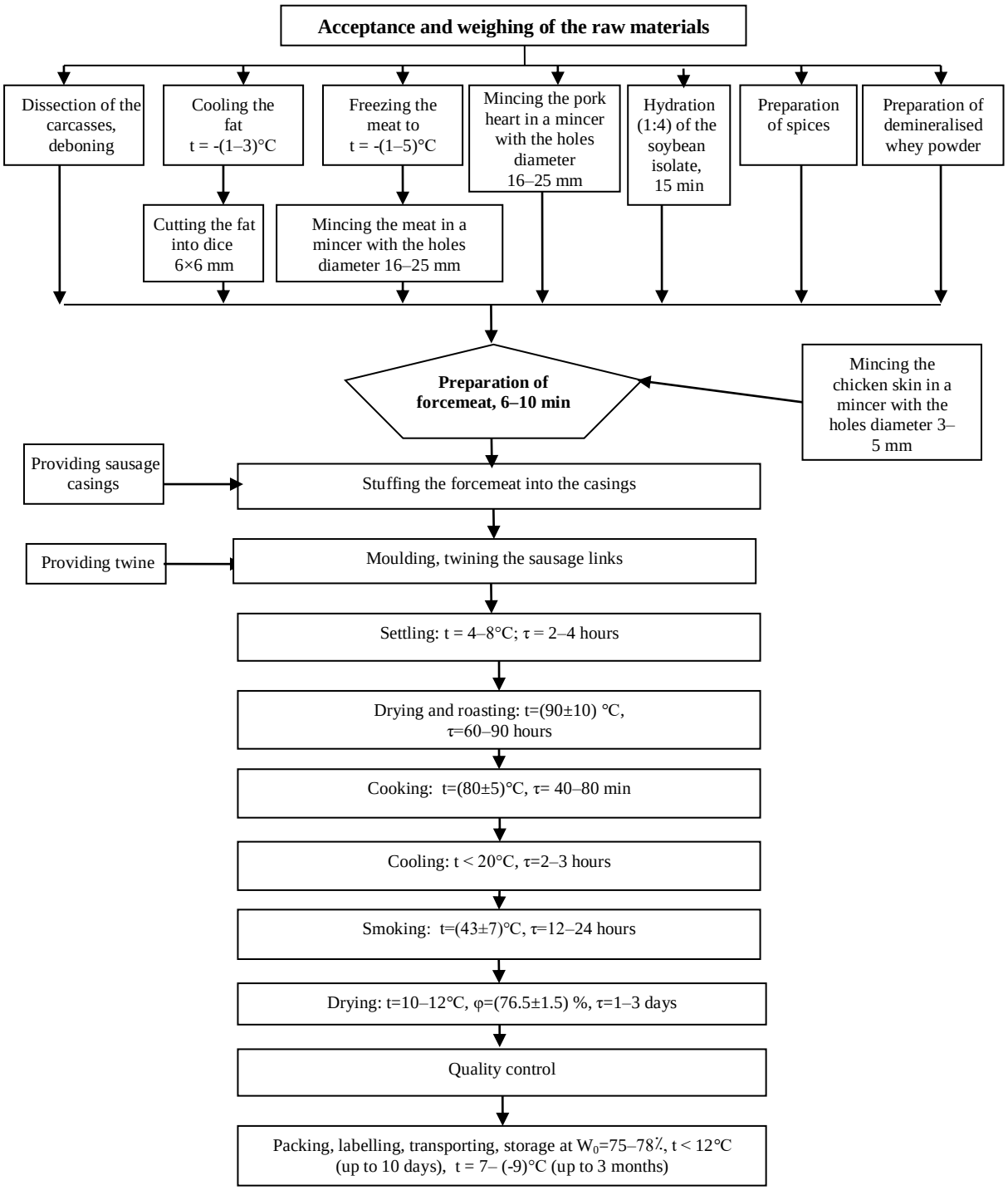

Fig. 1. Process chart of manufacturing semi-smoked sausage with duck meat

The number of mesophilic aerobic and facultative anaerobic microorganisms (NMAFAM) was determined by the method prescribed by SSTU 8446:2015.

The presence of *E. coli* group bacteria (coliform bacteria) was checked according to SSTU 8446:2015.

The amino acid composition of the sausages was determined by ion-exchange column chromatography with the amino acid analyser BIOTRONIK (Germany). The content of bound essential and nonessential amino acids was calculated in g per 100 g of the product (SSTU ISO 13903:2009). To prepare the samples, the weighed portion (0.1 g) is placed in a stoppered test-tube, and covered with 10 cm^3 of distilled water and 10 cm^3 of concentrated hydrochloric acid. The test-tube is tightly sealed and placed in a dry-heat oven, with a temperature of 130°C for 8 hours. The hydrolysate obtained is filtered through a cotton filter and washed with distilled water, its volume being 3 times as much.

The resulting solution is transferred to a porcelain cup and evaporated on an electric hot plate to the volume 0.5–1.0 cm^3. The sample obtained is then diluted with distilled water and filtered through a paper filter into a 50 cm^3 test tube. The filter is washed until the test tube is filled to 35–40 cm^3. Quantitative determination of amino acids is carried out by taking 1 ml and adding 1 cm^3 of the buffer solution with pH=2.2. The sample is passed through a membrane filter with the pore diameter 0.45 μm. 50 μl of the purified sample is selected and introduced into the chromatographic ion exchange column of the analyser. The analysis is then carried out automatically by the preset program for 115 minutes. After the completion of the analysis, the resulting chromatogram is interpreted, and the peak areas of each amino acid are calculated by the external standard method.

Table 1 – Recipes of the semi-smoked sausage samples

Ingredients	Control sample	Recipe 1	Recipe 2	Recipe 3
Basic raw material, kg, per 100 kg of unsalted raw material				
Peking duck meat	55	50	45	40
Semi-fat pork	32	–	–	–
Mid-back pork fat	13	15	15	15
Pork hearts	–	20	20	20
Soybean isolate	–	5	5	5
Demineralised whey powder	–	5	5	5
Soluble fibre (Fibra 110)	–	5	5	5
Chicken skin	–	–	5	10
Spices and auxiliary materials, g, per 100 kg of unsalted raw material				
Salt	3000	2874	2586	2300
Sugar	100	100	100	100
Black pepper	100	100	100	100
Sodium nitrite	5	5	5	5
Ground nutmeg or coriander	50	50	50	50
Fresh garlic, peeled	200	200	200	200

The fatty acid (FA) content of the sausages was determined by gas-liquid chromatography with an automated gas chromatographer Kupol-55 (SSTU ISO 15885/IDF 184:2008). To determine the FA, a sample was prepared by lipid extraction. A mixture of chloroform-methanol (1:2) and water in the ratio 30:3 ml was added to 6 g of the sample. The mixture was homogenised for 2 min. at room temperature.

The homogenised sample was centrifuged. The residue was re-extracted with 38 ml. mixtures of chloroform:methanol:water (1:2:0.8) in the homogeniser for 2 min. The extract was separated by centrifugation, the combined supernatants were diluted in 20 ml of chloroform and 20 ml water. The water-methanol and chloroform phases were separated by centrifugation. The lower layer of chloroform concentrated on a rotary evaporator at a temperature of 30–35°C. The residue was dissolved in 10 ml of chloroform.

For fattening, 10 g of fat, 3.9 g of KOH, and 50 cm^3 of 96% ethyl alcohol were combined. For 2–3 hours, the mixture was heated with a reflux condenser in an inert gas atmosphere, with the flask occasionally shaken. After this, the mixture was cooled, diluted with distilled water (1:1), neutralised with 10% H_2SO_4 to pH=7, and acidified to pH=2. The mixture was extracted in 200 ml divalent funnel by sulphuric ether. The procedure was repeated three times with the ratio 1:0.5. The combined ether extracts were washed twice with distilled water, and then dried with anhydrous sodium sulphate.

The extract was concentrated on a rotary evaporator at a temperature not higher than 40°C. After being heated in a bain-marie for 50 min., the extract was diluted with water in the ratio 1:1. Then hexane extracts were obtained. The hexane was evaporated on a rotary evaporator to give chromatographically pure methyl alcohols of fatty acids that were dissolved in hexane and chromatographed on the Kupol-55 chromatograph (Russia) on the 100 mm long column SP 2560 (USA).

The amino acid score (%) was calculated by (1) [15]:

$$AS = AAx / AAs \cdot 100, \quad (1)$$

where AS – amino acid score; AA_x – amino acid in the protein under study; AA_s – the same amino acid in standard protein or according to the FAO/WHO Amino Acid Scale [16,17] used as a standard to calculate the amino acid score.

The absolute measurement error was determined by means of Student's *t*-test, with the confidence interval P=0.95, the number of repeat determinations 3–4, the number of parallel tests of the samples 3.

Results of the research and their discussion

The results of calculating the nutritional value of meat-containing semi-smoked sausages are shown in Table 2.

Table 2 – Nutritional value of the samples under study

Parameters	Control sample	Sample 1	Sample 2	Sample 3
Protein content, g/100 g	12.81	16.65	16.76	16.87
Fat content, g/100 g	48.21	33.18	32.06	31.03
Carbohydrates content, g/100 g	–	4.27	4.27	4.27
Fibre, г/100 г	–	5	5	5
Energy value, kcal	485.13	382.3	372.66	363.83

The results presented in Table 2 indicate that the protein content of the control sample was 12.81 g/100 g, which is by 29.98–31.69% lower than in the experimental samples. The fat content decreased by 0.31–0.48%. Unlike the control sample, the experimental ones contained dietary fibre, which is explained by the use of soybean isolate and the soluble dietary fibre Fibra 110. The energy value of the tested samples varied depending on the duck meat content and in total decreased by 21.19–25.00%. The results of the sensory evaluation of the meat-containing semi-smoked sausages are presented in Fig. 2. The tasting panel noted the good appearance of the products, the pleasant taste and smell, the juicy texture, and the appropriate colour.

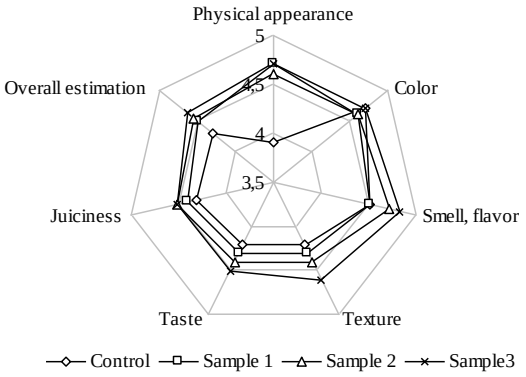

Fig. 2. Sensory characteristics of the control and the experimental samples

Combining animal and vegetable raw materials in semi-smoked sausages can result in microbiological damage. For this reason, the meat-containing semi-smoked sausages have been studied for microbiological safety. The results of the study are presented in Table 3.

The results demonstrate that in the samples with Peking duck meat No. 2 and 3, the NMAFAM is higher than in the control, but the value of these parameters is within the norm (2.5×10^3) [17,18]. The search for *E. coli* group bacteria has not detected these microorganisms in any of the samples.

According to the comprehensive assessment of the samples of forcemeat and meat-containing semi-smoked sausages, and by their functional and technology parameters [19], the best combination of the selected raw materials is Recipe 3. This sample has been selected for further study of its biological value.

The results of studying the biological value by the number of essential amino acids in meat-containing semi-smoked sausage with Peking duck meat are presented in Table 4. The study of meat-containing semi-smoked sausage with Peking duck meat has allowed identifying all essential amino acids. Analysis of the amino acid compositions of the samples has shown that among the essential AA, the highest content is that of valine (6.11 g/100 g of protein) and isoleucine (4.68 g/100 g of protein). Evaluation of the protein quality by the amino acid score (AAS) has found no limiting amino acids. The AAS of all essential amino acids was higher than 100%. This parameter for other amino acids ranged from 100.77 for threonine to 122.20% for valine. The biological effectiveness by the fatty acid content of meat-containing semi-smoked sausage with Peking duck meat can be seen from Table 5.

Table 3 – Microbiological parameters of semi-smoked sausages

Parameters	Samples of sausages			
	Control	1	2	3
NMAFAM, CFU/g, not more than	1.24×10^3	1.89×10^3	1.93×10^3	1.96×10^3
E. coli group bacteria in 0.001 g	Not found	Not found	Not found	Not found

Table 4 – Results of studying the biological value of proteins of meat-containing semi-smoked sausage with Peking duck meat

No.	Type of amino acid	Standard (FAO/WHO), g/100 g of protein	Concentration, g/100 g of the product	Concentration, g/100 g of protein	Amino acid score, %
Essential amino acids					
1	Valine	5.0	1.03	6.11	122.20
2	Methionine	1.8	0.33	1.96	108.89
3	Isoleucine	4.0	0.79	4.68	117.07
4	Leucine	7.0	1.23	7.29	104.14
5	Phenylalanine+Tyrosine	6.0	1.09	6.46	107.67
6	Lysine	5.5	1.10	6.52	118.55
7	Threonine	4.0	0.68	4.03	100.77

Table 5 – Results of studying the fatty acid composition of meat-containing semi-smoked sausage with Peking duck meat

Fatty acid type	Concentration, g/100 g of fat
Saturated fatty acids (SFA)	
Myristic C14:0	1.35
Palmitic C16:0	25.36
Margaric C17:0	2.15
Stearic C18:0	14.61
Arachidic C20:0	0.87
Total SFA	44.34
Monounsaturated fatty acids (MUFA)	
Palmitoleic C16:1	0.39
Oleic C18:1 trans	0.57
Oleic C18:1 cis	39.41
Total MUFA	40.37
Polyunsaturated fatty acids (PUFA)	
Linoleic C18:2 trans	0.12
Linoleic C18:2 cis	14.40
A-linolenic C18:3	0.77
Total PUFA	15.29

The fatty acid composition of meat-containing semi-smoked sausage was represented mainly by SFA: palmitic (25.36%), stearic (14.61%), and myristic (1.35%) acids, and by UFA: oleic (39.41%), linoleic (14.40%), and α-linolenic (0.77%) acids.

The analysis of the fatty acid content of meat-containing semi-smoked sausage with Peking duck meat confirms that the concentration of the oleic acid cis-isomer in this product is at the level of 39.41 g/100 g of fat. The total amount of PUFA was 15.29 g/100 g of fat, which included a high concentration of linoleic acid cis- and trans-isomers (14.52 g/100 g of fat) that belongs to the ω-6 family.

The nutritional value of modern meat products is determined primarily by their protein content. On the other hand, low-fat foods are becoming more and more popular. The replacement of semi-fat pork with pork hearts and protein-containing ingredients of vegetable and animal origin has made it possible to increase the protein content of semi-smoked sausages and to reduce significantly the concentration of fat by 31.18–35.64%. According to the high protein content, the products developed can be used as part of a strategy to prevent or treat obesity by reducing the body fat mass, with the muscle mass retained [20,21].

Determination of microbiological parameters is an integral part of a comprehensive assessment of food quality and safety. To check whether semi-smoked sausages with Peking duck meat and protein-containing components conform to the standard, all the samples have been tested for NMAFAM and *E. coli* group bacteria. The sausages developed are unstable in terms of sanitary-hygienic safety, but their microbiological parameters are within the normal limits, which confirms the product's microbiological safety.

The amino acid composition of meat-containing semi-smoked sausage with Peking duck meat demonstrates that this product is a valuable source of all essential amino acids. The sausage contains a large proportion of valine metabolised into the muscular tissue, normalises the nervous system, protects the myelin sheath of nerve cells, provides coordinates the body, stimulates mental activity, takes part in the synthesis of glycogen and pantothenic acid [22].

Fatty acids of the products are represented mainly by saturated acids: palmitic (25.36%), stearic (14.61%) acids; and by unsaturated: oleinic (39.41%), linoleic (14.40%), α-linolenic (0.77%). A relatively high PUFA content is a risk that oxidative processes can take place in the product during storage. To slow down the oxidative damage of fats and prolong the shelf life, prospective is the use of natural antioxidants, such as rosemary extract, cranberry extract, and other compositions [23,24].

It has been experimentally established that in the lipids of meat-containing semi-smoked sausage with Peking duck meat, the level of MUFA is 40.37%, PUFA – 15.29%, SFA – 44.34% of the total amount of fatty acids. The fatty acid composition of a food product is called balanced if it has the following ratio of certain fatty acid types: PUFA:PUFA:SFA – 1:6:3. According to nutritionists, the recommended ratio of fatty acids of the family ω-6 (linoleic, α-linolenic, and arachidonic acids) to those of the family ω-3 (α-linolenic, eicosapentaenoic, and docosahexaenoic acids) in a healthy diet should be 8:1, and in medical nutrition, from 3:1 to 5:1 [25,26]. It has been experimentally established that in the meat-containing semi-smoked sausage developed, this ratio was 10:1, because the recipe included duck meat that was high in PUFA.

Conclusions

1. It has been determined that when Peking duck meat is combined with non-meat protein-containing ingredients (pork heart, demineralised whey powder, soybean isolates, chicken skin) in meat-containing semi-smoked sausage, we can obtain high quality and nutritionally valuable products.

2. It has been proved that the developed variants of meat-containing semi-smoked sausages are high-protein, low-fat, and low-calorie foods according to the analysis of their nutritional value. It has been confirmed that duck meat can be combined with protein ingredients of different origins to increase the protein content in the developed products by 29.98–31.69% and to reduce the mass fraction of fat by 31.18–35.64%.

3. The organoleptic evaluation has confirmed that combining Peking duck meat with protein-containing raw materials of different origins improves the appearance of the products, their taste and smell, texture and colour. The study of the microbiological parameters of the sausages developed has indicated that the number of mesophilic aerobic and facultative anaerobic microorganisms in all the samples tested was within the normal limits. The

study of the number of *E. coli* group bacteria has not detected these microorganisms in any of the samples.

4. The high biological value due to the essential amino acid content and the biological efficiency due to the content of fatty acids of the ω-6 and ω-3 families have been confirmed. It has been determined that when Peking duck meat is combined with non-meat types of protein-containing raw materials (pork hearts, soybean isolate, demineralised whey powder) in meat-containing semi-smoked sausage, it allows obtaining nutritious products of high quality.

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ДОСЛІДЖЕННЯ ХАРЧОВОЇ ТА БІОЛОГІЧНОЇ ЦІННОСТІ НАПІВКОПЧЕНОЇ М'ЯСОМІСТКОЇ КОВБАСИ КОМБІНОВАНОГО СКЛАДУ

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Анотація. У роботі доведено доцільність комбінування м'яса качки регіонального походження з іншими видами білоквмісної сировини в складі м'сомісткої напівкопченої ковбаси. Аналогом для розробки нової рецептури та технології напівкопченої ковбаси з комбінуванням м'яса качки регіонального походження з іншими видами сировини була рецептура напівкопченої ковбаси із м'ясом качки та напівжирною свининою, до складу якої також входив шпик боковий та спеції. Розроблені рецептури містили м'ясо качки Пекінської, замість свинини напівжирної серце свиняче, соєвий ізолят, суху демінералізовану молочну сироватку, шкурку курячу та препарат розчинних харчових волокон. В модельних зразках напівкопченої ковбаси вивчали якісні характеристики, показники мікробіологічної безпеки, харчову та біологічну цінність. Аналіз результатів органолептичної оцінки показав, що комбінування у рецептурах м'яса Пекінської качки та білкових препаратів різного походження покращує зовнішній вигляд виробів, смак та запах, консистенцію та колір. Вивчення мікробіологічних показників розроблених ковбас свідчить про те, що кількість мезофільних аеробних та факультативно-анаеробних мікроорганізмів в усіх досліджуваних зразках була в межах норми. Дослідження кількості бактерій групи кишкової палички не виявило вказаних мікроорганізмів в жодному із зразків. На підставі аналізу харчової цінності продуктів доведено, що розроблені варіанти м'ясомістких напівкопчених ковбас мають високий вміст білку, низьку концентрацію жиру і є низькокалорійними харчовими виробами. Сполучення білкових інгредієнтів різного походження дозволяє підвищити вміст білку в розроблених продуктах на 29,98–31,69%, знизити масову частку жиру на 31,18-35,64%. Підтверджено високу біологічну цінність за вмістом незамінних амінокислот і біологічну ефективність за вмістом жирних кислот родини ω-6 і ω-3. Визначено, що при комбінуванні м'яса качки з не м'ясними видами сировини та білковими препаратами, а саме серця свинячого, соєвого ізоляту, сухої демінералізованої молочної сироватки в складі м'ясомісткої напівкопченої ковбаси, можливо виробляти повноцінні за харчовою та біологічною цінністю продукти з високими якісними показниками.

Ключові слова: пекінська качка, м'ясомістка напівкопчена ковбаса, харчова, біологічна цінність.

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