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OPTIMIZATION OF PROTEIN-LIPID COMPLEX BY ITS FATTY ACID AND VITAMIN COMPOSITION

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Abstract
The polycomponent protein-lipid compositions are traditionally used in minced meat products to regulate nutritional value, functional, technological and organoleptic characteristics of the finished product. The present article presents the results of research aimed to creation of antioxidant-enriched protein-lipid complex (PLC) with the optimal ratio ω3: ω6 of PUFA. The ratio of lipid component was optimized by linear programming method, where the recommended ratio of ω-6: ω-3 of PUFA as 10: 1 was used as term of limitation. In result of calculations the fatty component was obtained by blending of rendered beef fat with soybean oil and sunflower oil in the following ratio: rendered beef fat — 73%, sunflower oil — 15%, soybean oil — 12%. After that the PLC formulation was optimized by research of influence of the introduced protein complex in amount from 4% to 10% and the fatty component in amount from 40% to 43% on index of shear stress of the PLC. The introduced amount of protein, fat and water is taken in ratio 1:(4–7):(4–7) commonly used in the meat processing industry to form the functional and technological characteristics of the minced meat. In result of experiments the following PLC formulation was adopted, which provides the necessary stable consistency of the mixture: protein complex — 9%, fatty component — 42%, water — 49%. To enrich meat products with vitamins and antioxidants it is proposed to include into PLC an extract obtained with microwave field 800 W from the Daurian rosehips which grows in the Far East region. The obtained PLC has a high water-retaining capacity; it remains stable while heating and it can be stored for five days without any visible signs of deterioration, as the peroxide value remains within the permissible limits. PLC features optimal ratio of ω-6: ω-3 of PUFA, equal to 10:1, and a high value of the total antioxidants equal to 5.4 mg/g.

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Introduction

The creation of qualitatively new food products is one of the key directions of the state policy in sphere of healthy nutrition.

In the meat processing industry a great attention is paid to the technologies of minced meat products with introduction of polycomponent emulsions, suspensions, pastes, etc. For rational use of animal protein and lipids it is possible to introduce into those compounds by—products, for example, by—products of the II category, mechanically deboned poultry meat, poultry skin, pork skin, pork blood and its formed elements, fat raw materials undesirable for their adding in free form into minced meat in significant amount, for example — beef kidney fat, interior fat, abdominal fat and others.

Scientists of the meat processing industry nowadays offer a wide range of formulations of protein—fat complex prepared on the basis of water, plasma or stabilized blood at various ratios of protein, fat and liquid component. A wide diversity of protein preparations with high functional and technological characteristics is offered as sources of protein.

As components of protein—fat emulsions it is proposed to use chicken skin, which contains up to 25% of low—melting fat, as well as cedar nuts cake, containing up to 30% of vegetable fat [1]. To stabilize the properties of minced meat pasty made of chicken liver and mechanically deboned poultry meat, cedar cake, soy isolate and chicken skin were added in a ratio of 2.5: 1: 2.5. The optimal dose of 20% protein—fat emulsion introduction into the pasty recipe was found. It was established that use of a protein—fat emulsion contributes to enrichment of the product with essential substances, provides high consumer properties, and also solves the problem of rational use of raw materials, in particular chicken skin [1].

In order to partially replace pork fat in emulsified meat products, it is proposed to use functional emulsion gel based on chia plant and olive oil. The functional and technological properties, rheological parameters and texture of the developed emulsion gel have been analyzed. It was established that introduction of a functional emulsion gel contributes to increase in degree of gelation, decrease of moisture release and provides positive effect on the color characteristics of the finished product [2].

The work [3] is devoted to research of the functional and technological properties of beef liver and development of a protein—fat emulsion on its basis. When creating the emulsion, the authors used rendered beef fat, milk powder and soy isolate “Pro—Vo”. As a result of analysis of the ob-

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tained data it was found that when the content of fat phase in protein—fat emulsion was equal to 48.3%, after heat treatment of this composition its stratification into fractions was observed.

For the preparation of mixtures with a rational ratio of fatty acids ω-6: ω-3 in two—component (10:1, 5:1) and three—component (5:1) mixtures, sunflower, pumpkin, and linseed oils are used. The combination of mixtures of vegetable oils with a rational ratio of fatty acids ω-6: ω-3 was substantiated. The introduction of developed fortified blended vegetable oils and protein—fat emulsions based on them in amount of 15–20% allows balancing the product in terms of fatty acid and vitamin content [4].

Serdaroğlu, M. et al. obtained results of this development, producing and analysis of a double emulsion with extra virgin olive and linseed oil [5]. It was found that introduction of this emulsion in composition of a meat product allows increasing of total protein content, reducing fat content, which contributes to prolongation of shelf life, and improves technological parameters.

The possibility to obtain protein—fat emulsion on the base of animal protein Capremium 95 and powder from pomace of red—fruited rowanberries is considered [6]. The composition of the emulsion was determined as follows: Capremium 95 — from 10.5% to 11.0%; powder obtained from pomace of red—fruited rowanberries — from 6.5% to 7.0%; fatty component — from 19% to 20%. During the research it was found that introduction of a protein—fat emulsion increases the nutritional value and yield of the finished product without reducing the quality properties of the finished product.

Lukin A. A. proposed a partial replacement of meat raw materials with a protein—fat emulsion in amount of 5–10%. The influence of protein—fat emulsion on physicochemical and organoleptic characteristics of finished sausages was considered; the nutritional value of sausages was calculated. Improving of the functional and technological characteristics of the minced meat system with the emulsion was observed [7].

The research of the amino acid composition and the degree of digestibility of control sample and experimental samples of cooked sausages which were cooked with protein—containing emulsion additives is presented in the article [8]. It was found that application of this protein—emulsion additive allows replacing part of the main raw material without deteriorating the amino acid composition. Also the authors note an improvement in quality characteristics of the finished product.

When introducing the fatty component into a product, attention is paid not only to its fatty acid composition, but also to its biological efficiency which can be measured by one of its criteria — i. e. the ratio of polyunsaturated fatty acids.

The possibility of enriching turkey meat with linseed oil was shown. The introduction of this additive made it possible to provide the desired ratio of omega-6: omega-3 in minced meat systems with the help of vegetable oils, providing their nutrient—adequate balance not more than 10 units [9].

The method of blending vegetable oils into optimized fatty acid composition was studied in [10], the fatty acid composition of vegetable oils and soybean fat emulsion were compared. The developed soy—fat emulsions provide the human body with polyunsaturated fatty acids (PUFA) of the omega-6 and omega-3 families in recommended ratio. The emulsion is recommended as a fatty component in pasties of meat, fish and offal.

The possibility of using oil seeds (sesame seeds, sunflower seeds, pumpkin seeds) for production of minced meat semi—finished products was confirmed [11]. The chemical composition of sesame, sunflower and pumpkin seeds was studied. The optimal ratio of plant and animal components in terms of functional, technological and organoleptic properties was obtained. A recipe for chopped semi—finished products was developed.

For young children nutrition the targeted researches were carried out, and canned meat was developed. The chemical composition and biological value of canned food for children made of quail and chicken meat, olive and linseed oil, chicken liver, quail eggs, buckwheat or rice, mineral calcium fortifier obtained from chicken eggshells, salt and water were calculated [12]. It was found that finished products feature high biological value, possess an optimal ratio of omega-6 to omega-3 of polyunsaturated fatty acids, and are a good source of minerals and vitamins.

The use of banana flour and tapioca as a source of natural antioxidants was suggested by the authors in the article [13] in meatballs production. The optimal doses of banana flour and tapioca flour were defined at 5% each. The authors note the high content of phenols and tannins in the studied samples and recommend production of the product as functional.

The possibility of using phytoextracts (rosemary extract in amount of 0.1%, extract of green tea in amount of 0.05%) in production of frozen meat semi—finished products was studied. For uniform distribution in semi—finished products, the extracts were added during the process of the emulsion preparation. It was found that during the entire storage time of the samples (180 days) the researched semi—finished products featured high organoleptic assessment. The values of acid, peroxide and thiobarbituric value in experimental samples were lower than in the control ones, which confirms the slowing down of lipid oxidation processes [14].

The antioxidant activity of water extracts obtained from various parts of plants of lamellar (labiate) family — mint, garden mint, lemon balm and violet basil was confirmed. The extracts can be used as antioxidants in composition of vegetable oils and fat—containing products like minced meat. It was shown that extracts from violet basil have the highest antioxidant activity, the least was observed in garden mint extracts [15].

Researchers consider the optimization of the fatty component in minced meat systems as one of the important ingredients that possess high physiological activity [16, 17, 18, 19].

When creating healthy food products it is assumed to use raw materials of natural origin, which in case of their systematical application have a positive regulatory effect on certain human systems of organs or their functions, thus improving physical health and quality of life. Among the wide range of food products the share of meat products in population diet is quite high. Meat products are a source of basic substances necessary for life of a human body. However the content of substances with antioxidant properties in meat products is low in comparison with vegetable raw materials.

Therefore, research on creation of functional meat products fortified with plant materials rich in antioxidants is relevant.

Thus the relevant direction of research in sphere of creating healthy food products is the optimization of the composition of protein—lipid complexes with high nutritional value. In this regard the purpose of this study was to create a formulation of a protein—lipid complex with the optimal ratio of ω-6: ω-3 of polyunsaturated fatty acids and introduction of phytonutrients rich in antioxidant activity.

Objects and methods

Blended fatty component from rendered beef fat, soybean oil and vegetable oil, extract from Daurian rosehips, protein—lipid complex, and minced meat were taken as the object of research. To achieve the aims set in the research, the studies were run to create a protein—lipid complex containing, firstly, a fatty component with an optimal ratio of ω-6 and ω-3 polyunsaturated fatty acids, and secondly, a plant component with a high content of biologically active substances.

To ensure the optimal ratio of ω-6: ω-3 polyunsaturated fatty acids, it was envisaged to blend the fatty component based on rendered beef fat, to which oils containing ω-6 and ω-3 polyunsaturated fatty acids, such as soybean oil and sunflower oil, were selected.

Among the plant raw materials, interest was aroused by the fruits of the Daurian rosehip — a wild—growing unpretentious shrub, the fruits of which are rich in antioxidants. The rosehip extract was prepared as follows: the rosehips were carefully sorted by their quality. Then the sorted, full—fledged fruits were thoroughly washed with cold water. Then the fruits were dried at moderate temperatures (no more than 80 °C), bringing down their moisture content to 13–15%. The extract was retrieved with a water—alcohol solution with the help of electromagnetic microwave field with 800 W of capacity.

During the experiment, the following research methods were used. The mass fraction of moisture was determined by the arbitration method, by drying a weighed portion of the sample till its constant weight. Sand was placed in a weighing bottle and dried at a temperature of 103 ± 2 °C for 30 min. Then the weighing bottle with a closed lid was cooled in a desiccator, then weighed on a precision analytical balance. After that the weighed sample (weight was equal to 5 g) was introduced into a weighed weighing bottle with sand with an accuracy of 0.0001 g, 5 cm^3 of ethanol was added and mixed. The bottle was placed in a water bath and heated till disappearing of ethanol odor. Then the test sample was introduced and dried for 2 hours in a drying cabinet ShS-80–01 SPU manufactured by "Smolenskoye SKTB SPU" (Russia) at a temperature of 103 ± 2 °C, then cooled and weighed. The mass fraction of moisture was calculated as difference in the mass of the sample before and after drying. The mass fraction of protein was determined by the Kjeldahl method, based on mineralization of organic matter with subsequent determination of nitrogen content. The sample under consideration was thoroughly crushed and placed on the bottom of a flask with a capacity of 50 cm^3. 1–3 cm^3 of concentrated sulfuric acid, 1 g of a mixture of copper sulfate and potassium sulfate were added. Then the flask was heated until a brown color appeared and cooled down at room temperature. 2–3 cm^3 of hydrogen peroxide solution (mass concentration 30%) was added and heating continued on until colorless mineralizate was obtained. The mineralizate was cooled, poured into a flask with a volume of 250 cm^3, diluted to the mark with distilled water, and stirred. In a volumetric flask (with capacity of 100 cm^3), 5 cm^3 of the obtained mineralizate was diluted to the mark with distilled water. In order to execute the staining reaction, 1 cm^3 of the re—diluted mineralizate was introduced into a test tube, 5 cm^3 of reagent 1 was added (10 g of phenol and 0.05 g of sodium nitroprusside were dissolved in distilled water in a volumetric flask with capacity of 1.000 cm^3 and the volume of the solution was diluted up the mark with distilled water) and 5 cm^3 of reagent # 2 (5 g of sodium hydroxide was dissolved in distilled water in a volumetric flask with capacity of 1.000 cm^3. After cooling the initial solution of sodium hypochlorite was added to achieve its mass concentration of 0.42 g / dm^3 or 0.2 g of sodium dichloroisocyanurate. The volume of the solution was diluted with distilled water up to the mark) and stirred (the control solution was being prepared in parallel). In 30 minutes the optical density of the solutions was determined using a photometer KFK-3–01–30MZ. Main technical characteristics of the device: wavelength range 304.6–990 nm; the emitted spectral interval — no more than 5 nm; range of readings: transmittance — 0.1–100%, optical density — 0–3 B, concentration, concentration units — 0.001–9999; the limit of the permissible value in basic absolute error when measuring spectral ratio of directed transmission is 0.5%; working length of cuvettes — 1.3.5.10.20.30.50.100 mm. Measurements were taken in reference to the control solution.

The mass fraction of fat was determined with the help of Soxhlet extraction device by repeated extraction of fat with a solvent from a dried test sample. The test sample weighing 3.0 ± 0.0002 g after drying was transferred into a filter paper tube (pre—weighed) and placed in the Soxhlet extractor. The approximate duration of the extraction was 5–6 hours with solvent draining frequency 5–6 times per 1 hour. The quality and completeness of degreasing was checked by drop of the solvent to filter paper. The process was considered complete in absence of a grease stain on the filtering paper after evaporation of the solvent. At the end of extraction, the tube was removed from the extractor, dried and weighed. The amount of fat was determined by the difference between the mass of the tube before and after fat extraction.

The water and fat—retaining capacity was determined from one sample by sequential determination of moisture and fat content separated after stirring the sample for 1 min in a homogenizer, then leaving to rest for 5 minutes, then again stirring for 1 min and leaving for 5 minutes. After that the analyzed protein—fat system was placed in centrifuge tubes and was centrifuged for 10 min at a speed of 3000 rpm. The released moisture with fat was withdrawn and the content of the components was determined. The difference in moisture and fat content in the sample and in the released supernatant liquid was used to determine the water and fat retention capacity. The stability of the protein—lipid complex after heat treatment was determined as follows: a test sample was placed in test tubes, closed and heated up in water bath at 85 °C for 30 minutes, then the samples were immediately placed into refrigerator, kept there for 24 hours at 4 °C, and at this point the amount of released moisture was determined. The ultimate shear stress (ULS) was determined by a penetrometer by immersing of an indenter into the researched sample. The principle of this method is based on determining the depth of an indenter immersion of a certain mass into the analyzed sample. The container for the product was filled with the test sample, the surface was leveled with a spatula or knife, setting its level relative to the zero division of the instrument scale. The scale determined the depth of immersion of the indenter cone into the product.

The total content of antioxidants was determined by the amperometric method with the help of device “Tsvet Yauza-01—AA”. This device is designed to determine the total content of antioxidants in food, beverages, dietary supplements and medicinal products, as well as in technical products (the device is manufactured by NPO “Khimavtomatika”, Russia).

The specific gravity of fat was found by calculating the ratio of fat weight (at temperature of 18 °C) to weight of the same volume of water at this temperature. The melting point of the fat mixture was determined by melting of the hardened fat mixture in capillary with recording of the melting temperature. The pour point of the fat mixture was found from the average pour point (temperature of hardening). The optical density of Daurian rosehip fruit extract was determined using a photoelectric photometer KFK-3–01–30MZ. The peroxide value was determined by a method of measuring oxidation of hydroiodic acid with peroxides, followed by titration of released iodine. In a conical flask with a volume of 200 ml a weighed portion of a test sample of 1 g was added, 10 ml of chloroform, 10 ml of glacial acetic acid and 0.6 ml of potassium iodide were added as well. The content of the flask was stirred with rotary movements and left for 3 minutes to sit in a dark place. Then 100 ml of distilled water was poured in, stirred and 1 ml of 1% starch solution was added. Titration was run with 0.01 N sodium thiosulfate solution until the blue color disappeared. The experiment on control sample was carried out in parallel.

Results and discussion

When planning the composition of the protein—lipid complex (PLC) for finely ground meat products, studies were aimed to optimize the composition of PLC in terms of fatty component biological efficiency. The high nutritional and energy value of finished meat products does not prove the high degree and efficiency of their digestion. The biological efficiency of the fatty component, or the ratio of polyunsaturated fatty acids, especially ω-6, ω-3 PUFA play special role in formation of nutritional value of food products.

It is known that animal fats are depleted in PUFAs. Fish oils and vegetable oils are the richest in PUFAs.

In the research the experimental studies were run to increase the efficiency of the fatty component of PLC to ensure the optimal ratio of ω-6: ω-3 polyunsaturated fatty acids. This ratio is recommended for healthy people 1:10, in food products recommended for therapeutic and prophylactic nutrition 1: (2–5).

To achieve a balance of fatty acids the raw beef fat, which has a dense, solid consistency due to its fatty acid composition, is blended with deodorized vegetable oils of low cost and nutritional value.

The disadvantage of natural beef fat is a quite high pour point of 37–41 °C; to reduce this point the sample was heated at a temperature of 85–95 °C, which ensures maximum and rapid defatting of raw materials.

After rendering the pour point of beef fat dropped significantly — by ten degrees almost, and it amounted to 27–31 °C, although it was still quite high. For further reduction of the point vegetable oils were introduced into the blend, as those vegetable oils have a low pour point — from minus 15 °C to minus 19 °C and possess high nutritional value.

To design a protein—lipid complex containing a given ratio of ω-6: ω-3 of polyunsaturated fatty acids equal to 10: 1, first we studied their content in rendered beef fat and some vegetable oils. Analysis of literature data allowed selecting two types of vegetable oils for their blending to beef fat — sunflower and soybean oils, which contain a sufficient amount of ω-6 acids around 5–10 times more than ω-3 acids (Table 1).

Table 1. Composition of fatty components

Fatty acids*	Rendered beef fat, x	Refined sunflower oil, y	Soybean oil, z
Fatty acids (sum)	94.70	95.0	94.90
Saturated:	50.90	11.30	13.90
Capronic	—	—	—
Caprylic	—	—	—
Capric	0.10	—	—
Lauric	0.60	—	—
Myristic	3.40	—	Traces
Pentadecane	0.70	—	—
Palmitic	24.70	6.20	10.30
Margarine	1.40	—	—
Stearic	20.0	4.10	3.50
Arachinic	—	0.30	—
Behenic	—	0.70	Traces
Lignoceric	—	—	—
Monounsaturated:	40.60	23.80	19.80
Myristoleic	1.10	—	—
Palmitoleic	3.0	Traces	—
Oleinovaya	36.50	23.70	19.80
Gadoleic	—	Traces	—
Erukovaya	—	0	—
Polyunsaturated:	3.20	59.80	61.20
Linoleic acid 6	2.50	59.80	50.90
Linolenic 3	0.60	—	10.30
Arachidonic 6	0.10	—	—
Eicosadienoic 3	—	—	—
Docosodienic 6	—	—	—

The content of polyunsaturated fatty acids of the ω-6 and ω-3 groups in the selected fatty components is presented below in Table 2.

Table 2. Content of PUFA groups of ω-6 and ω-3 in fatty components

Fatty acids	Beef fat, x	Sunflower oil, y	Soybean oil, z
PUFA ω-6	2.60	59.80	50.90
Linoleic	2.50	59.80	50.9
Arachidonic	0.10		
PUFA ω-3	0.60	0	10.30
Docosodienic	—	0	0
Linolenic	0.60	0	10.30

Based on content of these fatty acids in the test samples and reference ratio of PUFA of the ω-6 group to PUFA of the ω-3 group as 10: 1, an equation was drawn up where we assume that the mixture contains x kg of beef fat, y kg of sunflower oil, and z kg of soybean oil. In this case the equation haw the following form:

$$\frac{2{,}6x + 59{,}8y + 50{,}9z}{0{,}6x + 10{,}3z} = \frac{10}{1},$$

As a result of simplifying this expression we obtain the following equation

$$x = 17{,}59y - 15{,}32z$$

To solve this equation we admit an arbitrary choice of vegetable oils. In this case we chose: the amount of sunflower oil — from 20 to 25 kg, soybean oil — from 15 to 20 kg, and by solving the equation the amount of beef fat was calculated (Table 3).

Table 3 shows the results of calculations of obtained variants of the blended fat mixture. To select the most optimal option the indicator of the average pour point and the average melting point of the obtained fat mixtures were investigated (Figure 1).

Table 3. Variants of recipes for fat mixture

# of blend	Beef fat, x		Sunflower oil, y		Soybean oil, z		Total, %
	kg	%	kg	%	kg	%	%
1	45.4	53.1615925	20	23.4192037	20	23.4192037	100
2	78.31	66.1905164	21	17.7499789	19	16.0595047	100
3	111.22	73.5484724	22	14.5483402	18	11.9031874	100
4	144.13	78.2762179	23	12.4911747	17	9.2326074	100
5	177.04	81.5702175	24	11.0578695	16	7.37191301	100
6	209.95	83.9967994	25	10.0020004	15	6.00120024	100

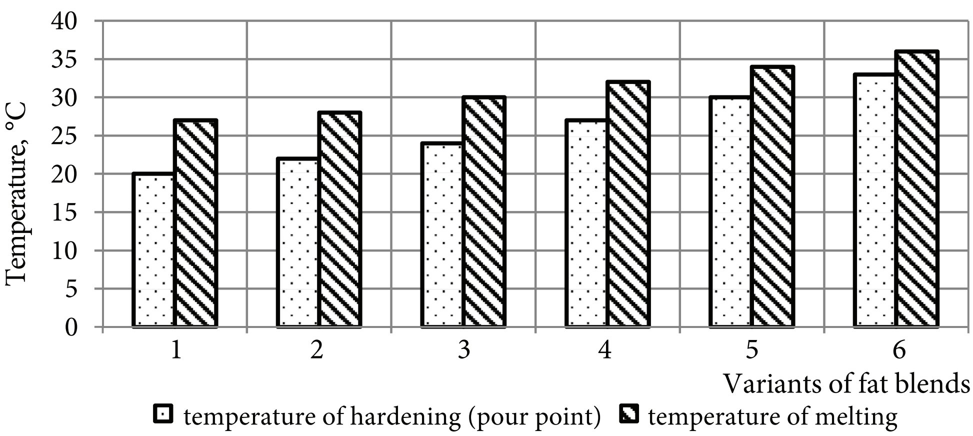

Figure 1. Average values of melting and pour points for fat mixtures

The data in Figure 1 indicate that the average values of the pouring and melting temperatures of the obtained variants of fat mixtures vary due to different ratios of fatty components, including hard—melting beef fat, albeit it was in melted state. From the data obtained it is obvious that in options 4–6 the considered values increase, that's why option 3 was chosen which provides pour point is about 25 °C — this is favorable from the point of view of organoleptic properties. The optimal composition of fat mixture is as follows: rendered beef fat — 73%, sunflower oil — 15%, soybean oil — 12%.

The physicochemical parameters of obtained fat mixture were determined, the results are presented below in Table 4.

Table 4. Physical and chemical parameters of the fat mixture

Specific gravity at 18 °C, kg/m^3	Melting point, °C	Pour point, °C	Ratio ω-6: ω-3
934.2	30–33	21–24	10:1

In order to create a protein—lipid complex with high functional and technological properties, the additive Skinprot A105 based on pork skin was chosen as a protein component. This choice is explained by results of tests of the proposed preparations. The proposed preparation, which is a finely ground cream—colored powder, remains stable after heat treatment, and it is recommended for use in minced meat and fish products. The formulation of the protein—lipid complex was improved by studying the influence of amount of the introduced protein preparation which varies from 4% to 10%, and introduction of the fatty component within limits from 40% to 43%, on ultimate shear stress value of PLC. The introduced protein preparation was limited in its amount according to the authors' information [20] that the critical concentration necessary to create gel—like structure in protein preparations varies within 5.5% to 9%. The amount of the added fatty component was taken based on the ratio of the protein preparation: fat: water as 1:(4–7):(4–7) commonly accepted in the meat industry to form the necessary functional and technological properties of minced meat products. The data obtained are presented below in Figure 2.

The data presented above in Figure 2 show that increase of injected protein preparation amount up to 9% promotes an increase in ultimate shear stress value, beyond certain point the rate of increase in ultimate shear stress value decreases.

As a result of the analysis of obtained data, the formulation of the protein—lipid complex was obtained, which provides the necessary stable structure and consistency of the mixture: protein preparation = 9%, fatty component = 42%, water for hydration = 49%. Vegetable raw materials are used to enrich meat products with essential micronutrients. We proposed to include into PLC composition a plant component — this is extract from the fruit of Daurian rosehip, which grows in the regions of Transbaikal and in the Far East region. The results of earlier studies of the vitamin composition of the Daurian rosehips showed that vitamin C in them reaches 1250 mg%, β— carotene — 6.71 mg%, vitamin E — 170.25 mg%, flavonoids — 6.8–15.6%, organic acids — 2.0–2.4% [21, 22, 23].

To increase the efficiency of the extraction process of biologically active substances of rosehips, microwave field with a power of 800 watts was used. It is known that the electromagnetic microwave field enhances the rate of substances extraction. To determine the efficiency of the extraction process, the values of the optical density of the control sample (not processed with the microwave field) and experimental sample (processed with the microwave

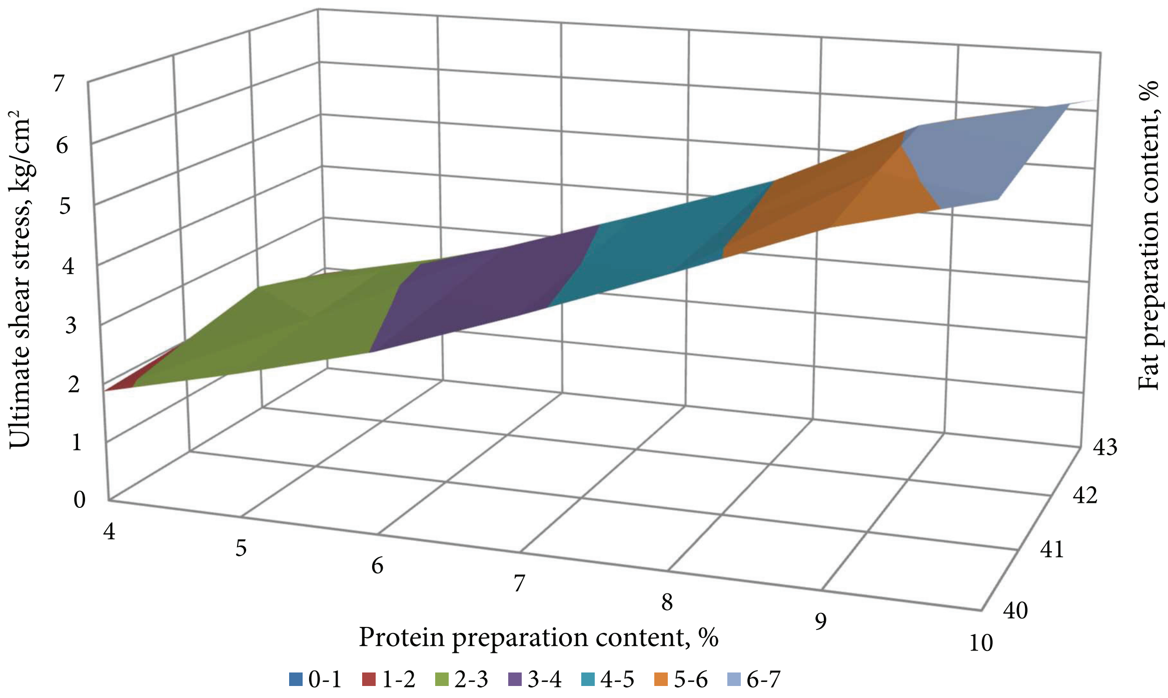

Figure 2. Optimization of the formulation of the protein—lipid complex

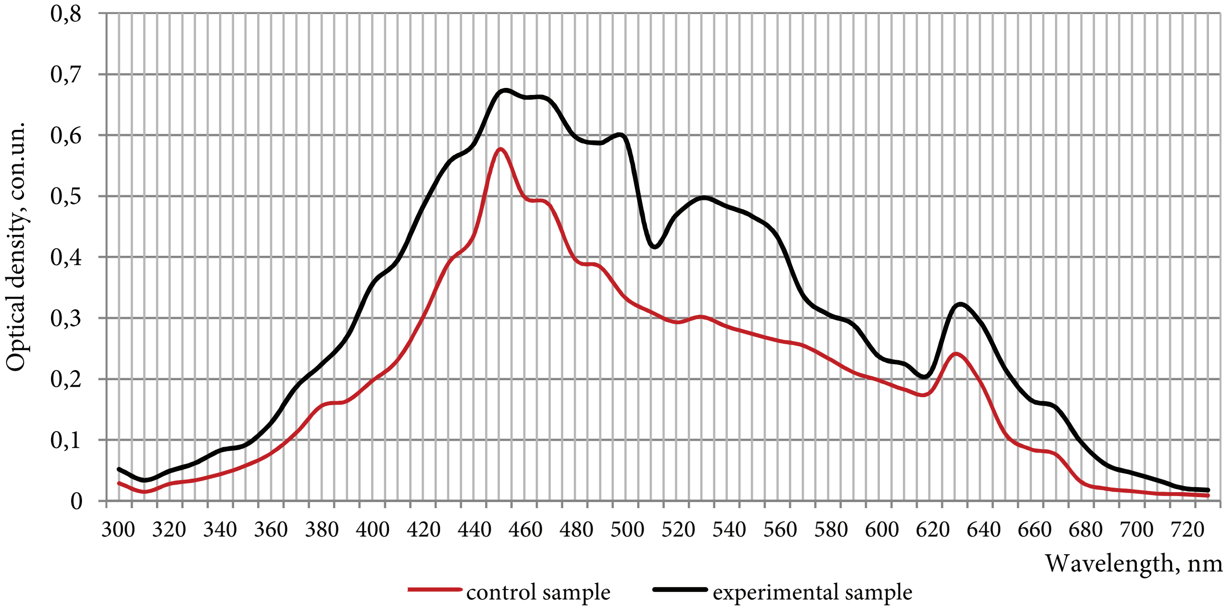

Figure 3. Optical density of rosehip extracts

field) water—alcohol extracts of the Daurian rosehips were compared (Figure 3). A water—alcohol solution is adopted as an extractant agent based on its high extracting capacity, its availability and low cost. The extraction modes were determined experimentally, the ratio of the extractant and the extracted object was chosen as 5:1 based on the analysis of the accepted recommendations for production of plant extracts.

The data in Figure 3 show the occurrence of peak optical density within the wavelength range of 440–500 nm peculiar for anthocyanins, which possess high antioxidant properties. A higher value of optical density was noted in the experimental sample, which was obtained using a microwave field, in this period compared to the control sample, which confirms the higher degree of extraction of biologically active substances.

Analysis of the organoleptic characteristics of the infusion showed that the solution is transparent, red—brown in color, has a slightly tart taste due to tannins, but has no bitterness. A high value of summary antioxidants in the extract was noted, it was equal to 131.8 mg / g. At the next stage the experiment was run to optimize the dose of the rosehip extract added. It was recommended to introduce from 4% to 8% of extract at the expense of share of water, added at the stage of preparation and thorough stirring of the mixture components. The resulting mixture was kept for 3–4 hours and the ultimate shear stress was measured (Figure 4).

Analysis of the data in Figure 4 showed that in case of adding 4% of extract, the value of the ultimate shear stress (USS) was 6.22 kg/cm^2. When the applied dose of the extract increased to 5%, the USS value remained at the same level (6.24 kg/cm^2). Further increase of dose to 6% leaded to a decrease in the USS value to 6.15 kg / cm^2, and then a more intensive decrease was observed at dose of 7% — to 5.84 kg/cm^2, at 8% — to 5.42 kg/cm^2. The decrease of USS value of the protein—lipid complex along with an increase in the content of rosehip extract was possibly related to the acidic medium of the extract, which could affect the formation of the spatial structure of PLC.

Further the sample was analyzed for its organoleptic properties with the help of external examination of the PLC with added rosehip extract. It was found that the introduction of the extract in amount of more than 6% causes a color change to purple and, with a further increase, to violet. Due to this regularity a dose of 6% of the rosehip extract was taken into the PLC composition. The enriched PLC recipe was adopted in the following ratio of components: Skinprot A105 additive 9%, Daurian rosehip extract 6%, lipid mixture 42%, water 43%.

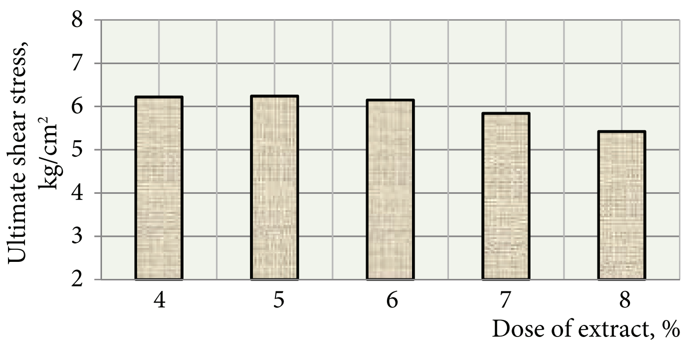

Figure 4. Influence of the dose of extract added into the PLC composition on the ultimate shear stress value

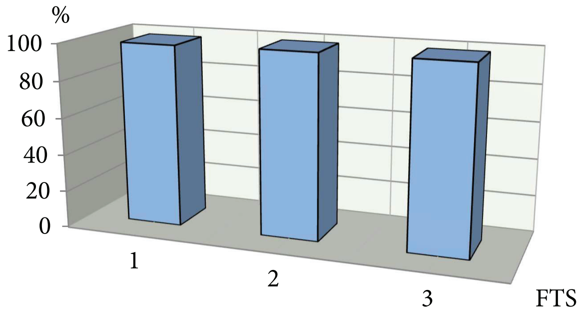

Figure 5. Functional and technological characteristics PLC
1 — water—retaining capacity; 2 — fat—retaining capacity;
3 — stability of system

The functional and technological characteristics of PLC were studied, which showed the absence of moisture and fat losses in the samples under consideration after heat treatment and after additional exposure (test for stability) (Figure 5).

High value of water— and fat—holding capacity of the protein—lipid complex was noted. One hundred percent stability of the complex was found, which was defined in the following way — the protein—lipid complex was placed in test tubes, closed and heated in a water bath to 85 °C for 30 minutes, then the samples were immediately placed in a refrigerator, kept there for 24 hours at 4 °C, and its water—holding capacity was reviewed.

An important characteristic of a food product is the preservation of its quality during storage, which can be determined organoleptically as well as chemically — the preservation is tested by peroxide value, which shows the degree of development of oxidative processes of lipids in the product. We studied the storability of PLC without added extract — control sample, and studied the one with the rosehip extract — experimental sample. The change of peroxide value of the protein—lipid complex during five days of storage at a temperature of (2–4) °C was studied (Figure 6).

The obtained data showed that in the studied samples at the initial point the peroxide value was 0.02 mmol O_2/kg. While in the samples kept for 24 hours a difference between the control sample and experimental sample is noticeable, and from 48 hours a sharp increase in the peroxide value can be noted in the control sample, i. e. up to 1.31 mmol O_2/kg, which proves the continuity of lipid peroxidation in fat—containing system and the further dynamics of a sharp increase of studied parameter is maintained throughout the entire 120 hours of the experiment. If we consider the experimental sample then it can be noted that the curve of values is stable, the increase in the value occurs rather slowly on the 96th day. For instance the peroxide value is only 0.72 mmol O_2/kg. The rosehip extract rich in antioxidants such as vitamin C, anthocyanins, flavonoids, carotene and others, contributes to interruption of the chain of chemical oxidative reactions of lipid fatty acids in the experimental sample.

On the basis of the experiments, a technological scheme for the production of PLC was developed, which includes the hydration of the protein preparation with water, then introduction of Daurian rosehips extract, and at the end of the process the lipid mixture in parts are added with thorough stirring. PLC looks like a well—emulsified pink disperse system. PLC with Daurian rosehip extract can be used in minced meat products, for example, minced semi—finished products.

According to the developed scheme the PLC was developed with extract of Daurian rosehip and the qualitative values were studied, which are presented in Table 5.

Table 5. Composition and properties of enriched PLC

Parameter	Value	Parameter	Value
Contents		Antioxidants, total, mg/g	5.4
Moisture, %	43.27 ± 0.6	Ratio ω-6: ω-3	10:1
Protein,%	8.19 ± 0.2	Stability in heat processing, %	100.0
Fat,%	42.98 ± 0.7	Peroxide value in 120 hours, mmol O/kg of fat	0.94 ± 0.1
Vitamin C, g%	102.3 ± 0.3	Vitamin E, mg%	18.3 ± 0.2

As shown by the results of studies of qualitative indicators (Table 5), PLC has high hydrophilic properties, is stable when heated, can be stored for five days without visible signs of deterioration, and the peroxide value remains within the permissible limits. PLC features optimal ratio of ω-6: ω-3 of PUFA equal to 10:1, availability of vitamins C and E, and high value of the total content of antioxidants equal to 5.4 mg/g.

Conclusion

In result of the experiment the formulation of antioxidant—enriched protein—lipid complex with optimal ω3:

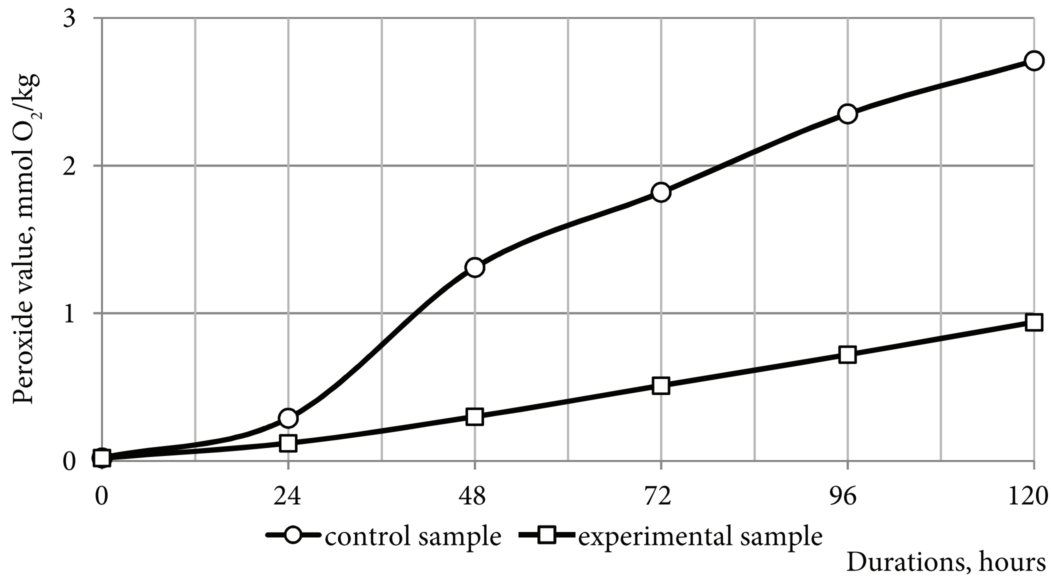

Figure 6. Peroxide values in PLC during storage

ω6 ratio of polyunsaturated fatty acids was optimized. The fatty component was prepared by blending of rendered beef fat with soybean and sunflower oils in the ratio: rendered beef fat 73%, sunflower oil — 15%, soybean oil — 12%. To enrich the protein—lipid complex with vegetative antioxidants the water—alcoholic extract of rosehips is introduced into the composition. The rosehip extract was obtained using a microwave field. The formulation of the protein—lipid complex was adopted, which provides the necessary stable consistency of the mixture: protein preparation — 9%, fatty component — 42%, water for hydration — 49%. Research results have shown that PLC possesses high water—retaining capacity, it is stable when heated, it can be stored for five days without visible signs of deterioration, since the peroxide value remains within the permissible limits. The protein—lipid complex features the optimal ratio of ω-6: ω-3 PUFA equal to 10: 1, availability of vitamins E and C and high value of total antioxidants equal to 5.4 mg/g.

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