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IMPROVING THE TECHNOLOGY OF RESTRUCTURED HAM-TYPE PRODUCTS FROM TURKEY MEAT AND PSE PORK

I. Shevchenko[1], Doctor of Engineering Sciences, Professor
G. Polishchuk[2], Doctor of Engineering Sciences, Professor
O. Topchii [1], PhD, Associate Professor
Ye. Kotliar[3], PhD, Associate Professor
T. Osmak [2], PhD, Associate Professor
[1] Department of meat and meat products technology
[2]Department of milk and dairy products technology
National University of Food Technologies, 68 Vladimirskaya St., Kyiv, Ukraine, 01601
[3]Department of milk technology, oil and fat products and beauty industry
Odessa National Academy of Food Technologies, 112, Kanatna St., Odesa, Ukraine, 65039

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Correspondence:

Ye. Kotliar
E-mail: yevhenii11@ukr.net

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Abstract. The research has proved the practical importance of using a biopolymer complex of thermostable animal proteins with functional and technological properties as a component of restructured ham-type products. It has been established that the water-holding and fat-holding capacity and the stabilising power of meat products significantly increase due to the introduction of the biopolymer complex developed by the authors, which contains sodium caseinate, buttermilk powder, and blood plasma Vepro 75 PSC. The experiments have confirmed that a protein-in-fat emulsion based on a biopolymer complex of thermostable animal proteins, a protein stabiliser obtained from turkey skin, and pork and turkey fats can be used as a component of restructured ham-type products from PSE pork and turkey meat. Thus, 5, 10, 15, and 20% of the protein-in-fat emulsion added to the formulations of restructured hams from low-fat pork and turkey meat increase the water-holding capacity of model meat systems by 7.49–9.05%, and their fat-holding capacity by 8.11–9.32%. Regular patterns have been established in how the stability of the functional and technological properties of the protein-in-fat emulsion changes throughout storage, depending on the nature and the content of a protein preparation (Vepro 75 PSC, sodium caseinate, buttermilk) and on the fat composition. It has been proved that the introduction of a protein-in-fat emulsion into the composition of hams allows obtaining products with improved and persistently high consumer properties. It has been confirmed that 0.35% of powdered sweet potato juice, in the presence of 0.025% of the starter culture of *Staphylococcus carnosus*, can be included in the composition of restructured ham-type products from PSE and turkey meat to colour them rosy-red, thus making it unnecessary to use sodium nitrite, a hazardous chemical. Sweet potato juice powder used in the presence of 0.025% of *Staphylococcus carnosus* has been found to reduce the residual amount of sodium nitrite to 3.10–3.11 mg/100 g, because nitrate transforms into nitroso compounds more completely. The results of the study are of practical significance and will be helpful in expanding the range of restructured ham-type products of enhanced nutritional value.

Key words: biopolymer complex, sweet potato juice powder, *Staphylococcus carnosus* starter culture, colouration, restructured ham-type products.

Introduction. Formulation of the problem

Besides the economic factors making meat products competitive, there are other ones, which are becoming more and more important. They include the problems of increasing the products' nutritional and biological value, their environmental and safety according to domestic and international standards, in particular, to the Technical Regulations of the EU countries. In the context of Ukraine's international integration, manufacturing high-quality, safe, and environmentally friendly meat products is a task of special importance. On analysing the diet of different social groups in Ukraine, it has become clear that today's consumption of meat and meat products cannot satisfy the body's need in proteins, primarily in those of animal origin [1,2]. The protein content of a finished meat product determines its biological and nutritional value. That is why an important objective of a technological process is full utilisation of additional protein sources and the maximum realisation of their properties.

Throughout the last decade, researchers from different countries have been persistently searching for alternative protein-containing raw materials. The most promising ones include not only byproducts obtained from slaughter and processing poultry and animal carcases, but also concentrates and isolates of plant and animal proteins [3,4]. That is why it is so vital to study factors determining the quality, safety, and consumer properties of products to be sold in shops.

A priority area of science and technological practice is creating theoretically grounded ways of developing new technologies of restructured ham-type products. These ways are aimed at modelling their composition in accordance with the current biomedical requirements. Still great is the interest to processing meat raw materials where autolytic processes are of non-traditional character. The decreasing supply of meat raw materials and increasing occurrence of PSE defective meat make it necessary to improve the existing technologies that would allow efficiently utilising these materials [1-6]. A solution to this problem can be using protein-containing biopolymer complexes with functional and technological properties that would result in meat products of sustained quality and full biological value.

Introduction. Formulation of the problem

Today's range of meat products is expanding due to new raw materials with certain functional properties and by improving the existing technologies. Attempts to use individual protein additives in the traditional technologies of restructured hams do not produce the desired effect, because the resulting meat systems are not functional enough [7,8]. The most promising way to wider application of animal proteins is combining them based on their biological balance and functional compatibility, and thus, implementing new approaches to developing technologies of meat products, in particular, of restructured hams.

Animal proteins are the ones effective as emulsifiers and structure stabilisers due to their high water-binding and fat-binding capacity. To stabilise emulsions, it is practical to use protein preparations, which allows enriching a finished product with nutrients a person needs. Functional and technological proteins of animal origin include a group of preparations based on collagen-containing raw materials and on proteins obtained from biologically complete raw materials like plasma proteins or pork trimmings [1-6]. Plasma-based preparations are more effective, in particular, their fat-binding capacity is higher, so they can be applied to stabilise protein-in-fat emulsions [7-9]. Unlike meat proteins, those of milk do not contain purine bases, which, when excessive, hamper the metabolism in the body [9-13].

The studies by E. Dickinson, N. Kenijz, A. Nesterenko, D. Shkhalakhov, H. Feiner prove that the juiciness and tenderness of meat products greatly depend on fat in their composition [4-8]. However, fat should be added to meat systems but as emulsions, since in this form, fat is better stabilised by the protein component and assimilated by the human body. Emulsified fat and vitamins dissolved in it are effectively absorbed in the digestive tract due to a larger interface with enzymes involved in digestion [10,11].

On the other hand, when developing new restructured hams of high quality and safety, the chemically hazardous substances present in their composition must be replaced with natural ingredients too.

To reduce the proportion of sodium nitrite added to salt-preserved meat, today's technologies use various colouring additives. However, even natural colouring compounds of plant origin cannot ensure a product's full toxicological safety: they can contain undesirable components such as alkaloids or physiologically active glycosides. Synthetic food colourants have significant technological advantages over those of natural origin: they are less sensitive to the conditions of technological processing and storage, and they produce bright, easily replicated colours. However, unlike natural colourants, they show no bioactivity, contain no flavouring agents and vitamins, can be carcinogenic, mutagenic, or allergenic [8].

The colourant FruitMax® by the company Chr. Hansen is a plant concentrate based on sweet potatoes Hansen™. The colourant is fully compliant with the General Food Law Regulation (EC) 178/2002 (with the latest amendments) and European Regulation No. 1881/2006/EC, which prescribes the threshold levels of certain food ingredients. The nitrite-reducing starter culture is *Staphylococcus carnosus*. The colour intensity, flavour, and aroma of meat products are determined by the effect of staphylococci present in the composition of starter cultures. According to Chr. Hansen's recommendations, the plant concentrate FruitMax® has the colouring properties that make it possible, in the presence of the nitrite-reducing starter culture *Staphylococcus carnosus*, to use powdered sweet potato juice instead of sodium nitrite in order to colour restructured ham products made from low-myoglobin raw meat.

Thus, further research is needed on how meat product technologies can use protein-in-fat emulsions based on a complex of functionally compatible animal proteins and a plant concentrate, which, even in small quantities, can significantly affect the technological processes and the formation of the quality of finished products [8,11,12].

The **purpose of the research** is improving the technology of restructured ham-type products from turkey meat and PSE pork by using protein-in-fat emulsions and a natural colouring preparation in their composition.

The **objectives** of the research:

1. To give theoretical reasons for using a biopolymer complex of animal proteins in the composition of protein-in-fat emulsions (PFE) and restructured ham products.

2. In order to control the properties of exudative muscular tissue of PSE pork, to study whether part of the meat raw material can be replaced with PFE, and to determine by experiment how much of it restructured hams should contain.

3. To study whether sweet potato juice powder can be used as a colouring ingredient in the composition of restructured hams high in myoglobin-free raw materials, and to recommend how to use it in the technology of restructured hams made from low-myoglobin meat.

Research materials and methods

The materials selected for the research were turkey meat (DSTU (State Standard of Ukraine) 3143:2013), low-fat pork (DSTU 7158:2010), plasma protein Vepro 75 PSC from Veos (Netherlands), sodium caseinate and powdered buttermilk from DairyCo (Ukraine), the colourant FruitMax® (Denmark). The colourant used was a plant concentrate from Chr. Hansen based on a combination "sweet potato Hansen™ + colourant FruitMax®." Powdered sweet potato is dark red, easily soluble in water, and the pH of its 10% solution is 2.7–3.4. The nitrite-reducing starter culture used was *Staphylococcus carnosus*, of the genus *Staphylococcus*, from Chr. Hansen (Denmark). The functional and technological properties of the biopolymer complex with a well-balanced amino acid content (sodium caseinate, buttermilk, plasma 75 PSC, in the ratio 1:1:1) were studied on model meat systems based on low-fat PSE pork (50%) and turkey meat (50%) [8].

To improve the sensory qualities of restructured ham-type products of enhanced biological value and to achieve their well-balanced amino acid and fat composition, a rational formulation of a protein-in-fat emulsion has been developed. Linear programming was used to calculate the fat composition for the PFE from turkey and pork fats by the criterion of optimality of polyunsaturated fatty acids, with the recommended ratio of the essential fatty acids ώ-3:ώ-6 being 67:33.

The composition of PFE 1 (control): boiled pork skin 14%, pork fat 43%, drinking water 43%.

The composition of PFE 2: biopolymer complex 1%, protein stabiliser from turkey skin 13%, pork fat 14.2%, turkey fat 28.8%, drinking water 43%.

The composition of PFE 3: biopolymer complex 2%, protein stabiliser from turkey skin 12%, pork fat 14.2%, turkey fat 28.8%, drinking water 43%.

The composition of PFE 4: biopolymer complex 3%, protein stabiliser from turkey skin 11%, pork fat 14.2%, turkey fat 28.8%, drinking water 43%.

The composition of PFE 4: biopolymer complex 4%, protein stabiliser from turkey skin 10%, pork fat 14.2%, turkey fat 28.8%, drinking water 43% [6, 8].

To prepare PFE in a chopper Talsa K15neo, a biopolymer complex of animal proteins was pre-hydrated in water for 5×60 s. The raw fat material was chopped separately at the rate 3000×60 s^{-1} for (3–5)×60 s at 10°C. Then it was added to the chopper with animal proteins, and further emulsified for 3×60 s. To lower the temperature and obtain a stable emulsion, some of the water was introduced as ice.

The model meat systems based on low-fat pork (42.5%), turkey meat (42.5%), and the PFE (15.0%) were supplemented with 0.30%, 0.35%, and 0.40% of sweet potato juice powder FruitMax® in the presence of 0.025% of *Staphylococcus carnosus*. The control sample was a meat system where the colour was stabilised by adding 0.0075% of sodium nitrite.

The mince samples obtained were massaged in a tumbler Inwestpol MAL-20 for 6 hours according to the programme the authors found suitable and efficient (rotation 15×60 s, pause 15×60 s), with the vacuum level in the tumbler not less than 90%, and the temperature 4°C. When the time remaining to the end of massaging was 15×60 s, powdered sweet potato juice and a starter culture of *Staphylococcus carnosus* diluted in warm water were added. On completion of massaging, the meat mass was shaped baguette-like into pieces of up to one kilogram, left in a settling chamber for 180×60 s at 4–6°C while the reaction of reduction of nitrate to nitrite was taking place, and heat-treated in a combi steam oven Unox until the temperature inside the product was 70±2°C.

Before and after the heat treatment, the sensory parameters of all the samples were determined: their appearance, cross-sectional view, smell, taste, juiciness, consistency. Other parameters studied included the physicochemical (pH, content of moisture, protein, ash, fat, residual content of $NaNO_2$), functional and technological (emulsion stability, water-binding, emulsifying and fat-holding capacities, yield), and mechanostructural ones (cutting force, critical shearing stress). The content of total pigments and nitroso pigments was found too.

The sensory parameters were determined on a five-point scale according to DSTU 4823.2, the moisture content according to DSTU ISO 1442:200, the content of protein substances in the product according to DSTU ISO 1871:2003, the fat content according to DSTU ISO 1443:2005, the mass fraction of ash by DSTU ISO 936:2008.

The water-binding capacity (WBC) of the objects of research was determined using the press method of R. Grau and R. Hamm (in V. Volovinska and B. Kelman's modification). The method is based on exudation of water from a 300 mg portion of material pressed for 10 minutes with a 1 kg load. The parameter is measured by the size of the spot left on a sheet of filter paper after it has sorbed the moisture exuded. The spot of the pressed meat is outlined with a pencil, and the size of the wet spot (the outer one) is calculated from the difference between the total area of the spot and that of the spot left by the product (meat). The content of bound moisture was calculated according to the formula:

$$WBC = \frac{(A - 8.4B)100}{A} \quad (1)$$

where WBC is the content of bound moisture, % of the total moisture;

A is the total moisture content in the weight portion under analysis, mg;

B is the area of the wet spot, cm^2.

The stability of the emulsion (ES) obtained from coarse-cut raw material was determined by heating at 80°C for 30×60 s followed by cooling with water for 15×60 s. Then four calibrated centrifuge tubes, each 50 cm^2 in volume, were filled with the emulsion and centrifuged at the rotation frequency 500 s^{-1} for 5×60 s. After that, the volume of the emulsified layer was measured. The emulsion stability was calculated according to the formula:

$$ES = \frac{V_1}{V_2}100 \quad (2)$$

where V_1 is the volume of oil emulsified, cm^2;
V_1 is the total volume of the emulsion, cm^2.

The emulsifying capacity (EC) was determined after centrifuging the mixture of oil, water, and emulsion at the rotation frequency 500 s^{-1} for 10×60 s. After that, the volume of the oil emulsified was measured, and the emulsifying capacity was calculated according to the formula:

$$EC = \frac{V_1}{V_2}100 \quad (3)$$

where V_1 is the volume of oil emulsified, cm^2;
V_1 is the total volume of the oil, cm^2.

The bound moisture in the samples under study was quantified using the device *Axis*. The laboratory moisture-analysing scales from the company *Axis* meet the standards of GOST (State Standard) 24104-88. The prepared samples under analysis were put on a single-use foil dish that was placed into the drying chamber of the moisture-analysing scales. The device was then adjusted, and the material dried. The end of drying was signalled by a special sound.

The pH of all the products was measured according to DSTU ISO 2917-2001 using a laboratory pH meter of the OR-205/1 family.

The content of total pigments was established according to DSTU ENV 12014-3:2003. The colour characteristics were determined in the colour measuring system dCIELab: D65-10, using the software Demo Painti, by the spectra of the image on a spectrophotometer X-riteCi 7600/Ci 7800 equipped with a unit for solid bodies ISO 15076-1:2010. A function programme able to find regression coefficients was written in the Mathcad 15 environment. The programme was used to build mathematical models of the colouration of restructured ham products containing powdered sweet potato juice combined with nitrate-reducing microorganisms as a colourant.

The experiments were done in triplicate. The research involved the methods of mathematical planning of experiments, processing of the data, and their visualisation using computer techniques. The findings were processed by means of the spreadsheet Excel 2003, 2007, the problem-oriented software package for mathematical calculations Mathcad, MATLAB, and statistical data processing.

Results of the research and their discussion

To enrich restructured ham products with complete protein from an additional source, a biopolymer complex of animal proteins has been composed and calculated. By its essential amino acid content, it is close to the FAO/WHO standard. The complex includes the protein Vepro 75 PSC, sodium caseinate, and buttermilk in the ratio 1:1:1 respectively [10]. Considering the fact that the emulsifying capacity of proteins is widely used to obtain fat emulsions, it has been investigated how well the biopolymer complex and its components can emulsify fat. The findings are presented in Table 1.

It has been established that the emulsifying capacity of the biopolymer complex is by 4.2% lower than the value of this parameter for plasma proteins Vepro 75 PSC, and is by 5.8% and 8.2% higher than that of the proteins of, respectively, sodium caseinate and buttermilk. When expressing the data obtained in terms of the protein contained in the ingredients under study, it becomes clear that the proteins in the composition of the biopolymer complex emulsify fat somewhat more effectively than sodium caseinate and buttermilk do (by 5.8% and 8.2% respectively).

Table 1 – Emulsifying properties of the biopolymer complex of animal proteins and its components (n=3; P≥0.95)

Components	Mass fraction of protein, %	Emulsifying properties, %		Emulsion stability, %
		of a component	of protein	
Biopolymer complex of animal proteins	68.3±3.2	75.4±3.3	110.4±4.5	68.8±3.2
Sodium caseinate	94.2±3.1	98.5±4.1	104.6±4.6	71.0±3.3
Vepro 75 PSC	75.3±3.1	86.3±3.9	114.6±4.8	66.2±2.9
Buttermilk powder	36.3±1.5	37.1±1.0	102.2±4.6	64.2±2.7

It may be because the presence of both hydrophobic and hydrophilic groups in the same protein chain determines a certain distribution of molecules on the interface of the water and fat phases. The hydrophilic protein groups are oriented towards water, and the hydrophobic ones towards fat. This orientation, which has a form of a strong adsorption layer on the phase interface, reduces the surface tension in dispersed systems and makes them aggregatively stable and at the same time viscous [7,8].

By its emulsion stability (Table 1), the biopolymer complex of animal proteins is inferior to 2.2% sodium caseinate, but forms a more stable emulsion than blood plasma and buttermilk do (by 2.6% and 4.6% respectively) [9,10]. This is due to the synergistic interaction of the proteins selected.

To develop recommendations how to use the biopolymer complex as a functional and technological ingredient in the formulations of restructured hams from low-fat pork and turkey meat, we have analysed the chemical composition and functional and technological properties (FTP) of the model meat systems containing different amounts of this ingredient.

Fig. 1 shows the functional and technological properties of the protein-in-fat emulsions developed differing in their composition and containing the biopolymer complex of animal proteins.

The emulsions obtained remain stable when heated to 70–72°C, which is clear from the results of determining the emulsion stability (Fig. 1). The samples PFE 4 and PFE 5 have the maximum values of this parameter (62.4 to 62.7%), which means that these emulsions more firmly hold water and the fat component in their protein matrix. Analysis of the findings indicates better functional and technological characteristics of PFE 4, which is made using 3% of the biopolymer complex. This may be because combining blood plasma with non-plasma proteins (sodium caseinate, buttermilk powder) significantly increases the strength of gels and their water-absorption and fat-absorption capacity after heat treatment [10, 14].

The most significant parameter characterising the state and properties of the muscular tissue proteins, the functionality of the PFE and the whole meat system is the water-binding capacity. The study of the water-holding capacity (WHC) of the heat-treated samples from turkey meat and PSE pork has proved that with PFE 4 introduced, meat systems from turkey meat and PSE pork bind and hold water better (Fig. 2).

Analysis of the research data has shown that with an increase in the PFE content of the model meat systems under study, their WHC increases by 2.97, 3.74, 6.16, and 6.30%. It has been found that the meat systems have the highest WHC when the PFE content is 15 and 20%. So, the more PFE the test samples of restructured hams contain, the higher is the WHC of the meat systems from turkey meat and exudative pork, as compared with the control sample containing no PFE. Thus, with the minimum PFE content (5.0%), the WBC of a meat system is by 2.17% higher than it is in the control sample, and the difference in the WBC values of the experimental sample containing 20% of PFE and the control one is 8.16%. It can therefore be said that under these conditions, the biopolymer complex of animal proteins contained in the PFE is able to bind not only water for its own hydration, but also some moisture contained in accordance with the formulation. This has a positive effect on the WBC of model meat systems from turkey meat and PSE pork [1-6].

Analysis of the samples containing different amounts of the PFE has shown that adding 15 and 20% of it results in the most significant weight loss (Fig. 2). These results may be due to specific features of the composition of the biopolymer complex of animal proteins, to their quantities and functional compatibility [7, 8].

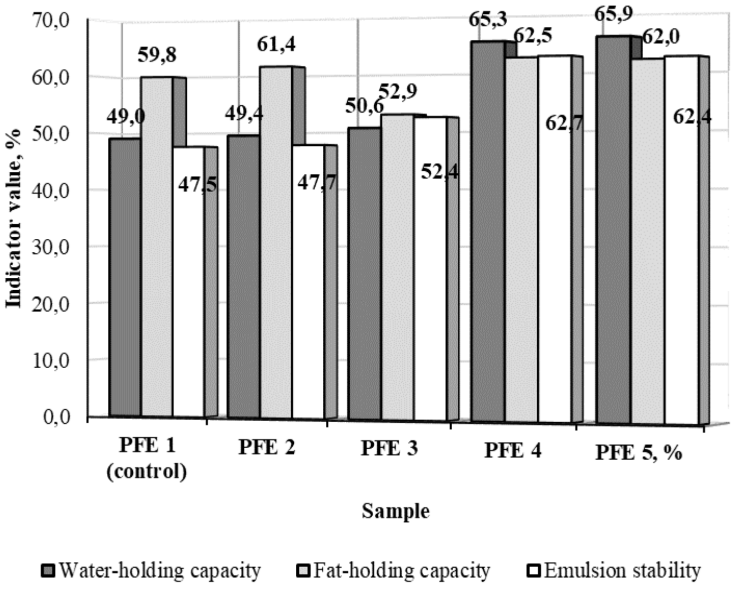

Fig. 1. Functional and technological characteristics of the PFE with the multifunctional animal protein composition

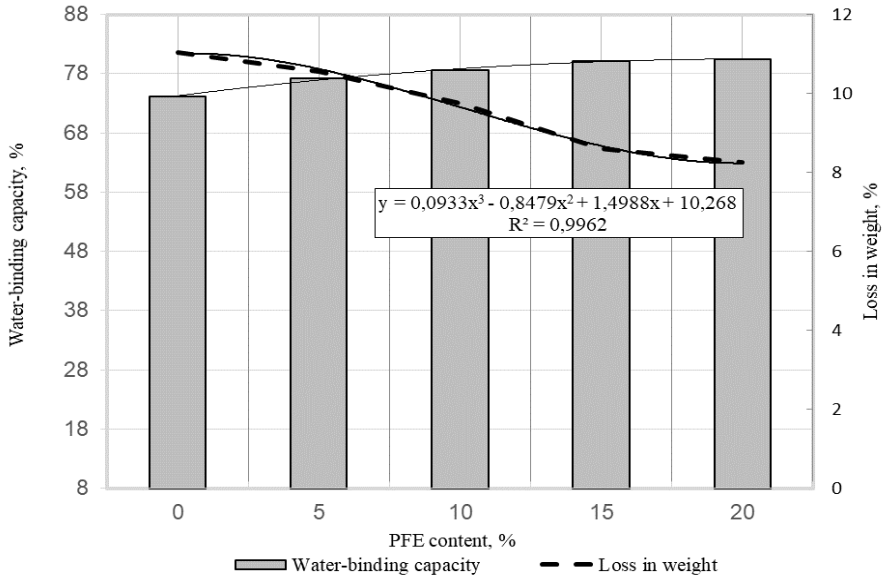

Fig. 2. Dependence of the WHC and losses in weight in heat-treated model meat systems from turkey and PSE meat on different PFE contents

When the mass fraction of the PFE in the experimental samples increases to 20%, this leads to a further decrease in weight losses during heat treatment, because a larger amount (4%) of the biopolymer complex is introduced. The change in this parameter, though, is less significant. The data on the weight losses in the model hams heated to 70±2°C correlate with the results of determining the WBC of their model meat systems. Besides, they indicate that the biopolymer complex can hold not only hydrated water, but also some moisture contained in accordance with the formulation. This has a positive effect on the WHC of model meat systems from turkey meat and PSE pork [2].

Table 2 shows the results of studying the physicochemical, functional, technological, and mechanostructural characteristics of restructured hams from turkey meat and PSE pork [10].

Thus, the research results have allowed establishing that different quantities of the PFE introduced into the formulations of the model samples have a positive effect on their physicochemical properties. The changes in the values of these parameters are proportional to the increase in the PFE content. The model samples with different PFE contents have different functional properties, which are mostly better than those of the control samples and can be intentionally modified to a certain extent. This makes it possible to choose a combination of raw ingredients that allows retaining the traditional sensory qualities of meat products as fully as possible [15, 16].

Analysis of the data in Table 2 shows that the PFE in the composition of restructured hams from low-fat pork and turkey meat (added in the quantities 5, 10, 15, and 20%) increases the water-holding capacity of model meat systems by 7.49–9.05% and the fat-holding one by 8.11–9.32%. A further increase in the content of the emulsion (up to 25%) has no pronounced effect on the WHC.

Table 2 – Physicochemical, functional and technological parameters, and mechanostructural properties of the samples of restructured hams (n=3; P≥0.95)

Parameters	PFE content, % of the weight of a sample				
	0	5	10	15	20
Mass fraction of moisture, %	69.0±2.2	71.0±2.3	71.6±2.8	73.4±2.2	74.8±2.2
Mass fraction of protein, %	16.6±0.2	16.1±0.2	15.6±0.2	15.1±0.2	14.8±0.6
Mass fraction of fat, %	13.6±0.6	12.0±0.2	11.9±0.4	10.6±0.5	9.5±0.5
Mass fraction of ash on a dry basis, %	0.70±0.001	0.73±0.001	0.74±0.001	0.74±0.001	0.74±0.001
pH	5.9±0.2	6.21±0.2	6.23±0.22	6.24±0.1	6.2±0.1
WHC, %	67.6±2.1	75.1±2.1	75.6±2.2	76.19±2.28	76.6±2.1
FHC, %	68.5±2.3	76.6±2.3	76. 9±2.3	77.5±2.3	77.8±2.0
Yield, %	112.1±2.4	117.2±2.3	121.1±2.4	127.3±2.5	132.5±2.3
Residual $NaNO_2 \times 10^{-3}$	3.92±0.02	3.74±0.01	3.65±0.01	3.54 ±0.01	3.47±0.01
Cutting force, $Pa \times 10^{-5}$	1.84±0.02	1.73±0.02	1.68±0.02	1.65±0.02	1.62±0.02
Critical shearing stress, kPa	21.84±0.67	21.23±0.44	20.75±0.65	20.09±0.62	19.91±0.59

This dependence can be explained by the increased mass fraction of protein in the PFE and, consequently, in the composition of the restructured hams. With 5–20% of the emulsion added, the fat-holding capacity of the ham samples has been registered to grow by 9.3%, as compared with the control. A higher proportion of the PFE (up to 25%) in the restructured hams from low-fat pork and turkey meat results in no increase of the parameter.

Generally, using the PFE definitely improves the structure of restructured hams, and this is also confirmed by the results of studying their mechanostructural properties (cutting force, critical shearing stress). The functional and technological properties of the samples, too, show the positive dynamics of changes, which results in larger output of finished products and in reduced losses during heat treatment. The research has confirmed that using emulsions with the composition suggested improves a product's consumer properties. At the same time, this can be a solution to the problem of utilising turkey skin. The biological value of this secondary raw material, due to its well-balanced amino acid composition, is over 88% [17].

Nevertheless, the decisive factor for any food products developed is their sensory evaluation. The general sensory rating of the experimental samples of restructured hams is quite high (Fig. 3).

The sensory evaluation results have shown that the test samples have a juicier consistency though are still resilient, elastic, and monolithic, as compared with the control samples. The taste and smell of the experimental ham samples are better than those of the control ones, the latter being of a drier and harder consistency. Indirectly, it has also been established by the results of studying the output of heat-treated samples of restructured hams (Table 3). Tasting has shown that the samples with 20% of the PFE had a pronounced sweetish hint of taste, whereas the products with 15% of the PFE or less were not too sweet and tasted better than the control products.

Based on the physicochemical, biological, and sensory examination of the model samples of restructured ham products, preference was given to those with 15% of the PFE.

The next stage involved considering whether sweet potato juice powder could be used as a colouring ingredient in the composition of restructured hams high in myoglobin-free raw materials (Table 3) [10].

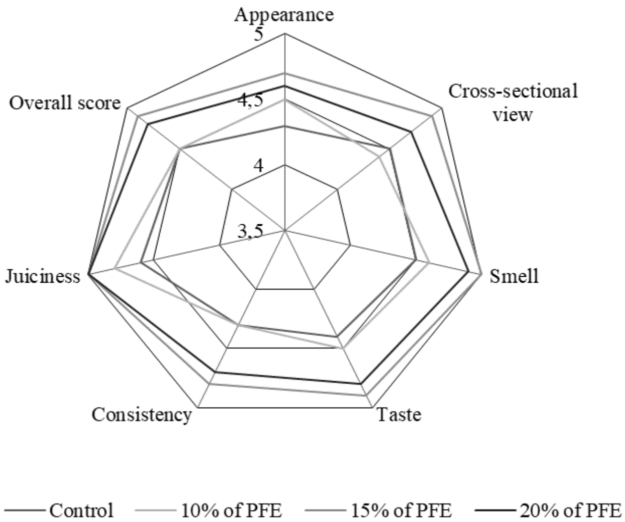

Fig. 3. Sensory evaluation of the model samples of the restructured ham-type products from turkey meat and PSE pork with different PFE contents

Table 3 – Effect of sweet potato juice powder on the formation of nitroso pigments in the model samples of restructured hams (n=3; P≥0.95)

Quantity of sweet potato powder in a meat system, %	Total pigments, absorbance units	Content of the NO pigment, % of the total pigment	Quantity of the residual nitrite, mg/100 g
0 (control $NaNO_2$)	0.089±0.001	73.03±0.15	3.26±0.03
0.30	0.083±0.019	76.53±0.18	3.12±0.05
0.35	0.079±0.001	77.22±0.20	3.10±0.03
0.40	0.078±0.001	79.49±0.21	3.11±0.03

It has been established that 0.35–0.40% of the sweet potato-based juice concentrate FruitMax® intensifies the formation of nitroso pigments. With a lower nitrite content, a product develops an intense pink colour characteristic of meat products [15, 18–21]. When the colouration of restructured ham products is formed by using sweet potato juice powder in the presence of 0.025% of *Staphylococcus carnosus*, it allows reducing the residual content of sodium nitrite in the product and avoiding the accumulation of carcinogens. This follows from the data on the proportion of the nitroso forms of pigments to the total pigments in the samples analysed, which is 77.22–79.49%. Based on the results obtained (Table 4), one can affirm that six hours of colour formation in meat products is enough for the formation of nitroso pigments that colour raw meat materials.

Table 4 – Effect of the duration of maturation on the formation of nitroso pigments in the model samples of restructured hams with 0.35% of powdered sweet potato (n=3; P≥0.95)

Stage of the technological cycle of production	Content of pigments, absorbance units		
	Total pigments	NO pigment	Content of the NO pigment, % of total pigments
4 hours of salting	0.089±0.003	0.056±0.001	62.92±0.11
5 hours of salting	0.087±0.002	0.058±0.001	66.67±0.19
6 hours of salting	0.079±0.002	0,061±0.002	77.22±0.20
7 hours of salting	0.078±0.001	0,062±0.002	79.49±0.15

The identical nitroso pigment content in the test samples compared with the control may be due to the fact that nitrite-reducing microorganisms *Staphylococcus carnosus* transform the nitrate from the plant raw materials into nitrite that interreacts with the myoglobin of the meat. This leads to the formation of the NO pigment, which is responsible for the rosy-red colour typical of meat products and promotes fuller transformation of nitrate into nitroso compounds [15, 19–21].

These are the mathematical models that adequately describe how the Lab coordinates of the colour of the experimental and control samples depend on the NO pigment's content (its percentage of the total pigments) and on the FruitMax® concentration (%):

$$z_1 = 0.00019 + 8.346x - 0.144x^2 - -4.321b_2y - 0.018y^2 + 0.104xy \quad (4)$$

$$z_2 = -0.000016 - 0.264x + 0.0077x^2 + +0.377b_2y + 0.0017y^2 - 0.0091xy \quad (5)$$

$$z_3 = 0.000004 + 0.764x - 0.0089x^2 - -0.839b_2y - 0.0007y^2 + 0.0017xy \quad (6)$$

The polynomials obtained (1, 2, 3) demonstrate a combined effect that the NO pigment's percentage of the total pigments (x) and the FruitMax® concentration (y) have on the colour intensity (z) in the model samples of restructured ham products within the framework of an experiment.

The graphical 3D models built using the software Statistica 10 are shown on Fig. 4-6.

Finding the extrema of the mathematical relation has made it possible to determine the optimum range of the content of the plant component FruitMax® providing the sufficient intensity of colouration.

Thus, it has been proved that the plant component FruitMax® can be used, in the amount 0.35–0.40%, to reduce the residual sodium nitrite down to 3.10–3.11 mg/100 g in restructured ham products from PSE pork and turkey meat. This is possible due to fuller transformation of nitrate into nitroso compounds, which results in intense rose-red colour.

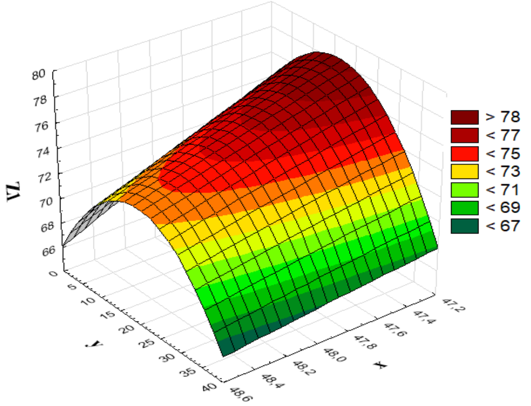

Fig. 4. Graphical 3D model showing how the CIELab colour coordinate L (the intensity of light shades) depends on the NO pigment's content and concentration

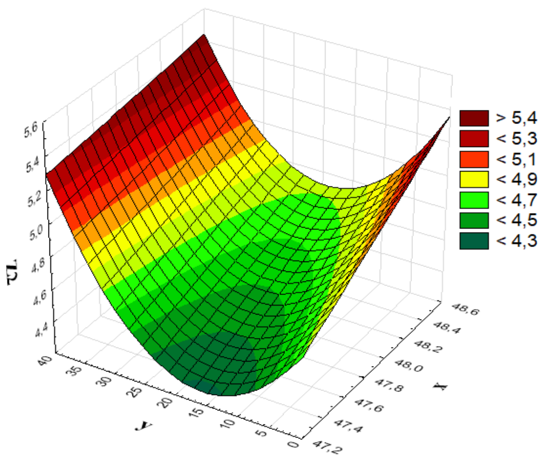

Fig. 5. Graphical model showing how the coordinate A (the red colour intensity) depends on the NO pigment's content and concentration

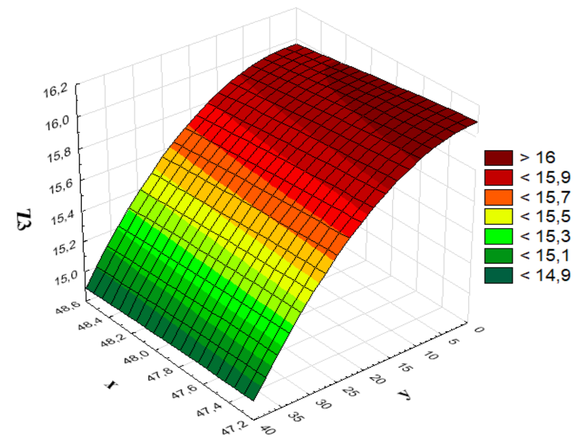

Fig. 6. Graphical 3D model showing how the coordinate B (the yellow colour intensity) depends on the NO pigment's content and concentration

Conclusion

The comprehensive study has allowed theoretically substantiating that the PFE based on a biopolymer complex of animal proteins, a protein stabiliser obtained from turkey skin, pork and turkey fats can be used as a component of restructured ham-type products and ensures their high quality and the stability of a technological process.

It has been established that 5, 10, 15, and 20% of the PFE added to the formulations of restructured hams from PSE pork and turkey meat increase the water-holding capacity of model meat systems by 7.49–9.05%, and their fat-holding capacity by 8.11–9.32%. It has been proved that 15% of the PFE introduced into the composition of restructured hams makes meat products highly structured, improves their sensory, physicochemical, and mechanostructural characteristics.

It has been theoretically grounded and experimentally confirmed how promising it is to use 0.35% of sweet potato juice powder, in the presence of 0.025% of the starter culture of *Staphylococcus carnosus*. Using this component allows achieving the rosy-red colour of restructured ham-type products without using chemically dangerous sodium nitrite. The use of sweet potato juice powder in the presence of 0.025% of *Staphylococcus carnosus* has been found to reduce the residual amount of sodium nitrite to 3.10–3.11 mg/100 g, because nitrate transforms into nitroso compounds more fully.

The biopolymer complex of animal proteins, protein-in-fat emulsions, and the plant concentrate FruitMax® with nitrite-reducing microorganisms may have good practical potential if applied in technologies of meat products made from animal raw materials of different types.

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УДОСКОНАЛЕННЯ ТЕХНОЛОГІЇ РЕСТРУКТУРОВАНИХ ШИНКОВИХ ВИРОБІВ З М'ЯСА ІНДИКА ТА ЕКСУДАТИВНОЇ СВИНИНИ PSE

І.І. Шевченко [1]Доктор технічних наук, професор, *E-mail*: irinanuht@ukr.net
Г.Є. Поліщук [2]Доктор технічних наук, професор, *E-mail*: milknuft@i.ua
О.А. Топчій [1] кандидат технічних наук, доцент, *E-mail*: oksanatopchiy@ukr.net
Є.О. Котляр [3] кандидат технічних наук,доцент, *E-mail*: yevhenii11@ukr.net
Т.Г. Осьмак [2] кандидат технічних наук, доцент, *E-mail*: osmaktg@ukr.net
[1] кафедр а технології м'яса і м'ясних продуктів
[2] кафедра технології молока і молочних продуктів
Національний університет харчових технологій, вул. Володимирська,68, м. Київ, Україна, 01601
[3] кафедра технології молока, олійно-жирових продуктів та індустрії краси
Одеська національна академія харчових технологій, вул. Канатна, 112, м. Одеса, Україна, 65039

Анотація. Доведено доцільність використання біополімерного комплексу з термостабільних тваринних білків, які володіють функціонально-технологічними властивостями, у складі реструктурованих шинкових виробів. Встановлено значне підвищення вологоутримуючої, жироутримуючої та стабілізуючої здатності м'ясних виробів за рахунок уведення до їхнього складу розробленого біополімерного комплексу, що містить казеїнат натрію, суху маслянку та плазму крові Vepro 75 PSC. Експериментально підтверджено можливість використання у складі реструктурованих шинкових виробів зі свинини PSE та м'яса індика білково-жирової емульсії на основі біополімерного комплексу з термостабільних тваринних білків, стабілізатора білкового з індичої шкурки, свинячого та індичого жирів. Так, введення білково-жирової емульсії у кількості 5, 10, 15 та 20% до складу рецептури реструктурованих шинок зі свинини нежирної та м'яса індика збільшує вологоутримувальну здатність модельних м'ясних систем на 7.49–9.05%, а жироутримувальну – на 8.11–9.32%. Встановлено закономірності зміни стабільності функціонально-технологічних властивостей білково-жирової емульсії впродовж зберігання від природи і вмісту білкових препаратів: Vepro 75 PSC, казеїнат натрію, маслянка та складу жирової композиції. Доведено можливість одержання стабільно високих та покращених споживчих властивостей шинкових виробів за рахунок уведення до їхнього складу білково-жирової емульсії. Із метою надання реструктурованим шинковим виробам зі свинини PSE та м'яса індика рожево-червоного забарвлення та уникнення використання хімічно небезпечного нітриту натрію підтверджено можливість використання у їхньому складі порошку соку батату у кількості 0.35% в присутності 0.025% стартової культури *Staphylococcus carnosus*. Встановлено, що використання порошку соку батату в присутності 0.025 % *Staphylococcus carnosus* знижує залишкову кількість нітриту натрію до 3.10–3.11мг/100г, за рахунок більш повної трансформації нітрату в нітрозосполуки. Результати дослідження мають практичну значимість та сприятимуть розширенню асортименту реструктурованих шинкових виробів підвищеної харчової цінності.

Ключові слова: біополімерний комплекс, порошок соку батату, стартова культура *Staphylococcus carnosus,* забарвлення, реструктуровані шинкові вироби