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EFFECT OF CHICKEN BONE PASTE ON THE PHYSICO-CHEMICAL AND FUNCTIONAL-TECHNOLOGICAL PROPERTIES OF PÂTÉ MASS

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Keywords: *meat bone paste, pâté mass, technology, chemical composition, nutritional value, fine grinding*

Abstract
The article describes the development of priority directions for improving the economic efficiency of poultry farming, as well as a complex of prospective scientifically substantiated measures that ensure dynamic development of the industry in modern conditions. The technology for obtaining chicken meat-bone paste from chicken bones by fine grinding is described in this article. Experimental samples of pate masses were developed with the addition of chicken meat-bone paste from 5 to 25% instead of poultry meat in the recipe. The influence of the degree of addition of chicken meat-bone paste on the chemical composition, functional-technological and structural-mechanical properties of pâté masses was studied. The addition of chicken meat-bone paste to pâté masses leads to an increase in the ash content from 1.3% in the control sample to 2.74% in the sample with 25% meat-bone paste. With an increase in the amount of meat-bone paste, there is a tendency towards a decrease in the fat content, but the product is enriched with minerals, and its energy value increases. The trend of increasing protein content is observed. Thus, the protein content in the control sample was 16.46%, and with the addition of 25% chicken meat-bone paste, it increased to 17.11%. The water-binding capacity (WBC) index in the experimental samples with the addition of meat-bone paste increased by 11.09% compared to the control sample. The addition of chicken meat-bone paste up to 25% leads to a slight decrease in WBC. Increasing the percentage of replacement of poultry meat with chicken meat-bone paste up to 20% leads to an increase in WHC (from 69.6 to 72.6%). It has been found that the maximum values of functional-technological properties of pâté mass are achieved when adding 20% chicken meat-bone paste, further increase in the content of chicken meat-bone paste leads to the appearance of looseness in the pâté mass and a decrease in the yield during thermal processing.

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Introduction

The meat and meat product market represents a vital segment of the global food market, both in terms of capacity and number of participants. Its leading role is determined not only by the volumes of production and consumption of meat and its processed products but also by their value as the primary source of animal-origin protein. In 2022, meat production worldwide exceeded 340 million tons including 135 million tons of poultry meat. Poultry meat volumes increased from 125 million tons in 2019 to 135 million tons in 2022 [1]. The chicken meat market was the largest segment of the animal-based protein market, accounting for 266.7 billion dollars or 83.5% of the total volume in 2019 [2]. Poultry meat production in Kazakhstan was 282 thousand tons in 2021 and was expected to reach 320 thousand tons in 2022.

Growing consumption of chicken in increasingly diverse and ready-to-eat forms has led to an excess of by-products in recent years. Processing chicken results in a large amount of by-products that can be used as a source of protein [3]. In deep processing of poultry, in addition to the most valuable parts (breasts and thighs), parts with significantly lower muscle tissue content are obtained — carcasses, wings, necks, and others.

During the processing of chicken, a large amount of waste is generated, some of which contain significant amounts of valuable nutrients. One such waste product is chicken bones, which are mainly underutilized or used in a limited capacity in animal feed production [4]. The effective utilization of bones is crucial to prevent environmental pollution. The utilization of bones is one of the mandatory and extremely important tasks for most modern meat processing plants. The main reason for its emergence is the constant and active growth of waste from production in the meat industry as a whole. Therefore, the rational and efficient processing of bones becomes an ideal solution to a whole range of problems in the industry [5].

During the mechanical deboning of poultry meat, two products are obtained: meat mass (mechanically separated meat) and bone residue. The meat mass is a finely ground, pasty, viscous mass ranging in color from light pink to dark red (depending on the raw material being processed), with no off-odor. The bone residue is a coarsely ground meat-bone mass ranging in color from light pink to dark red (depending on the type of raw material being processed), with no off-odor [6].

The valuable bio-potential of secondary meat and bone raw materials is determined by their high concentration of biologically active substances, such as collagen, amino acids, fatty acids, calcium, phosphorus, and others. The content of mineralized collagen in this raw material can reach 50% or more of its weight. Therefore, it is expedient to use it in functional food additives of osteotropic and gerodietic direction, which should include low-molecular-weight proteins of collagen origin and minerals [7].

Chicken bones account for about 25% of the total weight of a whole chicken and are an important source of animal protein and a byproduct of chicken processing. Dried chicken bones contain 12.0–35.0% protein, mostly collagen. Chicken bone is high in calcium and is good for bone growth. Chicken bones contain approximately 19% protein, 9% fat, and 15% ash [8, 9]. The elemental composition of bone tissue is characterized by the following data (in %): CaO — 52; MgO — 1.2; P_2O_5–40.3; Na_2O — 1.1, K_2O — 0.2; Cl — 0.1; F — 0.1; CO_2–5.0 [10, 11].

Typically, the use of bones in the food industry is limited due to their coarse and gritty texture, and bones are still primarily used as animal feed or plant fertilizers due to their low cost. To increase the added value of animal bones, some of them are used for intensive processing, including the production of protein hydrolysates from chicken bones [12], and the extraction of gelatin using pre-alkaline treatment [13].

Ultrasound pretreatment is used for enzymatic extraction of protein from chicken bones [14]. In [15], enzymatic hydrolysis is used to obtain collagen from bones of spent hens, and fermentable collagen has wider prospects for the use in functional nutrition and medicine, as well as being an effective way for complete complex utilization of chicken bones. Budnik and Peshuk (2021) developed boiled sausages using 5% to 20% bone paste instead of beef and determined that the optimal amount is 10%, with histological studies revealing fine-grained and homogeneous microstructures with large vacuoles filled with fat [16].

Because of the rapid growth of chicken farming and the need for sustainable and renewable high-quality protein sources, as well as the importance of resource utilization, food security, and environmental principles, the effective utilization of chicken bone waste in food production and processing remain a pressing issue that requires urgent attention. Therefore, the comprehensive and high-value utilization of by-products has attracted increasing attention and become a relevant topic in applied research in recent years. The above makes it possible to assert that the development of theoretical foundations and practical application of deep zero-waste processing of poultry bones and its use in new technologies of functional meat products for enriching them with valuable macro- and microelements and food nutrients are currently relevant issues [17, 18].

The aim of this study is to investigate the effect of adding chicken bone paste on the physicochemical and functional-technological properties of pâté masses.

Materials and Methods

The objects of the research were chicken meat-bone paste obtained by finely grinding chicken bones and pâté masses with the addition of chicken meat-bone paste.

Chicken meat-bone paste production

In the first stage of the research, a technology for obtaining chicken meat-bone paste was developed. The technological scheme for obtaining chicken meat-bone paste is presented in Figure 1.

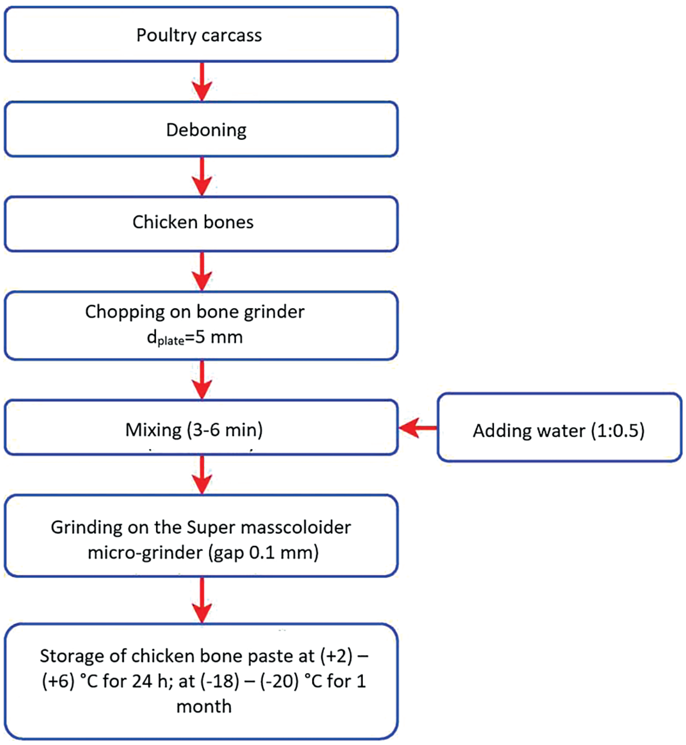


Figure 1. Process flowchart of chicken bone paste production

Samples for the study were bones from the neck, breast, legs, wings, and carcasses of chickens obtained after slaughter. The raw materials were subjected to initial processing at the first stage, except for the neck part. Next, the bones were pre-frozen for 1 hour at a temperature ranging from –18 to –20 °C in freezers. After freezing, the chicken bones were ground using a grinder with a mesh diameter of 5 mm. The samples of ground meat-bone mince were mixed in a mixer with gradual addition of ice water from 25 to 50% of the mass of the mince. Mixing was carried out for 3 to 6 minutes until the complete binding of water and ground bone mass. The obtained samples of bone mass were further ground using a microgrinder "Supermasscolloider" (Masuko Sangyo Co., Japan) with a gap between the grinding wheels of 0.1 mm. This resulted in the formation of chicken meat-bone paste with a uniform, homogenous consistency.

Development of experimental samples of pâté with chicken meat-bone paste

At the next stage, experimental samples of pâté with the addition of meat-bone paste from 5 to 25% instead of poultry meat were developed (Table 1). As a control sample, we used the production method and recipe of meat pâté, the recipe of which includes poultry meat, beef liver, pork fat, onion, carrot, parsley (dry root), broth, and spices. Experimental samples were developed with the addition of chicken meat and bone paste.

Table 1. Formulation of pâté mass

Ingredient	Control	Experimental samples with the addition of chicken meat and bone paste				
		V1	V2	V3	V4	V5
Chicken meat	60.70	55.70	50.70	45.70	40.70	35.70
Beef liver	17.60	17.60	17.60	17.60	17.60	17.60
Chicken bone paste	0	5	10	15	20	25
Pork fat	5.30	5.30	5.30	5.30	5.30	5.30
Onion	6.30	6.30	6.30	6.30	6.30	6.30
Carrots	5.70	5.70	5.70	5.70	5.70	5.70
Parsley (dry root)	0.60	0.60	0.60	0.60	0.60	0.60
Ground black pepper	0.05	0.05	0.05	0.05	0.05	0.05
Common salt	1.05	1.05	1.05	1.05	1.05	1.05
Broth	2.70	2.70	2.70	2.70	2.70	2.70
Total	100	100	100	100	100	100

The determination of the overall chemical composition was carried out by the method of single sample of the investigated sample. The method involves the sequential determination of the moisture, fat, ash, and protein content in a single sample of the product, using a device for the accelerated determination of moisture and fat content in meat and dairy products.

The moisture content was determined according to ISO 1442:1997[1] by drying a sample of the meat product at 150 °C temperature for 60 min. The fat content was determined according to ISO 1443:1973[2] by using of a Soxhlet apparatus for fat extraction, and the calculation of fat content based on the weight of the extracted fat and the weight of the initial sample. The ash content was determined according to ISO 936:1998[3] by weighing the analyzed sample before and after incineration to determine the weight of the ash. The protein content was determined by calculation.

The determination of the water binding capacity was based on the extraction of moisture by the test sample under light pressure, sorption of the released water by filter paper, and determination of the amount of separated moisture by the size of the spot it left on the filter paper.

To determine the water-holding (WHS) and fat-holding capacities (FHC), the standard method was used using a milk butyrometer. The evaluation of the water-holding capacity is based on the difference between the moisture content in the meat mixture and the amount of moisture released during thermal processing. The fat-holding capacity of the meat mixture is determined as the difference between the fat content in the sample and the amount of fat released during thermal processing.

Water-holding capacity (*WHC*, %) was determined by the formula:

$$WHC = W - MGC, \quad (1)$$

moisture generating capacity (*MGC*, %)

$$MGC = a \cdot n \cdot m^{-1} \cdot 100, \quad (2)$$

where

W — total mass fraction of moisture in the sample,%;
a — butyrometer division value; $a = 0{,}01$ cm^3;
n — number of divisions;
m — sample weight, g.

Fat-holding capacity (*FHC*, %) was determined by the formula:

$$FHC = g_1 \cdot g_2^{-1} \cdot 100, \quad (3)$$

where

g_1 — mass fraction of fat in the sample after heat treatment, %;
g_2 — the same before heat treatment, %.

Mass fraction of fat in the sample (*g*, %)

$$g = [10^4 \cdot \alpha \cdot (n_1 - n_2) \cdot m_1]/m_2, \quad (4)$$

where

α — coefficient characterizing such a fat content in the solvent, which changes the refractive index by 0.0001%;
n_1 — refractive index of a pure solvent;
n_2 — refractive index of the test solution;
m_1 — weight 4,3 cm^3
α — monobromonaphthalene, g;
m_2 — sample weight, g.

The active acidity (pH) of the medium was determined according to ST RK ISO 2917–2009[4] using a pH-150MI device (LLC "Izmeritelnaya Tekhnika", Russia), by immersing two electrodes into a solution and fixing the pH value on the scale of the device. The solution (aqueous extract) was prepared from the crushed product with water (in a ratio

[1] ISO 1442:1997 "Meat and meat products — Determination of moisture content" Technical Committee: ISO/TC34/SC6 Meat, poultry, fish, eggs and their products, 1997.

[2] ISO 1443:1973 "Meat and meat products — Determination of total fat content" Technical Committee: ISO/TC34/SC6 Meat, poultry, fish, eggs and their products, 1973.

[3] ISO 936:1998 "Meat and meat products — Determination of total ash" Technical Committee: ISO/TC34/SC6 Meat, poultry, fish, eggs and their products, 1998.

[4] ST RK ISO 2917–2009. "Meat and meat products. pH determination. Control method". Astana: State Standard of the Republic of Kazakhstan, 2010. — 16 p.

of 1:10). The pH was measured after 30 minutes of standing at a temperature of 20 °C.

Statistical analysis

Statistical analysis was performed using Statistica 12.0 (STATISTICA, 2014; StatSoft Inc., Tulsa, OK, USA). After checking normal distribution and variance homogeneity (Shapiro–Wilk), the differences between samples were evaluated using oneway ANOVA. The Tukey HSD test was used for means comparisons. Differences were considered to be statistically significant at $p \leq 0.05$. Data are presented as mean values ± standard deviation (SD).

Results and discussion

At the subsequent stage, the chemical composition of pâté masses with the addition of meat-bone paste ranging from 5 to 25% in the formulation was investigated. The results are presented in Table 2.

Table 2 shows that the addition of chicken meat-bone paste to the composition of pâté masses leads to an increase in the ash content from 1.3% in the control sample to 2.74% in the sample with 25% meat-bone paste. A slight decrease in the moisture content was noted in the samples.

Increasing the amount of meat-bone paste in the formulation of pâté masses tends to decrease the mass fraction of fat, but also results in an enrichment of the product with mineral substances and an increase in its energy value.

In [19], it was noted that a decrease in the fat content was observed in meat sausages with the addition of mechanically deboned poultry meat.

Other authors have found that the addition of mechanically deboned poultry meat in an amount of 20% to the formulation of sausages leads to a decrease in the moisture content, while the addition of cooked chicken skin did not affect the moisture content, but increased the ash and protein content [20].

In [21], it was noted that increasing the content of mechanically deboned poultry meat in meat sausages leads to a product with the higher moisture content and lower protein content.

There is a tendency towards an increase in the protein content. For instance, the protein content in the control sample was 16.46%, while with the addition of 25% chicken meat-bone paste, it increased to 17.11%.

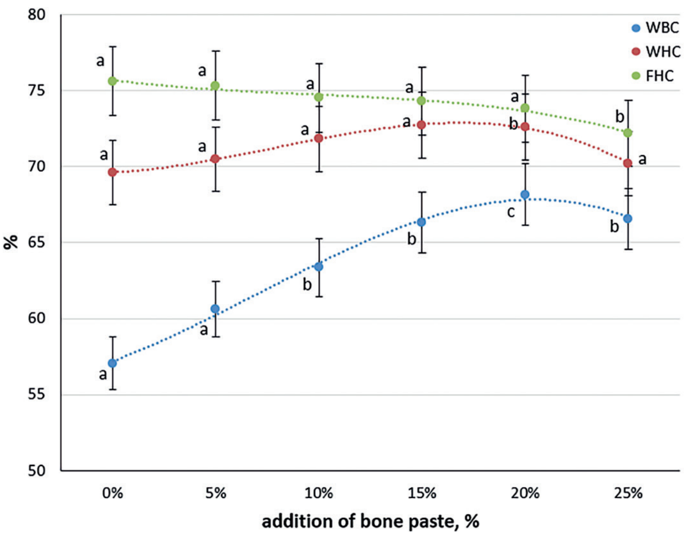
The results obtained indicate that the introduction of meat-bone paste into the recipe instead of meat improves the content of total protein, which influences its amino acid composition, and hence the level of biological value.

Chemical composition analysis showed that pâté mass with meat-bone paste has a sufficiently high content of protein and fat, and its main feature is a high content of mineral substances. Thus, the addition of meat-bone paste to the recipe of meat pâté leads to an increase in the protein and ash content, and a decrease in the fat content.

Changes in functional and technological properties and pH of pâté masses with the addition of chicken meat-bone paste

The obtained pâté masses were evaluated for their functional and technological properties, specifically, their water-binding capacity (WBC), water- and fat-holding capacities (WHC and FHC, respectively), and pH were determined. The functional and technological properties were analyzed to establish the dependencies of WBC, WHC, FHC, pH on the amount of added chicken meat-bone paste.

The analysis of the data for the water-binding capacity (WBC) (Figure 2) shows that this parameter increased by 11.09% (from 57.06 to 68.15%) in the experimental samples with the addition of chicken bone paste compared to the control sample. It was found that adding up to 25% of chicken bone paste leads to a slight decrease in WBC. A low water-binding capacity affects the loss of moisture and soluble substances during heat treatment.



[a–f] means with different uppercase letters differing significantly among different samples of pâtés ($p < 0.05$)

Figure 2. Variation of WBC, WHC and FHC of pâté mass depending on the addition of chicken bone paste (n, %)

Table 2. Chemical composition of pâté masses

Parameter	Control	Experimental samples with the addition of chicken meat and bone paste				
		V1	V2	V3	V4	V5
Moisture, %	62.54 ± 0.81^{a}	62.43 ± 0.82^{a}	62.34 ± 0.71^{a}	62.26 ± 0.88^{a}	62.14 ± 0.83^{a}	62.01 ± 0.86^{a}
Protein, %	16.46 ± 0.21^{a}	16.59 ± 0.16^{a}	16.74 ± 0.18^{a}	16.86 ± 0.20^{a}	16.98 ± 0.19^{a}	17.11 ± 0.18^{a}
Fat,%	19.7 ± 0.06^{b}	19.40 ± 0.04^{b}	19.13 ± 0.06^{b}	18.79 ± 0.05^{b}	18.48 ± 0.07^{a}	18.14 ± 0.05^{a}
Ash, %	1.3 ± 0.19^{a}	1.58 ± 0.23^{b}	1.79 ± 0.13^{c}	2.09 ± 0.18^{d}	2.40 ± 0.14^{e}	2.74 ± 0.17^{f}
Energy value, kcal/100g	243.14	240.96	239.13	236.55	234.24	231.7

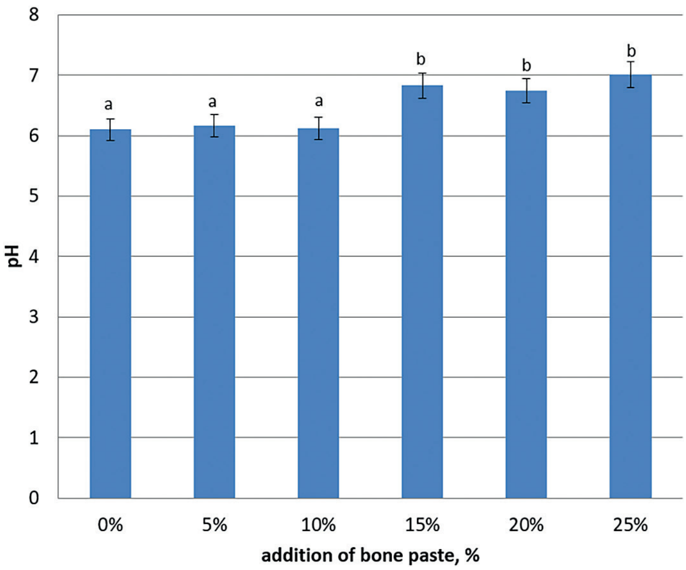
[a–f] means within the same row with different uppercase letters differing significantly among different samples of pâtés ($p < 0.05$)

Increasing the percentage of poultry meat substitution with chicken bone paste up to 20% leads to an increase in the water holding capacity (WHC) from 69.6 to 72.6%. However, adding more than 20% results in a decrease to 70.2%. The improvement in both water-holding and binding capacity can be attributed to the increase in proteins (collagen) in the pâté mixture, which is capable of swelling and has good water-holding properties. Collagen fibrils mainly undergo swelling and softening due to the presence of free water. The increased water content in collagen reduces the temperature required for its coagulation, thereby promoting water retention in the pâté mixture and improving its texture [22,23].

The value of the fat-holding capacity (FHC) decreases with the addition of chicken meat and bone paste from 75.6% in the control sample to 72.2% when 25% is added. The addition of chicken meat-bone paste does not lead to a significant decrease in the fat-binding capacity, as collagen fibers weakly retain fat components in the interprotein spaces.

Based on the conducted research, it has been established that the maximum values of the functional and technological properties of the pâté mass are achieved when adding 20% chicken meat bone paste. Further increase in the content of chicken meat bone paste leads to the appearance of looseness in the pâté mass and a decrease in the yield during thermal processing. Thus, the most recommended option is to add 20% chicken meat bone paste instead of poultry meat in the recipe of meat pâté.

There was no significant difference in the pH value between the experimental and control samples. Although the pH value of the experimental sample was slightly shifted towards alkaline (Figure 3).



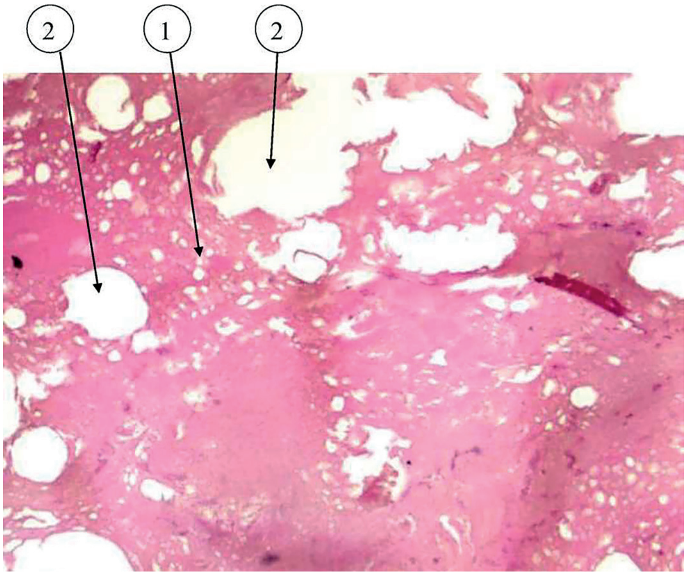
a–f means with different uppercase letters differing significantly among different samples of pâtés ($p < 0.05$)

Figure 3. Variation of pH of pâté mass depending on the addition of chicken bone paste (n, %)

The addition of mechanically deboned chicken hydrolyzate to the sausage recipe lowers the pH. The results indicate that hydrolysates of mechanically deboned chicken meat can potentially improve the physicochemical properties of sausages in meat production [24].

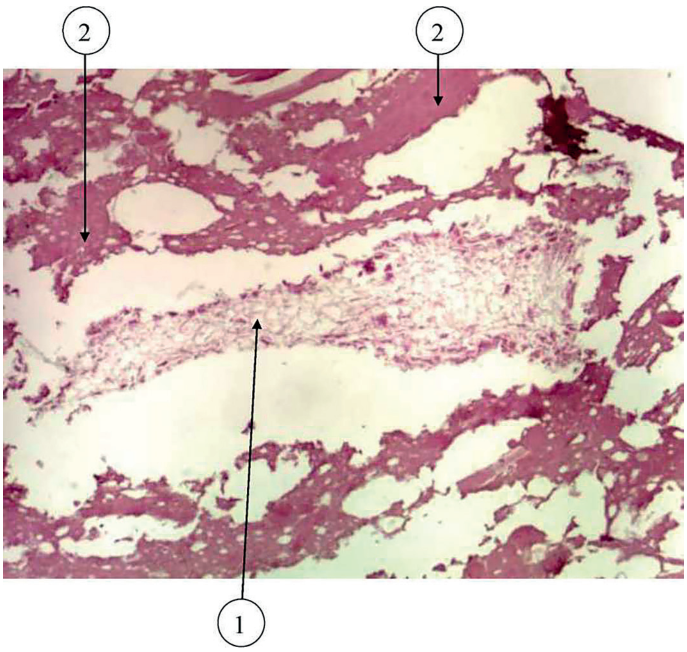
The impact of replacing poultry meat with chicken meat and bone paste on the physico-chemical and functional-technological properties of pâté masses was studied, and an optimal level of 20% chicken meat and bone paste addition was determined.

Pâtés are characterized by fine raw material grinding, which affects the product's consistency. Histological studies were conducted to determine the degree of influence of the introduced chicken meat and bone paste on the recipe of meat pâtés. Figures 4 and 5 depict control samples of meat pâté.



1 — with small vacuoles, 2 — with large vacuoles. Xe × 400.

Figure 4. Microstructure of control pâté mass



1 — areas of plant tissue among the poultry meat tissue mass, 2 — individual fragments of poultry meat muscle fibers and a structureless mass with many vacuoles of different sizes. X ×400.

Figure 5. Microscopic structure of the control sample

Microscopic examination of the control sample of meat pâté did not reveal any fragments of dense connective tissue, but showed masses consisting of fragments of muscle fibers, epithelial cells of the liver with sparsely located nuclear elements, and elements of loose connective tissue. In addition, there were particles of plant tissue with preserved nuclear elements among the tissues of the poultry meat, and particles of plant tissue with a characteristic histological structure and pronounced nuclear elements on the periphery of the plant ingredient fragment in the pâté. The structure was fairly homogeneous, with some areas being less dense due to the presence of a large number of vacuoles, and other areas being denser, representing homogeneous masses of pâté with inclusions of small vacuoles.

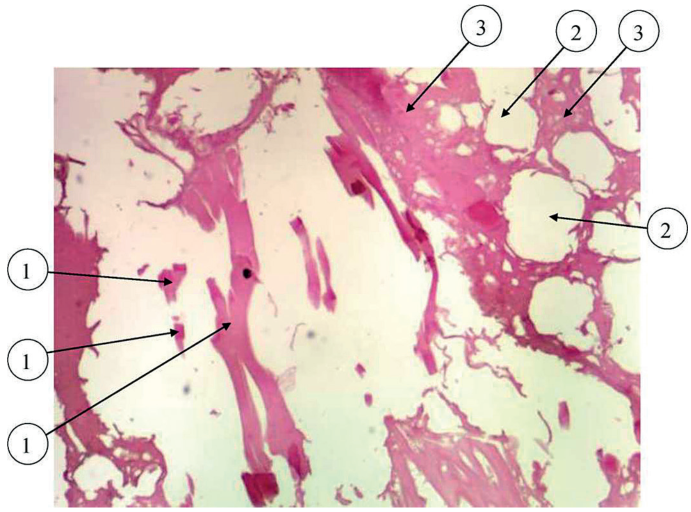
The experimental meat pâté sample contains cross-sectioned muscle fibers and vacuoles in the finely structured mass of the pâté. Microscopic examination of the pâté structure reveals predominantly small particles of various tissues of the poultry meat (small fragments of muscle fibers, fibers of loose connective tissue, and particles of dense connective tissue) and plant-origin tissues. There are also densely packed particles of poultry meat tissues with vacuoles and inclusions of plant tissue particles. The sample contains pieces formed by fat cells. The particle distribution in the experimental sample is relatively uniform throughout the product volume compared to the control sample (Figures 6 and 7). Unlike the control pâté sample, the experimental pâté sample contains inclusions of dense connective tissue upon microscopic examination of the microstructure.

Gezgin et al. [25] developed a technology and recipe for sausages with the addition of mechanically deboned poultry meat. In samples of thermally processed chicken sausage, a higher amount of bone and cartilage tissue was detected during histological analysis.

Nagdalian et al. [26] conducted a quantitative analysis of the microstructure characteristics of sausage with added mechanically separated poultry meat, and determined the characteristics of bone and cartilage inclusions in the samples. Multiple round voids with a diameter of 50–150 μm can be observed in the microphotographs of all samples. Botka-Petrak et al. [27] analyzed mechanically deboned meat from broiler chickens and found that connective and muscle tissue were the main components, while diffusely scattered cartilage tissue was low in content. Cartilage and a small amount of bone tissue were observed in the samples.

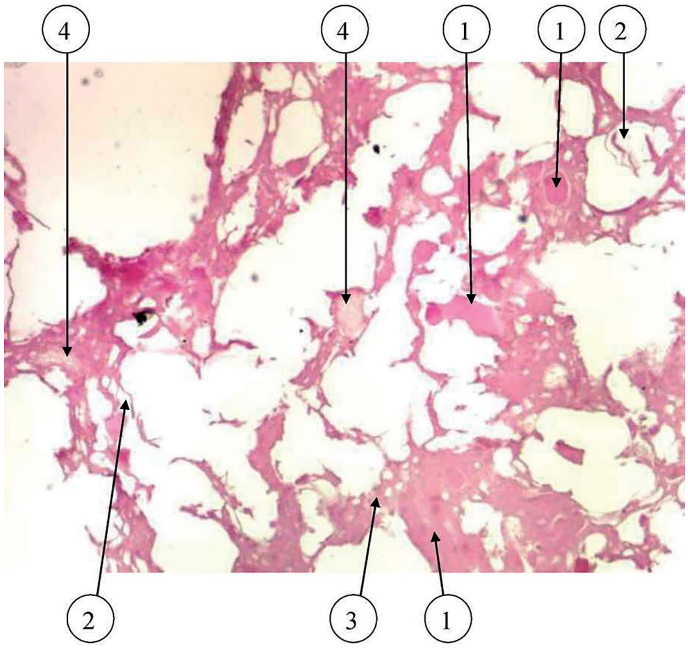
Antipova et al. [28] have developed a method for the rational use of the bone remains of poultry. The resulting mass of the bone residue consists of pieces of bone up to 3 cm in size and a small amount of fleshy tissues (about 5%). Histomorphological studies confirm the presence of a strengthened structure — bone tissue. It has been established that the mass fraction of protein in the bone residue is 25%, fat — 18.9% by weight of the raw material.

Therefore, the structure of the experimental sample with the addition of chicken meat and bone paste differs from the control sample in the presence of dense connective tissue inclusions and particles of bone tissue.



1 — transversely longitudinally dissected muscle fibers, 2 — vacuoles, 3 — homogeneous pate mass. X × 400

Figure 6. Microscopic structure of the experimental sample of pâté mass



1 — small fragments of muscle fibers, 2 — connective tissue fibers, 3 — particles of bone tissue, 4 — tissue of plant origin. X × 400

Figure 7. Microscopic structure of the experimental sample of pâté mass

Conclusion

Thus, as a result of the conducted experimental studies, a comprehensive processing of chicken meat-bone raw materials into fine-dispersed meat-bone paste has been proposed and the effect of its addition level (from 5% to 25%) on the physico-chemical, functional-technological properties, and microstructure of pâté masses has been studied. The nutritional value, functional-technological and structural-mechanical properties, pH, microscopic structure of pâté masses were determined, and the possibility of using chicken meat-bone paste instead of the main raw material in the production of meat pâtés was demonstrated. As a result of the studies, it was established that the maximum values of functional-technological properties of the pâté mass are achieved with the addition of 20% chicken meat-bone paste. Further increase in the content of chicken meat-bone paste leads to the appearance of looseness in the pâté mass and a decrease in the output during thermal processing. The most recommended approach is to add 20% chicken meat-bone paste as a replacement for chicken meat in the recipe for meat pâté. A comparative analysis of the chemical composition showed that the addition of chicken meat-bone paste increases the ash and protein content of the pâté mass while decreasing the fat and moisture. Histological analysis revealed that the experimental meat pâté sample had transversely sectioned muscle fibers and vacuoles in the fine structure of the pâté mass. In contrast to the control pâté sample, the experimental pâté sample showed inclusions of dense connective tissue upon microstructural examination. Based on the conducted research and obtained results, the chicken meat-bone paste is a viable option for the use in the recipe of meat products as a replacement for the primary raw material.

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