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INFLUENCE OF THE HYDROTHERMAL TREATMENT TEMPERATURE CONDITIONS ON POULTRY MEAT

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Abstract. The poultry production is growing rapidly every year. Having a rapid pace of development and reproduction, and greater affordability, the poultry products are in high demand from the population. In this regard, the industry is in demand for deep processing of poultry meat, which is not only economically feasible, but also makes it possible to expand the scope of use of this product. The complex morphological structure of the poultry complicates its use as the main raw material for meat products, and poultry meat is mainly sold in the form of natural semi-finished products with a limited shelf life. It is possible to expand the range of poultry products through the production of canned food. A new technology for the production of pasteurized canned poultry meat was developed at the Department of Meat, Fish and Seafood Technology of the Odessa National Academy of Food Technologies. This technology involves hydrothermal treatment of the raw materials, hot boning, mixing of components of the formulation and pasteurization. This article reveals the issue of the first stage of production, namely the establishment of rational meat hydrothermal treatment conditions. The problem of choosing the heat treatment conditions is extremely important, because depending on the process conditions and the final heating temperature, the transformation of the components and the properties of the finished products differ significantly. The paper studies the effect of temperature in the range from 65 to 95°C in 5°C increment on the rate and degree of cooking of collagen, the formation of the required structure of the product (hydrogel base filled with individual muscle fibers), hardness and tenderness of meat. It is established that the optimal processing temperature of poultry meat is 65°C. The meat processed at this temperature had the highest degree of collagen cooking, the highest viscosity of the broth, the lowest shear stress, and the best organoleptic characteristics.

Keywords: meat products, thermal treatment, collagen, protein denaturation, cooking loss.

Introduction. Formulation of the problem

The poultry meat is becoming increasingly popular around the world. The rapid growth of poultry meat production is influenced by a number of factors: intensive production methods, profitability, availability of feed components, high level of mechanization, rapid development of the catering network, and constantly growing consumer demand [1-3].

The range of poultry products is mainly presented in the form of natural semi-finished products, which have a short shelf life. In this regard, the industry needs to produce long-term storage products, the production technology of which involves deep processing of the poultry meat.

The development of a new technology for the production of pasteurized canned meat from broiler chickens is aimed at expanding the range of meat products made of natural products, with improved organoleptic characteristics, high nutritional value and rational use of raw materials for poultry processing production.

The first stage of production of pasteurized canned food involves hydrothermal treatment of the hindquarters of the broiler chicken meat. The choice of raw meat is justified by the fact that: poultry meat is available and grown in large quantities; the poultry hindquarters are considered a dietary product due to a certain combination of proteins and fats, which has high nutritional and biological value. It is important to note that the connective tissue in the hindquarters contains a lot of collagen during prolonged cooking [4]. The use of collagen, which turns into a liquid part, is useful for people suffering from osteochondrosis, bone fractures, as well as for regular consumption by those whose bones are very fragile, and to improve the condition of hair, skin and nails [5]

Analysis of recent research and publications

For the development of a new technology for making pasteurized canned poultry, a modern culinary meat dish, which has a common name “Rillettes”, was taken as the basis. “Rillettes” (French “rillettes”) is a type of meat pate that has the appearance of a spreadable mass, not crushed by grinder, but with fibers and pieces of meat [6]. The technology of this product is diverse, but its main operations are associated with long-term pre-boiling of raw meat at high temperatures, if necessary, boning and mixing all the components of the recipe. “Rillettes” is edible no more than 72 hours subject to refrigerated storage (temperature not higher than 6°C) [7].

The thermal treatment conditions, which are mainly applied in various recipes of the “Rillettes”, are not scientifically substantiated. This circumstance makes it impossible to apply this technology in industrial conditions. The most problematic is the stage of the technological process associated with the processing of raw meat at high temperatures, because boiling in the technology of preparing “Rillettes” takes place within 3-10 hours at a temperature of 90-100°C.

High processing temperatures negatively affect the quality and biological value of the meat. The strict conditions of heat treatment of meat cause a decrease in the digestibility of proteins, which result in decrease in the bioavailability of amino acids and adversely affect the nutritional qualities of the meat products. Decreased protein digestibility does not only account for the poor availability of amino acids, but also has risk factors for human health, as non-hydrolyzed proteins are fermented by the intestinal flora into mutagenic products, which can cause colon cancer [8,9].

To date, a modern approach to cooking meat is low-temperature long-time (LTLT) [10]. LTLT technology is caused by the fact that the denaturation changes of the protein, which are accompanied by its deployment, begin at a temperature of 35-40°C. Denaturation of sarcoplasmic and myofibrillar proteins begins at 40-50°C [11].

Myosin, the main muscle protein, is the most sensitive to temperature. When heated to a temperature above 40°C, it denatures completely [12].

Simultaneously with denaturation, the polypeptide chains aggregate due to the occurrence of random secondary salt and hydrogen bonds between protein molecules. The occurrence of these bonds results in blocking of polar groups, and as a consequence in a decrease in the hydrophilicity of the denatured protein, reducing its solubility.

With increasing temperature and duration of heating, the degree of coagulation changes increases, while the higher the degree of aggregation, the slower the digestion of protein [11, 13].

In vitro studies [8] demonstrated that meat protein digestibility was lower in rats which were fed with boiled beef treated at high temperatures (100°C for 210 minutes) than in those fed with raw meat or meat cooked at moderate temperatures (up to an internal temperature of 60 to 64°C).

Due to the significant amount of connective tissue in the meat quarters of broiler chickens, the effect of temperature on collagen is important.

The studies [14] have demonstrated that collagen denaturation occurs in the temperature range between 53 and 67°C. Initially, this is due to the rupture of hydrogen bonds, which weaken the fibrillar structure, and then there is a compression of the collagen molecule. When heated to a temperature of 60°C to 70°C, the collagen fibers shrink to a quarter of their length. Heat-resistant intermolecular bonds are involved in the stabilization of collagen fibers, and with subsequent heating, they form gelatin [4,15].

The structural changes in proteins that occur after heating at 60-80°C for one hour result in the fact that collagen present in the epimysium has no significant changes after heating, while collagen in the perimysium and endomysium takes the form of granules at a temperature of 60°C , and their gelatinization begins at 80°C [16]. The gelatinization involves the breakdown of helical collagen structures into random helices, resulting in the formation of gelatin, which in contrast to “native” collagen is soluble in warm water [17].

A number of studies [18-20] have demonstrated that the use of long-term heat treatment at relatively low temperatures makes it possible to obtain a meat product with high nutritional and biological value, increased tenderness and better appearance, compared with the product treated at high temperatures.

Thermal treatment of meat should be the minimum necessary to bring the product to a state of culinary readiness, the formation of all the desired organoleptic characteristics and achieve safety without compromising quality, nutritional and biological value.

In this regard, to ensure safety, high product quality and justification of the cost-effective technology for production, it is necessary to scientifically substantiate the parameters of each operation of the technological process.

The purpose of the study is to establish rational hydrothermal treatment conditions for the hindquarters of broiler chickens. To achieve this purpose, the following **tasks** were set:

- to study the influence of hydrothermal treatment regimes on the condition of the connective tissue of broiler chicken meat;
- to determine the influence of temperature and thermal treatment time on structural and mechanical parameters;
- to determine the influence of processing conditions on the organoleptic characteristics of the meat.

Research materials and methods

The hindquarters of broiler chickens produced by TM "Nasha Ryaba" were used as experimental material. The thermal treatment process was performed in a multi-cooker Redmond SkyCooker RMC-C42S (USA).. The studies were performed in the temperature range from 60 to 95°C in increment of 5°C at atmospheric pressure.

The hydrothermal treatment of meat with a temperature of 5°C was started at a heating medium temperature of 35°C with a gradual increase in temperature so that the difference between the temperature in the center of the raw meat and the heating medium was 25–30°C. The temperature of the heating medium and the product was monitored using a thermocouple and a probe thermometer Testo 108 (Germany). When the set temperature of the heating liquid (65–95°C) was reached, the heating was finished, and further the temperature was maintained at the level of the maximum allowable temperature in the meat center for each experiment, and the meat was kept at this temperature. The criteria for termination of the duration of processing were organoleptic parameters, residual acid phosphatase activity of not more than 0.006% and easy possibility of boning meat.

To measure the transformation of connective tissue, the degree of collagen boiling and changes in the kinetic viscosity of the broth were studied. The method of studying the degree of boiling of collagen is based on determining the difference in the content of oxyproline in raw and cooked meat after removal of the products of hydrothermal decomposition of collagen [21]. A portion of 5 g of minced hydrothermally treated meat was repeatedly washed from gluten with distilled water (50–55°C), followed by centrifugation and removal of liquid by means of a centrifuge ОПН-8 (Kyrgyzstan) at 2500 rpm for 10 minutes The residue was quantitatively transferred for hydrolysis in a conical flask with an air cooler. After hydrolysis in 6 M HCl for 6-7 hours, the content of oxyproline was determined, which characterizes the amount of fibrillar connective tissue proteins in a portion of meat. The content of oxyproline in raw meat was determined in parallel.

Given that the elastin content in the endomysium and perimysium of the muscles is relatively small and, in addition, elastin contains only about 2% of oxyproline, it was considered possible to conditionally attribute all oxyproline found in a portion of meat to collagen. The degree of collagen boiling in % was calculated by the formula:

$$X = \frac{(A-B)}{A} \cdot 100 \qquad (1)$$

where: A – the amount of oxyproline in a portion of raw meat, mg;

B – the amount of oxyproline in a portion of boiled meat, mg.

The effect of the hydraulic module on the kinetic viscosity of the broth was studied using a capillary glass viscometer ВПЖ-2 (State Standard GOST 10028-81) with a capillary tube diameter of 0.99 mm. The studies were performed at a temperature of 65°C, the ratio of meat to water is from 1:1 to 1:2.5.

In the course of work, the structural and mechanical parameters were also studied, namely the shear stress, by means of the Structure meter CT-1. The sample was cut manually, in the form of a square with sides of 1×1 cm. The"Struna" indenter was applied to determine the shear stress. The prepared studied sample was carefully placed on the table so that it is perpendicular to the direction of movement of the indenter. The indenter was installed in the socket of the measuring head and fixed with screws, after which the mode of operation of the device was set. By pressing the digit buttons, the mode number "4 General method" was entered. Then, by pressing the "Start" button, the cutting tool was activated, which carried out cutting of the sample. At the beginning of the interaction, the indenter is "pressed" into the sample, but after a certain deformation has occurred, the intermolecular bonds in the sample begin to break down, and the cutting process takes place. The force required to cut the sample was recorded on the instrument panel [22].

The shear stress was determined by dividing the force affecting the product by the area of the string passing over the surface of the product, according to the formula

$$\sigma_{cp} = \frac{F}{A} \qquad (2)$$

where: F- shear stress, H;

A - cut surface area, cm^2.

In addition, the meat weight loss after thermal treatment was determined by the calculation method (weighing samples before and after thermal treatment), and the organoleptic studies were performed [23]. Organoleptic studies were performed using a five-point rating scale. Based on the obtained points, the total score of each sample was calculated. The study was conducted by 6 taste-testers. The parameters, such as appearance, consistency, color, odor and taste were determined in all samples.

Experimental studies were performed in five replicates. The obtained results are presented in units of the SI international system.

Results of the research and their discussion

Changes in the connective tissue proteins play an important role in studying the effects of different temperatures on the meat system and obtaining a tender product, especially taking into account the large amount of connective tissue in the meat quarters of broiler chickens. At the end of the hydrothermal treatment, the degree of collagen boiling was studied. The results are presented in Fig. 1.

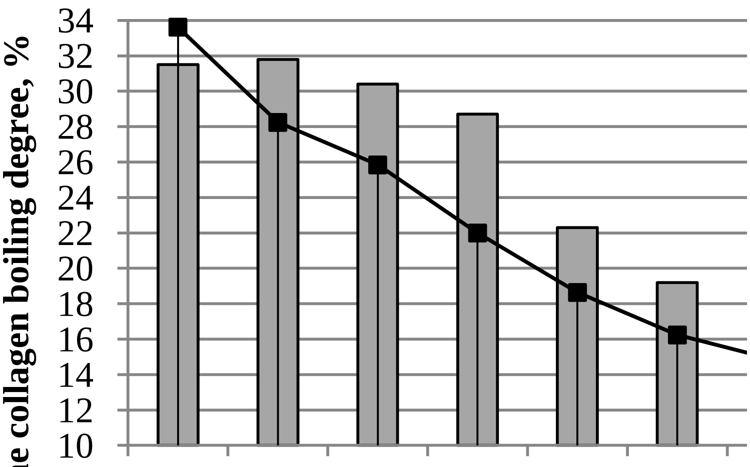

Fig. 1. The collagen boiling degree depending on the hydrothermal treatment temperature

The results of the study demonstrate that the lowest degree of collagen boiling was observed in samples treated at a temperature of 80°C to 95°C, and the highest (31.8%) degree is in a sample treated at a temperature of 65°C for 380 minutes. The longest process of hydrothermal treatment was at a temperature of 60°C (492 min.), while the collagen boiling degree was almost the same as during treatment at 65°C. Thus, it is established that the best results to achieve set purpose are observed at a temperature of 65°C.

These results are consistent with studies [4, 14], which demonstrated that the denaturation of collagen occurs at different temperatures in the range of 58–67°C and depends on the content of proline and hydroxyproline, as well as the raw material. Initially, this is due to the rupture of hydrogen bonds, which weaken the fibrillar structure, and then there is a compression of the collagen molecule. When heated to a temperature of 60°C to 70°C, the collagen fibers shrink to a quarter of their length. Heat-resistant intermolecular bonds are involved in the stabilization of collagen fibers, with subsequent heating, they form gelatin. The studies [24] have shown that collagen completely denatures at 55–70°C after destruction of the proteoglycan network. In addition, the studies [25] demonstrate that with increasing exposure time at a temperature close to 60°C, there is a prolonged degradation of collagen after 3 hours of treatment.

One of the criteria for obtaining the structure of the product is the transition of collagen into the broth and the formation of a viscous solution. After denaturation of collagen, the compounds with lower molecular weight are formed: gelatin, gelatose, gluten, which after cooling form the broth jell able to retain a large amount of water in its structure [26, 27]. The kinetic viscosity of the liquid part of the product is an indicator of gelation. The ratio in meat broth to water was 1:2. The results of kinetic viscosity are presented in Fig.2.

The results of the study demonstrate that the highest value of the kinetic viscosity of the broth was in the sample treated at 65°C (1,836 mm^2/s), and the lowest values are in the samples treated at temperature of 90°C (1,206 mm^2/s) and 95°C (1,199 mm^2/s). This is due to the fact that the transition from collagen to gluten requires that all the cross-links between the polypeptide chains in the collagen macromolecule be destroyed, and this requires long-term processing.

After treatment at 60°C, the kinetic viscosity was slightly lower than the viscosity of the broth obtained during hydrothermal treatment at 65°C, which is consistent with studies [28] which indicate more intense changes in the connective tissue at 65°C than at 60°C.

The results of the kinetic viscosity study demonstrate that the long-term heat treatment at 65°C affects the transformation of collagen to a greater extent than less long-term at 80-95°C. Prolonged slow heating at a temperature of 65°C to the greatest extent promotes the transformation of collagen and its transition into broth, which is extremely important for the formation of the required hydrogel structure of the product. This is due to the fact that the transition from collagen to gluten requires that all cross-links between polypeptide chains in the collagen macromolecule be destroyed, and this requires long-term processing and appropriate temperature [29].

In order to obtain a specific structure of the product, it is necessary to obtain a hydrogel base. The broth gelation depends not only on the temperature and time parameters of processing, but also the ratio of the mass of raw materials and water. The results of the study of the hydraulic module effect the kinetic viscosity of the broth are presented in Fig. 3.

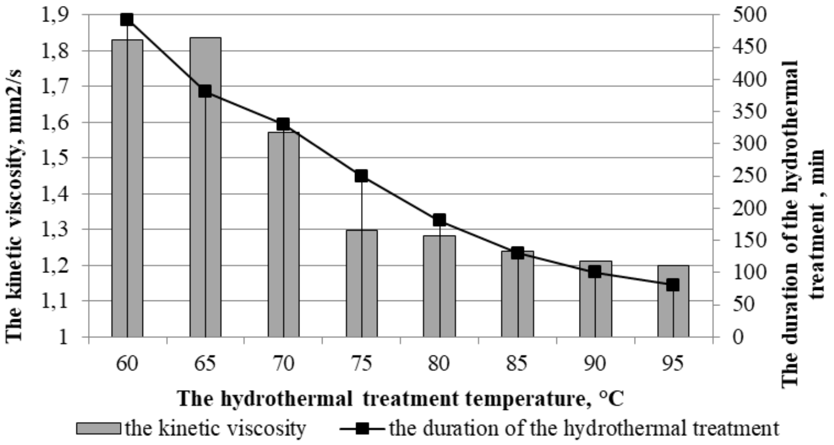

Fig. 2. The value of the broth kinetic viscosity depending on the hydrothermal treatment temperature

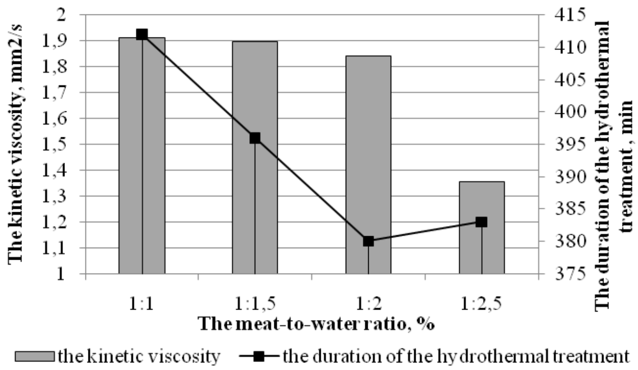

Fig. 3. The value of the broth kinetic viscosity depending on the hydraulic module

The study results demonstrated the dependence of the hydraulic module on the value of kinetic viscosity. As the amount of water increased, the kinetic viscosity of the broth decreased, and the sample with a meat-to-water ratio of 1:1 had the largest value, while the sample with ratio 1:1.25 had the smallest value. It is important to note that the meat-to-water ratio affected the duration of processing. The kinetic viscosity results in the samples with hydromodule of 1:1, 1:1.5, and 1:2 did not differ significantly, however, the duration of the hydrothermal treatment was significantly different. The reason for these results is that at in the hydromodules of 1:1 and 1:1.5 the raw materials were not heated evenly. The small difference in the processing time of the samples with the hydraulic module of 1:2 and 1:2.5 is explained by the greater time spent for heating a larger amount of heating medium. From the results of the study it was found that the best meat-to-water ratio to obtain the required hydrogel base is 1:2.

It is known that the temperature of the heating medium affects the water displacement from the meat system and the transition of water-soluble components into the broth. As a result of moisture loss, the meat loses its juiciness and becomes coarser.

The issue of weight loss is considered from two positions: firstly, with rapid heating there is a significant shrinkage of muscle fibers and loss of moisture with soluble substances that pass into the broth, and secondly, collagen with slow prolonged heating dissolves to a greater extent.

The paper studied meat weight loss, which demonstrated the transition of components of the meat system in the broth. The Figure 4 shows a graph of meat weight loss when reaching the maximum allowable temperature in the center of the meat and at the end of the hydrothermal treatment process depending on the processing temperature.

The study results show that with increasing temperature in the middle of the meat the weight loss increases. The largest weight losses occurred in the sample treated at a temperature of 95°C. There was a slight difference in the samples treated at the maximum allowable temperature of 65°C and 70°C when the corresponding temperature in the center was reached, but at the end of the hydrothermal treatment the difference was 4.4%.

The results are explained by the fact that collagen thermal denaturation causes a rupture of bonds, which results in shrinkage, because the hydroxyl groups stabilize the structure of collagen, and water forms hydrogen bonds between the hydroxyl groups and hydroxyproline. Compression of the collagen surrounding the myofibrils results in physical limitations on these structures and the water is displaced. As a result of shrinkage, the amount of water contained in the tissue system decreases with increasing temperature and, as a result, the hardness of the product increases [30].

When assessing the impact of temperature treatment on the characteristics of meat, its tenderness and juiciness is one of the main quality criteria that should be considered when determining the optimal heat treatment conditions. Tenderness is considered one of the qualitative characteristics [31, 32] and an important factor that determines the acceptability of the meat product for consumers [33].

Due to the fact that the hardness of meat is caused by the denaturation changes in proteins, the studies have been conducted that characterize the strength and hardness of the meat system - the shear stress (Fig. 5).

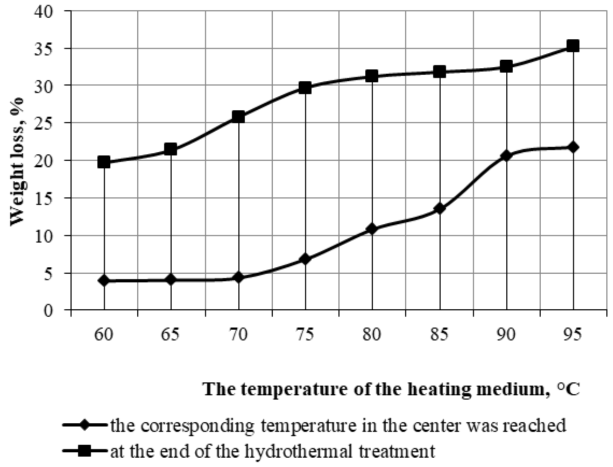

Fig. 4. Weight loss of meat depending on the hydrothermal treatment temperature

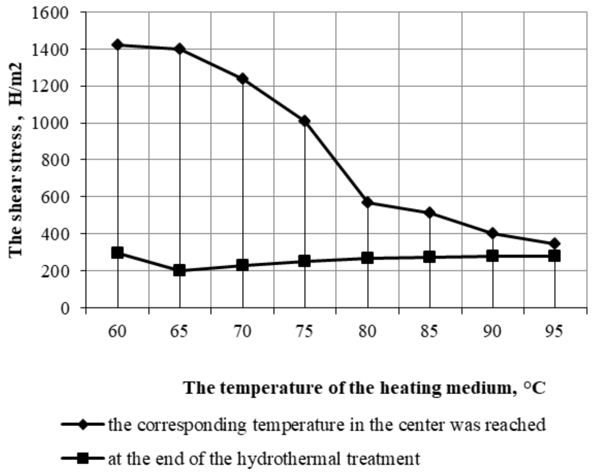

Fig. 5. Shear stress voltage depending on the hydrothermal treatment temperature

Studies of the shear stress demonstrated that when the temperature in the center of the meat reached 60 and 65°C, the shear stress was the highest (1419 H/m^2, 1401 H/m^2) in comparison with the samples heated to a higher temperature. However, at the end of the hydrothermal treatment process, the value of the shear stress in the sample treated at a temperature of 65°C is the lowest (203 H/m^2). A comparative evaluation of the shear stress study results indicates that the temperature of heat treatment to a greater extent affects the hardness of the meat, and the increased exposure time at moderate temperatures increases the tenderness of the meat.

The reason for the lowest shear stress at the end of treatment at 65°C may be prolonged degradation of the connective tissue, as well as the fact that prolonged exposure to temperature reduces the strength of myofibrils by weakening the forces holding them together. At higher temperatures, changes in myofibrils cause increased hardness [12, 34].

The literature sources indicate that processing at temperatures close to 60°C for a long time not only avoids the increase in meat hardness observed at higher temperatures, but also improves the tenderness of the meat in 4 hours of maturation [35]. Similar findings were confirmed in studies with pork [36,37] and beef [10,38].

The organoleptic parameters – appearance, smell, color, taste and consistency - play an important role for the consumer in assessing the quality of the meat and meat products. These characteristics largely determine the quality of products when evaluated by the consumer and are the main factors influencing his choice. Therefore, studies of the effect of hydrothermal treatment temperature on the sensory properties of the product and the results are presented in Table 1.

Table 1 – Organoleptic characteristics of hydrothermally treated samples of meat of broiler chickens (at 65°C)

The test samples	Appearance	Taste	Smell	Consistency	Color	Overall rating
60	5	4.3	5	4.7	5	4.8
65	5	5	5	5	5	5.0
70	5	4.9	5	4.9	5	4.9
75	5	4.8	5	4.8	5	4.9
80	5	4.5	5	4.8	5	4.8
85	5	4.5	5	4.5	5	4.8
90	5	4.3	5	4.5	5	4.7
95	5	4	5	4	5	4,6

It was found that the sample treated at a temperature of 65°C had the best taste characteristics. It had the best consistency, and the meat was tender and juicy. The meat processed at 85°C, 90°C and 95°C seemed to be the hardest. The samples treated at 90°C and 95°C seemed dry, especially compared to other samples.

The samples did not differ in terms of color and odor. The muscle tissue was evenly colored, light in color, which is typical for the cooked poultry.

The results demonstrated that the duration of treatment to a greater extent affects the transformation of collagen, its solubility and the transition to broth, than the temperature.

It is seen from the results of the study that the optimal temperature for processing of poultry meat is 65°C, because with increasing temperature, moisture loss increases, and the product becomes dehydrated, its hardness increases, therefore the meat processed at 65°C had the least shear stress values and the best organoleptic characteristics.

The change in the structural and organoleptic characteristics of meat is caused by the fact that during the heating process the proteins denature and cause structural changes in meat, such as shrinkage of muscle fibers, aggregation and gel formation of sarcoplasmic proteins, as well as shrinkage and dissolution of connective tissue [12]. It is assumed that the denaturation of structural proteins in meat accounts for the heat shrinkage of the fiber and associated water loss due to reduced ability of denatured proteins to retain water [39].

At temperatures above 60°C, the connective tissue and muscle fibers cooperatively contract longitudinally, and after 65°C the changes occur more intensely, the degree of shrinkage increases with increasing temperature. This is mainly based on the fact that intramuscular collagen (mainly perimysial) is compressed in the longitudinal direction at a temperature of 64°C [28].

The low-temperature prolonged effect of processing on connective tissue causes its degradation, which results in decrease in the shear stress, in addition, at high temperatures, th structural changes in myofibrils cause hardness of the meat.

The disadvantage of hydrothermal treatment at a temperature of 65°C is the duration of the process, therefore the purpose of further research is to reduce the duration of hydrothermal treatment without compromising the quality parameters of poultry meat.

Conclusion

1. On the basis of the conducted physicochemical, structural-mechanical and organoleptic studies the rational modes of hydrothermal treatment of meat of broiler chickens, namely 380 min at a temperature of 65°C, are established.

2. It is demonstrated that long-term low-temperature treatment at a temperature of 65°C is more conducive to the transformation of collagen and its transition into broth than less long-term treatment at higher temperatures. Thus, the degree of collagen boiling is 1.4% higher in samples treated at 65°C than 70°C, and 13.7% compared to treatment at 95°C, which is extremely important for the efficient deboning of meat and obtaining the necessary product structure.

3. The positive effect of the LTLT treatment method on the tenderness and organoleptic characteristics of the meat base to create a new product is confirmed. As the temperature increased and the processing time decreased, the weight loss of the meat increased and the shear stress index decreased, which characterizes the strength and hardness of the meat system. Samples treated at 65°C had the highest organoleptic grades and had a juicy and delicate taste.

4. Further work will be aimed at studying the possibility of reducing the duration of hydrothermal

treatment at a temperature of 65°C without compromising the quality of the product.

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ВПЛИВ ТЕМПЕРАТУРНИХ РЕЖИМІВ ГІДРОТЕРМІЧНОГО ОБРОБЛЕННЯ НА М’ЯСО ПТИЦІ

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Анотація. Виробництво м’яса птиці стрімко зростає з кожним роком. Продукція птахівництва, маючи швидкі темпи розвитку і відтворення, більшу доступність за ціною, користується підвищеним попитом на свою продукцію у населення. У зв'язку з цим у промисловості виникає запит на глибоку переробку м’яса птиці, що не тільки економічно доцільно, а і дозволяє розширити сферу використання цього продукту. Складна морфологічна будова птиці ускладнює її використання у якості основної сировини для м’ясних продуктів і в основному м’ясо птиці реалізується у вигляді натуральних напівфабрикатів, що мають обмежений термін зберігання. Розширити асортимент продукції птахівництва можливо за рахунок виробництва консервів. На кафедрі «Технології м’яса, риби і морепродуктів» Одеської національної академії харчових технологій була розроблена нова технологія виробництва пастеризованих консервів з м’яса птиці. Дана технологія передбачає гідротермічне оброблення сировини, гаряче обвалювання, змішування компонентів рецептури та пастеризацію. У даній статті розкрито питання першого етапу виробництва, а саме встановлення раціональних режимів гідротермічного оброблення м’яса. Проблема вибору режимів температурного оброблення вкрай важлива, оскільки в залежності від умов процесу і кінцевої температури нагрівання трансформація складових частин і властивості готових продуктів істотно розрізняються. У роботі проведені дослідження впливу температури в діапазоні температури від 65 до 95°C з кроком 5°C на швидкість та ступінь розварюваності колагену, утворення необхідної структури продукту (гідрогелева основа наповнена окремими м’язовими волокнами), жорсткість та ніжність м’яса. Встановлено, що оптимальною температурою оброблення м'яса птиці є 65°C. М’ясо оброблене при даній температурі мало найвищу ступінь розварювання колагену, найбільшу в’язкість бульйону, найменший показник напруги зрізу та найкращі органолептичні показники.

Ключові слова: м’ясні продукти, температурне оброблення, колаген, денатурація білка, втрати маси.

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