Influence of heat-induced changes in meat proteins on the quality characteristics of the finished product

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Abstract. In order to identify the coagulation-denaturation changes in proteins for the development of heat treatment modes and the production of products with specified characteristics, a set of changes in the dynamics of the degree of denaturation and the electrophoretic profile of proteins was studied. Qualitative structural changes of proteins in model products from the scapular part of pork halves with signs of NOR and PSE were studied by electrophoresis in polyacrylamide gel in the presence of sodium dodecyl sulfate. The analysis of these changes made it possible to develop new and adjust the existing technological modes of processing meat raw materials. The prospects of using LT-LT heat treatment modes for whole-muscle cooked pork products with signs of NOR and PSE are shown. The results showed a higher activity of tissue proteases in PSE-pork compared to NOR, which carry out the proteolysis of "heavy" proteins. The largest number of protein fractions in the model products from PSE-pork is visualized in the zone of "medium" proteins with a molecular weight of 20 to 100 kDa. Minimal changes in the fractional composition occur at 50-55°C in myofibrillar proteins and 65°C in sarcoplasmic proteins.

1. Introduction

Meat in the process of heat treatment is considered as a biotechnological system consisting of four main subsystems. The first subsystem includes two types of macromolecular substances—proteins and fats, the second subsystem includes biologically active substances—vitamins and enzymes, the third subsystem is chemically active substances that determine the active state of the protein system: solutions of salts, acids, bases, and the fourth subsystem is water. The basic elements of this system are proteins, since their transformations in the process of heat treatment determine the consumer properties of the finished product and its energy value.

From the point of view of food technology, denaturation is the most important change in the proteins of all tissues when heated. The greatest interest, from the point of view of food technology, is the study and analysis of denaturation changes in myofibrillar proteins myosin, actin, actomyosin, tropomyosin, as the main carriers of the functional and technological properties of the finished product.

Denaturation changes in myoglobin, a protein that causes the color of meat after heat treatment, are of great importance in the technology of meat products. Among the sarcolemma proteins, heat-induced changes in collagen are of the greatest interest and practical importance, since the digestibility and functional and technological properties of the finished product depend on its hydrothermal decomposition.

It should be taken into account that individual proteins or fractions of proteins studied in isolation outside the tissue differ significantly in their physicochemical and biological properties from the same
proteins that are components of the protein systems of protoplasm and individual structural elements of muscle fiber [1].

One of the most important changes that occur in the process of heat treatment is the change in the water-holding capacity of meat and meat products.

Most researchers believe that the decrease in water retention and moisture loss during heating of meat are associated with denaturation and changes in the conformational structure of the protein [2, 3].

In the process of heat treatment, the number of acidic and basic groups of proteins decreases, which affects the pH value and, as a result, causes a shift in the isoelectric point of muscle proteins, which leads to a decrease in water retention capacity.

The release of moisture from meat during heat treatment is accompanied by the loss of mineral substances that pass into the cooking medium due to the difference in the concentrations of the corresponding substances in the product and the cooking medium, which negatively affects the nutritional value of the finished product [4].

Destructive changes in proteins during the heat treatment of meat products are accompanied by a decrease in their biological value due to the breakdown of amino acids [5]. It was reliably established that during the heat treatment of meat products, amino acid losses are observed, however, their value directly depends on the type, method and temperature of heat treatment, the type of meat product and the raw materials from which it is made, as well as the methods of chemical analysis that were used by scientists [6, 7].

In the process of heat treatment of meat and meat products, its native properties are lost as a result of protein denaturation, the initial configuration of protein molecules is transformed, hydration and moisture-holding capacity change, which in turn affects the juiciness and tenderness of the finished product [8].

Denaturation changes in proteins directly affect such important characteristics of meat products as nutritional and biological value, functional-technological, structural-mechanical and color characteristics [9].

Thus, the aim of the study was to identify coagulation-denaturation changes in proteins by various methods, in particular, by electrophoresis for the development of heat treatment modes and the production of products with specified characteristics. The task of the study was to determine the relationship of changes in the electrophoretic composition of protein fractions with a number of functional and technological properties and to propose rational temperatures for heat treatment of pork of various quality groups. In order to develop LT-LT heat treatment modes for the production of cooked pork products of various quality groups, it is necessary to justify the optimal temperatures in the center of the product [10, 11].

The hypothesis of the study was the assumption of the relationship between the temperature index in the center of the product and the destructive-denaturation changes in proteins with the quality characteristics of the finished products.

2. Materials and methods

The traditional process of heat treatment of whole-muscle cooked pork products is characterized by heating the product until the temperature reaches 68-72°C in the center. For LT-LT heat treatment, heating to lower temperatures in the center of the product is characteristic.

For this purpose, model products from the shoulder part of pork half-carcasses with signs of NOR and PSE, salted and molded in accordance with GOST R 53643 – 2009 weighing 3 kg, with a diameter of 90 mm, were subjected to experimental cooking in the temperature range from 40°C to 80°C in the center of the product with a step of 5°C. A set of changes in the dynamics of the degree of denaturation and the electrophoretic profile of proteins was studied. To achieve these goals, qualitative structural changes of proteins were studied by electrophoresis in polyacrylamide gel in the presence of sodium dodecyl sulfate [1, 12].

The lower temperature limit corresponds to 40°C in the center of the product, since at this temperature the denaturation of meat proteins begins. This is the minimum temperature of low-temperature heat
treatment. The upper temperature limit – 80°C in the center of the product is due to the fact that at this temperature, most of the meat proteins denature. This temperature is the maximum in the product centre in the production of whole-muscle and restructured products.

3. Results and discussion

Many properties of meat and meat products are determined by changes occurring in proteins under the influence of technological and exogenous factors. A detailed analysis of these changes can contribute to the development of new and adjustment of existing technological modes of processing meat raw materials, in particular, LT-LT modes of heat treatment of whole-muscle cooked pork products with signs of NOR and PSE [13].

The effect of heat treatment on the degree of denaturation of myofibrillar proteins of the model product from NOR-and PSE-pork is shown in figure 1.

![Figure 1. Dynamics of changes in the degree of denaturation of myofibrillar proteins of the model product from NOR-and PSE-pork, %.

The obtained results indicate that the minimum degree of denaturation of myofibrillar proteins is in the temperature range of 40-50°C. In this temperature range, the degree of denaturation of myofibrillar proteins of model products from NOR-and PSE-pork is characterized by a certain dispersion, which is within the experimental error and is 0.77% at 40°C with a further increase to 4.29% at 50°C.

An increase in the heat load on the product to 55°C in the center leads to an increase in the degree of denaturation to 11.97% and 12.11% for model products from NOR-and PSE-pork, respectively. A further increase in the temperature in the center of the model product to 60°C is accompanied by a sharp increase in the degree of denaturation of myofibrillar proteins by 32.81% and 33.59% for products made from NOR-and PSE-pork, respectively.
The subsequent increase in temperature in the range from 60°C to 80°C leads to a linear increase in the degree of denaturation of myofibrillar proteins to 69.11% and 75.78% for products made from NOR- and PSE-pork, respectively. At the same time, the degree of denaturation of myofibrillar proteins of model products from PSE-pork was 5% - 8% higher than the same indicator for NOR meat.

![Figure 2. Dynamics of changes in the degree of denaturation of sarcoplasmic proteins of the model product from NOR-and PSE-pork, %.

The nature of denaturation changes in sarcoplasmic proteins differs from myofibrillary ones (figure 2). It follows from the obtained data that in the model products from PSE-pork in the temperature range from 45 to 55°C in the center, there is a sharp increase in the degree of denaturation of sarcoplasmic proteins from 3.32% to 39.01%. At the same time, in model products made from pork of the NOR group, at 55°C in the center, the degree of denaturation is 16.78% lower than in products made from PSE-pork.

A further increase in the heat load on the product from 55 to 70°C leads to a uniform increase in the degree of denaturation of sarcoplasmic proteins to 67.06% and 80.91% in model products made from NOR and PSE pork, respectively. At 75°C in the center of the product, the degree of denaturation of sarcoplasmic proteins in model pork products of the NOR group is 86.12%, which is 3.97% higher than in products made from PSE-pork. A similar situation is observed at 80°C. Taking into account the literature data [2, 14, 15], indicating the relationship between the moisture-binding and fat-binding capacity of the ratio of sarcoplasmic and myofibrillar proteins, it can be assumed that at a temperature of 45-55°C in the center of the product, less mass loss will be observed during the heat treatment of products from NOR and PSE-pork.

However, the degree of denaturation of myofibrillar and sarcoplasmic proteins cannot characterize the complete picture of changes occurring during the heat treatment of model products from NOR and PSE-pork [8, 16].
The electrophoresis method was used to determine the dynamics of changes in the electrophoretic profile of myofibrillar proteins of model products from NOR-and PSE-pork during cooking from 40°C to 80°C in the center with a step of 5°C (figure 3).

![Image](image_url)

**Figure 3.** Electrophoregrams of myofibrillar proteins of the model product from NOR-(a) and PSE-pork (b).

Analysis of electrophoregrams (figure 3) and densitograms (figure 4) of myofibrillar proteins of model products from NOR - and PSE-pork, not subjected to heat treatment, showed that in model products made from PSE-pork, the number of protein fractions with different electrophoretic mobility is 3 fractions higher than in products from pork of the NOR group. The total number of protein fractions of the electrophoretic spectrum for model pork products with traditional autolysis was twenty-three fractions, and for exudative pork products – twenty-six fractions.

The largest number of protein fractions in the model products from PSE-pork is visualized in the zone of "medium" proteins with a molecular weight of 20 to 100 kDa.

In model pork products of the NOR group, "heavy" proteins with a molecular weight of 150-200 kDa are visualized quite clearly, while in model products from PSE-pork they belong to minor proteins.

The results obtained indicate a higher activity of tissue proteases in PSE-pork compared to NOR, which carry out the proteolysis of "heavy" proteins, which is confirmed by the studies of a number of scientists [17, 18]. A further increase in the heat load to 50 °C in the center leads to a change in the number of fractions of myofibrillar proteins of model products from NOR-and PSE-pork (figure 5).

Thus, at 50°C in model products from pork of the NOR group, protein fractions with a molecular weight of 200 and 100 kDa pass into the minor state, and proteins with a molecular weight of 150 kDa are completely eliminated. In the model products from PSE-pork, proteins with a molecular weight of 13, 14, 15 and 16 kDa pass to the minor state.
Thus, during the electrophoretic fractionation of proteins of model pork products, the patterns of destructive changes in the myofibrillary and sarcoplasmic protein fractions were revealed. It is established that the minimum changes in the fractional composition occur at 50-55°C in myofibrillar proteins and 65°C in sarcoplasmic proteins.
Figure 5. Densitograms of myofibrillar proteins of the model product from NOR-(a) and PSE-pork (b) heat-treated to 50 °C in the center. The peaks of the curves on the densitogram correspond to the protein fractions on the electrophoregram.

4. Conclusion
In the course of electrophoretic fractionation of proteins of model products from NOR- and PSE-pork, the patterns of destructive changes in myofibrillar and sarcoplasmic protein fractions were revealed. It was found that minimal changes in the fractional composition occur at 50°C - 55°C for myofibrillar proteins and 65°C for sarcoplasmonic proteins.

The analysis of the obtained results on the change in the degree of denaturation and the electrophoretic profile of proteins in the model pork products relative to the increase in temperature in the center showed that the temperature range of 50C-60C is the optimal range for minimizing losses during cooking, obtaining a juicier product with the preservation of nutritional value, regardless of the quality of the raw material.

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