**Technology of Producing Fermented Natural Meat Semi-Finished Products**

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**Abstract:** With the aim of the rational utilization of meat raw materials during the tenderization of beef, the hip, lateral, and outer cuts of meat were processed using microbial enzyme preparations, such as Protosubtilin G10x, as well as control samples treated with 2% table salt (NaCl). These cuts are typically tough and are not commonly used in public catering for the preparation of natural meat semi-finished products. Fermentation was applied to these cuts to soften the meat, followed by the preparation of natural meat semi-finished products. Both control and experimental meat samples, as well as the resulting natural meat products, were analyzed.

**Keywords:** biological catalyst, enzyme preparation, muscle fibers, natural meat maturation, histological studies, microbiological studies, chemical analyses, lateral and outer meat cuts, meat tenderization.

**INTRODUCTION**

Enzymes (from Latin *fermentum* – fermentation, starter), or enzymes, are specific proteins that increase the rate of chemical reactions in the cells of all living organisms. Each type of enzyme catalyzes the transformation of specific substances (substrates), sometimes only a single substance in a single direction. Therefore, a vast number of different enzymes are responsible for the numerous biochemical reactions in cells [1].

A key property of certain proteins is their catalytic activity. Proteinaceous substances capable of catalytically accelerating chemical reactions are called enzymes. The role of enzymes in the life processes of animals, plants, and microorganisms is enormous. To date, several thousand individual enzymes have been identified in biological systems, and several hundred have been isolated and studied.

Biological catalysts differ significantly from inorganic catalysts in several respects. Being proteins, enzymes possess all the characteristic properties of proteins, including thermal lability, dependence on the pH of the medium, specificity, and susceptibility to activators and inhibitors [2].

A technology for producing fermented natural meat semi-finished products such as beefsteak, langet, and entrecôte has been developed. The action of enzymes on meat has been studied, along with chemical, histological, and microbiological analyses, digestibility tests, and organoleptic evaluation of the quality of the products.

The application of enzymes in meat processing is based on the enzymatic hydrolysis of proteins, which alters the structure of muscle fibers and improves the taste and organoleptic properties of the final product [3]. Many specialists believe that treatment of muscle tissue with proteolytic enzymes significantly accelerates the natural maturation of meat and secondary by-products (Category II), allowing an increase in the yield of portioned and small-cut semi-finished products (beefsteaks, langets, entrecôtes, etc.) by 30–50%. Digestibility increases by 20%, thermal processing time is reduced by 30%, and taste and aroma improve. The production cost of semi-finished products decreases by approximately 30%. Enzymes partially hydrolyze proteins, promoting the solubility of the actomyosin complex, its breakdown into free amino acids, increased protein molecule hydration, and a higher content of bound water in the meat during curing [4,5].

Enzymes of plant, animal, and microbial origin can be used for meat tenderization. Microbial strains represent the most cost-effective and accessible source of proteolytic enzymes [6].

Enzymes are proteins characterized by the presence of an active site (or active group) responsible for their catalytic properties. Enzymes can be divided into single-component enzymes, consisting only of a protein portion, and two-component enzymes, which include a protein part (feron) and a non-protein part (agon). The agon is also referred to as the proteolytic group [7].

Characteristics of products, raw materials, and semi-finished products**:** Enzyme preparations are concentrates of enzymes obtained from microorganisms and contain inert substances alongside the active enzymes. They are used in food production as catalysts of relevant biochemical processes [8].

In the early development of enzymology, research focused primarily on digestive enzymes (pepsin, trypsin, chymotrypsin) and fermentation processes, which remain the most thoroughly studied. Today, enzyme preparations are increasingly used in meat production technology. Improvement of taste, aroma, texture, color stabilization, and acquisition of specific properties during processing largely depends on the enzymes present in meat. However, the concentration of intracellular enzymes in the muscles of farm animals is typically low, and some anatomical parts of the carcass contain higher amounts of connective tissue, resulting in tougher meat and slower maturation [9].

Treatment of meat with proteolytic enzymes allows the use of cuts that are complete in composition but naturally tough, such as the hind limbs, shoulder, and brisket. Treatment with the enzyme preparation collagenase produces significant structural changes, ensuring effective tenderization, consistent with assessments of structural-mechanical and functional-technological properties [10].

The use of enzymes in modifying meat raw materials allows for the rational utilization of protein resources and increases the biological value of meat sauces by enhancing the proportion of collagen proteolysis products. Enzyme preparations, along with extractive, aromatic, and flavoring substances that stimulate digestive secretions, improve the digestibility of the main components of the dish [11]. For instance, a promising method for processing secondary collagen-rich meat raw materials is enzymatic modification. Compared to physicochemical methods, it allows targeted regulation of properties, improved digestibility of collagen protein, and cost-effective implementation.

One of the promising directions in improving the quality of meat products is the use of enzyme preparations. Their application in meat processing is based on enzymatic hydrolysis of proteins, altering the structural elements of meat and improving its biochemical and physicochemical quality indicators. Wider implementation of enzyme preparations in production will be facilitated by the development of effective methods for treating raw materials with enzymes (biocatalysts) [12].

Based on the above, the aim of this study was to develop a technology for meat fermentation in the production of natural beef semi-finished products.

Histomorphological features of first- and second-grade beef during enzymatic treatment were investigated, the changes in functional-technological and structural-mechanical properties of the meat raw materials were determined, and the effect of enzyme preparations on the color characteristics of meat products was assessed.

A comprehensive study of the beef tenderization process using microbial proteolytic enzyme preparations and the development of a technology for meat semi-finished products was conducted [13].

Конец формы

**METHODS**

To achieve the stated goal, the following tasks were set and addressed:

-to justify the selection of the enzyme preparation and determine its main characteristics;

-to develop a fermentation technology for natural meat semi-finished products using the hip, lateral, and outer cuts of beef;

-to develop the method and conditions for the fermentation of beef;

-to scientifically substantiate the formulation of meat semi-finished products from fermented beef;

-to study the effect of the enzyme preparation on a range of quality indicators of meat and final meat products;

-to determine the physicochemical characteristics of meat and develop a method for preparing meat semi-finished products;

-to determine the technical and economic indicators of the developed technology.

The tenderizing effect of the microbial proteolytic enzyme preparation **Protosubtilin G10x** on beef has been established [14].

The object of the study was the microbial proteolytic enzyme preparation **Protosubtilin G10x** intended for food applications, as shown in Figure 1. The carcass cutting of beef is illustrated in Figure 2, and the deboned lateral and outer beef cuts, which are not typically used for the preparation of natural meat semi-finished products (beefsteak, langet, entrecôte).

The proteolytic activity of the enzyme Protosubtilin G10x was determined using the Anson method. The concentration of the enzyme applied to beef and its temperature optimum were also investigated [15].

The microbial proteolytic enzyme preparation Protosubtilin G10x is yellow-gray in color, with a proteolytic activity of 70 U/g. A 0.01% solution of Protosubtilin G10x containing 2% table salt was prepared, and this enzyme solution was introduced into the hip, lateral, and outer beef cuts at 5% of the meat mass using an injection method. The meat cuts were held for 1 hour at a temperature of 38–40 °C, allowing fermentation to occur.

After fermentation, the meat was stored in a refrigerator at 4 °C for one day. Control meat samples were also stored under the same conditions. Both the fermented and control meat samples were subsequently used to prepare natural meat semi-finished products.

Beef from the lateral and outer cuts of the hip, obtained from both fermented and control raw materials, was analyzed along with the final product. A scientifically substantiated technological scheme for the production of beef semi-finished products from the lateral and outer cuts of fermented raw meat was developed, allowing for improved quality, an expanded product range, and increased output of meat semi-finished products. The normative yields, thermal processing conditions, and storage periods for the fermented products were determined.Начало формы

Конец формы

The results of the work have been implemented in production. The produced natural meat semi-finished products received high evaluations from tasting panels. The production of fermented natural meat semi-finished products demonstrated significant economic benefits.

The experimental design, research objects, and methods are presented in a schematic form. A brief characterization of the research objects is provided, the selection of studied indicators and parameters is justified, and the methods for their determination are described.

**RESULTS**

Natural meat semi-finished products were prepared as beefsteak, langet, and entrecote. Natural meat semi-finished products consist of two approximately equal-sized pieces of meat. They are intended for frying as whole pieces. Only the most tender parts of the carcass are used for their production—tenderloin, and the muscles of the dorsal, lumbar, and hip regions—which constitute 14–17% of the weight of a beef carcass.

Meat from other parts of the carcass (muscles of the hind leg, shoulder, and brisket), although complete in protein composition, is naturally tougher and is typically used for stewing or for preparing minced meat. It can be used for portioned semi-finished products only after tenderization, which can be achieved through prolonged maturation or the application of enzyme preparations. Under the action of enzyme preparations, the processes responsible for tenderness, juiciness, taste, and aroma of the meat are accelerated two- to threefold [16].

To improve meat tenderness, enzyme preparations are suitable whose action does not reduce the nutritional value of the meat and does not break down amino acids, but induces certain structural changes in proteins, similar to those occurring during natural meat maturation. For artificial tenderization of tougher carcass cuts, microbial proteolytic enzymes can be used, allowing the yield of beef suitable for natural semi-finished products to increase by 25–27%.

Natural meat semi-finished products are produced in all types: t-and-bone. They consist of pieces with a specified proportion of mmuscle-only and meaeat tissue. Muscle-only semi-finished products are cut from leftover raw material after portioned semi-finished products are prepared, as well as from large, tougher pieces not suitable for portioned products (shoulder and sub-shoulder parts and trimmings from Category I beef). Meat-and-bone small-cut semi-finished products are produced from neck, chest, rib, lumbar, pelvic, sacral, and tail bones, as well as brisket (including ribs), with a defined meat content obtained from combined beef deboning.

Natural meat semi-finished products should have an unexposed surface, color, and odor characteristic of good-quality meat, with firm muscle tissue free from tendons, coarse connective tissue, cartilage, or broken bones. For semi-finished products from the hip, the surface membrane and fat tissue may remain. Deviations in mass and shape are permitted up to 10% of the portion weight. The assortment and characteristics of natural meat semi-finished products are presented in Table 1.Начало формы

**TABLE 1.** Assortment and characteristics of natural meat semi-finished products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Raw materials** | **Semi-finished product** | **Characteristics of the semi-finished product** | **For public catering, portion weight, g** | **For retail trade, portion weight, g** |
| Tenderloin | Natural beefsteak | Piece of meat with irregular rounded shape, thickness from 20 to 30 mm | 80, 125 | 125 |
| Shoulder | Langet | Two approximately equal-mass pieces of meat with irregular rounded shape, thickness from 10 to 12 mm | 80, 125 | 125 |
| Longissimus dorsi muscle | Entrecôte | Piece of meat elongated or irregularly rounded in shape, thickness from 15 to 20 mm | 80, 125 | 125 |

According to this technology, the outer and lateral cuts, which are typically not used for the production of natural meat semi-finished products, were utilized. These parts of beef are the toughest and have a relatively large mass (3–5 kg). In the experiments, meat that had been chilled for up to 2 days was used. For the study, enzyme solutions were prepared at concentrations of 0.01% and 0.5%. The enzyme was dissolved in a 2% table salt (NaCl) solution prepared with distilled water. The selected meat was cut into pieces for frying, weighing 80–125 g, which were injected with the enzyme solution at 0.01% concentration for the first series of experiments and at 0.5% concentration for the second series. The amount of enzyme solution added was 5% of the meat piece mass. Control samples were injected with a 2% table salt solution in the same proportion.

The temperature of the enzyme solutions for the first and second series of experiments was 38 °C and 40 °C, respectively. At these same temperatures, the fermented and control meat samples were held for 1 hour and then stored in a refrigerator at 2–4 °C for 1–2 days. Each day, the corresponding samples (fermented and control) were taken from the refrigerator, prepared into portioned semi-finished products—beefsteaks, langets, and entrecôtes (according to the adopted technological instructions)—and fried in vegetable oil at 155–180 °C (with the amount of oil being 5–10% of the semi-finished product mass). For the finished products, yield was determined, and organoleptic evaluation was conducted, as presented in Table 2.

**TABLE 2.** Yield of natural semi-finished product after thermal processing

|  |  |  |  |
| --- | --- | --- | --- |
| **Semi-finished product** | **Control, 2% NaCl, yield** | **Experimental, 0.01% enzyme concentration, yield** | **Experimental, 0.5% enzyme concentration, yield** |
| Beefsteak | 63,1 | 68,9 | 70,6 |
| Langet | 63,3 | 67,9 | 70,6 |
| Entrecôte | 59,8 | 66,3 | 70,3 |

It was established that on the second day of storage, at an enzyme concentration of 0.01%, the yields of beefsteaks, langets, and entrecotes were 68.9%, 64.9%, and 66.31%, respectively, whereas at an enzyme concentration of 0.5% the corresponding yields were 63.8%, 66.5%, and 65.3%. For comparison, the yield of natural semi-finished products prepared from beef tenderloin is not less than 63%. Based on the obtained data, it can be concluded that increasing the enzyme concentration from 0.01% to 0.5% does not lead to an increase in the yield of finished products; however, an increase in the holding (aging) time makes it possible to significantly improve this indicator. At an enzyme concentration of 0.5%, changes in the meat structure were observed, and the meat became excessively loosened. These results are consistent with the data reported by A.S. Ratushny.

After thermal processing, the control samples of semi-finished products showed a yield of finished products equal to that of traditional products prepared from tenderloin on the third day of storage; however, they remained tough. The mass fraction of moisture in fermented natural portioned semi-finished products after thermal processing was higher than in the control samples. Although the control samples reached a yield comparable to that of tenderloin-based products on the third day of storage, they were characterized by greater toughness. The organoleptic evaluation of the quality of fermented natural meat semi-finished products was higher than that of the control samples. Organoleptic assessment was carried out using a five-point scale, and the results are presented in Table 3.

**TABLE 3.** Organoleptic evaluation of natural meat semi-finished products

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Name of Samples** | **Color** | **Appearance** | **Taste and aroma** | **Texture (consistency)** | **Juiciness** | **Overall evaluation (overall score)** |
| Control samples | | | | | | |
| Beefsteak | 3,1 | 3,1 | 3,5 | 3,6 | 3,6 | 3,4 |
| Langet | 3,5 | 3,5 | 3,7 | 3,9 | 3,7 | 3,7 |
| Entrecôte | 3,1 | 3,1 | 3,6 | 3,6 | 3,6 | 3,4 |
| Experimental samples with 0,01% enzyme concentration | | | | | | |
| Beefsteak | 4,8 | 4,9 | 4,9 | 4,9 | 5,0 | 4,9 |
| Langet | 4,9 | 4,9 | 4,9 | 5,0 | 5,0 | 4,9 |
| Entrecôte | 4,8 | 4,8 | 4,9 | 4,9 | 4,9 | 4,9 |
| Experimental samples with 0,5% enzyme concentration | | | | | | |
| Beefsteak | 4,8 | 4,8 | 4,2 | 4,3 | 4.3 | 4,4 |
| Langet | 4,8 | 4,8 | 4,4 | 4,3 | 4,3 | 4,5 |
| Entrecôte | 4,8 | 4.8 | 4,3 | 4,4 | 4,4 | 4,5 |

Fermented natural semi-finished products underwent minimal changes in their original shape during frying. The release of meat juice ceased significantly earlier than in the control samples, and the products rapidly acquired the gray-brown color characteristic of fried meat. In contrast, the control pieces were strongly deformed during frying. The organoleptic evaluation of fried natural semi-finished products, prepared from the hip section’s outer and lateral cuts of beef after treatment with the microbial enzyme preparation Protosubtilin G10x, demonstrated that the taste and juiciness of the products improved, the meat became tender, softer, and easier to chew. The influence of the microbial enzyme preparation Protosubtilin G10x on the microstructure of the muscle tissue of the hip section’s lateral and outer beef cuts during fermentation was also studied. The muscle tissue microstructure was examined 48 hours after injection of the enzyme solution.

The results of the study showed that, after fermentation of the muscle tissue, the meat exhibited more pronounced destructive changes, characterized by the presence of numerous microcracks and transverse, scale-like disruptions of the muscle fibers. The muscle fibers were swollen, with occurrences of fragmented fibers and the formation of fine-grained protein masses in these areas, predominantly located beneath the sarcolemma. This indicates the preservation of the myofibrillar substance within the structure of the muscle fibers. Changes in the microstructure of the muscle tissue following fermentation indicate that the enzyme preparation Protosubtilin G10x promotes the acceleration of meat maturation and improves its technological properties.

The effect of the microbial-derived enzyme Protosubtilin G10x on beef from the hip section (lateral and outer cuts) was investigated. The microbiological quality of the final products—control samples and experimental samples fermented with 0.01% and 0.5% concentrations of Protosubtilin G10x (dissolved in a 2% sodium chloride solution prepared with distilled water)—was evaluated. Analysis of the microbiological results showed that 1 g of product contained the following microbial counts: the total number of aerobic and facultative anaerobic microorganisms in both the fermented and control samples of the finished products was high, ranging between 200 and 300 microbial cells. Lactic acid aroma-forming bacteria were present at 85 microbial cells in the control samples and 110 microbial cells in the fermented samples. Lactic acid–producing bacteria were present at 105 microbial cells in both the control and fermented samples. No bacteria of the genus Proteus, Salmonella, spore-forming anaerobes, or coliform bacteria were detected in any of the three products.

Thus, the use of the microbial enzyme Protosubtilin G10x for meat fermentation renders the meat microbiologically safe and suitable for the production of meat products. The potential of utilizing the hip section, lateral, and outer cuts of beef treated with Protosubtilin G10x for the production of natural meat semi-finished products was investigated. Experimental studies were conducted to evaluate shear stress, consistency, yield after frying, and overall quality assessment of the meat semi-finished products. The effects of different concentrations of the enzyme Protosubtilin G10x on various quality indicators of natural meat semi-finished products are presented in Table 4.

**TABLE** **4.** Effects of different concentrations of the enzyme protosubtilin G10x on certain quality indicators of natural meat semi-finished products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sample** | **Shear stress, Avg. 104 Pa** | **Cutting work, A. А.102 J/m2** | **Overall organoleptic quality assessment, points** | **Yield, %** |
| Control samples | 9,16 0,27 | 5,56 0,16 | 3,5 | 62 |
| Experimental samples with 0,01% enzyme concentration | 4,91 0,14 | 3,05 0,09 | 4,9 | 68 |
| Experimental samples with 0,5% enzyme concentration | 2,23 0,08 | 1,65 0,04 | 4.5 | 70,5 |

The table presents the results of studying the effects of Protosubtilin G10x on shear stress and yield after thermal processing of the samples. These data confirm that the treatment of beef, specifically the hip portion and lateral and outer cuts of the carcass, with the enzyme preparation, along with sensory and instrumental evaluation of the sample consistency after salting, demonstrates that the enzyme promotes softening of the meat structure. These findings are consistent with previously reported literature on the tenderizing effects of Protosubtilin G10x on muscle tissue proteins.

**RESULTS AND DISCUSSION**

Experience shows that artificially introduced protease preparations into raw meat provide an effect analogous to autolytic transformation of protein structures; however, the maturation processes under their influence proceed 3–5 times more intensively and are completed in a shorter period. Although proteolytic enzyme preparations differ in their specificity toward meat proteins such as myosin, collagen, and elastin, the final outcomes of these processes share many similarities.

The intensity and depth of protein structure transformations depend on enzyme dosage, physicochemical conditions, duration of treatment, and application method. The action of proteolytic enzymes ultimately leads to significant changes in meat proteins and the system of extractive substances.

Practical experience in the meat industry demonstrates the high efficiency of enzyme application for the following purposes: accelerating meat maturation, tenderizing tough meat, improving the quality and nutritional value of meat products.

The application of the enzyme Protosubtilin G10x for meat treatment is based on enzymatic protein hydrolysis, resulting in modifications of structural elements of meat and improvements in its biochemical and physicochemical quality indicators.

In meat processing, multi-grade trimming of meat is traditionally practiced, requiring significant manual labor. This process removes up to 3% of collagen-containing inclusions in the form of tendons, sinews, and fascia, which in consumer cooperatives is typically not used for food purposes but redirected as feed to fur farms.

It has also been established that muscle proteins, in combination with connective tissue, stimulate gastrointestinal motility, enhance digestive secretions, and positively affect the gut microbiota. However, the functional and technological properties of collagen-containing raw materials are insufficient to achieve the desired effect in forming quality product indicators. A promising approach is the fermentation of collagen-rich raw materials. Many studies positively assess the use of various enzyme preparations for tenderizing tough meat in the production of semi-finished products.

Analysis of the literature indicates that enzymatic treatment of lower-grade meat raw materials holds great potential for increasing the availability of high-quality dietary protein. The application of enzyme preparations with collagenase activity in semi-finished product manufacturing remains an urgent issue. To justify technological regimes and methods of enzyme application, it is necessary to study their physicochemical characteristics and biochemical properties. Of practical importance is the study of the effects of external technological factors (pH, temperature, presence of activators and inhibitors) on the proteolytic activity of enzyme preparations.

It has been established that enzyme preparations used to improve meat quality should have the following properties: they should alter connective tissue (cleave the mucopolysaccharide complex, reduce connective tissue resistance to heat, and stimulate collagen and elastin hydrolysis); exert minimal effects on muscle tissue; have a high optimal temperature for action while retaining partial activity during heat treatment; operate optimally in weakly acidic or neutral environments; and be safe for human consumption.

Practical application shows that not all enzymes with high proteolytic activity achieve the desired effect on meat. Some strongly catalyze the hydrolysis of muscle fiber proteins but have little effect on connective tissue proteins, which are responsible for meat toughness. The efficacy of meat treatment depends significantly on enzyme action optimum, the nature of activators and inhibitors, and the specificity for breaking peptide bonds during the hydrolysis of animal proteins.

Protosubtilin G10x solution applied to meat trimmings containing tendons and muscle fascia allows hydrolysis of collagen fibers into peptides. This enzyme preparation specifically hydrolyzes collagen peptide bonds formed by proline. It is characterized by high mass fractions of hydroxyproline (1%) and proline (7.5%). The degree of collagen hydrolysis under its action reaches 75–87.5%. The use of proteolytic enzyme preparations on meat before culinary processing improves meat grade and facilitates more complete assimilation of hydrolyzed proteins in the human gastrointestinal tract.

The most effective tenderizers for tough meat are enzyme preparations capable of hydrolyzing intramuscular connective tissue proteins after heat denaturation. Therefore, enzyme preparations with high-temperature activity optima are of particular interest. At the same time, the biochemical and microbiological characteristics of meat require many technological operations (maturation, salting) at low positive temperatures. According to A.S. Ratushny, most known animal- and microbe-derived enzymes effective in meat processing have proteolytic activity maxima around 50 °C, with papain showing the highest activity at 60–70 °C.

The action of enzymes is based on hydrolyzing peptide bonds in muscle proteins, softening coarse fibers and connective tissue, which significantly improves meat tenderness, organoleptic properties, and yield of the final product. Enzyme activity and tenderizing effect depend on raw material type, enzyme used, temperature, pH, salts, duration of exposure, concentration, and method of application.

In industry, the primary application of Protosubtilin G10x is for stimulating maturation, tenderizing tough meat, and processing Category II by-products. Biotechnological methods for tenderizing meat and modifying raw material properties are primarily used for low-grade meat intended for producing natural meat semi-finished products. Maturation intensification and tenderization techniques can be applied alone or in combination.

It should be noted that all known enzymes efficiently hydrolyze muscle fiber proteins, but most have weak effects on native collagen and elastin. To improve the efficacy of microbial enzyme preparations, the following directions are being developed:further search for microbial strains capable of synthesizing proteolytic enzymes with high collagenase and elastase activity, Combination of enzyme preparations,integration of physicochemical and biochemical factors in tough meat processing (e.g., ultrasound with enzymatic treatment, sodium chloride with enzymatic treatment, etc.).

Studies show that enzyme-treated meat has higher biological, biochemical, instrumental, and organoleptic quality. Therefore, further research on enzyme application in meat processing has undeniable prospects and practical significance.

Based on research results, analysis, and quality assessment of natural meat semi-finished products, optimization of ingredient composition and development of methods to improve technological properties of meat raw materials for natural semi-finished products are justified. The mechanism of proteolytic action of Protosubtilin G10x (containing 2% NaCl) on hip portion, lateral and outer cuts of beef was studied, including its effects on native and denatured muscle and connective tissue. Dependencies of proteolysis product accumulation on pH, duration, and temperature of fermentation were established.

Conditions for enzymatic treatment of tough meat with Protosubtilin G10x were justified: temperature 40 °C, enzyme concentration 0.01% and 0.05%, and fermentation duration 1 hour, to improve technological properties and for subsequent production of natural semi-finished products.

Theoretical calculations using Protosubtilin G10x for natural semi-finished products (beefsteak, langet, and entrecote) were carried out in accordance with modern medical-biological requirements for meat products intended for regular diet.

Comparative evaluation of beefsteaks produced by the proposed and traditional recipes showed that experimental steaks exceeded controls in tenderness, juiciness, flavor, balance of amino acid and fatty acid composition, protein-to-fat ratio, calcium and phosphorus content, higher water-binding capacity, and lower weight loss (by 2.5%) after heat treatment. The overall quality index of traditionally prepared beefsteaks was 0.678, while that of optimized beefsteaks was 0.889.

Fermented natural meat semi-finished products with 0.01% Protosubtilin G10x showed higher organoleptic characteristics, with no significant differences in physicochemical or microbiological parameters compared to controls.

After fermentation, beef hip portion, lateral and outer cuts became softer than control samples, confirmed by physicochemical and histological studies.

Formulations and technological schemes for producing fermented natural meat semi-finished products from hip portions (lateral and outer cuts) were developed. During processing, enzyme preparations exhibited intensive action on muscle tissue and coarse fibrous meat tissues.

Treatment of tough meat with Protosubtilin G10x significantly accelerates the technological process and sharply reduces shear stress in the final natural meat semi-finished products compared to other methods.

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