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FERMENTATION PROCESS OF BEEF EFFECTED BY ITS PHYSICAL AND CHEMICAL TRAITS

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The processes of natural fermentation of raw meats, as well as intensive technologies based on them, make it possible to provide rheological characteristics of finished products acceptable to consumers, especially the products made from beef. Biochemical changes in raw materials caused by the action of enzymes make it possible to provide acceptable functional and technological properties, intensify the production process, improve the storage capacity of products, raise the nutritional value of finished products and the degree of digestibility of meat products by humans. ***Relevance of the topic.*** *Introduction of advanced technologies in the domestic meat processing industry.* ***The subject*** *is oxidative properties of fermented beef.* ***The purpose*** *of the work is a scientific substantiation of the most rational ways of fermenting meat raw materials, establishing requirements for raw materials for the production of fermented meat.* ***Research methods.*** *Statistical processing of the obtained results was performed based on the calculation of arithmetic mean values and the mean square error.* ***The results of the study.*** *A dry fermentation method was chosen for 18 days at a temperature of (2±2)°C, humidity – (75- 80)%. It was determined that the pH value on the first day of storage (fermentation) in two experimental samples of the long back muscle isolated from the carcasses of Aberdeen Angus bulls has an overestimated value (more than 6.2 units), which characterizes their possible involvement in the DFD meat group; according to the sensorial evaluation, the meat of these samples has certain differences: a darker color and a tougher texture than in other experimental samples. It has been established that in terms of structural and mechanical parameters, meat from different breeds of experimental animals also has differences: elasticity ranges from 18.2 kN/m^2 to 28.3 kN/m^2, penetration forces - from 152.3 kN/m^2 to 465.3 kN/m^2, which is associated with different pH levels. It has been established that during storage, the rheological properties of beef improve: the penetration force decreases, the elasticity increases. A positive effect of fermentation for 18 days at a temperature of (2 ± 2)°C on the consumer characteristics of meat was also found.*

Keywords*: aberdeen-angus meat breed, pH value, sensorial characteristics, structural and mechanical characteristics, dry fermentation, fermented beef, charolais meat breed*

ВПЛИВ ФІЗИКО-ХІМІЧНИХ ВЛАСТИВОСТЕЙ ЯЛОВИЧИНИНА ЕФЕКТИВНІСТЬ ЇЇ ФЕРМЕНТАЦІЇ

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Процеси природної ферментації м'ясної сировини, а також базовані на них інтенсивні технології дозволяють забезпечити прийнятних для споживачів структурно-механічних характеристик готових продуктів – особливо виготовлених з яловичини. Біохімічні зміни сировини, спричинені дією ферментів, дозволяють забезпечити її прийнятні функціонально-технологічні властивості, інтенсифікувати виробничий процес, покращити здатність продукції до зберігання, підвищити харчову цінність готової продукції та ступінь засвоюваності м'ясних продуктів організмом людини. ***Актуальність теми****. Впровадження передових технологій в вітчизняній м'ясопереробній галузі.* ***Предмет досліджень*** *– окисні показники ферментованої яловичини.* ***Мета роботи*** *– наукове обґрунтування найбільш раціональних способів ферментування м'ясної сировини, встановлення вимог до сировини для виробництва ферментованого м'яса.* ***Методи досліджень.*** *Статистичне оброблення отриманих результатів виконували на основі підрахунку середньоарифметичних значень і середньої квадратичної похибки.* ***Результати досліджень.*** *Обрано сухий спосіб ферментації протягом 18 діб при температурі (2±2)°С, вологості – (75-80)%. Визначено, що показник pH на першу добу зберігання (ферментації) у двох дослідних зразках найдовшого м'язу спини, виділеного з туш бугаїв абердин-ангуської породи, має завищене значення (більше ніж 6,2 од.), що характеризує їх можливу причетність до групи DFD м'яса; згідно з проведеним органолептичним оцінюванням м'ясо цих зразків має певні відмінності: темніший колір і більш тверду консистенцію, ніж у інших дослідних зразках. Встановлено, що за структурно-механічними показниками м'ясо від різних порід дослідних тварин також має відмінності: еластичність коливається від 18,2 кН/м^2 до 28,3 кН/м^2, зусилля пенетрації – від 152,3 кН/м^2 до 465,3 кН/м^2, що пов'язано з різним рівнем pH. Встановлено, що під час зберігання поліпшуються структурно-механічні властивості яловичини: зусилля пенетрації знижується, еластичність підвищується. Також виявлений позитивний вплив ферментації протягом 18 діб при температурі (2±2)°С на споживчі характеристики м'яса.*

Ключові слова: *абердин-ангуська м'ясна порода, величина pH, органолептичні характеристики, структурно-механічні характеристики, суха ферментація, ферментована яловичина, шароле м'ясна порода*

Formulation of the problem. Over the millennia that have passed since man began to eat animal meat, many technological methods and technical means have been worked out to improve the consumer qualities of this valuable protein raw material. In particular, the processes of natural fermentation of meat raw materials were studied and mastered, and intensive technologies were proposed on their basis, which make it possible to provide structural and mechanical characteristics of finished products acceptable to consumers, especially those made from beef [1, 2], the processing of which very often requires special selected enzyme preparations [3,4] or complex mixtures with their use [5, 6]. To intensify the process, special technological equipment is used [5-7]. Biochemical changes occurring in raw materials under the action of enzymes contribute to the modification of its functional and technological properties, reducing the duration of the production cycle, increasing the nutritional value of finished products, improving digestibility by the human body and storage stability [8].

The quality of meat suitable for further culinary processing largely depends on the degree of its maturation, that is, the level of development of autolysis. Autolysis is the process of changing the chemical composition, structure and properties of meat after the slaughter of an animal under the influence of its own enzymes. The enzymatic breakdown of glycogen is the trigger for the development of further physicochemical and biochemical processes. In the process of autolysis, tenderness, juiciness, taste, aroma, etc. are formed.

Therefore, the key issue in the formation of quality is the determination of changes in meat under the influence of various factors, in particular, during its fermentation. Changes in the properties of meat develop in a certain sequence in accordance with the main stages of autolysis: hot meat, rigor mortis, completion of rigor, meat maturation, deep autolysis [9, 10]. The characteristics of the stages of beef autolysis are presented in Table 1 [11].

Table 1

Characteristics of the stages of beef autolysis – adapted from [11]

№	Stage	Time, h	t,°C	pH, units	Characteristic
1	Hot meat	2-4	0-4	7.2	Tender, juicy, withoutpronounced smell and taste
2	Rigor mortis	3-48	0-4	6.3	Elastic, dry meat with a sour taste
3	Completion of rigor. Maturation.	120 and more	0-4	5.5	Soft, juicy meat with acharacteristic taste and smell

Autolysis is the process of decomposition of meat tissue components under the influence of its enzymes that retain their catalytic activity for a long time; the reason for autolysis is the cessation of oxygen access to the tissues. The process takes place in the tissues of the animal immediately after slaughter, while the meat has an elastic texture, pink-red color and high water-holding capacity, while its aroma is weakly expressed. In the first hours of autolysis, glycolytic processes predominate. This leads to the accumulation of lactic and phosphoric acid, resulting in a decrease in the pH value of muscle tissue.

Due to the breakdown of glycogen and the accumulation of lactic and orthophosphoric acids (as a result of dephosphorylation of intermediate products of glycolysis: glucose phosphates, and later – creatinephosphate and nucleotides), the reaction of the muscle tissue environment is shifted to the acid side. In healthy not tired animals, the pH value of the meat immediately after slaughter is in the range of (6-7) units. Then it decreases and in the state of rigor mortis can reach pH 5.6-6.1 and below [12].

Under the influence of autolysis, there is a change in the qualitative characteristics of meat, such as mechanical strength, sensorial and technological properties, resistance to microbiological processes. The basis of meat autolysis is a change in the carbohydrate component, which occurs at the biochemical level. Changes in hardness and water-holding capacity occur within 5 to 7 days after slaughter at a temperature of 0 to 4°C.

The aroma and taste become noticeable after (2-4) days after slaughter at a temperature of 0 to 4° C, after 5 days they are well expressed. Taste characteristics reach the highest intensity on (10-14) days [13].

The maximum change in the strength properties of meat coincides with the maximum development of the rigor process. In the process of rigor mortis, the moisture-binding capacity of meat decreases and reaches a minimum by the time of the most complete development of rigor mortis. But rigor mortis does not occur immediately, but after the glycogen stores in the muscles run out.

Hot meat should not be used in cooking because the flavor and aroma properties of such raw materials are minimally pronounced [14, 15].

The maturation of meat occurs as a result of keeping it for a certain time at low (plus) temperature values. Ripe meat has a high nutritional value due to changes in protein compounds, taste and aroma indicators under the influence of its own enzymes. Meat maturation is the aging of meat raw materials, during which a number of autolytic chemical transformations occur, which positively affects physical, chemical and sensorial properties of meat (density, tenderness, juiciness, pronounced taste and smell) [9, 15]. That is, the maturation of meat allows achieving desirable sensorial parameters indicators, improve the rheological properties of meat, but at the same time bears the risk of spoilage and loss of a valuable product [16].

Processed meat raw materials at industrial enterprises are heterogeneous in terms of quality and are characterized by non-identical post-slaughter processes. In raw materials with PSE properties, the breakdown of glycogen to lactic acid is completed almost after (45-60) min. from the moment of slaughter, while in DFD meat post-slaughter glycolysis is not profound or practically does not occur due to the low content of ATP and glycogen in the muscles until the moment of slaughter. The fulfilled analysis of the literature data shows that deviations in the nature of the development of autolytic processes in PSE and DFD muscle tissue, one way or another, are associated with different courses of glycolytic processes [12]. PSE and DFD meat differ in appearance, physical and chemical properties [14].

The most important indicator of meat quality is the pH value, since its changes in the process of autolysis entail significant practical consequences. It is known that fresh meat has a pH value in the range of (6-7) units. After 24 hours of autolysis at a temperature of 0 to 4 °C, the pH value reaches a minimum value of (5.5-5.6) units. The decrease in pH leads to the following results: the resistance of meat to the action of putrefactive microorganisms increases; the solubility of muscle proteins decreases, their level of hydration, moisture-binding ability due to the approach of the pH of meat to the isoelectric point of proteins (4.7-5.4) also decreases; the activity of tissue cathepsin enzymes increases (optimal pH for them is 5.3) and the action of calcium ions is manifested, an increase in the concentration of which in the sarcoplasm of cells increases the activity of enzymes; there is swelling of connective tissue collagen and hydrolysis of muscle proteins at subsequent stages of autolysis [17].

Currently, there are different ways of fermenting meat, in particular beef: dry, wet, combined, chemical, enzymatic. Each of them has its own advantages and disadvantages. For example, the advantages of wet ripening include high hygiene and low microbiological risks; higher maturation rate under vacuum compared to dry maturation [18]. Beef aging (also ripening, fermentation) is the preparation of meat using the initial stages of autolysis before its heat treatment. The main purpose of dry aging beef is to enhance the natural taste and aroma of meat. Characteristics of the chamber for dry ripening: temperature – from 1°C to 3°C, humidity – about (50-60)%, constant air circulation. Stages of maturation (fermentation): 21; 35; 90 days. It shall be noted that during dry ripening, up to a third of the mass of meat is lost due to moisture loss, which affects the price of the final product. Only high-quality beef should be subject to long-term fermentation. This is the basic requirement for the production of fermented meat. Long-term maturation is a process that requires a lot of energy and strict adherence to all regimes; usually, raw materials of a higher price category, including high-quality marbled beef, are subjected to maturation [19]. Marbled meat in the form of steaks rightfully belongs to

delicacies, as it has a special taste due to intramuscular fat, evenly distributed in the form of fatty layers between muscle fibers. Marbling of beef provides a consistent and pronounced formation of taste and aroma during maturation [20]. During the heat treatment of products from such meat, the fat layers melt, filling the meat with juice, and it acquires a unique softness and tenderness. Marbling has its own gradations depending on the intensity, that is, the frequency of white inclusions in the fibers. The higher the marbling, the more tender the steak. American statisticians calculated the steak quality coefficients depending on the degree of marbling of meat raw materials. The American gradation of meat suggests three levels of marbling (in order of increasing): select, choice, premium [21].

High-quality beef with the desirable signs of marbling is a new product on the Ukrainian market. In many countries of the world, technologies for growing young cattle of beef breeds, schemes for the production and evaluation of high quality beef have long been developed. In Ukraine, according to published information, the experience of growing meat breeds of cattle for the production of high-quality beef is in the Research Farm "Askaniyskoye" (Kherson region), Private Agricultural Enterprise after. T.G. Shevchenko, which is part of the Asnova holding (Kyiv region), Organic Farming Product LLC (Cherkasy region), Eurosem LLC, a division of Eridon (Pereyaslav-Khmelnitsky district, Kyiv region). The number of such enterprises is constantly growing, so we should hope for an effective growth in the production of high-quality marbled beef, that is, the research we carry out has all the necessary signs of relevance.

The subject of research is the technological properties of high-quality beef with signs of marbling.

The purpose of the work is a scientific substantiation of the most rational ways of fermenting meat raw materials, establishing requirements for raw materials for the production of fermented meat.

Materials and methods of research. Longissimus dorsi, separated from the carcasses of bulls between the 12th vertebra and the 13th vertebra of the Aberdeen Angus (experimental samples No. 1-No. 4) and Charolais (experimental samples No. 5-No. 8) meat breeds, was used as the object of research. From each breed for research, raw materials were isolated from carcasses obtained from 4 animals.

Studies were carried out on days 1 and 18 of exposure (dry fermentation) at a temperature of (2 ± 2)°C.

In the course of the research, physical, chemical, sensorial, microbiological and rheological paramiters were determined:

- pH – potentiometrically using a measuring device – a pH meter. pH was measured in the longissimus dorsi separated from the carcasses of these breeds. The measurement was carried out on day 1 and day 18 after slaughter. The meat was kept at a temperature of (2±2)°C;

- marbling index – according to the formula:

$$X = \frac{C \cdot 100}{N},$$

where X is the marbling index;

C is the content of intramuscular fat;

N is the content of protein nitrogen,%;

- sensorial evaluation – visually;

- rheological (elasticity, penetration force) – with the use of the universal experimental machine "SANS".

Statistical processing of the obtained results was performed based on the calculation of arithmetic mean values and the mean square error.

Research results. Producers from all over the world, using years of experience, have come to the conclusion that some processes for the production of high-quality beef should remain unchanged for any country, namely:

- use of specialized breeds of cattle (Aberdeen Angus or Black Angus, Hereford, weight,

etc.). This is due to the fact that meat marbling, which is one of the main characteristics of high-quality beef, is primarily due to a genetic predisposition – a number of genes are associated with it, in particular, the GG genotype of the GH gene;

- implementation of the final high-calorie grain fattening for at least 100 days. Feeding rations may vary by region and country. Corn, barley and other grains may be used;
- the presence of a high culture of production: comfortable conditions for keeping cattle, free access to water and feed, no stress during transportation;
- introduction of a traceability system "from field to fork", beginning with the selection of animals, life-time evaluation of their productivity and ending with the finished product;
- implementation of long-term storage to achieve the best rheological and sensorial characteristics.

A list of requirements for the production of high quality beef is given in Fig.1.

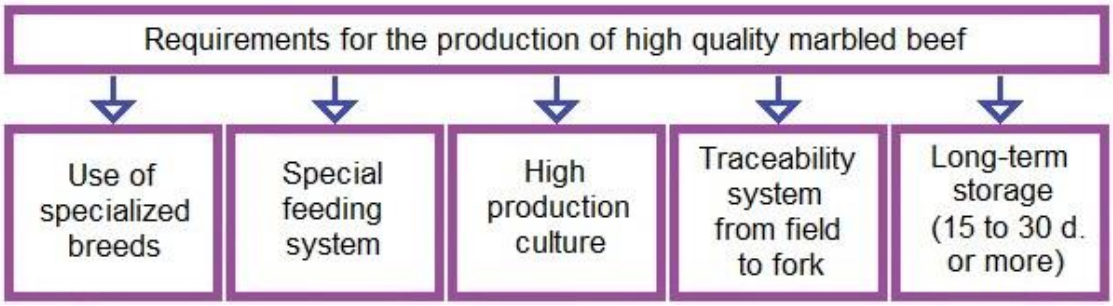

Fig. 1. Requirements for the production of high quality marbled beef

The above general requirements are followed by all world producers of high quality beef. However, the system of classification and evaluation of beef in different countries is somewhat different, although some general criteria apply here, such as live weight and carcass weight, color of muscle and adipose tissue, degree of marbling, pH. The main approaches to the classification of live animals and their carcasses in some countries are presented in Table. 2.

In the world, researchers have come to the conclusion that none of these factors is decisive, and neither the breed, nor the marbling, nor the age can separately guarantee the high consumer characteristics of the product – each step in the production and processing of beef in one way or another affects the final result and consumer assessment. In this regard, it became necessary to regulate the production of high-quality beef, its classification and evaluation at the state level. To do this, it is necessary to study the mechanisms of formation of the above requirements for high-quality beef and the impact of various factors on them.

For research, a dry maturation method was chosen, which provides the formation of the necessary characteristics and is quite simple to perform. According to the existing characteristic [22], high-quality beef is chilled beef with a specified level of marbling, subcutaneous fat thickness, meat and subcutaneous fat color, obtained from highly productive young cattle, sold no earlier than 120 hours from the moment. Highly productive young cattle – bulls and heifers of specialized meat breeds aged from 8 months to 24 months, castrated bulls aged from 8 months to 30 months, fattened from the moment of subtraction from the mother mainly on green fodder, during the final stage of fattening (at least 100 days before slaughter) – on balanced high-calorie feed rations with at least 70% nutritional value due to grain concentrates.

In information sources there are publications on the quality of long-term meat, but they are very few and they refer to meat obtained from certain breeds of cattle and the conditions of their cultivation and slaughter in other countries. In this regard, the study of the quality of beef of long-term storage of Ukrainian production has scientific and practical value.

An important indicator of the quality of meat is the pH value. It indicates the degree of suitability of meat for storage and subsequent cooking. Normal pH for beef is from 5.6 to 6.0 units after 24 hours of exposure after slaughter [23]. If the pH is greater than 6.2, then the meat may show signs of DFD. The pH values were measured in the longest muscle of the back

isolated from the carcasses of the indicated breeds. The measurement was carried out on day 1 and day 18 after slaughter. The meat was kept at a temperature of (2 ± 2)°C. At the same time, the sensorial properties of meat raw materials were evaluated. The results obtained are presented in tables 3 and 4.

Evaluation of the degree of marbling confirms that the bulls of selected breeds are highly productive young animals, since fat gaps in a fairly large amount are clearly visible on the muscle section. The marbling index ranges from (70-80)%, that is, it is optimal (which should be (70-85)% according to the recommendations).

Table 2

Classifying systems of high quality beef

Criteria of evaluation	Country		
	Canada	Australia	USA
Carcass quality criteria	13 quality categories, including: Prime, AAA, AA, A (for carcasses of young animals related to high-quality beef)	Depending on genderand age	5 classes depending on gender and age
Carcass output	From 59% – for thePrime category; up to 53% – for categoryA	No data	No data
The degree of marbling (by the number of fatty inclusions)	4 degrees – from excellent tosatisfactory	No data	Scale from 1 to 6
Subcutaneous fat thickness	No less than 2 mm	No less than 3 mm (at 13th rib level)	No data
Muscular development	4 categories – from good to excellent	No data	No data
Color of muscle tissue	Bright red	Red	Scale from 1 to 7
Color of fat	White	White	No data
Structure of muscle tissue and fat	Tough	No data	No data
pH	No data	No more than 5,7 in 24 h after slaughter	No more than 5,7 in 24 h after slaughter
Area of “muscle eye”, cm^2	No data	No data	No data
Note. Marbling, color, muscle tissue and fat, subcutaneous fat thickness, muscle eye area are assessed between the 12th and 13th ribs.			

Table 3

Dynamics of p during the storage of beef

Parameter	Breed							
	Aberdeen-Angus				Charolais meat			
	sample 1	sample 2	sample 3	sample 4	sample 5	sample 6	sample 7	sample 8
pH in 1st day ofaging	5.91	6.23	6.26	6.01	5.84	5.71	6.00	5.75
pH in 18th day of aging	5.92	6.25	6.26	6.00	5.86	5.73	6.03	5.76

When measuring pH, it was noted that in different samples, even of the same breed, this indicator is somewhat different. In our opinion, the determining factor in the formation of this characteristic of meat is not only the genotype, but also the factors of the external environment (feeding, maintenance, transportation). Similar relationships have been found by many researchers and therefore they must be taken into account when creating optimal conditions for feeding and keeping animals. The organoleptic evaluation of the prototypes is also somewhat different: beef with a higher initial pH has a darker color, a tougher texture, and a slight off-flavor. The pH indicator practically does not change in all samples at the end of storage. It is known that a slight increase in pH can be observed in the case of the development of putrefactive microflora and the accumulation of proteins with an alkaline reaction as a result of decomposition products.

Table 4

Quality parameters of beef after 18 days of aging

Breed, sample number	Parameter	
	Marbling index	Appearance, color, taste, smell, texture
Aberdeen-Angus: sample 1	Good	The presence of a crust of drying of a dark color. The color on the cut is from red to dark red, the taste is pronounced meaty, the aroma is pleasant, delicate texture. In samples No. 2 and No. 3, a slightly pronounced foreign smell is felt, the consistency of these samples is more rigid, the color is darker than that of other samples.
sample 2	Good	
sample 3	Good	
sample 4	Good	
Charolais meat: sample 5	Good	
sample 6	Good	
sample 7	Good	
sample 8	Good	

Due to the protective effect of the drying crust, which is a kind of barrier, the total number of microorganisms did not exceed the permissible levels in all samples. Also, in our opinion, low primary contamination in this case also plays an important role. Probably due to this factor, the signs of DFD properties in samples No. 2 and No. 3 do not significantly affect the activation of microflora development processes. That is, an important requirement when using long-term aging of beef is to ensure sanitary and hygienic conditions during the preparation and aging of meat.

The process of aging meat is accompanied by a change in texture. Therefore, we studied the structural and mechanical properties of prototypes. The results are presented in table. 5. The results obtained indicate that the strength characteristics of muscle tissue are directly dependent on its structure, i.e. determined by the processes of autolysis, in particular, the nature of the change in pH. Thus, meat with higher pH values after the first day has a tougher structure, as a result of which the penetration force is higher than that of samples with a lower pH value. Elasticity indices correlate with the strength index results: minced meat with higher penetration force values has lower elasticity.

According to the results of studies, on the 18th day there is a decrease in the penetration force due to the development of destructive changes in muscle fibers under the action of enzymes. Accordingly, the elasticity increases. The conducted studies show that according to some physical, chemical, rheological and sensorial characteristics, the meat of research animals has differences associated with the nature of the course of autolytic changes, which in turn depends on the influence of various factors.

Table 5

Rheological parameters of beef

Breed, sample number	Parameter			
	Elasticity, кN/m^2		Penetration force, kN/m^2	
	aging for 1 day	aging for 18 days	aging for 1 day	aging for 18 days
Aberdeen-Angus: sample 1	16.56	18.20	240.80	230.80
sample 2	19.43	23.40	386.63	350.63
sample 3	20.06	21.12	480.25	465.30
sample 4	18.83	22.90	350.72	302.40
Charolais meat: sample 5	22.43	28.30	185.50	175.90
sample 6	21.49	23.45	169.42	160.12
sample 7	23.40	25.80	181.25	170.10
sample 8	20.56	22.90	160.43	152.30

Conclusion. Based on the results of the analysis of classification schemes for high-quality beef using existing evaluation criteria, a dry fermentation method was selected for 18 days at a temperature of (2 ± 2)°C, humidity – (75-80)%.

Changes of parameters in the process of fermentation of Aberdeen-Angus beef and Charolais meat breeds were studied. It was determined that, in terms of marbling, the selected breeds belong to highly productive young animals, which is a condition for obtaining high-quality fermented beef.

It was determined that the pH value on the first day of storage (fermentation) in two experimental samples of the long back muscle isolated from the carcasses of Aberdeen Angus bulls has an overestimated value (more than 6.2 units), which characterizes their possible involvement in the DFD meat group; according to the sensorial evaluation, the meat of these samples has certain differences: a darker color and a tougher texture than in other experimental samples.

It has been established that in terms of rheological parameters, meat from different breeds of experimental animals also has differences: elasticity ranges from 18.2 kN/m^2 to 28.3 kN/m^2, penetration forces – from 152.3 kN/m^2 to 465.3 kN /m^2, which is associated with different pH levels.

It was found that after storage of all samples for 18 days, the pH slightly increases, which is associated with the development of microflora. At the same time, the total number of microorganisms does not exceed the standard values in all samples, which is explained by the low primary contamination of meat.

It has been established that during storage, the rheological properties of beef improve: the penetration force decreases, the elasticity increases. A positive effect of fermentation for 18 days at a temperature of (2 ± 2)°C on the consumer characteristics of meat was also found.

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