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Amino acid composition of beef depending on the breed and age of dairy bulls

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Abstract The quality composition of beef is ensured by a significant variation in the content of essential and non-essential amino acids and their ratios and depends on many factors, the most important of which are the breed and age of the animals. They contribute to the accumulation of individual amino acids in their bodies and determine the quantity and quality of the protein formed. The study identified 16 amino acids in the longest back muscle of bulls from the studied breeds, 9 of which are essential and 7 are nonessential. Certain breeds found to be an advantage in the amino acid composition of beef during the age range of bulls from 3 to 21 months, due to breed-specific features of the fractional composition of muscle proteins formed during a certain period of their growth. Among the essential amino acids, lysine showed the dominant amino acid, accounting for 5.02-7.85% of the total mass fraction of protein. Among the nonessential amino acids, the content of glutamine varied from 10.93% to 12.66% of the mass fraction of protein. The significant interbreed was differed in the content of amino acids such as lysine, histidine, arginine, serine, proline, alanine, methionine, leucine, and tyrosine result in the formation of specific qualities and biological values of beef protein for each studied breed.

Keywords: Acid, Amino age, Beef, Breed, Longest back muscle, Bulls

Introduction

The primary objective of the livestock industry was to supply the population with raw materials and food (Nanka *et al.*, 2018; Aliiev *et al*., 2022; Poberezhets *et al.,* 2023). Meat from various animal species is the most important product for ensuring a healthy and balanced human diet worldwide. However, beef ranks only third in global meat production and shows promise in meeting the growing consumer demand. The quality of beef is affected by various factors, including the type of feed (Scollan *et al.,*

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2006; Jacques *et al.,* 2011; Van Elswyk and McNeill, 2014; Yaremchuk *et al.,* 2022; Farionik *et al.,* 2023), breed (Christensen *et al.,* 2011), sex of the animals (Hollo *et al.*, 2001; Hanzelkova *et al.,* 2011), climatic conditions, slaughtering and processing methods (Guerrero *et al.,* 2013; Di Luca *et al.,* 2013; Rodionova *et al.,* 2021), and the impact of abiotic factors (Mylostyva *et al.,* 2023; Yermishev, 2023), veterinary and sanitary conditions (Paliy *et al.,* 2019; Jeffer *et al.,* 2021; Zavgorodnii *et al.,* 2021). Meat is absorbed by the human body at a rate of almost 95% due to its high-quality protein content in the form of essential amino acids. These amino acids are necessary for the full synthesis of proteins, minerals, vitamins, and fatty acids. Red meat differs from white meat, such as pork and chicken, in terms of its iron, zinc, vitamin B_{12}, and fatty acid composition (Williams and Droulez, 2010). Therefore, there is a high demand for lamb and beef red meat in tropical countries due to dietary customs and traditions. Changes in consumer preferences significantly impact the perception of the ideal composition and properties of the final product (Šubrt *et al.,* 2002). There are also controversial issues regarding the role of amino acids. Amino acids play a key role in determining the quality of meat by providing nutritional value and flavor (Cai *et al.,* 2010; Reicks *et al.,* 2011).

Amino acids are small organic compounds that serve as the building blocks of protein, act as a source of energy, and serve as precursors for biologically active molecules. In fresh meat, glutamic acid and phenylalanine are the main amino acids, while arginine and lysine predominate in cured products (Lopesa *et al.*, 2015). Beef contains a significant amount of both alanine and aspartic acid (Florek *et al.*, 2017). Some amino acids can work as regulators of gene expression and cell signaling (Nelson and Cox, 2008). Twenty amino acids are essential for the creation of proteins in the body. Some of them can be synthesized - the so-called nonessential amino acids - but essential amino acids cannot be produced in the body in the required amount, and their deficiency affects protein regeneration (Nelson and Cox, 2008; Applegate and Angel, 2008). In recent years, due to the increased genetic potential of cattle, there have been significant changes in the norms of animal requirements for amino acids and their regulated content in products. This is especially true for animals in fattening. It is important to justify these changes in-depth, taking into account numerous factors, including breed and age. It is important to note that a comparison of eight different breeds of meat bulls, all of similar age and weight, and raised under the same conditions in Southern Czech Republic, showed significant differences in the levels of saturated and unsaturated amino acids in the longest muscle of the back, depending on the breed. This is consistent with the results obtained by (Subrt *et al.*, 2002; Hollo *et al.*, 2007; Lee *et al.*, 2019). However, these data contradict the findings of (Jeong *et al.,* 2012), which did not find any significant differences in the amino acid content of the meat of bulls from three breeds

fed for six months in the climatic conditions of Korea. It is important to consider the detailed studies (Hollo *et al.,* 2001; Koutsidis *et al.,* 2008; Cho *et al.,* 2020), which revealed variations in the content of specific amino acids in animal meat based on their sex. Several studies (Watanabe *et al.,* 2004; Jayasena *et al.,* 2013; Kim *et al.,* 2016; Kodani *et al.,* 2017; Bischof *et al.,* 2022) have shown that the amino acid profile in meat is dependent on the age of the animals. Additionally, evidence suggests that feeding conditions also affect the distribution of amino acids in animal meat (Nicastro *et al.,* 2000; Hollo *et al.,* 2007; Lee *et al.,* 2019). While acknowledging the valuable contributions of foreign scientists to the assessment of the nutritional value of beef meat by amino acid profile, it is important to note the lack of similar research on domestic dairy cattle breeds, particularly bulls raised intensively for meat.

Materials and methods

Ethical standards for conducting research

The experiments conducted on animals do not contradict the current legislation of Ukraine (Article 26 of the Law of Ukraine 5456-VI of 16.10.2012 "On the Protection of Animals from Cruelty") as amended as of 04.08.2017, and the "General Ethical Principles for Animal Experiments" adopted by the First National Congress on Bioethics (Reznikov, 2003) and international bioethical standards (materials of the IV European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Purposes (Strasbourg, 1986; Simmonds, 2017). The research program was reviewed and approved by the Bioethics Committee of the Institute of Animal of Animal Science of the National Academy of Agrarian Sciences of Ukraine in accordance with the current procedure.

The experiment's location and the principle of group formation

The experiment was conducted in the production conditions of the basic farm of the Institute of Animal of Animal Science of the NAAS in the Kharkiv region, using purebred bulls of Holsteinized Black-and-White, Red Steppe and Angler dairy breeds. Three groups of 25 bulls each were formed and kept untethered in group sections of the same facility until they were 4 months old. After that, they were tethered until the end of the intensive growing period.

The way of feeding

During the growing period (from 30 days to 21 months of age), the experimental animals were fed diets of the same nutritional value, taking

into account detailed feeding standards, which provided for 900-1000 g of average daily gain. The level of feeding during the growing period was high and was designed to identify potential opportunities for increasing meat productivity and achieving a live weight of 550-650 kg by bulls at the age of 18-21 months. The total nutritional value of the feed consumed by the bulls during the growing period in the context of the experimental breeds was 48.0 hundredweight, 46.9 hundredweight, and 44.9 hundredweight of energy feed units. One energy feed unit accounted for 106 g, 105 g, 102 g of digestible protein, respectively. The ratio of the main components of the diets (on average by groups) was characterized by the following indicators: the concentration of energy available for metabolism in 1 kg of dry matter - 289 MJ; energy-protein ratio - 13.62 g; calcium to phosphorus ratio 1.84:1; fiber content in dry matter - 22.3%.

Evaluation of meat productivity

The formation of meat productivity of bulls was evaluated at 3, 6, 12, 21 months of age. Three heads were selected from each breed group with a live weight corresponding to the group's average weight for control slaughter. Slaughter was performed under the production conditions of the meat processing plant. To determine the changes in the amino acid profile of the longest back muscle related to breed and age, samples were collected from each carcass at specified age periods, at the level of 9-12 ribs, and subsequently freed from connective tissue.

Analysis of amino acids in samples from the longest back muscle

The amino acid content was analyzed using ion-exchange liquid column chromatography on an automatic amino acid analyzer T-339 M manufactured by Microtechna (Czech Republic) in 100 μL of hydrolyzate with the following sequence of phosphate-buffered amino acid eluates from the column: asparagine, threonine, serine, glutamine, proline, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, lysine, histidine, arginine. The percentage of essential and nonessential amino acids is the sum of the content of the latter, the concentration of each of which was determined by adding an alcohol solution of ninhydrin (pH 5.8) at 98 °C for 24 hours, followed by photometry of the stained samples. The content of the amino acids cysteine and tryptophan was not recorded in the absence of the corresponding standard solutions required for the construction of the calibration curve. The amino acid content was calculated as a percentage of the mass fraction of protein content in samples of the longest back muscle of the studied breeds. The mass fraction of protein was calculated using a conversion factor of 6.25 multiplied by the mass fraction of total nitrogen determined with Nessler's reagent after wet ashing the

material in sulfuric acid and expressed as a percentage of the mass fraction of the longest back muscle samples of bulls. Ammonium sulfate was used as a standard solution for the preparation of the calibration curve for the determination of total nitrogen content. The amino acid index was calculated by the ratio of essential and nonessential amino acids.

Statistical processing of research results

Statistical data processing was performed using the licensed software STATISTICA 10.0 (StatSoft) for Windows.

Results

It has been found that the general pattern for all breeds is an age-related increase in the mass fraction of protein in the flesh of bull carcasses from 18.49-20.19% at 3 months of age to 20.52-21.00% at 21 months of age (Table 1). The average concentration of the mass fraction of protein by breed at 12 months of age was 19.72%, while its highest content was found in the flesh of Black-and-White bulls at 21 months of age (21.00%). The difference in the corresponding indicator between bulls of the Red Steppe and Black-and-White breeds at the age of 3 months reached statistical significance at the level of $P<0.05$, however, between animals of the Black-and-White and Angler breeds $P<0.001$, Red Steppe and Angler breeds $P<0.001$. At 6 months of age, the difference in protein mass fraction between the analogues of Angler and Red Steppe breeds decreased to $P<0.05$, and at 12 months of age, on the contrary, increased to $P<0.001$. At 21 months of age, no significant differences between the breeds were found in the content of the mass fraction of protein in beef.

The content of the limiting amino acid lysine in the samples of carcass flesh of 3-month-old bulls varied within breeds from 5.02% to 5.42% with an increase at 21 months of age from 5.93% to 6.57%. The highest lysine content was found in Angler beef at 12 months of age (7.85%), which exceeds the average by breed by 1.47%. The age-related interbreed difference in the lysine content in the carcass flesh of 3-month-old bulls of Black-and-White Red Steppe breeds was reliable and was at the level of $P<0.01$, as well as between animals of Angler and Black-and-White breeds ($P<0.01$), although between the groups of Angler and Red Steppe breeds it became highly significant ($P<0.001$). At the age of 12 months, the difference between the peers of Angler and Red Steppe breeds decreased to $P<0.05$. At the same time, at the age of 21 months, the flesh of bulls of both Black-and-White versus Red Steppe and Black-and-White versus Angler breeds in terms of the content of this amino acid in both cases of comparison was significantly different at the level of $P<0.001$, and Red Steppe versus Angler breed - $P<0.05$.

Table 1. Formation of essential amino acids in the composition of carcass flesh proteins of dairy bulls throughout ontogeny, presented as a percentage of protein. The study included three heads in each group and of the corresponding age, %

Protein and amino acid content	Age, moths	Breed		
		Holsteinized Black-and-White	Red Steppe	Angler
Protein	3	19.52±0.24	20.19±0.10	18.49±0.07
	6	19.83±0.34	19.78±0.11	20.05±0.02
	12	19.76±0.33	20.26±0.13	19.15±0.06
	21	21.00±0.28	20.78±0.20	20.52±0.14
Lysine	3	5.20±0.05	5.02±0.01	5.42±0.05
	6	6.09±0.28	6.37±0.14	6.31±0.12
	12	6.45±0.49	6.30±0.29	7.85±0.55
	21	6.57±0.07	6.15±0.06	5.93±0.08
Histidine	3	2.58±0.05	2.78±0.14	2.33±0.11
	6	3.58±0.40	2.67±0.08	2.99±0.26
	12	4.44±0.26	3.47±0.27	4.10±0.12
	21	3.66±0.14	3.78±0.03	3.66±0.05
Arginine	3	3.63±0.20	3.49±0.02	3.59±0.10
	6	3.98±0.27	3.70±0.19	3.82±0.05
	12	6.59±0.41	6.31±0.38	7.15±0.48
	21	4.55±0.25	4.79±0.07	4.80±0.09
Threonine	3	2.76±0.19	3.41±0.07	3.21±0.08
	6	4.23±0.36	3.50±0.12	3.50±0.30
	12	4.48±0.11	5.10±0.13	4.90±0.91
	21	4.15±0.09	3.36±0.05	4.21±0.10
Valine	3	3.13±0.07	3.15±0.07	3.16±0.02
	6	3.98±0.49	3.38±0.18	3.54±0.22
	12	4.47±0.34	3.99±0.56	4.59±0.60
	21	3.40±0.03	3.70±0.05	3.28±0.05
Methionine	3	0.98±0.20	1.25±0.12	1.45±0.07
	6	1.78±0.31	1.67±0.02	1.39±0.16
	12	1.98±0.17	2.01±0.27	2.10±0.29
	21	1.93±0.08	1.94±0.02	1.49±0.02
Isoleucine	3	2.55±0.11	2.77±0.19	3.10±0.12
	6	2.44±0.38	2.31±0.65	3.74±0.38
	12	4.50±0.43	3.75±0.43	4.06±0.33
	21	3.93±0.05	3.80±0.07	4.39±0.04
Leucine	3	4.59±0.27	4.99±0.13	5.48±0.06
	6	5.28±0.02	5.42±0.40	5.30±0.07
	12	5.82±0.14	6.50±0.49	5.90±0.47
	21	5.12±0.12	5.25±0.10	5.65±0.09
Phenylalanine	3	3.01±0.10	3.00±0.04	3.17±0.04
	6	3.46±0.11	3.18±0.08	3.98±0.35
	12	3.86±0.36	3.84±0.53	4.45±0.38
	21	3.94±0.10	3.69±0.02	3.32±0.04

The concentration of the amino acid histidine was found to increase with age in the flesh of bull carcasses, ranging from 2.33-2.78% at 3 months to 3.47-4.44% at 12 months. A moderate decrease was observed at 21 months of age in beef samples to 3.66-3.78%. The highest concentration of histidine, at 4.44%, was found in the flesh of Black-and-White bulls at 12 months of age. There was a significant interbreed difference in the amino acid content of beef from 3-month-old bulls of Black-and-White and Angler breeds ($P<0.05$). At 6 months of age, the difference was also significant in peers of Black-and-White and Red Steppe breeds ($P<0.05$). At 12 months of age, the difference was significant in groups of Black-and-White and Red Steppe breeds ($P<0.05$), and in Angler and Red Steppe breeds ($P<0.05$). At 21 months of age, the difference was significant in animals of Red Steppe and Angler breeds ($P<0.05$).

The beef of bulls within the studied breeds and ages did not differ in terms of the amino acid arginine, and its content ranged in the amplitude of values from 3.49-3.63% at 3 months of age to 4.55-4.80% at 21 months of age. The increase in arginine concentration is characterized by wider limits, and therefore a greater difference between the values for each group, but it is not statistically significant.

Comparison of samples of bull carcasses flesh in terms of threonine concentration revealed an age-related increase from 2.76-3.41% at 3 months of age to 4.48-5.10% at 12 months of age and a decrease at 21 months of age to 3.36-4.21%. The maximum content of this amino acid was identified in the flesh of Red Steppe carcasses at 12 months of age (5.10%), and the minimum - in Black-and-White carcasses at 3 months of age (2.76%). The statistical processing of the results revealed a reliably significant difference in the threonine content in beef samples at 3 months of age between bulls of Red Steppe and Black-and-White ($P<0.01$) and Angler and Black-and-White breeds ($P<0.05$); at 12 months of age - Red Steppe and Black-and-White breeds ($P<0.01$). A similar reliable significance for this indicator was observed at 21 months of age between animals of Black-and-White and Red Steppe ($P<0.001$) and Angler and Red Steppe breeds ($P<0.001$). At the age of 6 months, no interbreed differences in threonine content in carcass samples were recorded in bulls.

Particular attention is drawn to the constancy of the concentration of the amino acid valine in beef, which did not change significantly in the age dynamics from 3 to 21 months of age. In particular, at 3 months of age it was 3.13-3.16%, at 21 months of age - 3.28-3.70%. Instead, the difference in the content of the corresponding amino acid between bulls of Red Steppe and Black-and-White breeds at 21 months of age was highly significant ($P<0.001$), between peers of Black-and-White and Angler breeds it was significantly lower ($P<0.05$), and between animals of Red Steppe and Angler breeds at $P<0.01$ it ranked second. Considering the main trends in the formation of the amino acid methionine, it is important to emphasize its

lowest content in the flesh of the carcasses of experimental animals, both depending on the breed and age, which ranged from 0.98-1.45% at 3 months of age with a slight increase to 1.49-1.94% at 21 months of age, with the exception of the Angler breed, the level of which in the flesh of bulls of 12 months of age was 2.10%. The analysis of laboratory data of the breed distribution of beef by the content of this amino acid proved the existence of a statistically significant difference only between Angler and Black-and-White peers at 3 months of age, which was marked by the lowest level of significance ($P<0.05$). At the same time, with an increase in the period of bulls rearing to 21 months of age, it reached a maximum between these breed groups ($P<0.001$). In the interval from 6 to 12 months of age, no statistically significant difference in the concentration of methionine in beef was recorded in any of the breeds.

A different picture was observed in the content of the amino acid isoleucine: from 3 to 12 months of age, its increase in the bulls' flesh ranged from 2.55-3.10% to 3.75-4.50% with a slight slowdown in the rate of this process at 21 months of age to 3.80-4.39%. In the breed aspect, the highest concentration of isoleucine (4.50%) is inherent in Black-and-White beef at 12 months of age, against the background of its lowest value in samples of 6-month-old bulls (2.31%). The largest statistically significant difference in both cases of comparison ($P<0.001$) in the content of this amino acid was at 21 months of age between bulls of Angler and Black-and-White and Angler and Red Steppe breeds. Its values between Angler and Black-and-White breeds at 3 months of age occupied an intermediate position ($P<0.01$), while at 6 months of age the level of their significance between these breeds decreased to $P<0.05$.

Taking into account the results of the laboratory analysis of the flesh taken from the carcasses of bulls, the general nature of the formation of the amino acid leucine was confirmed, which almost did not differ in age. The distribution spectrum of this amino acid in beef gradually expanded from 4.99-5.48% at 3 months of age to 5.12-5.65% at 21 months of age. Instead, the highest content of this amino acid was found in the flesh of carcasses of Red Steppe animals at 12 months of age (6.50%). By the level of statistical significance at 3 months of age, bulls of both Angler and Black-and-White, and Angler and Red Steppe breeds did not differ significantly, reaching $P<0.01$ in both cases of comparison. Beef samples taken from bulls aged 21 months of Angler breed in terms of leucine content, being not inferior to the previous breeds, were superior in quality to samples of Black-and-White and Red Steppe breeds with the same statistically significant difference ($P<0.01$). Starting from 6 to 12 months of age of bulls inclusively, there was no statistically significant difference in the leucine content in the carcass flesh of the studied breeds.

The age of bulls did not affect the concentration of the amino acid phenylalanine in the carcass flesh in ontogeny. In particular, at 3 months of

age it was 3.00-3.17%; at 6 months of age - 3.18-3.98%; at 12 months of age - 3.84-4.45% and at 21 months of age - 3.32-3.94%. The highest content of this amino acid was recorded in samples of Angler beef at 12 months of age (4.45%). Despite the similarity of beef samples in terms of phenylalanine content during the total period of bulls' rearing, differences were found between individual breeds: at 3 months of age between Angler and Red Steppe breeds ($P<0.01$); at 6 months of age - between peers of Black-and-White and Red Steppe ($P<0.05$) and Angler and Red Steppe breeds ($P<0.05$); at 12 months of age - between the groups of Black-and-White and Red Steppe breeds ($P<0.05$), with a high statistically significant difference between the peers of Black-and-White and Angler ($P<0.001$) and Red Steppe and Angler breeds ($P<0.001$).

The general dynamics of quantitative changes in the content of aspartic acid in muscle tissue coincides with most amino acids, namely, its gradual age-related increase from 3 to 21 months of age from 6.32-6.47% to 7.38-7.97% (Table 2). The highest content of this amino acid was found in the flesh of carcasses of Black-and-White bulls at 21 months of age (7.97%). Instead, a significant difference in the content of aspartic acid in the carcass flesh at 3 months of age was found between Angler and Black-and-White bulls ($P<0.01$); at 6 months of age - between animals of Angler and Black-and-White breeds ($P<0.05$); at 21 months of age - between peers of Black-and-White and Red Steppe ($P<0.001$) and Black-and-White and Angler breeds ($P<0.01$). At 12 months of age, no significant difference between breeds was observed.

In contrast to the concentration of aspartic acid in beef, another feature of its deposition in ontogeny was found with regard to the content of the nonessential amino acid serine: an increase from 3 to 12 months of age of bulls from 2.97-3.43% to 3.65-4.16%, while by 21 months of age, on the contrary, a slowdown to 3.16-3.94%. The maximum value of this amino acid is inherent in the samples taken from the flesh of Angler bulls at 12 months of age (4.16%). At the same time, a significant difference between the samples in the content of this amino acid occurred only in Angler and Red Steppe breeds at 3 months of age ($P<0.001$), Angler and Red Steppe breeds ($P<0.05$) - at 6 months of age, and Black-and-White and Angler breeds, as well as Red Steppe and Angler breeds ($P<0.001$) in both cases of comparison - at 21 months of age.

The development of the process of formation of the amino acid proline in beef was similar to the amino acid serine at all key stages of the experiment. With the prolongation of the bulls' rearing time to 12 months of age, a slight increase was observed from 2.44-4.25% to 3.65-4.83%, however, at the age of 21 months, a decrease in the level of proline deposition in beef to 2.10-2.34% was observed, with the highest accumulation in samples taken from Angler animals at 12 months (4.83%). It should be noted that at the age of 3 months in the samples of flesh

obtained from the carcasses of bulls of Black-and-White and Red Steppe, and Angler and Red Steppe breeds, the statistically significant difference in the content of this amino acid was the largest ($P<0.001$), Angler and Black-and-White breeds $P<0.05$; at 6 months - animals of Red Steppe and Angler breeds $P<0.001$; at 12 months - Angler and Red Steppe breeds $P<0.001$, and at 21 months - animals of Angler and Red Steppe breeds $P<0.01$.

Table 2. Formation of nonessential amino acids in the composition of carcass proteins of dairy bulls throughout ontogeny presented as a percentage of protein. The study included three heads in each group and of the corresponding age, %

Amino acid name	Age, moths	Breed		
		Holsteinized Black-and-White	Red Steppe	Angler
Asparagine	3	6.32±0.03	6.47±0.25	6.47±0.03
	6	6.94±0.01	6.80±0.45	7.30±0.15
	12	7.95±0.21	7.39±0.57	7.69±0.36
	21	7.97±0.06	7.38±0.06	7.52±0.12
Serine	3	2.97±0.74	2.99±0.07	3.43±0.01
	6	3.62±0.33	3.09±0.12	3.45±0.08
	12	3.95±0.32	3.65±0.12	4.16±0.27
	21	3.79±0.08	3.94±0.03	3.16±0.07
Glutamine	3	10.93±0.19	11.22±0.14	11.52±0.24
	6	12.08±0.06	11.89±0.42	12.16±0.59
	12	12.44±0.46	11.25±0.34	12.66±0.39
	21	12.00±0.19	11.27±0.10	11.17±0.14
Proline	3	4.07±0.03	2.44±0.12	4.25±0.06
	6	3.38±0.38	4.05±0.09	2.81±0.11
	12	4.33±0.26	3.65±0.28	4.83±0.12
	21	2.10±0.14	2.12±0.03	2.34±0.06
Glycine	3	3.97±0.21	4.04±0.11	4.11±0.02
	6	4.09±0.07	4.15±0.18	3.97±0.32
	12	4.37±0.37	4.28±0.96	4.86±0.52
	21	4.27±0.04	4.30±0.02	4.65±0.05
Alanine	3	4.81±0.22	4.55±0.02	5.05±0.12
	6	4.84±0.08	4.93±0.29	5.00±0.01
	12	6.46±0.33	6.00±0.71	6.33±0.62
	21	4.14±0.04	4.50±0.04	4.56±0.09
Tyrosine	3	2.38±0.06	2.64±0.01	2.59±0.08
	6	3.30±0.36	2.67±0.14	2.86±0.09
	12	3.48±0.27	3.15±0.40	3.68±0.42
	21	2.36±0.06	2.23±0.04	3.05±0.04

In the case of the amino acid alanine, rearing bulls from an early age (3 months) to reaching the age of sexual maturity (12 months) leads to its consistent increase in beef samples from 4.55-5.05% to 6.00-6.46%. Subsequently, there is a general age-related decrease in this indicator and at 21 months of age it is 4.14-4.56% with maximum values in samples of flesh of Black-and-White carcasses at 12 months (6.46%). Breed differences in the content of the corresponding amino acid in the carcass flesh made it possible to achieve high statistical significance at 3 months of age of bulls between Angler and Red Steppe breeds ($P<0.001$); at 21 months of age - between animals of Angler and Red Steppe and Angler and Black-and-White breeds ($P<0.001$) in both cases of comparison).

A similar situation regarding the age-related similarity of the deposition of the amino acid alanine in the flesh samples was observed for tyrosine, the level of which increased from 2.38-2.64% to 3.15-3.68% during 3-12 months of bulls' growth, while decreasing from the corresponding indicator at 12 months to 2.23-3.05% in the next age period. In turn, the highest concentration of this amino acid was recorded in samples taken from 12-month-old Angler bulls (3.68%). It should be emphasized that only at the age of 3 months between animals of the Red Steppe and Black-and-White breeds the difference became statistically significant ($P<0.001$), Angler and Black-and-White breeds ($P<0.05$), and at the age of 21 months - between the peers of Angler and Black-and-White ($P<0.001$) and Angler and Red Steppe breeds ($P<0.001$).

The course of the distribution of the amino acid glutamine in the age aspect of qualitative changes in beef was indicative, since its content occupied a dominant share among the other nonessential amino acids in the mass fraction of protein. In particular, the dynamics of glutamine accumulation reached peak values at the age of 12 months - 11.25-12.66%, after 9 months of their rearing the intensity of this process slowed slightly and settled at 11.17-12.00%. The most pronounced activation of the accumulation of this amino acid in beef samples, which was statistically significant, was found in bulls of 12 months of age of Black-and-White and Red Steppe breeds ($P<0.05$), Angler and Red Steppe breeds ($P<0.05$), as well as in 21 months of age of Black-and-White and Red Steppe breeds ($P<0.01$), Black-and-White and Angler breeds ($P<0.01$).

The rate of increase of the amino acid glycine in the flesh was distinguished by a slight wave-like character by age periods of bulls' growth. In particular, if within 12 months there was an increase in its content from 3.97-4.11% to 4.28-4.86%, then at 21 months of age it stabilized at 4.27-4.65% against the background of the highest concentration values in samples taken from the flesh of Angler bulls (4.86%), as well as highly reliable statistical significance only between animals of Angler and Black-and-White ($P<0.001$), and Angler and Red Steppe breeds ($P<0.001$) in this age period.

Regarding the total content of amino acids, a clear trend can be observed in the age dynamics of changes in bulls' growth: their age increases up to a certain ontogenetic limit, the values of the total amount of amino acids also increase, and then mainly decrease (Table 3).

In particular, their lowest level was recorded in samples of beef from bulls of 3 months of age (63.88-68.33%), the highest - 12 months of age (80.64-89.31%), while in animals of 21 months of age it decreased to 72.20-73.88% and occupied an intermediate position. Most amino acids were contained in the flesh of carcasses of Angler animals at 3 months of age (89.31%). Instead, the quantitative content of both essential and nonessential amino acids in beef samples was almost at the same level in all periods of bulls' rearing, except for 3 months of age. When comparing the studied groups with each other, it was found that a statistically significant difference in this indicator was observed only at 3 months of age of bulls between Angler and Black-and-White ($P<0.001$), as well as between Angler and Red Steppe breeds ($P<0.001$).

Table 3. Age-related changes in the ratio of amino acids in the composition of flesh proteins of dairy bulls. The study included three heads in each group and of the corresponding age, %

Indicator	Age, months	Breed		
		Holsteinized Black-and-White	Red Steppe	Angler
Amino acid sum	3	63.88±1.11	64.31±0.33	68.33±0.16
	6	73.42±3.71	71.27±2.90	71.38±1.63
	12	85.57±2.59	80.64±6.77	89.31±6.04
	21	73.88±2.80	72.20±4.02	73.18±3.72
including: substitutable	3	28.43±0.24	29.86±0.11	30.91±0.06
	6	35.17±2.43	32.97±1.23	33.83±0.52
	12	42.59±1.25	41.27±3.78	45.10±2.74
	21	37.25±1.63	36.46±2.68	36.73±1.70
nonessential amino acids	3	35.45±0.88	34.45±0.43	37.42±0.10
	6	38.25±1.28	38.30±1.67	37.55±1.11
	12	42.98±1.53	39.37±2.99	44.21±3.30
	21	36.63±1.62	35.74±2.46	36.45±2.02
Ratio: substitutable to essential amino acids	3	0.80±0.01	0.87±0.01	0.83±0.01
	6	0.92±0.03	0.86±0.01	0.90±0.01
	12	0.99±0.02	1.05±0.02	1.02±0.02
	21	1.02±0.02	1.02±0.01	1.00±0.01

It is necessary to confirm the results obtained above regarding the increased age-related ability of bulls to accumulate amino acids, including essential ones, in the composition of beef in the period from 3 months from 28.43-30.91% to 41.27-45.10% at 12 months and a reduced intensity of this process in the period from 12 to 21 months of age to 36.46-37.25%. However, under these conditions, such a factor as breed affiliation, in all three cases of comparison of flesh samples, positively influenced the formation of the total amount of essential amino acids with the same high significance level only at 3 months of age and amounted to $P<0.001$ between Red Steppe and Black-and-White, Angler and Black-and-White, and Angler and Red Steppe breeds.

Significant quantitative changes in the quality of beef in the age dynamics were also found by the amount of essential amino acids. In particular, their increase from 3 months to 12 months of age from 34.45-37.42% to 39.37-44.21%, and then a decrease to 35.74-36.63% at 21 months of age of bulls. As indicated by the studies, a significant difference in the total amount of nonessential amino acids is observed only in the flesh of 3-month-old bulls of Angler and Black-and-White ($P<0.05$), and Angler and Red Steppe breeds ($P<0.001$).

A distinctive age-specific feature of the amino acid profile of bull carcass flesh is the existence of a clear trend towards an increase in the ratio of the sum of essential amino acids to nonessential amino acids: 0.80-0.87 at 3 months of age to 1.00-1.02 at 21 months of age. The increase in the values of this ratio in beef samples with the age of bulls was reflected in the most noticeable differences depending on their breed: at 3 months of age between Red Steppe and Black-and-White ($P<0.001$), Angler and Black-and-White ($P<0.05$), and Red Steppe and Angler breeds ($P<0.01$); at 6 months of age - between Angler and Red Steppe breeds ($P<0.01$), and at 12 months of age - between Red Steppe and Black-and-White breeds ($P<0.05$).

Discussion

Beef proteins are a highly nutritious group of nutrients. In terms of nutritional value, they have a superior amino acid composition compared to most other types of meat, particularly in the balance of essential amino acids and the level of protein absorption by the human body. However, beef is inferior to pork and chicken in terms of qualitative fat content and protein absorption by the human body (Robert *et al.,* 2018; Lopez and Mohiuddin, 2023). At the same time, the qualitative ratio of quantitative characteristics of cattle meat is influenced by a wide range of morphological, biological, and physiological factors. Among the most powerful factors are the age and breed of the animal. In this context, it is important to determine the breed and age characteristics, as well as the patterns of formation of the amino acid composition of beef from domestic dairy bulls raised intensively for

meat. Our research is shown that the amino acid profile of the beef samples studied was within the range of average species values, but had slight differences compared to those of other breeds. It has been proven that the qualitative composition and quantitative content of amino acids in the longest back muscle of Black-and-White, Red Steppe and Angler bulls of dairy breeds is mostly dependent on their breed. These findings align with previously published data presented in the works of (Subrt *et al.*, 2002; Hollo *et al.*, 2007; Lee *et al.*, 2019). It is important to note that while there is a clear difference in the overall amino acid spectrum of muscle tissue in bulls of different breeds, the effect of age on their formation is less significant. The age-related changes in the formation of amino acid content that were recorded in the experiment are consistent with the findings of other researchers in the literature (Hollo *et al.*, 2001; Koutsidis *et al*., 2008; Cho *et al.*, 2020). Bull meat is characterized by a high proportion of lysine amino acid in the total amount of essential amino acids (5.02-7.85%) and saturated amino acids, particularly glutamine, which ranged from 10.93% to 12.66% of the protein mass fraction. Glutamic amino acid was also found to be present in high amounts in beef, according to studies by Florek *et al.,* 2017. The ratio of essential to nonessential amino acids in the muscle tissue samples of all bull groups was close to optimal. The diverse patterns of changes in the content of most amino acids between breeds contribute to the formation of the specific quality and biological value of beef protein for each breed.

Thus, the qualitative composition and quantitative content of amino acids in the longest back muscle of bulls of Black-and-White, Red Steppe and Angler dairy breeds is mainly determined by their breed and varies with age. In the longest muscle of the back of bulls of the studied breeds, 16 amino acids were identified, of which 9 are essential and 7 are nonessential. Among the essential amino acids, the amino acid lysine quantitatively dominates (5.02-7.85%), among the saturated ones - glutamine, the content of which in the samples varied from 10.93% to 12.66% of the mass fraction of protein. The established reliable interbreed difference in the content of amino acids lysine, histidine, arginine, serine, proline, alanine, methionine, leucine, tyrosine, etc. contributes to the formation of the quality and biological value of beef protein specific to each studied breed.

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