Amino Acid Composition of Cow's Milk of the North Caucasus Black-and-White Breed

V. I. TRUKHACHEV, S. A. OLEINIK*, A. M. ERSHOV, N. Z. ZLYDNEV, A. A. POKOTILO,
V. E. ZAKOTIN, E. N. CHERNOBAI, A. A. KHODUSOV
FSBEI HE Stavropol State Agricultural University,
Stavropol,
RUSSIAN FEDERATION

**Corresponding Author*

Abstract: - The study of the amino acid composition of dairy raw materials, as shown in numerous studies of domestic and foreign authors, is relevant for conducting breeding work on genetic improvement of dairy, optimizing the system of raising animals of various sex and age groups, including lactating cows to prolong the productive longevity period. The purpose of the research was to study the amino acid composition of the milk of cows of the black-and-white Holsteinized breed, considering genotypic, age-related aspects, as well as with an increase in cow milk protein content. Studies on the composition of amino acids in milk were carried out on cows of a black-and-white breed of a pedigree breeding unit of the Stavropol Territory, the Russian Federation. The obtained results showed that the amino acid content in the black-and-white cow milk in the conditions of the North Caucasus corresponds to the parameters characteristic of the black-and-white Holsteinized breed, while the ratio of essential and interchangeable amino acids, considering age and genetic factors, varies in the range of 0.945-0.951, which is typical for high-quality milk. It was also found that in the process of increasing the protein content of cows by 0.2 abs. percentage from a protein level of 3.10% to 3.30%, a more intensive increase in essential amino acids in relation to interchangeable amino acids is observed, while the ratio of essential to interchangeable amino acids statistically significantly ($p<0.05$) increased by 1.66%, which is of particular importance for planning measures for the genetic improvement of protein content herds of black-and-white cattle.

Key-Words: - Amino acids, milk, cattle, black-and-white breed of dairy cattle, lactation of cows, protein, essential amino acids.

Received: March 25, 2023. Revised: November 21, 2023. Accepted: December 24, 2023. Published: February 26, 2024.

1 Introduction

Dairy cattle breeding is one of the most important agriculture branches, since it determines the production of milk and dairy products, which are a source of protein of animal origin. The introduction of large-scale breeding methods is aimed at increasing milk yields in cows, while the concentration of milk protein is of particular importance, which in turn largely determines the biological value of milk as a whole, as indicated by, [1].

The use of dairy raw materials has an extensive character, due to the presence of a wide range of biologically active substances in milk, which have, among other things, an antioxidant character. At the same time, when trying to replace cow's milk in animal feeding diets with so-called "vegetable milk", which is a suspension of soy, oat, sesame and other grain types, there is a significant diet depletion of essential amino acids, since the utilitarianism coefficient of this type of "milk" is in the range of 16-61%, that is, none of vegetable protein types can serve as a full-fledged substitute for cow milk protein as indicated by, [2], [3].

The protein and amino acid composition of milk depends primarily on cow breeds, that is, on genetic factors. The study of the amino acid composition of the milk of Holstein cows and their crossbreeds with Simmentals showed that in pasture maintenance conditions the milk of purebred Simmental cows contained 8.7% more essential amino acids - lysine and methionine, while the infusion of blood of the Holstein breed contributed to a certain decrease in these amino acids in milk, as indicated by, [4].

The study of the function of various amino acids in the protein nutrition of cows, as well as the study of their metabolism in cows, has been

performed by many authors, [5], [6], [7], [8], [9], [10], [11], [12]. The effect of protein supplements, differing in the profile of amino acids and the content of non-degradable protein in the rumen, on post-instrumental amino acid intake and milk productivity was studied. In addition, the authors studied the amino acid metabolism of plasma and other nutrients in the mammary glands. Meanwhile, it was shown that histidine was the first amino acid to limit milk protein synthesis and that the mammary gland can regulate the absorption of amino acids according to the body's needs, [13].

Studies have been conducted where the limiting role of amino acids such as Met, Lys or His has been shown. If the deficiency of one of the limiting amino acids was restored, there was an increase in milk protein content associated with an increase in the concentration of essential amino acids. Moreover, the ability of the mammary glands to overcome the shortage of precursors for circulating milk was discovered, [14].

When studying the reaction of cows to a deficiency of limiting amino acids, it was found that the content of milk protein seems to be sensitive to the introduction of amino acids into rennet, and methionine itself does not affect lactation rates in cows. The replacement of lysine deficiency led to an increase in milk protein yield by 16%. The essential amino acids Lys and Met are probably the most restrictive for lactating cows receiving a corn-based diet. The composition of the diet ingredients will determine which amino acids will have the most restrictive character in terms of their concentration in blood plasma, [15].

In the structure of the essential amino acids of milk, according to many authors, [3], [4], [5], lysine, leucine, and valine have the greatest specific gravity, the content of which in cow milk was in the range of 0.184-0.307 g%, the level of tryptophan was 2-3 times lower. The structure of milk interchangeable amino acids was dominated by glutamic and aspartic amino acids and serine (0,177-0,624/100 g). At the same time, the specific weight of essential and non-essential amino acids was approximately equal, which indicates a sufficiently high biological value of the milk under study.

The widespread use of milk in the cultivation of repair young also makes issues of balancing the amino acid composition of animal feeding diets important and relevant, which is also indicated by the research of the authors, [6], [7], [8], [9], [11].

Thus, the study of milk amino acid composition is an actual scientific and practical direction, since in addition to food use, dairy raw materials are also of particular importance for dairy cattle breeding, since milk is widely used in the cultivation of young animals. At the same time, the issues of balancing the amino acid composition of animal feeding diets are relevant, which is also indicated by the research of the authors, [16], [17], [18], [19].

When studying the effect of certain amino acids on the fermentation process, it was shown that the addition of the amino acids cystine, serine, arginine, proline, aspartic acid and glutamic acid to the lactic medium during lactic acid fermentation helped to improve the fermentation process and improve the quality of the product. the final dairy product, [9].

The control of the level of amino acids in milk is also of particular importance for dairy cattle breeding, a group of authors showed a positive relationship between the content of amino acids in blood and milk in lactating cows; amino acid deficiency caused a decrease in the biosynthesis of milk protein by animals, [16]. Research by the authors, [17], showed that in the process after a calving period up to 70 days, the concentration of biologically active substances and amino acids isoleucine, leucine, phenylalanine, lysine, histidine, methionine, and tryptophan continued to decrease in milk and skeletal muscles of lactating cows, which characterizes the complexity of recovery processes in animals after calving. At the same time, other studies have shown that the introduction of the amino acids leucine, isoleucine and valine in a protected form into the feed of lactating cows contributed to the recovery of animal body weight after calving, improved lipogenesis processes in the body, increased protein levels in milk, increased the content of urea nitrogen in plasma and urea nitrogen in milk, the concentration of free valine in plasma and reduced liver lipidosis in dairy cows during early lactation, [18], [19].

Similar results were also obtained by other researchers, [20], who, when introducing protected forms of the amino acids methionine, threonine, isoleucine and leucine into the feeding of lactating cows, including diets with a reduced protein content (12% crude protein), found an increase in milk and lactose yield to the level of diets with a high protein content (16% crude protein), and this tended to an increase in milk protein yield.

Attempts by some researchers to achieve a similar effect due to intravenous infusion of the amino acids leucine, isoleucine and valine together with glucose did not lead to the effect of increasing the concentration of urea in the blood plasma of animals, which indicates the absence of changes in the catabolism of amino acids, the authors came to

the conclusion about the use of skeletal muscles by animals for protein accumulation. In turn, this underlines the importance of assessing the physical shape of animals and muscle recovery in cows in the postpartum period, [21].

The review of scientific and technical literature shows that the study of the amino acid composition of dairy raw materials, as shown in numerous studies by domestic and foreign authors, is relevant for planning and carrying out measures for the genetic improvement of dairy, optimizing the system of feeding and rearing dairy cattle of various sex and age groups, including lactating brood stock to prolong the period of animal economic use. The purpose of the research was to study the amino acid composition of the milk of cows of the black-and-white Holsteinized breed, considering genotypic, age-related aspects, as well as an increase in cow milk protein content.

2 Materials and Methods of Research

Studies on the composition of amino acids in milk were carried out on cows of a black-and-white breed of a pedigree breeding unit of the Stavropol Territory, the Russian Federation. The animals were kept in one farm condition, the conditions of feeding and maintenance ensured the milk productivity of the first-calf cows at the level of 8 thousand kg of milk per 1 cow per year. Milk quality assessment was carried out in an independent laboratory of milk quality control of the FSBEI HE Stavropol State Agrarian University, accredited by GOST ISO/IEC 17025-2019. For the research, raw milk was used, selected from 60 cows under the same feeding conditions and physiological state, during the milking period of 30-200 days after calving, considering the lactation number, protein content in milk, and linear affiliation of animals.

The analysis of milk amino acid composition was carried out on the AAA-400 amino acid analyzer of Czech production in the laboratory of the Scientific and Technical Center "Feed and Metabolism" of the Stavropol State Agrarian University, also accredited by GOST ISO/IEC 17025-2019.

The research results were processed by the method of variation statistics using the MS Excel computer program.

3 Research Results

The study of milk amino acid composition allowed us to establish that in the studied samples of milk of cows of the black-and-white Holsteinized breed, there is a complete set and a high concentration of essential and interchangeable amino acids (Table 1, Figure 1), which coincides with the results of other authors [1], [3], [4].

Glutamic acid (Glu) has the highest concentration of interchangeable amino acids in milk, an average 0.690%, there is a high content of proline (Pro) in the protein structure, an average 0.287%. There is also asparagine (Asp), which is, on average, 0.239. The difference in concentration of the remaining interchangeable amino acids is less than 0.200% ($p<0.05$). The content of cystine (Cys) is the minimum among the interchangeable amino acids and is 0.027%.

Among the essential amino acids, the largest amount was characterized by leucine (Leu) - 0.285%, lysine (Lys) - 0.270%, and valine (Val) - 0.182%. Their concentration was statistically higher than the rest of the indispensable amino acids ($p<0.05$). The content of tryptophan (Trp) - 0.061% was the smallest one.

The content of individual amino acids in milk is different, which is confirmed by their variability coefficient. The highest variability is characterized by such amino acids as isoleucine (Iie) – 9.8%, cysteine (Cys) – 8.9%, methionine (Met) – 7.3%, and the least variability was observed in threonine (Thr) – 4.4%. The amount of non-essential amino acids was 5.5% higher in proportion to indispensable amino acids ($p<0.05$). Thus, the content of amino acids in the analyzed milk can satisfy the animal and human body's need for them, which coincides with the opinion of other authors, [3], [4], [5].

The distribution histogram of the concentrations of individual amino acids in the structure of milk protein (Figure 1) exposes the above-described patterns. Meanwhile, it highlights the distribution of all amino acids into conditional 3 groups depending on their specific gravity in milk protein: about 20%: glutamic acid (Glu); up to 10%: aspartic acid (Asp), proline (Rho), leucine (Leu), and lysine (Lys); and 5% and below: all other amino acids.

Thus, the content of amino acids in the analyzed milk can satisfy the need for them in the animal and human body, which coincides with the opinion of other authors, [1], [3], [4], [5].

Analysis of the qualitative composition of milk proteins of black-and-white cows, depending on the age of lactation, is presented in Table 2. The data in

Table 2 indicate higher concentrations of both essential and non-essential amino acids in the milk protein of cows of 1 and 2 lactation in comparison with the milk of cows of 3 lactation, nevertheless, due to the high volatility of the actual data, the established difference in the amount of amino acids is not statistically significant (p 0.05), the concentration fluctuations are on average, in depending on the amino acid, 0.001-0.031%.

It was found that the milk of cows of 1-3 lactation among the essential amino acids has the highest concentrations of the following amino acids: lysine (Lys) and leucine (Leu) – 0.268-0.286%, followed by valine (Val), isoleucine (Iie), threonine (Thr), phenylalanine (Phe) – 0.133-0.187%.

Table 1. The amino acid content in milk of cows of black-and-white Holsteinized breed (n=60)

Amino acid	In % of the total milk composition, g/100 g	
	M± m,	% of milk protein
Alanine (Ala)	0.101 ±0.001	3.15
Aspartic Acid (Asp)	0.239±0.002*	7.44
Arginine (Arg)	0.106±0.001	3.29
Glycine (Gly)	0.058±0.001	1.81
Glutamic acid (Glu)	0.690±0.006*	21.48
Tyrosine (Tyr)	0.149±0.002	4.63
Serine (Ser)	0.170±0.002	5.29
Cystine (Cys)	0.027±0.001	0.84
Proline (Pro)	0.287±0.003*	8.93
Valine (Val)	0.182±0.003*	5.66
Histidine (His)	0.086±0.001	2.68
Threonine (Thr)	0.134±0.001	4.17
Methionine (Met)	0.088±0.001	2.74
Leucine (Leu)	0.285±0.003*	8.87
Isoleucine (Iie)	0.146±0.003	4.54
Lysine (Lys)	0.270±0.003*	8.4
Phenylalanine (Phe)	0.139±0.002	4.34
Tryptophan (Trp)	0.056±0.001	1.74
Sum of amino acids	3.213±0.029	100.0
Sum of essential amino acids	1.563±0.016	48.66
Sum of nonessential amino acids	1.649±0.014*	51.34
Ratio of essential to non-essential amino acids	0.948±0.004	-

** – The difference is statistically significant p<0.05 **

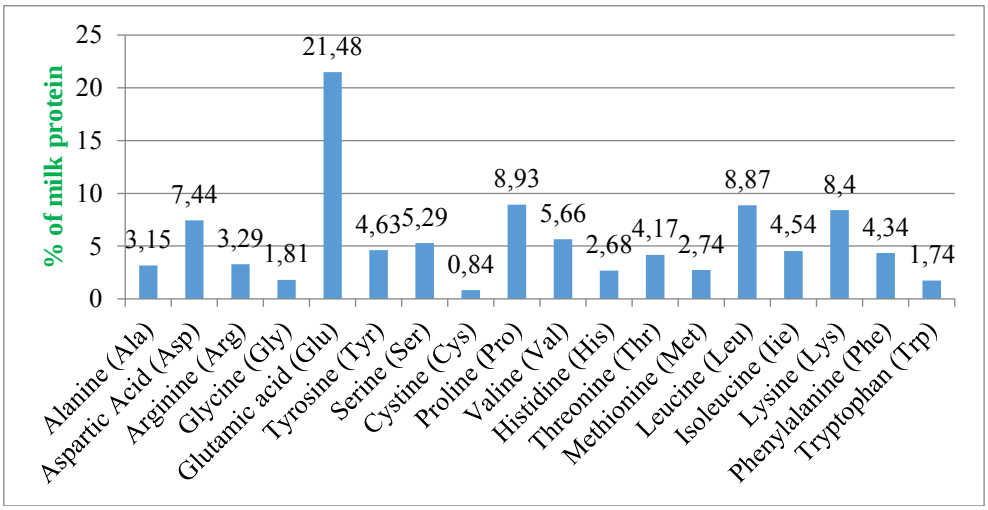

Fig. 1: The amino acid content in milk protein of cows of black-and-white Holsteinized breed

Table 2. Qualitative composition of cow milk proteins depending on age in lactation

Amino acid	In % of the total milk composition, g/100 g		
	1 lactation	2 lactation	3 lactation
Alanine (Ala)	0.099±0.002	0.101±0.002	0.102±0.001
Aspartic Acid (Asp)	0.240±0.002	0.237±0.004	0.239±0.004
Arginine (Arg)	0.107±0.003	0.106±0.002	0.105±0.002
Glycine (Gly)	0.057±0.001	0.059±0.002	0.057±0.001
Glutamic acid (Glu)	0.689±0.011	0.693±0.011	0.688±0.008
Tyrosine (Tyr)	0.151±0.003	0.148±0.003	0.149±0.002
Serine (Ser)	0.170±0.003	0.167±0.005	0.171±0.003
Cystine (Cys)	0.027±0.001	0.026±0.001	0.027±0.000
Proline (Pro)	0.288±0.009	0.289±0.006	0.283±0.004
Valine (Val)	0.180±0.006	0.187±0.005	0.180±0.004
Histidine (His)	0.086±0.002	0.086±0.002	0.085±0.001
Threonine (Thr)	0.133±0.002	0.134±0.003	0.136±0.003
Methionine (Met)	0.088±0.003	0.088±0.003	0.088±0.001
Leucine (Leu)	0.286±0.006	0.285±0.005	0.284±0.004
Isoleucine (Iie)	0.150±0.007	0.148±0.004	0.142±0.004
Lysine (Lys)	0.272±0.005	0.268±0.004	0.269±0.004
Phenylalanine (Phe)	0.138±0.004	0.140±0.003	0.140±0.002
Tryptophan (Trp)	0.057±0.001	0.057±0.001	0.056±0.001
Sum of amino acids	3.217±0.061	3.218±0.055	3.200±0.043
Sum of essential amino acids	1.649±0.025	1.652±0.028	1.646±0.022
Sum of nonessential amino acids	1.568±0.037	1.566±0.027	1.554±0.021
Ratio of essential to non-essential amino acids	0.950±0.009	0.948±0.004	0.945±0.005

Among the nonessential amino acids, the following amino acids have the highest concentrations: glutamic acid (Glu), proline (Rgo), aspartic acid (Asp) – 0.237-0.693%, followed by serine (Ser), tyrosine (Tyr), arginine (Arg), alanine (Ala) – 0.099-0.171%. Similar results were obtained in the other studies, [10].

The established differences in the content of amino acids in the composition of cow milk in the age aspect reflect the different biological roles of amino acids and their concentration in the feed consumed. It is obvious that in the process of stock breeding work with the domestic black-and-white breed, it is necessary to provide comfortable conditions for keeping animals and full feeding for animals at all stages of production use.

It is necessary to consider the functional features of black-and-white Holsteinized cattle to increase productive longevity, improve the qualitative composition of milk, and search for new effective methods of breeding dairy cattle, which is also indicated in other studies, [1].

The amino acid composition of milk of various linear affiliations is presented in Table 3.

Statistically significant differences in the content of amino acids in cow milk depending on the linear affiliation of breeding bulls have not been established due to the high volatility of the results.

Similarly, with the quality of milk from cows of various lactations, three groups of amino acids can be distinguished among the essential and nonessential amino acids: with the highest concentration of 0.240-0.685% among the nonessential amino acids, which includes glutamic acid (Glu), proline (Rgo), aspartic acid (Asp), and leucine and lysine among the essential amino acids with a concentration of 0.267-0.285%.

Table 3. The qualitative composition of milk proteins depending on the linear affiliation of cows

Amino acid	In % of the total milk composition, g/100 g		
	Montwick Chieftain 95649	Reflection Sovereing 198998	Vis Back Ideal 1013415
Alanine (Ala)	0.102±0.002	0.100±0.002	0.099±0.001
Aspartic Acid (Asp)	0.240±0.003	0.238±0.004	0.237±0.004
Arginine (Arg)	0.108±0.003	0.106±0.002	0.104±0.002
Glycine (Gly)	0.059±0.001	0.058±0.001	0.056±0.001
Glutamic acid (Glu)	0.685±0.009	0.693±0.012	0.692±0.009
Tyrosine (Tyr)	0.149±0.003	0.149±0.004	0.149±0.001
Serine (Ser)	0.172±0.003	0.169±0.005	0.167±0.003
Cystine (Cys)	0.026±0.001	0.026±0.001	0.027±0.001
Proline (Pro)	0.289±0.007	0.286±0.006	0.285±0.005
Valine (Val)	0.184±0.006	0.184±0.002	0.179±0.006
Histidine (His)	0.086±0.002	0.086±0.001	0.084±0.001
Threonine (Thr)	0.136±0.003	0.134±0.003	0.132±0.002
Methionine (Met)	0.087±0.002	0.089±0.003	0.088±0.002
Leucine (Leu)	0.284±0.006	0.285±0.005	0.285±0.004
Isoleucine (Iie)	0.148±0.007	0.148±0.003	0.144±0.006
Lysine (Lys)	0.267±0.005	0.271±0.005	0.271±0.004
Phenylalanine (Phe)	0.142±0.003	0.140±0.003	0.137±0.002
Tryptophan (Trp)	0.056±0.001	0.056±0.001	0.057±0.001
Sum of amino acids	3.222±0.055	3.218±0.058	3.195±0.047
Sum of essential amino acids	1.655±0.023	1.650±0.031	1.641±0.020
Sum of nonessential amino acids	1.566±0.032	1.568±0.027	1.554±0.028
Ratio of essential to non-essential amino acids	0.946±0.008	0.951±0.005	0.946±0.006

Table 4. Amino acid composition of proteins with different milk protein content

Amino acid, % of the total composition of milk	Protein content in milk, g/100 g			
	up to 3.10	3.11-3.2%	3.21-3.3%	over 3.31%
Alanine (Ala)	0.096±0.001	0.098±0.001*	0.102±0.003*	0.105±0.001*
Aspartic Acid (Asp)	0.233±0.004	0.231±0.001	0.243±0.005	0.246±0.001*
Arginine (Arg)	0.101±0.001	0.103±0.001	0.110±0.001	0.111±0.001*
Glycine (Gly)	0.054±0.001	0.057±0.002	0.059±0.001*	0.060±0.001*
Glutamic acid (Glu)	0.667±0.002	0.670±0.004	0.705±0.007*	0.713±0.004*
Tyrosine (Tyr)	0.145±0.002	0.143±0.003	0.149±0.002*	0.156±0.001*
Serine (Ser)	0.167±0.004	0.165±0.003	0.174±0.007	0.173±0.004
Cystine (Cys)	0.025±0.001	0.026±0.001	0.027±0.002	0.028±0.001
Proline (Pro)	0.272±0.001	0.277±0.001*	0.292±0.003*	0.301±0.003*
Valine (Val)	0.172±0.004	0.176±0.005	0.189±0.003*	0.192±0.002*
Histidine (His)	0.082±0.001	0.084±0.001	0.087±0.001*	0.089±0.001*
Threonine (Thr)	0.130±0.002	0.131±0.002	0.139±0.007	0.137±0.002*
Methionine (Met)	0.082±0.001	0.087±0.001*	0.088±0.002*	0.093±0.002*
Leucine (Leu)	0.274±0.002	0.275±0.003	0.287±0.004*	0.297±0.002*
Isoleucine (Iie)	0.137±0.004	0.139±0.004	0.152±0.007*	0.156±0.004*
Lysine (Lys)	0.261±0.001	0.260±0.002	0.272±0.010*	0.280±0.002*
Phenylalanine (Phe)	0.131±0.001	0.136±0.002	0.141±0.001*	0.146±0.001*
Tryptophan (Trp)	0.054±0.001	0.054±0.001	0.058±0.001*	0.059±0.001*
Sum of amino acids	3.082±0.005	3.113±0.002*	3.275±0.015*	3.343±0.013*
Sum of essential amino acids	1.493±0.005	1.511±0.003	1.589±0.019*	1.634±0.009*
Sum of nonessential amino acids	1.589±0.007	1.601±0.003*	1.686±0.004*	1.708±0.007*
Ratio of essential to non-essential amino acids	0.940±0.007	0.944±0.004	0.943±0.001	0.957±0.006*

** – The difference is statistically significant p<0.05**

The next group of nonessential amino acids with a concentration of 0.099-0.172% includes alanine (Ala), arginine (Arg), tyrosine (Tyr), and serine (Ser). In the essential amino acids in the same concentration range there are the amino acids alanine (Ala), arginine (Arg) tyrosine (Tyr), and serine (Ser), with an amino acid concentration of 0.099-0.172%.

The lowest concentration among the interchangeable amino acids in glycine (Gly) and cystine (Cys) is 0.026-0.059%, among the essential amino acids – in histidine (His) and tryptophan (Thr) – 0.056-0.086%.

Among these groups of amino acids, statistically significant differences in concentration in milk are observed, which certainly reflects their different biological role in the metabolic physiological, and biochemical processes of newborn young animals, for which, biologically, milk is produced in cows.

The some research also demonstrated the importance of controlling histidine (His), threonine (Thr), methionine (Met), leucine (Leu), isoleucine (Iie), lysine (Lys), phenylalanine (Phe), and tryptophan (Thr) in feeding animals, [22], [23].

The content, as well as the ratio of essential and non-essential amino acids in milk with an increase in the milk protein content, is of considerable interest.

With an increase in the protein content of cows, an increase in the concentration of all amino acids was noted in their milk. With an increase in the protein content of milk, statistically significant differences in the amount of amino acids are observed due to an increase in the amount of interchangeable amino acids, and with an increase in the protein content of milk above 3.2% due to a statistically significant increase in the amount of essential amino acids.

For a complete analysis of the changes in the amino acid composition of milk indicated in Table 4, we calculated the content (in %) of each amino acid in the composition of the sum of amino acids of milk with an increase in the concentration of milk protein from 3.10% to 3.30% (Figure 2).

The data obtained indicate that the increase in the protein content in milk was accompanied by an uneven and disproportionate increase in the content of individual amino acids, which is of particular importance in the practice of stock breeding work to increase the protein content of cows due to technological factors.

An increase in the protein content of cows leads to a greater increase in the concentration of essential amino acids in milk, the percentage of increase in the amount of essential amino acids was 8.63%, which is 1.66% more about the increase in the amount of nonessential amino acids. At the same time, the increase in the ratio of essential to nonessential amino acids has a statistically significant character ($p<0.05$) (Table 4).

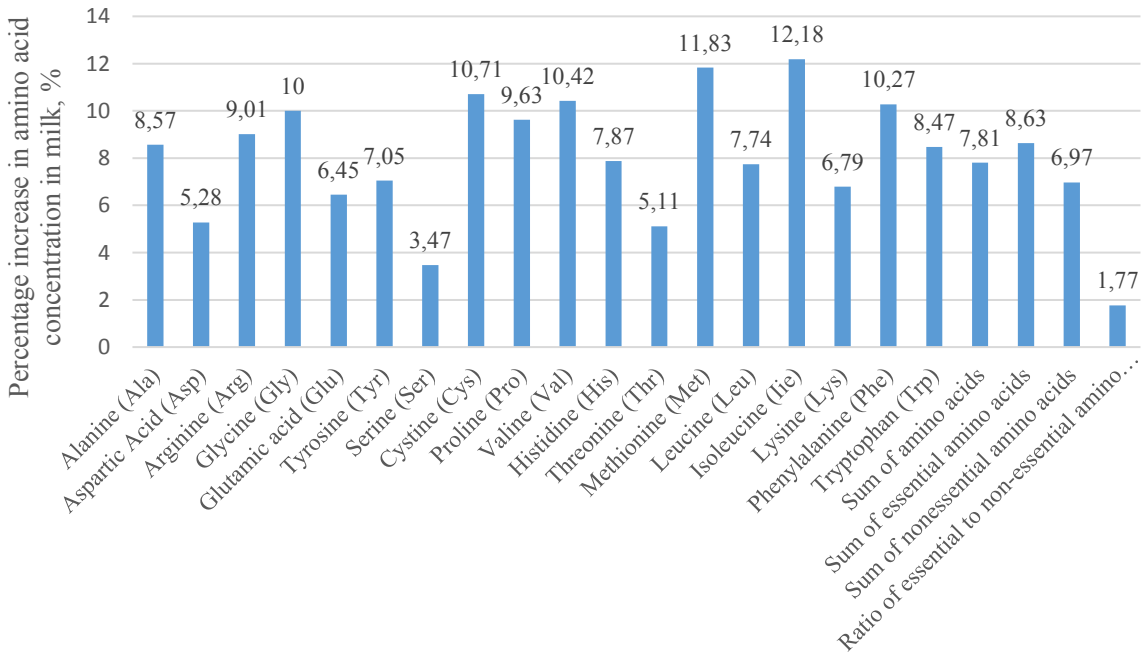

Fig. 2: Percentage increase in the amino acid content in milk with an increase in the milk protein concentration from 3.10% to 3.30%, %

Thus, breeding work with herds of Holstein cattle should be aimed at finding outstanding breeding bulls that affect productive indicators and improve the amino acid composition of milk, neutralize the negative impact of the processes of increasing milk productivity on reducing productive longevity, as well as improve the dairy business profitability, as shown in the work, [24].

4 Conclusions

1. The amino acid content in the black-and-white cow milk in the conditions of the North Caucasus corresponds to the parameters characteristic of the black-and-white Holsteinized breed, while the ratio of essential and interchangeable amino acids, considering age and genetic factors, varies in the range of 0.945-0.951, which is typical for high-quality milk.
2. In the process of increasing the protein content of cows from a protein level of 3.10% to 3.30%, there is a more intensive increase in essential amino acids relative to interchangeable amino acids, while the ratio of essential to nonessential amino acids statistically significantly ($p<0.05$) increased by 1.66%, which is of particular importance for planning measures for the genetic improvement of protein content of cattle herds a black-and-white breed.

Acknowledgments:
The research work on the study of the amino acid composition of the milk of breeding cows of the North Caucasus black-and-white breed was carried out with the financial support of the Ministry of Agriculture of the Russian Federation as part of the planned work.

References:

[1] Kosilov V.I., Yuldashbayev Yu.A., Kardalieva B.T., Amino acid composition of milk protein of first-calf cows, *Bulletin of KrasSAU*, No. 11. 2022, pp. 151-157. DOI: 10.36718/1819-4036-2022-11-151-157.

[2] Khan I.T., Nadim M., Imran M. Rahman Ullah, Muhammad Ajmal, Muhammad Hayat Jaspal. Antioxidant properties of milk and dairy products: a comprehensive review of current knowledge, *Lipid Health Dis,* Vol. 18, 2019, pp. 41. https://doi.org/10.1186/s12944-019-0969-8.

[3] Sokolova O.V., Comparative characteristics of the amino acid composition of cow's milk and the main types of "vegetable milk", IN COL. Food innovations and biotechnologies: a collection of abstracts of the *VII International Scientific Conference of Students, postgraduates and Young Scientists*, Vol. 1. Technologies of food production, quality, and safety, under the general ed. A. Yu. Prosekova; FSBEI HE Kemerovo State University, Kemerovo, Vol. 1. 2019, Pp. 381-382.

[4] Gosteva E.R., Kozlova N.N., Kulintsev V.V., Ulimbashev M.B., Amino acid composition of milk of Simmental cows and their crossbreeds with Holsteins, *Bulletin of the Kurgan State Agricultural Academy*, No. 1, 2018. Pp. 21-23.

[5] McDermott A., De Marchi M., Berry D. P., Visentin G., Fenelon M. A., N. Lopez-Villalobos, and McParland S., Cow and environmental factors associated with protein fractions and free amino acids predicted using mid-infrared spectroscopy in bovine milk, *J. Dairy Sci*. Vol. 100, 2017, pp. 6272–6284 https://doi.org/10.3168/jds.2016-12410.

[6] Mazhitova, A., Kulmyrzaev A., Determination of the amino acid composition of cow milk by liquid chromatography using pre-column derivatization, *Journal of Technical Sciences Manas*, Vol. 5, No. 3, 2017, pp. 25-34. EDN YMKFWX.

[7] Serena Niro, Mariantonietta Succi, Patrizio Tremonte, Elena Sorrentino,1 Raffaele Coppola, Gianfranco Panfili, and Alessandra Fratianni, Evolution of free amino acids during ripening of Caciocavallo cheeses made with different kinds of milk, *J. Dairy Sci*. Vol. 100, 2017, pp. 9521–9531 https://doi.org/10.3168/jds .2017-13308.

[8] Motonaka Kuroda, Keita Sasaki, Junko Yamazaki, Yumiko Kato, and Toshimi Mizukoshi. Quantification of the kokumi peptide, γ-glutamyl-valyl-glycine, in cheese: Comparison between cheese made from cow and ewe milk, *J. Dairy Sci*., Vol. 103, 2020, pp.7801-7807, https://doi.org/10.3168/jds.2020-18512.

[9] Jiahui Sun, Hongyu Chen, Yali Qiao, Gefei Liu, Cong Leng, Yanjiao Zhang, Xuepeng Lv, and Zhen Feng, The nutrient requirements of Lactobacillus rhamnosus GG and their application to fermented milk, *J. Dairy Sci*. Vol. 102, 2018, pp. 5971–5978 https://doi.org/10.3168/jds.2018-15834.

[10] Landi, N., Ragucci, S., Di Maro, A. Amino Acid Composition of Milk from Cow, Sheep

and Goat Raised in Ailano and Valle Agricola, Two Localities of 'Alto Casertano' (Campania Region), *Foods*, Vol. 10, 2021, pp. 2431. https://doi.org/10.3390/foods10102431.

[11] Lemosquet S., Delamaire E., Lapierre H., Blum J.W., Peyraud J.L., Effects of glucose, propionic acid, and nonessential amino acids on glucose metabolism and milk yield in Holstein dairy cows, *Journal of Dairy Science*, Volume 92, Issue 7, 2009, Pp. 3244-3257, ISSN 0022-0302, https://doi.org/10.3168/jd s.2008-1610.

[12] Curtis Richelle V., Kim Julie J. M., Doelman John, and Cant John P., Maintenance of plasma branched-chain amino acid concentrations during glucose infusion directs essential amino acids to extra-mammary tissues in lactating dairy cows, *J. Dairy Sci.* Vol. 101, 2017, pp. 4542–4553. https://doi.org/10.3168/jds.2017-13236.

[13] M.Korhonen, A.Vanhatalo, and P.Huhtanen. Effect of Protein Source on Amino Acid Supply, Milk Production, and Metabolism of Plasma Nutrients in Dairy Cows Fed Grass Silage, *J. Dairy Sci*., Vol. 85 (12), 2002, pp. 3336-3357. https://doi.org/10.3168/jds.S0022-0302(02)74422-6.

[14] T.L.Weekes, P.H.Luimes, and J.P.Cant. Responses to Amino Acid Imbalances and Deficiencies in Lactating Dairy Cows. *J. Dairy Sci.* Vol. 89, 2006, pp. 2177–2187.

[15] Schwab C. G., Satter L. D., and Clay A. B. Response of Lactating Dairy Cows to Abomasal Infusion of Amino Acids, *J. Dairy Sci.* vol 59 No 7, 1976, pp. 1254–1270.

[16] Zhang M. C., Zhao S. G., Wang S. S., Luo C. C., Gao H. N., Zheng N., and Wang J. Q., d-Glucose and amino acid deficiency inhibits casein synthesis through JAK2/STAT5 and AMPK/mTOR signaling pathways in mammary epithelial cells of dairy cows, *J. Dairy Sci.*, Vol. 101, 2017, pp. 1737–1746 https://doi.org/10.3168/jds.2017-12926.

[17] Yang Y., Sadri H., Prehn C., Adamski J., Rehage J., Dänicke S., Ghaffari M. H., and Sauerwein H., Targeted assessment of the metabolome in skeletal muscle and in serum of dairy cows supplemented with conjugated linoleic acid during early lactation, *J. Dairy Sci.*, Vol. 104, 2020, pp. 5095–5109 https://doi.org/10.3168/jds.2020-19185.

[18] Leal Yepes F.A., Mann S., Overton T.R., Ryan C.M., Bristol L.S., Granados G.E., Nydam D.V., and Wakshlag J. J., Effect of rumen-protected branched-chain amino acid supplementation on production- and energy-related metabolites during the first 35 days in milk in Holstein dairy cows, *J. Dairy Sci.* Vol. 102, 2018, pp. 5657–5672 https://doi.org/10.3168/jds.2018-15508.

[19] Leal Yepes F.A., Mann S., Overton T.R., Behling-Kelly E., Nydam D.V., and Wakshlag J.J., Hepatic effects of rumen-protected branched-chain amino acids with or without propylene glycol supplementation in dairy cows during early lactation, *J. Dairy Sci*. Vol. 104, 2021, pp. 10324–10337. https://doi.org/10.3168/jds.2021-20265.

[20] Zhao K., Liu W., Lin X. Y., Hu Z. Y., Yan Z. G., Wang Y., Shi K. R., Liu G. M., and Wang Z. H., Effects of rumen-protected methionine and other essential amino acid supplementation on milk and milk component yields in lactating Holstein cows, *J. Dairy Sci.* Vol. 102, 2018, pp. 7936–7947. https://doi.org/10.3168/jds.2018-15703.

[21] Richelle V. Curtis, Julie J. M. Kim, John Doelman, and John P. Cant. Maintenance of plasma branched-chain amino acid concentrations during glucose infusion directs essential amino acids to extra-mammary tissues in lactating dairy cows. *J. Dairy Sci.* 101, pp.4542–4553, https://doi.org/10.3168/jds.2017-13236.

[22] Zubia K.M., Akter A., Carter B.H., McDaniel M.R., Duff G.C., Löest C.A., Effects of supplementing milk replacer with essential amino acids on blood metabolites, immune response, and nitrogen metabolism of Holstein calves exposed to endotoxin, *Journal of Dairy Science*, Vol. 106 No. 8, 2023, https://doi.org/10.3168/jds.2022-22708.

[23] Abu-Ghazaleh A. A., Schingoethe D. J., and Hippen A. R., Blood Amino Acids and Milk Composition from Cows Fed Soybean Meal, Fish Meal, or Both, *Journal of Dairy Science* Vol. 84, No. 5, 2001, pp.1174–1181.

[24] Jun Zhang, Lu Deng, Xia Zhang, Yangchun Cao, Mengmeng Li, Junhu Yao. Multiple essential amino acids regulate mammary metabolism and milk protein synthesis in lactating dairy cows, *Animal Feed Science and Technology*, Volume 296, 2023, 115557, ISSN 0377-8401, https://doi.org/10.1016/j.anifeedsci.2022.115557.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

The research work on the study of the amino acid composition of the milk of breeding cows of the North Caucasus black-and-white breed was carried out with the financial support of the Ministry of Agriculture of the Russian Federation as part of the planned work.

Conflict of Interest

The authors have no conflicts of interest to declare.