Productivity and biological value of milk of cows of various eco-genetic types

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Abstract. The article gives comparative characteristics of the quality indicators of dairy raw materials obtained from Holstein first-calf heifers delivered to the Volgograd region of Russia from different countries. The research study consisted in processing the data of qualitative and quantitative indices of the cow’s milk production and assessing the nutritional and biological parameters of milk according to current standards. Differences on productivity, in the nutritional and biological values of milk depending on the ecological and genetic types of animals have been revealed. In terms of the milk yield for 305 days of lactation, the research has established the superiority of animal's of American selection compared with ones of German, Danish and Australian selection by 100 kg, 600 kg and 620 kg, respectively. The cows of German selection were registered to have the highest content of the weight fraction of milk fat, i.e., 4.01%. Australian Holstein heifers had the highest weight fraction of milk protein (3.24%) and amino acids (valine, isoleucine, leucine, lysine, methionine, tryptophan, phenylalanine, aspartic acid, cystine, arginine and histidine). Animals of Danish Holstein breed were noted for a higher content of macro- and microelements, i.e., calcium, magnesium, zinc, manganese, iodine and silicon. For animals of Danish and American selections, some activities to increase the weight fraction of milk protein have been recommended to perform.

1. Introduction

Along with improving fodder supply and large-scale implementation of intensive production technologies, the qualitative transformation of breeds due to imported high-quality cattle breeds belongs to main tendencies of dairy cattle breeding development in Russia. The cattle imported from different countries differ in their productivity and level of genetic potential. In supplying livestock, the climatic conditions of the supplier’s country and epizootic situation are taken into account.

All over the world, the Holstein cattle breed is considered unsurpassed in its adaptability to industrial technologies and high production. The main directions in breeding Holstein cows are increasing productivity, creating healthy strong animals that do not require additional costs for special care,
profitable milk production. In international practice, studies are known on the effects of various habitats, including the conditions of the hot tropics and subtropics, on the productivity and reproductive physiology of this breed [1,2]. In tropical countries, the combination of genetic potential productivity with adaptive ability of cattle to climate conditions is a strategic focus in dairy farming [3]. The researchers concluded that for livestock breeding, the adaptability of the breed to environmental conditions is an extremely important factor in choosing productive activities. At the same time, the limiting of them is the temperature mode, which can adversely affect milk production and the health of dairy cows.

In different parts of the world, the breed has its own characteristics, but it retains its main qualities, i.e., high milk production and good adaptability to modern industrial conditions of keeping and milking. The milk yield and milk fat content also depend on the climatic features of the region to grow in, diet and amount of feed nutrients [4,5].

In the Volgograd region of Russia, the Donskoe agricultural enterprise is a multi-purpose breeding plant with its own plant-growing and dynamically developing commercial dairy breeding animal husbandry. The herd in the breeding plant is formed mainly of black-and-white Holstein dairy cows imported from Germany, Australia, Denmark, USA and Holland. The total number of cattle is about 3,900 head; 1,550 of them are a dairy herd. The animals are provided with livestock buildings equipped according to the European standards; water in drinking bowls is always warm. The temperature inside the buildings is +10 °C. The production of the Holstein cows in the breeding plant is more than 9 thousand liters per year. Depending on the country of origin of animals, there are differences in terms of nutritional and biological values of milk.

In this regard, the study of the milk quality parameters of first-calf Holstein heifers imported from different countries is relevant and allows improving the selection strain in relation to the nutritional and biological value of milk, specifically for each eco-genetic type.

2. Purpose and methodology

The research studies were conducted on the Donskoe breeding agro-industrial enterprise in the Volgograd region, Kalachevsky rayon.

The research determined
- indices of milk production of heifers of different eco-genetic types according to the monthly control milkings;
- indices of the nutritional value of dairy raw materials from cows imported from different countries, i.e., the mass fraction of fat according to GOST R ISO 2446-2011; weight fraction of protein according to GOST 23327-98; and weight fraction of whey and casein proteins according to GOST R 54756-2011; and
- indices of biological value of dairy raw materials obtained from the heifers. For quantitative determination of essential amino acids, the high-performance liquid chromatograph LC-10 (Shimazi) using pre-column derivatization with a fluorimetric detector was applied. Macro - and microelement composition of raw milk was established by the method of mass spectrometry with inductively coupled plasma, following the manufacturer's recommendations.

Sampling of raw milk was carried out according to the current GOST 26809.1-2014 “Milk and milk products. Acceptance regulations, methods of sampling and sample preparation for testing. Part 1. Milk, dairy, milk compound and milk-contained products”. The test of significance of the data obtained were determined according to Student-Fisher.

3. Research results, discussion

Cattle breeds, while being developed and improved, obtained a number of biological and economic traits, including high milk production and good milk composition. The environmental conditions, affecting the yield, and also meat productivity, are the climate, content, feeding, care and others [6,7].

Holstein cattle brought to the Donskoe farm differed considerably in adaptation abilities and productive qualities.
The German Holstein breed of cows was characterized by high milk yield of first-calf heifers, production of more than 8200 kg of milk per lactation, stable milk production over many lactations, high level of resistance and good ability to adapt to the climatic factors of the Lower Volga region. The fat content in milk was 3.95 (4.07%) and protein content 3.21 (3.35%).

Australian Holstein cattle quickly adapted to the production system of the farm and local climatic conditions due to good health and strong bones. They are known for longevity both in Australia and in other countries. Animals had a relatively high reproductive capacity; the service period in the first calving was 86 days. The production of the first lactation was 7,087 kg of milk. In subsequent lactations, feeding animals with a variety of high-quality fodder and favorable keeping conditions in the farm allowed receiving up to 8000 kg for 305 days of lactation.

Danish Holstein breed is known for good health, good fertility and functional exterior and is noted for easy calving. The minimum production in the first lactation was 7494.0 kg; in the second one 7555.0 kg; in the third 8296.0 kg. The fat content in these lactations was 3.93-4.08-4.06%, which was confirmed by previous studies [8].

In terms of the milk yields, the Holstein cattle of the American selection surpassed their peers from other countries in the Donskoye farm. Their maximum production was 8710 kg with a fat content of 4.10%. This breed had very good return, up to 3 kg per minute. The animals are very massive; the weight of an adult cow can reach 700 kg and a bull 900 kg.

Holstein cattle of Dutch selection have a solid build, good slaughter weight and high fat content in milk of 4.2%.

The research study of the milk production of animals imported to the farm from Germany, Denmark, the USA and Australia found that the highest milk yield was obtained from German and American cows (Table 1).

With respect to the milk yield for 305 days of lactation, the first-calf heifers of the American selection exceeded their peers of the German selection by 100 kg, Danish selection by 600 kg (P>0.99) and Australian selection by 620 kg (P>0.99).

### Table 1. Performance of heifers of different ecological and genetic types (n=3)

| Parameter                        | Germany | Denmark | USA    | Australia           |
|----------------------------------|---------|---------|--------|---------------------|
| Milk yield for 305 days of lactation, kg | 8200±107.0 | 7700±105.0** | 8300±110.0 | 7680±102.5**       |
| Weight fraction of milk fat, %    | 4.01±0.01 | 3.93±0.02* | 3.97±0.02 | 3.92±0.01**        |
| Amount of fat in milk, kg         | 328.82±6.5 | 302.61±4.6* | 329.51±6.6 | 301.06±4.9*        |

A higher content of the weight fraction of milk fat of 4.01% was registered in cows of German selection. That was higher than the weight fraction of fat in milk of American selection cows by 0.04%; in milk of cows of Danish selection by 0.08% (P>0.95); and Australian selection by 0.09% (P>0.99). There were obtained 329.51 kg of fat from American selection cows, which was higher by 0.69 kg compared with cows of German selection, by 26.9 kg (P>0.95) with Danish one and by 28.45 kg (P>0.95) with Australian selection cows.

The study of the nutritional value of milk from cows of various eco-genetic types (Germany, Denmark, USA and Australia) showed that the highest weight fraction of protein was contained in milk from Australian Holstein cows, which was by 0.03% more than from their peers of the German Holstein cows, by 0.04% from American Holstein ones and by 0.13% from Danish Holstein cows (Table 2).

Milk of German Holstein cows was noted for a higher content of casein 2.4%, which was by 0.07% higher than that in milk from Australian cows, by 0.18% (P>0.95) from Danish cows and by 0.21% (P>0.95) from American cows. Higher values of whey protein were in milk from cows of American selection and made 0.96%, which was by 0.08% higher than its content in milk from Australian cows, by 0.09% from Danish ones and by 0.17 % (P>0.95) from German cows.
Table 2. Nutritional value of milk from cows of different eco-genetic types

| Parameter                  | Germany      | Denmark      | USA          | Australia    |
|----------------------------|--------------|--------------|--------------|--------------|
| Protein, %                 | 3.21±0.06    | 3.11±0.06    | 3.20±0.06    | 3.24±0.06    |
| including casein, %        | 2.4±0.05     | 2.22±0.03*   | 2.19±0.04*   | 2.33±0.06    |
| whey protein, %            | 0.79±0.04*   | 0.87±0.02    | 0.96±0.03    | 0.88±0.04    |
| Total nitrogen, %          | 0.53±0.004*  | 0.52±0.005   | 0.53±0.007   | 0.544±0.003  |

Many scientists believe that an important factor, affecting the protein content in cow's milk, and also meat productivity, is the heredity that is caused by breeding methods [9,10]. According to German experts, the low protein content in milk indicates a lack of energy, and its increased content evidences excessive amounts of energy in the diet of cows. General under-feeding or a serious lack of at least one feeding element leads to a decrease in milk yield and protein content in milk [11,12].

The protein content in milk from cows is also influenced by such factors as the physiological state of the animals, duration of the service and dry periods, calving season, individual characteristics and animal diseases [13,14].

The quality of the protein milk components reflects the amino acid composition. In this regard, the research determined the content of amino acids, including essential ones, not synthesized in the human body in milk from animals of all ecological-genetic types (Figure 1).

![Figure 1. Aminoacids](image_url)
The evaluation of the biological value of milk from cows of various ecological-genetic types was carried out by calculating the amino acid score by the formula: \( C = \frac{A_j}{S_j} \)

where \( C \) - is the amino acid score, expressed in \%; \( A_j \) - the content of the “\( j \)” essential amino acid in the protein of the product being evaluated, g / 100 g of protein; \( S_j \) - is the content of the “\( j \)” essential amino acid in the “ideal protein” (standard), g / 100 g of protein (Table 3).

### Table 3. Calculation of the amino acid score of milk of cows of various ecological-genetic types

| Essential amino acid | Standard of FAO/WHO, g / 100 g of protein | Germany | Denmark | USA | Australia |
|----------------------|----------------------------------------|---------|---------|-----|-----------|
| Valine               | 5.00                                   | 3.66    | 3.62    | 3.63| 3.68      |
| Isoleucine           | 4.00                                   | 4.56    | 4.55    | 4.52| 4.61      |
| Leucine              | 7.00                                   | 4.57    | 4.55    | 4.52| 4.59      |
| Lysine               | 5.50                                   | 4.65    | 4.63    | 4.61| 4.68      |
| Methionine           | 3.50                                   | 2.47    | 2.45    | 2.49| 2.52      |
| Threonine            | 4.00                                   | 3.72    | 3.70    | 3.68| 3.66      |
| Tryptophan           | 1.00                                   | 4.86    | 4.90    | 4.57| 4.97      |
| Phenylalanine        | 6.00                                   | 3.09    | 3.06    | 3.07| 3.10      |
| Result               | 36.00                                  | 31.58   | 31.46   | 31.09| 31.81     |

According to the results of the comparison of the amino acid composition of milk protein in cows of all ecological-genetic types with the amino acid composition of the reference protein, it can be concluded that the protein contained in the milk of heifers has a high nutritional value and satisfies the human body in essential amino acids.

Numerous scientific studies noted the effect of amino acids contained in the diet on the milk production of animals. The main limiting amino acids for dairy cows are lysine and methionine [15 and 16].

There was marked a positive relationship between the level of protein in milk and adequate feeding. A balanced nutritious diet with a sufficient amount of sugars, protein, trace elements and vitamins in the diet allowed increasing the level of milk protein by 0.3-0.4% or more. Furthermore, a decrease in milk protein indicated deficiencies in feeding [17 and 18].

Macro- and microelements were also determined as indices of biological value of milk (Table 4).

### Table 4. Content of macronutrients in milk from cows of various eco-genetic types (µg/g)

| Parameter     | Germany   | Denmark  | USA      | Australia |
|---------------|-----------|----------|----------|-----------|
| Calcium       | 1034.0±47.0 | 1080.0±56.0 | 1066.0±58.0 | 846.0±62.0* |
| Potassium     | 1543.0±94.0 | 1134.0±98.0* | 1304.0±95.0 | 1236.0±97.0 |
| Magnesium     | 121.0±6.0  | 133.0±5.0  | 126.0±4.0 | 106.0±8.0* |
| Sodium        | 482.0±54.0 | 486.0±56.0 | 490.0±52.0 | 487.0±59.0 |
| Phosphorus    | 979.0±77.0 | 913.0±74.0 | 1064.0±88.0 | 881.0±72.0 |

The milk from cows of Danish Holstein breed contained more macronutrients, i.e., calcium of 1080.0 µg/g was by 46.0; 14.0; and 234.0 (P>0.95) µg/g higher as compared with its content in milk from German, American and Australian Holstein cows, respectively; and magnesium of 133.0 µg/g was higher by 12.0; 7.0; and 27.0 (P>0.95) µg/g in comparison with its content in milk from German,
American and Australian Holstein cows, respectively. The amount of sodium in milk from cows of all eco-genetic types was approximately at the same level.

The potassium content in milk from German cows was by 409.0 (P>0.95); 239.0; and 307.0 µg/g higher compared with its content in milk from cows from Denmark, the USA and Australia, respectively. Higher values of phosphorus were found in milk from American cows and made 1064.0 µg/g, which was by 85.0; 151.0; and 183.0 µg/g higher than in milk from cows from Germany, Denmark and Australia.

Milk was examined with respect to the number of trace elements (Figure 2).

Figure 2. Content of microelements in milk from cows of different eco-genetic types

Milk from Danish Holstein cows contained more of these trace elements, µg/g, i.e., zinc (4.49±0.67), manganese (0.07±0.018), iodine (0.73±0.147) and silicon (30.46±4.57) compared with their values of milk from cows of German, American and Australian selections.

More copper and aluminum were found in milk from German cows, i.e., (0.32±0.063) and (1.19±0.18) µg/g, respectively; more iron in milk from American cows (0.92±0.184 µg/g); and lead from Australian cows (0.007±0.0021). The cobalt, boron, lithium, selenium and chromium contents were approximately at the same level, i.e., (0.003±0.0009), (0.3±0.065), (0.005±0.0015), (0.01±0.003) and (0.04±0.011) µg/g, respectively.

4. Conclusion
The conducted studies showed that the greatest amount of milk for 305 days of the first lactation was obtained from cows of American selection and made 8300 kg. Milk from German selection cows was noted for a higher content of the weight fraction of fat (4.01%). Milk from Australian Holstein heifers contained higher weight fraction of protein (3.24%) and a higher amino acid score of 31.81%. In milk from Danish Holstein cows, there was a higher content of macro- and microelements, µg/g, i.e., calcium of 1080.0; magnesium of 133.0; sodium of 1043.0; zinc of 4.49; manganese of 0.07; iodine of 0.73; and silicon of 30.46.

The Holstein cows of German and Australian selections were adapted to the conditions of the Volgograd region of the Russian Federation most successfully. Due to the fact that in breeding plants, the quality indices of milk are passed on from generation to generation, some activities for animals of Danish and American breeding to improve their milk composition, in particular, increase the indices of the milk protein content were recommended to perform.
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References
[1] Alves J R A, de Andrade T A A, Assis D D, Gurjao T A, de Melo L R B, de Souza B B 2017 Productive and reproductive performance, behavior and physiology of cattle under heat stress conditions. J. of Animal Behaviour and Biometeorology 5(3) 91–96 doi:10.14269/2318-1265/jabb.v5n3p91-96
[2] El-Tarabany M S, Roushdy E M, El-Tarabany A A 2017 Production and health performance of Holstein, Brown Swiss and their crosses under subtropical environmental conditions. Animal Production Sci. 57(6) 1137–1143 doi:10.1071/AN15809
[3] Monteiro C A S, Saravia H F R D, Leal G R, Camargo A J D, Serapiao R V, Ferreira A M R, Rodrigues A L R, Nogueira L A G, Oliveira C S 2018 Breed composition does not influence the performance of Holstein-Gyr crossbred as oocyte donors for OPU/IVP. Animal Reproduction 15(1) 71–74 doi: 10.21451/1984-3143-2017-AR978
[4] Gorlov I F, Ovchinikov A S, Mokhov A S, Fomin S D, Vorontsova E S, Karetikova A R and Slozhkenka M I 2018 Economic and biological peculiarities of golshchinsky breed cows of different ecological-genetic types. ARPN J. of Eng. and Applied Sci. 13(7) 2562–2570
[5] Glukhov D N 2011 Dairy cattle imported in Russia: features of adaptation and care. Agrarian Revie 5 30-40
[6] Gorlov I F, Lebedev A T, Galkov V Y, Orlyanskii A V, & Shlykov S N 2016 Effects of feed additives “yoddar-zn” and “gimalask-vet” on the productivity of beef cattle. Res. J. of Pharmaceutical, Biological and Chemical Sciences 7(5) 2518–2522
[7] Randelin A V, Kaydulina A A, Barmina T N, Vorontsova E S Production efficiency of dairy materials from Holstein cows of foreign breeding 2018 News of Nizhnevolzhsky agro-university complex: science and higher professional education 2(50) 207–212
[8] Gorlov I F, Bozhkova S E, Shakhbazova O P, Gubareva V V, Mosolova N I, Zlobina E Y, Mokhov A S 2016 Productivity and adaptation ability of holstein cow of different genetic selections. Turkish J. of Veterinary and Animal Sci. 40(5) 527–533 doi:10.3906/vet-1505-82
[9] Gorlov I, Sulimova G, Perchun A & Slozhenkina M 2017 Genetic polymorphism of the RORC, bGH, bGHR, LEP, LEPR genes in russian hornless cattle breed. Paper presented at the Engineering for Rural Development 16 201-206 doi:10.22616/ERDev2017.16.N038
[10] RUMINANT PHYSIOLOGY: Digestion, Metabolism, Growth and Reproduction 2000 Edited by P B Cronjé CABI Publishing 489
[11] Gulati A, Galvin N, Kennedy E, Lewis E, McManus J J, Fenelon M A, & Guinea T P 2019 Effect of reducing daily herbage allowance during early lactation on composition and processing characteristics of milk from spring-calved herds. Int. Dairy J. 92 69–76 doi:10.1016/j.idairyj.2019.01.008
[12] Paddick K S, DeVries T J, Schwartzkopf-Genswein K, Steele M A, Walpole M E, & Penner G B 2019 Effect of the amount of concentrate offered in an automated milking system on dry matter intake, milk yield, milk composition, ruminal digestion, and behavior of primiparous holstein cows fed isocaloric diets. J. of Dairy Sci. 102(3) 2173–2187 doi:10.3168/jds.2018-15138
[13] O'Sullivan M, Horan B, Pierce K M, McParland S, O'Sullivan K, & Buckley F 2019 Milk production of holstein-friesian cows of divergent economic breeding index evaluated under seasonal pasture-based management. J. of Dairy Sci. 102(3) 2560–2577 doi:10.3168/jds.2018-15559
[14] Mellouk N, Ramé C, Diot M, Briant E, Touzé J, Guillaume D, Dupont J 2019 Possible involvement of the RARRES2/CMKLRL1-system in metabolic and reproductive parameters in holstein dairy cows. Reproductive Biology and Endocrinology 17(1) doi:10.1186/s12958-019-0467-x
[15] Lean I J, de Ondarza M B, Sniffen C J, Santos J E P, & Griswold, K E 2018 Meta-analysis to predict the effects of metabolizable amino acids on dairy cattle performance. *J. of Dairy Sci.* **101**(1) 340–364 doi:10.3168/jds.2016-12493

[16] Schwab C G, & Broderick G A 2017 A 100-year review: Protein and amino acid nutrition in dairy cows. *J. of Dairy Sci.* **100**(12) 10094-10112 doi:10.3168/jds.2017-13320

[17] Nichols K, van Laar H, Bannink A, & Dijkstra J 2019 Mammary gland utilization of amino acids and energy metabolites differs when dairy cow rations are isoenergetically supplemented with protein and fat. *J. of Dairy Science* **102**(2) 1160-1175 doi:10.3168/jds.2018-15125

[18] Aisner I, Glukhov D 2017 Feeding high-yield cows with soy-free diets: secrets of success. *Livestock in Russia* **3** 54-56