Comparative evaluation of the milk composition of dairy cows in the Volgograd region

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Abstract. The article presents the results of determining the indicators of milk productivity of dairy cows in the Volgograd region. The studies processed the data of monthly control milking of five large agricultural enterprises of the region (LLC JV “Donskoe” Kalachevsky district, PZK “Put Lenina” Surovikinsky district, “Vostok” Nikolaevsky district, “PZK named after Lenin” Surovikinsky district, FSUE “Irrigated” Sovetsky district). A comparative characteristic of the milk yield of the presented breeds of cattle in different periods of the year is given. Physicochemical definitions of milk quality indicators were carried out according to generally accepted methods - fat content (GOST R ISO 2446-2011) and protein (GOST 23327-98). A comparative analysis of the fat and protein content in the milk of dairy cows by periods of the year is presented. To analyze the chemical composition of milk samples by inductively coupled plasma mass spectrometry (ICP-MS), a Nexion 300D quadrupole mass spectrometer (Perkin Elmer, USA) was used. The determination of the chemical composition of milk samples by inductively coupled plasma atomic emission spectrometry (ICP AES) was carried out using an Ortime 2000DV atomic emission spectrometer (Perkin Elmer, USA). The results obtained showed the content of chemical elements in the milk of cows in the summer period within the limits of permissible concentrations, including the content of heavy metals (cadmium, mercury, lead, arsenic). Studies carried out with milk samples obtained from animals from all experimental farms have shown that the controlled indicators of milk quality, the content of chemical elements correspond to regulatory documents and raw milk of all farms is recommended for use in the production of all types of fermented milk and dairy products.

1. Introduction
In the agriculture of the Russian Federation, the leading place is still given to the dairy sector in the breeding of cattle. While in the structure of the Russian meat market beef accounts for about 15% of the total consumption, cow's milk and its processed products account for more than 90% of the dairy market. In terms of profitability, milk production is second only to poultry. Only in January 2020, production of raw milk in Russia increased by 5.2% (up to 2.1 million tons) compared to the same period in 2019 [1].
The joint efforts of the state, science and business have achieved impressive results in the development of the sub-industry. According to the calculations of the Ministry of Agriculture of the Russian Federation, the production of raw milk in 2020 will amount to 31.6-32 million tons. It is predicted that by 2025 the level of milk production in farms of all categories will reach 34 million tons [2].

The dairy industry is facing the challenge of ensuring the Food Security Doctrine. The level of self-sufficiency in milk stipulated by the Food Security Doctrine (90%) has not been achieved. In this connection, it is necessary to continue to increase production to achieve the target of 90%. In agricultural organizations, the average productivity should be at least 6000 kg per year [3].

According to the latest information on milk yields and sales of milk, as of August 2020, the average milk yield from a cow per day in the Russian Federation was 17.85 kg. The highest indicator of the average milk yield per cow per day belongs to the Northwestern Federal District (20.68 kg). The three leaders here were the Leningrad region (24.90 kg), the Kaliningrad region (23.50 kg), the Vologda region (22.22 kg). In second place among the Central Federal districts, with an average milk yield of 19.13 kg. The top three regions - leaders in this indicator were Lipetsk region (23.10 kg), Vladimir region (22.80 kg), Belgorod region (22.26 kg). In third place is the Southern Federal District with an average daily milk yield of 18.92 kg. The highest values of milk yield were noted in Krasnodar Territory (22.10 kg), Volgograd Region (19.60 kg), Rostov Region (14.60 kg) [3].

Milk productivity characterizes the economic and biological characteristics of dairy cows. In world practice, it is generally accepted that the indicator of milk productivity of animals by 50-60% depends on the quality of feed and the level of feeding, by 20-25% - on selection work and reproduction, by 20-25% - on the conditions of keeping and milking technology. Therefore, a necessary condition for obtaining a high indicator of milk productivity from cows is complete feeding. With a milk yield of 4000 kg, 500 kg of dry matter is removed from the animal's body with milk, with a milk yield of 5000 kg - more than 635 kg. In general, during the lactation period, nutrients are transferred from the animal's body into milk, which in their amount often exceeds the weight of a cow. Breeding work should be carried out in the direction of increasing the milk productivity of animals, as well as improving the adaptability of cows to industrial technologies [4, 5].

The high rate of milk production of cows is associated with strong physiological stress of the whole organism. Animals must be well developed, able to eat large amounts of feed for processing it into milk, with a strong constitution and health. It is desirable that for lactation the milk yield of cows exceeded their live weight by 8-10 times or the value of the milk yield coefficient (multiplied by 100 the value of the ratio of milk yield per lactation to live weight) should be equal to 800-1000 kg. These indicators indicate a dairy type of cows.

2. A summary of the purpose and methodology
This study is aimed at studying the indicators of milk productivity of cows of different breeds of the Volgograd region, because the problem of improving the quality of raw milk is currently important and urgent. The work set the following tasks:

- study of the indicator of milk productivity of cows of different breeds;
- study of the chemical composition of milk;
- the efficiency of milk processing into dairy products.

The dairy herd was represented by the most widespread cattle breeds in the Volgograd region, including 300 Holstein cows of the agricultural enterprise "Donskoye" of the Kalachevsky district of the Volgograd region, 277 cows of the Simmental breed of the collective farm "Lenin’s Way" of the Surovikinsky district of the Volgograd region, 270 cows of the Ayrshire breed group of companies "Vostok" of the Nikolaevsky district of the Volgograd region, 250 red steppe cows of the breeding farm "PZK named after Lenin" of the Surovikinsky district, 190 cows of the Holstein-Friesian breed of the Federal State Unitary Enterprise "Irrigated" of the Soviet district of the Volgograd region.
The agricultural enterprise LLC JV "Donskoe" specializes in the field of dairy farming in the cultivation, maintenance and selection of Holstein cows - a breed of high-productivity dairy cattle and in the production of their own feed. In terms of the average milk yield per cow, the enterprise exceeds the regional average. The number of cattle is 3617 heads, the dairy herd is 1782 heads. Milk production in 2019 amounted to 14.6 thousand tons, productivity per cow - 9803 kg.

In the collective farm "Lenin's Way" (breeding farm-collective farm), animal husbandry is an important branch. Simmental cattle are bred here. The farm has 704 cows of this breed, of which 310 are dairy cows with a productivity per cow of 5414 kg/year.

The group of companies "Vostok" today is a modern, highly mechanized large agro-industrial enterprise. The breeding plant of the agro-firm contains 458 head of cattle, almost half of them are Ayrshire animals. Milk production volumes increased from 65.9 tons in 1996 to 1,800 tons in 2019. Profitability level in 2019 amounted to 16.1%.

The leading branch of the Lenin breeding farm-collective farm is animal husbandry, which accounts for 55.7% of the structure of marketable products. The share of processing of livestock products is 26.93%. Cattle are mainly represented by animals of the red steppe breed. The total livestock is 1520 heads, the milking head is 700 heads. In 2019, the enterprise received 2,940 tons of milk.

The main activity of FSUE "Irrigated" is the production and sale of agricultural products: milk, pedigree livestock, grain, forage crops. FSUE "Irrigated" is a breeding farm - a reproducer for breeding Holstein-Friesian cattle. The livestock of animals is 342 heads, of which 210 are milking. In 2019, the organization received 1400 tons of milk.

The studies were carried out in January - September 2020. For the research, five experimental groups of 50 animals were formed. Experimental group I consisted of animals of the Donskoye agricultural enterprise, Group II - Lenin's Way farms, Group III - Vostok, Group IV - animals of Lenin PZK farm, Group V - FGUP Irrigated.

During the study period, the following was determined:

- milk yield per lactation - according to the monthly results of control milking;
- physical and chemical indicators of milk - mass fractions of fat and protein according to generally accepted methods, according to GOST;
- the content of chemical elements in the milk samples of cows was determined using the methods of mass spectrometry with inductively coupled plasma and atomic emission spectrometry with inductively coupled plasma. Analyses were performed using Perkin Elmer equipment, USA: a Nexion 300D quadrupole mass spectrometer and an Ortima 2000DV atomic emission spectrometer.

The experimental data were statistically analyzed using the Statistic 10 software (StatSoft Inc.). In statistical analysis, Wilcoxon's test and Student's t-test were applied. To establish the relationship between different parameters, the calculation of correlation analysis and regression was carried out.

3. Research results, discussion

The results of determining the indicators of milk productivity are presented in table 1. The highest value of the average daily milk yield was noted in animals of the I experimental group in the spring period of lactation (29.13 kg), the smallest in cows in the IV group (14.3 kg) in the winter period, which was 14.83 kg. In general, in the 1st experimental group, the average daily milk yield gradually decreased from spring to autumn, the difference was 6.53 kg. The high value of this indicator in the spring is due to the intake of animal feed in the diet. For the II control group, the highest value of the average daily milk yield was determined in the summer period (19.3 kg), the lowest - (17.1 kg) in the winter period. The difference was 2.2 kg. For the III control group, the highest value of the average daily milk yield was determined in the winter period (25.20 kg), the lowest - in the autumn period (23.13 kg), which was 2.07 kg in difference. The average daily milk yield for the IV experimental group of animals during all periods of lactation was distinguished by a constant value, with a small difference between the extreme
values of the summer (14.58 kg) and winter periods (14.3 kg) of 0.28 kg. The value of the average daily milk yield for the V experimental group was distinguished by a sharp increase in the spring and summer periods of lactation. The difference between the highest and the lowest values of the spring (22.37) and autumn (15.2) periods was 7.17 kg.

The highest value of the indicator "Mass fraction of fat" was noted in milk obtained in the spring period of lactation, in Ayrshire cows (5.03%), the lowest - in the autumn period of lactation in animals of the Holstein-Friesian breed (3.82%). The difference between these values was 1.21%. In the first group of cows, the highest fat mass fraction was observed in the autumn period (4.83%), while the average daily milk yield was the lowest for the periods under consideration. The lowest value of the mass fraction of fat was noted in the spring period (3.98%), while the average daily milk yield was the highest. In cows of the II experimental group, the highest value of the mass fraction of fat in milk was noted in the winter period of lactation (4.34%), the lowest - in the autumn (4.09%), which in the difference was 0.25%. At the same time, the average daily milk yield in the winter period has the lowest value. The highest indicator of fat content in the milk of cows of the III experimental group was 5.03% in spring, the lowest - in summer (4.34%), which was 0.69% in difference. For the IV group of cows, a higher value of fat in milk was noted in the spring (4.36%), the lowest value - in the summer (3.98%), which was 0.38% in difference. A high fat content in the milk of cows of the V experimental group was noted in winter (4.11%), a lower value in autumn (3.82%), which was 0.29% in difference.

The highest value of the indicator "Mass fraction of protein" was noted in the milk of animals of the III experimental group, obtained in the autumn period of lactation (3.51%), the lowest - in the milk of animals of the II group, obtained in the winter period of lactation (3.09%). The difference was 0.42%. The largest value of the mass fraction of protein in the milk of animals of the I experimental group was noted in the autumn period of lactation (4.34%), the smallest - in the winter period (3.17%), the difference was 0.17%. In the autumn period from this group of animals milk with the highest value of the mass fraction of fat was also obtained. The highest protein content in the milk of cows of the II group was determined in the summer and autumn periods (3.28%), the lowest - in the winter period (3.09%), the difference was 0.19%. Moreover, for the smallest indication of the mass fraction of protein in the milk of cows of this group, the highest indicator of the mass fraction of fat is characteristic with the lowest indicator of the average daily milk yield. The highest value of protein in the milk of cows of the III group was observed in the autumn period (3.51%), the lowest - in the summer period (3.28%), which was 0.23% in difference. In the milk of cows of the IV group, the highest value of the mass fraction of protein was determined in the summer period of lactation (3.30%), the lowest in the autumn (3.11%). The difference was 0.19%. In the milk of cows of group V, the mass fraction of protein during all the periods under consideration changed insignificantly. The difference between the largest (summer period, 3.23%) and the smallest (autumn, 3.20%) values was 0.03%.

**Table 1.** Assessment of milk production of cows.

| Groups | Indicators | Winter lactation period | Spring lactation period |
|--------|------------|-------------------------|------------------------|
| I      | Average daily milk yield, kg | 29.05±0.35 | 29.13±0.42 |
| II     | Average daily milk yield, kg | 17.10±0.42<sup>c</sup> | 18.65±0.38 |
| III    | Average daily milk yield, kg | 25.20±0.56<sup>c</sup> | 24.25±0.32 |
| IV     | Average daily milk yield, kg | 14.30±0.29<sup>c</sup> | 14.44±0.39 |
| V      | Average daily milk yield, kg | 15.55±0.27<sup>c</sup> |           |

| Groups | Mass fraction of fat, % | Mass fraction of protein, % |
|--------|------------------------|-----------------------------|
| I      | 4.50±0.12              | 3.17±0.06                   |
| II     | 4.34±0.14              | 3.09±0.01                   |
| III    | 4.61±0.13              | 3.33±0.03                   |
| IV     | 4.35±0.15              | 3.32±0.03                   |
| V      | 4.11±0.14<sup>a</sup>  | 3.22±0.03                   |

| Groups | Mass fraction of fat, % | Mass fraction of protein, % |
|--------|------------------------|-----------------------------|
| I      | 3.98±0.15              | 3.23±0.03                   |
| II     | 4.13±0.16              | 3.14±0.02<sup>a</sup>       |
| III    | 5.03±0.14<sup>a</sup>  | 3.33±0.03                   |
| IV     | 4.36±0.13<sup>a</sup>  | 3.23±0.03                   |
Based on the results obtained for determining the indicators of milk productivity, it can be concluded that cows of the Holstein-Friesian breed are distinguished by high values of the average daily milk yield in the spring and summer periods of lactation, which is associated with the transition to juicy green fodder in these seasons. The data are also confirmed by previous studies [6, 7]. In Simmental cows, the average daily milk yield increases smoothly from winter to summer. In the autumn period, the milk yield decreases almost to the level of the winter period. Animals of the Simmental breed, in order to increase the value of the average daily milk yield, in the winter and autumn periods, need enhanced nutrition. Feed should be given with a sufficient amount of all nutrients [8]. In Ayrshire cows, the average daily milk yield gradually decreases from winter to autumn. Animals of the red steppe breed are distinguished by a small, compared to other cattle breeds, but a stable level of average daily milk yield. According to the content of the mass fraction of fat for animals of the Simmental breed, dynamics is characteristic: the higher the mass fraction of fat, the lower the value of the average daily milk yield and, accordingly, the lower the fat content in milk, the higher the value of the milk yield. In general, according to the experimental groups, the value of the indicator "Mass fraction of fat" in the winter and autumn periods of lactation were approximately at the same level, which is associated with a reduction in animal walking on pastures and the provision of concentrated feed of regulated composition. In the spring and summer periods, the value of this indicator was subject to fluctuations associated with an increase in the proportion of fresh vegetable feed.

In the milk obtained from the experimental groups of cows in the summer lactation period, the content of mineral substances was determined (table 2). It is known that the amount of minerals in milk is directly dependent on the feeding ration, season, environment [9].

Trace elements are of great physiological importance, determine the biological and nutritional value of milk. These include iron, copper, zinc, silicon, manganese, cobalt, molybdenum, iodine, fluorine, tin, chromium, aluminum, lead, etc. With their help, the construction and activity of vital hormones, enzymes and vitamins, the transformation of nutrients, entering the human body. 

Iron and copper in milk are associated with the shells of the fat globules. Zinc, manganese, iron, copper, iodine, aluminum, selenium, etc. are associated with casein and whey proteins. The enzymes include manganese, iron, and zinc. The composition of vitamins includes cobalt, the composition of hormones - iodine, copper, zinc. The amount of trace elements depends on the composition of milk, the conditions of its processing and storage. The content of zinc, copper, iron, silicon, aluminum and some others in milk is much larger.

It is known that trace elements, depending on their concentration, have either an inhibitory or an activating effect on enzymes. Trace elements, being in interaction with enzymes, affect the course of biochemical reactions in milk and the change in its constituent components during the production and storage of dairy products. So, zinc is a part of carbohydrase, molybdenum - xanthinosidase, iron -
peroxidase and catalase, magnesium, manganese, zinc and cobalt activate alkaline phosphatase. Copper inhibits alkaline phosphatase and lipase [10].

The concentration of trace elements undergoes changes during lactation, highly dependent on the presence of trace elements in the diet. In the case of regulating the microelement composition of milk, you should carefully study and analyze their content in the composition of the feedstock. It is also recommended to include some trace elements in animal feed rations [11]. At the same time, special attention should be paid to trace elements with important physiological significance for both the human body and the body of lactating animals. These elements include selenium, iodine and zinc. The antioxidant properties of selenium prevent peroxidation in cell membranes and suppress free radicals. Iodine regulates the function of the thyroid gland. Zinc is involved in most of the biochemical processes of the digestive system [12].

| The name of the element | The results of the determination of the experimental groups (µg/g) | macroelements | microelements |
|------------------------|---------------------------------------------------------------|---------------|---------------|
|                        | I                  | II             | III            | IV             | V              |
| Ca                     | 1240±124           | 1373±137       | 1220±122       | 1274±128       | 1256±126       |
| P                      | 989±148            | 1059±127       | 990±149        | 1015±101       | 978±138        |
| Mg                     | 114±11             | 120±12         | 108±11         | 106±10         | 112±11         |
| K                      | 2235±268           | 1850±222       | 2210±265       | 2102±236       | 2015±228       |
| Na                     | 401±40             | 489±49         | 391±39         | 384±37         | 405±40         |
| Fe                     | 0.29±0.088         | 0.35±0.105     | 0.27±0.08      | 0.30±0.092     | 0.032±0.098    |
| Se                     | 0.05±0.008         | 0.05±0.007     | 0.06±0.008     | 0.004±0.007    | 0.005±0.007    |
| Sn                     | 0.0009±0.00027     | 0.0009±0.0026  | 0.0008±0.00027 | 0.0009±0.00026 | 0.0007±0.00028 |
| Mn                     | 0.03±0.004         | 0.04±0.005     | 0.03±0.004     | 0.002±0.003    | 0.04±0.005     |
| Co                     | 0.004±0.0008       | 0.003±0.0007   | 0.004±0.0008   | 0.004±0.0008   | 0.003±0.0007   |
| I                      | 0.29±0.035         | 0.17±0.02      | 0.21±0.023     | 0.25±0.027     | 0.16±0.019     |
| Al                     | less than 0.09      | less than 0.09 | less than 0.09 | less than 0.09 | less than 0.09 |
| Cr                     | 0.03±0.005         | 0.03±0.005     | 0.08±0.012     | 0.05±0.007     | 0.04±0.006     |
| B                      | 0.26±0.031         | 0.29±0.035     | 0.32±0.038     | 0.28±0.034     | 0.30±0.036     |
| Li                     | 0.004±0.0007       | 0.008±0.0016   | 0.006±0.0013   | 0.004±0.0007   | 0.005±0.0010   |
| Ni                     | 0.06±0.009         | 0.06±0.009     | 0.06±0.01      | 0.005±0.009    | 0.004±0.008    |
| Sr                     | 0.5±0.06           | 0.58±0.07      | 0.62±0.075     | 0.64±0.077     | 0.05±0.06      |
| V                      | 0.003±0.0007       | 0.003±0.0006   | 0.02±0.002     | 0.004±0.0008   | 0.003±0.0007   |

Based on the results of the determination, it can be concluded that the content of macroelements: calcium, phosphorus, magnesium, potassium and sodium in general in milk samples obtained from all groups of animals was within the normal range. So, the normal calcium content in milk is 1000-1400 µg / g. The milk of the II experimental group of this element contains the greatest amount (1373 µg / g), the smallest - in the III group (1220 µg / g). The increased content of calcium ions is essential for the thermal coagulation of casein in the production of condensed milk. The content of calcium ions determines the rate of coagulation of milk by rennet. With their insufficient amount, milk coagulation does not occur.

The total content of the macronutrient phosphorus is 740-1300 µg / g. The largest amount of phosphorus was also determined in milk of the II experimental group (1059 µg / g), the lowest - in milk of the V group (978 µg / g). In relation to calcium, various forms of phosphorus affect the degree of dispersion and hydration of protein particles, the stability of particles during heat treatment and destabilization during rennet coagulation of milk [13].

The normal magnesium content in milk is 120-140 µg / g. The highest value of this element in the milk of the II experimental group (120 µg / g), the lowest - in the IV group (106 µg / g).

The value of potassium in milk ranges from 1350 to 100 µg / g, sodium - 300-600 µg / g. Citrates and phosphates of sodium and potassium ensure the salt balance of milk.
The use of trace elements is used in the dairy industry, for example, in the production of natural cheeses. Specific organoleptic characteristics of cheeses are formed due to biochemical transformations of milk constituents with the participation of enzymes at the stage of cheese ripening.

The work also conducted research on the content of chemical elements that determine the environmental safety of milk obtained in farms. These elements include mercury, arsenic, lead and cadmium, the concentration of which is standardized by regulatory documents (figure 1, 2).

In general, the content of cadmium and mercury in milk samples from all farms was below the concentration determined by regulatory documents. So, for cadmium, this value is 0.03 μg / g, the highest value of this element in the II experimental group is (0.0002 ± 0.0009 μg / g), the lowest is in the I and IV groups (0.0001 ± 0.0007 μg / g). The least amount of mercury was found in the milk of experimental group I (0.0008 ± 0.0021 μg / g).

The content of arsenic and lead in milk samples from all farms was also below the permissible concentration. Most of all, in comparison with the content in the milk of cows of other groups, arsenic
was contained in the II experimental group - (0.008 ± 0.0027 μg / g). In the groups as a whole, the arsenic content was at the same level (less than 0.0042 ± 0.009 μg / g). Lead was the least of all in milk obtained from cows of the I experimental group (0.0008 ± 0.00029 μg / g).

4. Summary and conclusions
As a result of the studies, it was determined that among the presented dairy breeds, the Holstein-Friesian animals have the highest productivity values, especially in the spring and summer periods of lactation. Animals of the Simmental breed, in order to increase the value of the average daily milk yield, in the winter and autumn periods, need enhanced nutrition. The highest content of fat mass fraction was noted in the milk of Ayrshire cows obtained in the spring period of lactation. The highest content of the mass fraction of protein was noted in the milk of the Ayrshire breed animals obtained in the autumn period of lactation. The content of macro- and microelements in milk samples obtained from all groups of animals was within the normal range. According to the content of chemical elements classified as heavy metals, milk obtained from all experimental farms is environmentally safe and can be recommended for use in the production of all types of fermented milk and dairy products.

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