Silicon-containing minerals as additives for farm animals

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Abstract. The article presents the results of scientific research on the use of silicon-containing minerals of the Ulyanovsk region deposit as feed additives. The materials prove that Silicon-containing additives based on natural zeolite and diatomite in the feeding of farm animals have a positive effect. The use of silicon-containing additives increases the growth processes in the body of young pigs, strengthens the strength of their bone tissue. Under the influence of application of additives, favorable conditions are created for the activity of cicatritial microflora. The use of application of additives for dairy cows helps to increase their productivity, improve the quality of milk composition, due to the intensive conversion of feed nutrients. The mechanism of Silicon-containing additives is due to the following processes: activation of enzymes of the gastrointestinal tract, increased absorption of nitrogen, vitamins and macro-and microelements; regulation of the composition and level of electrolytes, binding and excretion of toxins, harmful gases of heavy metals and radionuclides.

1 Introduction

Mineral elements are a significant part of feeding farm animals. We can notice that minerals are of particular importance. Animals constantly lose mineral elements with secreted products and metabolic products, such as feces, urine, and sweat. Their lack or excess causes significant damage to livestock and poultry farming inhibits the growth of livestock, reduces productivity and fertility, causes diseases and deaths, worsens the quality of products. Many scientists claim that mineral elements should enter the body in optimal ratios [1-3].

Farm animals and birds should receive vitamins, macro-and microelements with feed and feed additives. The mineral composition of the feed is subject to significant fluctuations and varies depending on the type of plants, soil type, vegetation stage, agricultural technology, weather conditions, method of harvesting and storage of feed, the technology of preparing them for feeding, on the ecological situation of the region. In addition, in some feeds, minerals are in a form that is difficult for animals to digest, or antagonists are present in them [4-5].

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In Russia, there are large deposits of silicon-containing minerals: zeolites, diatomite, flask, bentonite, rottenstone**,** montmorillonite, and others. These are mainly water-containing frame aluminosilicates that absorb water well (up to 40%) and give it away when heated. Silicon-containing minerals are sources of macro-and microelement. It adsorbents toxins, harmful gases and allergens, heavy metals, and radionuclides [6-7].

And they began to be used in biology, medicine, veterinary medicine, agronomy, industry, national and agriculture. The reason for such attention was the useful properties of silicon-containing minerals: ion exchange, adsorption, the function of a molecular sieve, the function of a catalyst. Due to these properties, silicon-containing rocks can: supply and enrich the body with macro- and microelements, including vital silicon, calcium, copper, manganese, etc.; bind and neutralize harmful gases, poisons and toxins during poisoning; take heavy metals and radionuclides out of the body; show the properties of a catalyst for oxidation-reduction reactions in the body, increase the activity of enzyme systems, activate the activity of beneficial microflora in the gastrointestinal tract; show anti-inflammatory and therapeutic properties, etc. [8-9].

Scientists ' attention is drawn to the discovery of special properties of silicon-containing minerals: ion exchange, adsorption, detoxification, supply of silicon and mineral elements. The ability of silicon compounds to adsorb amino acids and protein provides their rapid absorption in the stomach and intestines and increases the assimilation of feed. It is important to note that the bone tissue consists of silica, which gives it strength. Silicon helps to ensure the storage of calcium and other minerals in the bone, if silicon is removed from the diet, then calcium is also removed from the bones. The regulatory role of silicon in body is significant. Mineral homeostasis is normalized and body absorb the nutrients of the feed [10-11]. Disbalance, a lack of silicon in body leads to disorders and contributes to the development of diseases: bone softening; diseases of eyes, teeth, claws, skin and hair, cartilage; stones in liver and kidneys; atherosclerosis [12]. In Russia, new deposits of silicon-containing rocks (zeolite, diatomite, and others) have been discovered, which are located in the zone of Middle Volga region (Ulyanovsk Region) [6-12].

In this regard, the scientific search and development of new and highly effective feed products based on natural components are relevant. We established that increasing milk yield and fat content and improving the taste and nutritional value of the product. Also increases the absorption of nutrients in the feed ration and stimulates the activity of the microflora in the stomach intestines of animals, and removal of excess fluid, harmful substances, gases, toxins, heavy metals, and radionuclides from the body. We noticed the reduction of feed costs and increase of profitability of production.

New experimental data showed the effectiveness of silicon-containing natural additives for animals and birds in recent years.

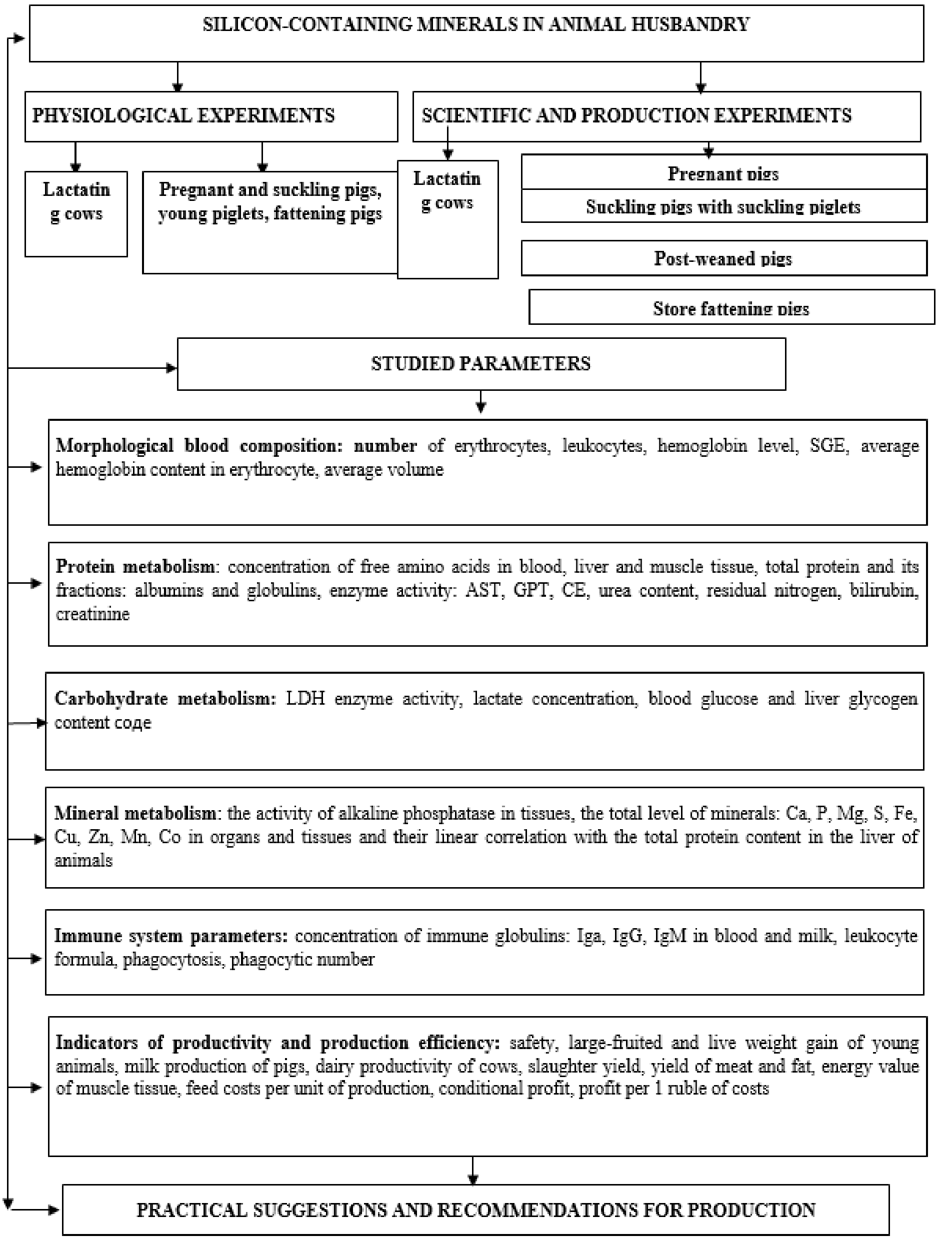

Fig. 1 Study volume and direction

In general, the use of silicon-containing natural additives ensures the yield and production of environmentally friendly products of high quality [8-13]. However, the use of silicon-containing additives treated with high and the latest technologies, using the procedure of enrichment with nutrients and biologically active substances remains poorly understood. The purpose of this work is to establish of using silicon-containing additives for farm animals. We organized this experiment to achieve scientific and economic (for a population of 50 to 300 animals in a group) and physiological (from 5 to 10 animals in a group). Dairy farm and pig farm in the Ulyanovsk region was the production platform.

2 Materials and Methods

We formed groups based on the principle of analogs: taking into account body weight, age, productivity, and physiological state. We singled out the control and experimental group. The content of animals in the groups was the same. We carried out feeding with the rations adopted on the farm, the difference was that the diet of the experimental group included a silicon-containing additive in the amount of 2% of the dry matter of the diet.

The research was carried out in the laboratory at the department "Morphology, physiology, and pathology of animals" and Interdepartmental Center of the Faculty of Veterinary Medicine of the Ulyanovsk State Agrarian University named after P.A. Stolypin. We used modern devices and equipment. And we studied the physiological parameters of the animal's body, kept records of productivity, product quality, the concentration of mineral elements, heavy metals. All data were processed using the program "Statistica".

Comprehensive studies were carried out at FSBEI HE Ulyanovsk SAU at the Department of Morphology, Physiology and Pathology of animals with quarry natural zeolite from 1996 to 2012, on the topic: «Increasing the productivity of farm animals by improving the systems of full-fledged feeding, breeding and technology in the conditions of the Middle Volga region» and «Physiological and biochemical aspects of the use of new biologically active substances in the current conditions of livestock production and environmental situation, ensuring the sustainable welfare of animals» state registration number 01200600146 and 01201157935. The volume and direction of the study are shown in picture 1.

The composition of zeolite-containing rock of the Ulyanovsk region deposit includes active phases: opal-cristobalite, montmorillonite, hydrosluda, calcite, the total cation exchange capacity is 93 ...106 mg-eq/100 g, while a significant role in the exchange belongs to silicon and calcium up to 88%, then potassium up to 8%, sodium up to 3%, magnesium up to 3%. The composition includes up to 40 mineral elements.

3 Results and Discussion

It has been experimentally established that the use of zeolite-containing rock from the Ulyanovsk region deposit as a feed additive for dairy cows in an amount of 2% of the dry matter of the diet increases the feed ability of coarse and juicy feeds by 6.10% and increases the use of nitrogen. Comparing the data in animals of the control and experimental groups, it can be noted that in the body of cows of the control group, an average of 6.9 g of nitrogen is retained, used for the formation of milk and 69.1 g is retained in the body. At the same time, the use of the additive contributed to an increase in these indicators to 16.7 and 91.3 g, including for the synthesis of milk: 21.3% of the ingested and 32.3% of the digested. Analysis of data on the milk productivity of experimental cows showed that in the group with the addition of zeolite, more milk was obtained on average for the period of the experiment per 1 dairy cow by 2.15 kg, which is 12.9% more than in the group of analogues. It was experimentally established that the addition of zeolite to the summer diet of cows contributed to an increase in the average daily milk yield: in May by 22.2% (up to 18.3 kg), in June - by 15.4% (up to 20.6 kg), in July - by 20.1% (up to 20.4 kg), in August - by 22.3% (up to 20.3 kg) compared with the control (figure 2).

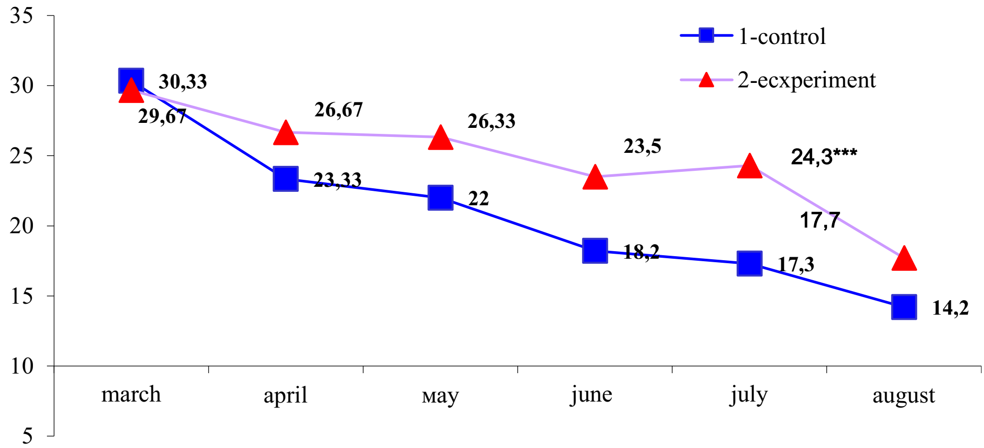

Fig. 2. Dairy productivity of cows when feeding zeolite-based additives

At the same time, there was a reduction in feed costs for obtaining 1 kg of milk of basic fat content - by 11.3%, by 1 ruble of costs 6.3 rubles of additional profit. The number of erythrocytes in the blood of cows increased by 17.4% ($P<0.05$), hemoglobin by 19.0% ($P<0.05$) and leukocytes by 21.5% ($P<0.02$) compared to the control.

The intensity of protein and mineral metabolism increased: the level of total protein increased by 9.4% ($P<0.05$), albumins by 37.2% ($P<0.05$); the activity of enzyme systems increased: aminotransferases, cholinesterases, lactate dehydrogenase, alkaline phosphatase. It is important to note that a reserve of mineral elements is created in the depot organs, so concentration of calcium ($P<0.01$), phosphorus and magnesium increases in blood; the level of iron increases in liver ($P<0.01$); the content of iron ($P<0.02$), copper and zinc ($P<0.05$) increases in spleen).

Consequently, a stock of macro- and microelements is formed in cow bodies, which can be used for body needs, including for assimilation of protein-containing and biologically active substances of feed.

In pig breeding, feeding zeolite-containing additive in pigs contributed to an improvement in morphological composition of blood, including an increase in red blood cells ($P<0.05$) and hemoglobin. Stimulation of protein metabolism, in particular, an increase in albumin fraction ($P<0.02$), an increase in protein in sow milk by 21.7% ($P<0.01$), a positive nitrogen balance, in which a decrease in urea levels by 32.2...15.3% was noted.

An increase in growth intensity of young pigs, which is confirmed by an increase in creatinine in their blood by 14.9...10.4% ($P< 0.05$). Increased carbohydrate metabolism, which is indicated by an increase in physiological standard of glucose by 16.1...19.5% ($P< 0.05$) and the activity of enzyme lactate dehydrogenase by 8.1...9.5 ($P<0.02$) %. Activation of mineral metabolism in pig bodies, which characterizes an increase in the activity of alkaline phosphatase ($P< 0.01$) and an increase in calcium ($P < 0.05$) in their blood.

Analysis of the concentration of macronutrients in the tissues of piglets showed that the addition of zeolite to their diet contributes to an increase in the levels of calcium (Ca), phosphorus (P) and magnesium (Mg) not only in the blood, but also in the liver and bone tissue (тable 1). Compared with the control in the liver of young pigs of the experimental group, the content of Ca increased by 14.8 and 18.2%, the concentration of P - by 6.0 and 20% and the level of Mg - by 9.3 and 17.8% compared with analogues in the control.

Table 1. Macronutrient content in piglets liver when using zeolite additives

Age of piglets	Group	Macronutrient content, g/kg SV		
		Ca	P	Mg
1 day.	1-control	2.7±0.029	6.7±0.25	1.07±0.033
	2- experiment	3.1±0.031	7.1±0.27	1.17±0.03
60 day.	1-control	2.2±0.028	7.5±0.28	1.13±0.033
	2- experiment	2.6±0.03	9.0±0.3	1.26±0.006 **

Note: **p<0.01 compared to the control

Table 2 shows that feeding a silicon-containing supplement to piglets increases the strength of the femurs by 17 and 21% to 154.81±10.81 and 722.29±47.30 kg/cm2, against 127.16±7.32 and 657.67±72.27 kg/cm2 in the control group.

Table 2. Macronutrient content in piglets liver when using zeolite additives

Group	Bone bending strength, kg/cm2	
	60 day.	105 day.
1-control	127.16±7,32	657.67±72.27
2- experiment	154.81±10,81	722.29±47.30

Table 3 shows that the introduction of zeolite additives into the diet of young pigs increases the weight of their femur by 13.27% and the length of the femur by 6.72% compared to the control.

Table 3. Measurements of the femur 60 days. piglets when using zeolite additives

Indicator	Group of animals	
	1-control	2- experiment
Bone mass, g	37.67 + 0.67	42.67 + 0.88*
	100.00	113.27
Bone length, cm	9.37 + 0.07	10.00 + 0.12*
	100.00	106.72

Note: *p<0,05 according to the control

An increase in general resistance of young pigs bodies, which is confirmed by an increase in such indicators as gamma globulins by 25.7% (P<0.05), IgG and IgA immunoglobulins (P<0.02) and leukocytes by 14...19.2% (P<0.05), against the background of a decrease in phagocytic number and phagocytosis by neutrophils.

Reproductive qualities of sows and growth rate of piglets have increased (тable 4). This is marked by an increase in such indicators as large-fruiting - by 19.6% (P<0.01), nest weight - by 13.2%, safety of young animals - 95.52%, absolute increase in live weight of weaned piglets - by 14.41% and decrease in feed costs per kg of increase by 16.61%. All indicators were considered in comparison with similar ones in the group of animal analogues.

Table 4. Sow productivity indicators when using zeolite additives

Indicator, units.	Group of animals	
	1-control	2- experiment
Number of sows, head	7	7
Multiple pregnancy, head	64	67
Krupnoplodnost, kg	0.92±0.023	1.10±0.021**
Piglet weight in 21 days, kg	4.54±0.063	5.14±0.062
Safety in 21 days, %	92.19	95.52

Note: **p<0,01 according to the control

The application of new technologies for processing zeolite-containing rocks, including various types of activation of a quarry mineral, then its enrichment with useful nutrients, in particular amino acids, showed the greatest effect than the use of natural non-activated raw materials. In this regard, as part of comprehensive research since 2017, we have been conducting research on the topic: «Metabolism, productivity, product quality, morphometric and physiological parameters of the body of animals and birds when using additives based on highly structured zeolite enriched with amino acids». During a 210-day scientific and production experiment on dairy cows formed into two groups of 100 cows, it was proved that feeding an additive based on highly structured zeolite enriched with amino acids to animals of the experimental group contributes to an increase in milk yield (figure 3) and milk fat content (kg).

At the beginning of the experiment, average daily milk yield in groups was at the same level of 30.3...29.7 kg, fat content of milk was 3.7...3.8%, and amount of milk fat was 1,143...1,147 kg. The use of an additive of highly structured zeolite enriched with amino acids contributed to an increase in average daily milk yield: in April by 14.3%, in May by 19.7%, in June by 29.3%, in July by 40.3% (at $p<0.001$), in August by 29.3% compared with the control. At the same time, there was an increase in milk fat content (kg): in April by 21.8%, in May by 21.3%, in June by 15.9%, in July by 21.7%, in August by 7.2%. At the same time, a noticeable effect on the change in fat content of milk has not been established.

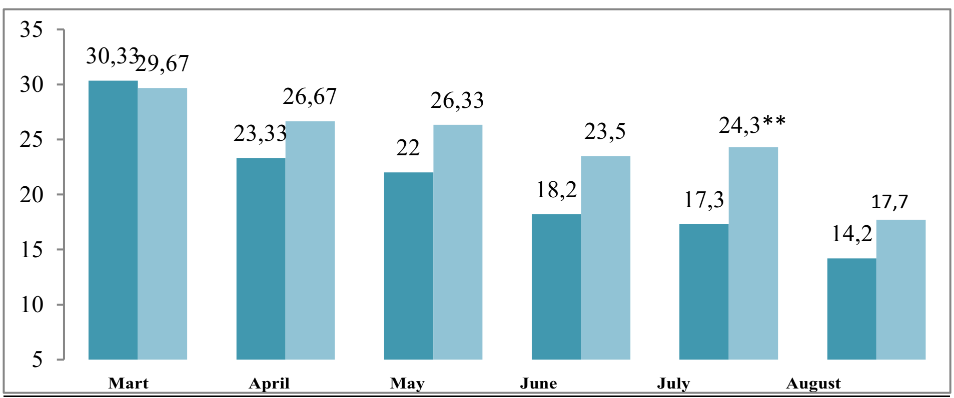

Fig. 3 Dynamics of average daily milk yield in cows when feeding additives based on highly structured zeolite enriched with amino acids

Note: ***p<0,001 according to the control

Thus, the positive effect of zeolite-containing rock of the deposit in the Ulyanovsk region on farm animal bodies is due not only to the presence of zeolite (clinoptilolite) in rock, but also content of minerals such as calcite (rich in amorphous calcium), montmorillonite and bentonite (smectite - layered silicates, ion exchangers, adsorbents with anti-inflammatory properties), glist , clays and other components is important. Due to the introduction of montmorillonite into mucous membrane of gastrointestinal tract, a thin protective film is formed, which reduces the effect of pathogens and soothes nerve endings. And the main thing is that both clinoptilolite and montmorillonite, bentonite are sources of silicon easily accessible to body. The use of new technologies, innovative processing and enrichment of zeolite-containing quarry mineral with amino acids makes it possible to strengthen the existing properties and increase the effectiveness of its action on the animal's body, contributing to an increase in productivity and quality of the products obtained. Diatomite is a mineral from ancient seaweed, leaves of which are fossilized and 70-90% consists of silicon, in a smaller amount contains oxides of iron and calcium, magnesium, copper chelates, manganese, zinc and vitamins of group B and K. It has been proven that feeding animals natural diatomite helps to reduce diseases of digestive tract, excretion of metabolic products and toxic substances that have come with food and are formed as a result of digestion increases the absorption of feed nutrients, contributes to the increase of animal productivity. Balancing the diets of cows through a diatomite-based additives helps to increase milk productivity. An increase in average daily milk yield by 24.7 % (at $p<0.05$), milk fat by 16.2% compared to table 5 analogues was revealed (figure 2).

Table 5. Indicators of dairy productivity of cows when feeding a diatomite-based additives

Period	Indicator, units	1 group control	2 group experiment
Before the experiment 3-4 months of lactation	Average daily milk yield per 1 cow, kg	19.55±0.93	19.44±0.24
	Fat content of milk, %	4.16±0.17	4.13±0.12
	Butterfat, kg	0.81±0.05	0.80±0.03
The experiment 4-5 months of lactation	Average daily milk yield per 1 cow, kg	16.67±0.87	20.78±1.29*
	Fat content of milk, %	4.07±0.12	3.81±0,12
	Butterfat, kg	0.68±0.05	0.79±0.06

Note: * - ($p<0.05$) compared to the control

The content of non-fat milk solid (NFMS) in the milk of cows of the experimental group was 9.74±0.10, compared to 9.61±0.08 in the control. This indicator shows the naturality of milk, high content of dry substances and smaller amount of water. The content of heavy metals such as cadmium and lead in milk of cows in all groups was within the permissible limits (Cd-0.03 mg / kg, Pb-0.1 mg/kg). The use of supplement contributed to a decrease in concentration of these elements in milk of cows of the experimental group by 13 ... 16 % compared to the control.

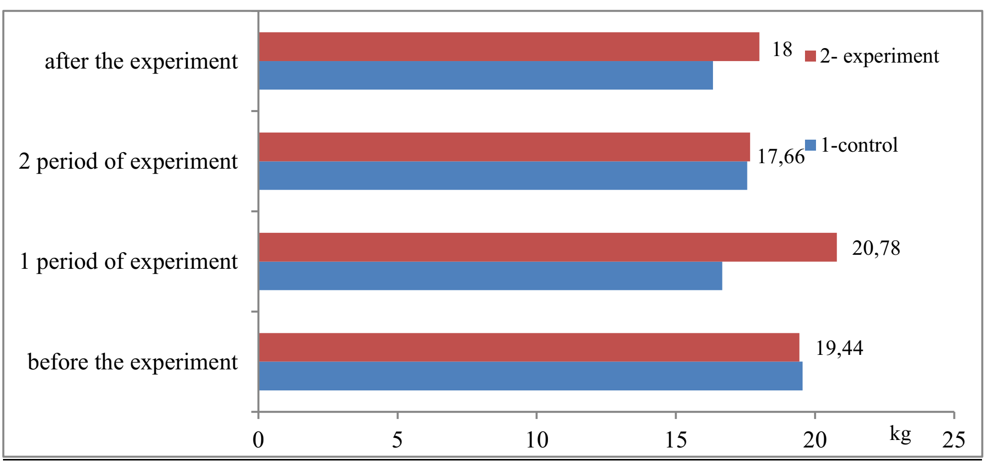

Fig. 4 Dynamics of the average daily milk yield of cows when feeding the diatomite-based additives, kg

The prolonging effect of the supplement, which is related to accumulation of reserve of mineral elements in animals body, is noted. It was established that feeding a diatomite-based additives to cows of the second group had a favorable effect on the quantity and quality of fatty acids in milk, table 6. There was an increase in saturated fatty acids by 4.0 %, in particular: capric - by 6.7 %, lauric - by 12.3 %, ($P<0.05$), myristic - by 13.3 % ($P<0.05$), palmitic - by 17.1 %, ($P<0.05$) in the fat fraction of cows milk of the experimental group compared with the control. At the same time, there was a decrease in the concentration of stearic acid by 27.3 % (P<0.05) and arachinic acid - by 27.6 % (P<0.05). Under the influence of supplement, favorable conditions are created for the activity of cicatritial microflora. These indicators show an increase in number of amylolytic microflora and the active synthesis of volatile fatty acids (VFA) in the rumen of cows, in particular acetate and 3-hydroxybutyrate. Active synthesis of these acids is possible only with an increase in the number of protozoa that synthesize microbial protein and the level of urease. The presence of sunflower oil in supplement increases the fraction of saturated fatty acids in the milk of cows of the experimental group.

Table 6. The content of saturated fatty acids in milk of cows when feeding a diatomite-based additives

Indicator	GOST 32261-2013	1 group control	2 group experiment
Olieic (C4:0)	2.4-4.2	2.987±0.171	2.783±0.098
Capron (C6:0)	1.5-3.0	2.193±0.105	2.170±0.140
Caprylic (C8:0)	1.0-2.0	1.440±0.074	1.457±0.088
Capric (C10:0)	2.0-3.8	3.413±0.159	3.643±0.113
Lauric (C12:0)	2.0-4.4	3.910±0.137	4.390±0.099*
Myristic (C14:0)	8.0-13.0	11.630±0.295	13.180±0.450*
Palmitic (C16:0)	21.0-33.0	25.280±1.632	29.593±1.781
Stearic (C18:0)	8.0-13.5	13.477±0.961	9.803±0.948*
Arachic (C20:0)	0.3	0.203±0.015	0.147±0.012*
Margaric (C17:0)	0.02-1.05	0.567±0.023	0.573±0.055
Behenic (C22:0)	0.1	0.097±0.007	0.070±0.010
Total saturated		**65.197±0.0809**	**67.810±1.084**

Note: * - (p<0.05) compared to the control

The composition of monounsaturated and poly-unsaturated fatty acids in cow's milk when using the supplement is presented in table 7. In the milk of cows of experimental group, concentration of monounsaturated fatty acids decreased by 7.4 % due to oleic acid. At the same time, the concentration of polyunsaturated fatty acids decreased by 13.7 %, mainly due to linoleic acid-by 14.5% and linolenic acid-by 10.2 %.

The indicators are given in comparison with the control. The use of a diatomite-based additives based on activated diatomite for dairy cows contributed to the improvement of the composition of milk fatty acids in the direction of increasing the concentration of capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0) and margarine (C17:0) fatty acids. Under the influence of supplement, favorable conditions are created for the activity of cicatritial microflora.

Table 7. Composition of monounsaturated and polyunsaturated fatty acids in cow's milk when feeding a diatomite-based additives

Indicator	1 group control	2 group experiment
Palmitoleic (C16:1)	1.157±0.119	1.167±0.137
Oleic (C18:1)	23.710±0.52	21.410±1.22
Decenoic (C10:1)	0.290±0.032	0.343±0.012
Myristoleic (C14:1)	0.733±0.103	0.993±0.058
Gondoinic (C20:1)	0.063±0.013	0.060±0.015
Total monounsaturated	**25.953±0.28**	**24.040±1.13**
Ecosadienoic (C20:2)	0.170±0.006	0.167±0.012
Linoleic (C18:2)	4.950±0.530	4.230±0.372
Linolenic (C18:3)	0.490±0.021	0.440±0.009
Linolenic c1	0.123±0.007	0.090±0.006*

Linolenic c2	0.367±0.015	0.357±0.012
Total polyunsaturated	**5.610±0.549**	**4.843±0.370**
Others	**3.240±0.071**	**3.373±0.078**

Note: * - ($p<0.05$) compared to the control

4 Conclusion

Silicon-containing additives based on natural zeolite and diatomite in the feeding of farm animals have a positive effect. The use of silicon-containing additives increases the growth processes in the body of young pigs, strengthens the strength of their bone tissue. Under the influence of application of additives, favorable conditions are created for the activity of cicatritial microflora. The use of application of additives for dairy cows helps to increase their productivity, improve the quality of milk composition, due to the intensive conversion of feed nutrients. The mechanism of Silicon-containing additives is due to the following processes: activation of enzymes of the gastrointestinal tract, increased absorption of nitrogen, vitamins and macro-and microelements; regulation of the composition and level of electrolytes, binding and excretion of toxins, harmful gases of heavy metals and radionuclides.

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