Research Article

The Influence of Highly Dispersed Metal Forms on Calcium and Phosphorus Metabolism in Polygastric Animals

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Abstract. Determining which forms of mineral feed additives can increase farm animal productivity is a key area of research. This study assessed the mineral composition of ruminal fluid and the effectiveness of calcium and phosphorus used by animals after the introduction of finely dispersed particles (FDP) of SiO_2 (group I) and FeCo (group II) with a hydrodynamic radius of 109.6 ± 16.6 and 265 ± 25 nm, respectively. The deposition and use of calcium and phosphorus in the body of the experimental animals exceeded the control values. In group I, 30.8% more calcium was deposited ($p \geq 0.05$), and in group II, the value was 30.3% ($p \geq 0.01$). In the experimental groups, the calcium utilization rate was 27.3% higher in group I ($p \geq 0.05$), and 28.2% higher in group II ($p \geq 0.01$) compared to in the control. Phosphorus deposition was 34% higher ($p \leq 0.01$) in experimental group I and 6% higher in experimental group II, compared with the control. Group I had a high utilization rate of phosphorus from the feed (with a 29% difference compared to the control). Comparison of the experimental groups revealed that the introduction of SiO_2 FDP promoted an increase in the concentration of silicon, phosphorus, and calcium in the ruminal fluid. The introduction of FeCo FDP was accompanied by a decrease in the concentration of iron and cobalt in the ruminal fluid. Thus, the use of feed additive in finely dispersed form in the diet of animals was accompanied by an increase in the use of calcium and phosphorus by the animal's body, which is advisable when intensifying milk and meat productivity. The obtained results require further research.

Keywords: finely dispersed forms of microelements, ruminants, calcium and phosphorus exchange, feeding

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1. Introduction

Currently, the problem of optimizing the mineral nutrition of farm animals is being solved using various mineral feed additives [1].

Studies of many authors indicate that highly dispersed forms in comparison with mineral salts are less toxic and their introduction into animal's body provides an additional

productive effect [2-6]. It is possible to correct a number of physiological processes in the body by means of highly dispersed forms [7,8].

From literary sources it is known that the inclusion of micronutrients of iron and cobalt in a highly dispersed form in the diet showed an increase in the content of calcium and phosphorus, since iron can promote the absorption of calcium, and calcium is closely associated with phosphorus in metabolism. It is known that calcium is necessary for normal formation of bone tissue of a growing organism and lactation of adult animals. In addition, calcium is an activator of the enzyme system and blood coagulation. Calcium is vital for the functioning of heart, muscles. It regulates the permeability of cell membranes, affects the availability of phosphorus, zinc and other elements. According to A.V. Skalny, phosphorus is located in biological media in the form of a phosphate ion, which is a part of inorganic components and organic biomolecules [9]. In animals, it is closely associated with calcium and vitamin D. Phosphorus is a part of bone tissue, and is found in phosphoroproteins, nucleic acids and phospholipids, it plays an important role in carbohydrate metabolism in the formation of ATP. Also, phosphorus is an essential component of cellular proteins.

It is known that feed is the main source of minerals for the body, but quite often it is not enough for an adequate nutrition of animals. In this regard, an urgent task is to replenish the deficiency of minerals in the diets of cattle.

Thus, this study is aimed at evaluating the use of mineral substances in the form of FDP in feeding young cattle.

2. Material and research methods

The studies were carried out in the Common Use Center of the Federal Research Center for Biological Systems and Agricultural Technologies of the Russian Academy of Sciences and Pokrovsky Agricultural College, a branch of Orenburg State Agrarian University.

To conduct a physiological experiment using pair analogue method, 3 groups (n = 5) of the Red Steppe bulls at the age of 13 months were formed. Animals of group I received SiO_2 FDP at a dose of 13 mg/kg, group II – finely dispersed FeCo alloy at a dose of 5 mg/kg live weight. Animals of the control group were not fed with FDP. To obtain ruminal contents, rumen fistulas were placed. Samples of cicatricial contents (300 ml) were obtained 6 hours after administration of FDP. During the preparatory period (10 days), the bulls were moved to tie-up housing, individual feeding. The experimental bulls were fed in groups.

Animal care and experimental studies were performed in accordance with instructions and recommendations of Russian Regulations, 1987 (Order No. 755 on 08/12/1977 the USSR Ministry of Health) and “The Guide for Care and Use of Laboratory Animals (National Academy Press Washington, DC 1996) ”. In the experiment, we made efforts to minimize animal suffering and to reduce the number of samples used.

Elemental composition of ruminal fluid of animals was studied in the laboratory of ANO Center for Biotic Medicine, Moscow (accreditation certificate No. ROSS RU.0001.22PYa05) by atomic emission spectrometry and mass spectrometry with inductively coupled plasma (Optima 2000 V, ”Perkin Elmer” USA) and mass-spectral research method (Elan 9000, Perkin Elmer, USA).

During the accounting period when food intake and its residues were recorded, average samples of feces (10%) and urine 3% of the total amount per day were collected, studies were carried out using the methods of zootechnical analysis. The content of calcium and phosphorus in feces and urine samples was determined by volumetric and colorimetric methods. These analyzes were carried out at the Testing Center of the Federal Research Center for Biological Systems and Agricultural Technologies of the Russian Academy of Sciences.

The obtained experimental data were subjected to conventional biometric processing using MS Excel 2007 software package. The reliability was assessed using Student’s t-test

3. Research results

Elemental composition of ruminal fluid. The inclusion of finely dispersed microelements in the diet had an effect on the amount of essential and conditionally essential chemical elements (Table 1). It was shown that animals from the experimental groups that were fed with diets containing silicon dioxide and cobalt iron alloy, an increase in the content of the following elements was observed: calcium by 32% and by 11%; phosphorus by 12% and 61%, silicon by 4% and 17.4%.

Table 1.

At the same time, a significant decrease in the cobalt content by 50% ($P \leq 0.05$) was noted in ruminal fluid of the animals from group II. In contrast to group II, I group had no significant differences in the concentration of essential trace elements after six hours of digestion.

Table 1: The difference in the concentration of chemical elements in ruminal fluid of animals of the experimental groups in comparison with control: A - SiO_2 FDP (group I); B - FeCo FDP (group II), %.

Element	Group		
	I	II	Control
Co	0,07±0,01	0,03±0,005*	0,06±0,008
Fe	105±10	98,7±4,74	99,5±9,95
Ca	683 ±68	575±58	518±52
P	410±41	592±59	367±37
Si	19,1±1,91	21,6±2,17	18,4±1,84
Note: * - P≤0.05			

Table 2: Average daily calcium balance in experimental animals, g/head.

Index	Group		
	I	II	Control
Introduced	71,20±0,115***	70,37±0,186**	69,43±0,260
Excreted in feces	37,91±1,616	37,49±1,641	41,82±1,057
Excreted in urine	6,10±0,3005	5,80±0,5689	6,78±0,0033
Deposited per 1 head	27,2±1,324*	27,07±1,944**	20,8±0,928
Deposited per 100 kg of live weight	8,16±0,382*	8,13±0,574**	6,26±0,275
Utilization rate, %	38,19±1,854*	38,46±2,690**	30,00±1,389
Note: * - P≤0.05; ** - P≤0.01; *** - P≤0.001			

Exchange of calcium and phosphorus. As a result of research, it was revealed that the use of finely dispersed microelements in animal feeding was accompanied by some changes in the use of calcium (Table 2).

The best use of calcium, both in absolute and in relative terms, compared with the control group, was registered in young animals of all experimental groups. In the body of experimental animals, more calcium is deposited: in group I - by 30.8% (P≥0.05), in group II - 30.3% (P≥0.01). In comparison with the control, the utilization rate was higher in group I by 27.3% (P≥0.05), in group II - 28.2% (P≥0.01).

Thus, the animals were provided with calcium, while bulls from the experimental groups used it better.

In preent studies, the exchange of phosphorus in the body of experimental animals was studied (table 3).

The use of highly dispersed forms of microelements made it possible to increase significantly the amount and degree of phosphorus absorption in feed. Thus, in group I weight of phosphorus assimilated by bull calves exceeded that in the control group by 5.11 g (40%) (P≤0.01).

Table 3: Average daily phosphorus balance in experimental animals, g/head.

Index	Group		
	I	II	Control
Introduced	41,87±0,017***	41,85±0,087***	40,40±0,208
Excreted in feces	18,13±0,928	22,78±0,318	22,87±1,488
Excreted in urine	3,57±0,2833*	3,14±0,4997	2,47±0,3333
Deposited per 1 head	20,17±0,668**	15,94±0,668	15,06±0,992
Deposited per 100 kg of live weight	6,14±0,171**	4,78±0,200	4,52±0,285
Utilization rate, %	48,17±1,582**	38,08±1,557	37,30±2,613
Note: * - P≤0.05; ** - P≤0.01; *** - P≤0.001			

During the experiment, the amount of phosphorus consumed with feed in the experimental groups was 3.6% higher (P≤0.01) than in the control group. In terms of the amount of phosphorus excreted with feces, insignificant differences are observed between control and experimental groups. More phosphorus by 44.5% (P≤0.05) was excreted with urine in group I relative to control. So, the phosphorus content in the urine of bulls of I and II experimental groups averaged 3.57 g and 3.14 g, while in the control - 2.47, it is 44.5% (P≤0.05) and 27.1% less. The use of phosphorus for deposition was higher in group I by 34% (P≤0.01) and by 6% in group II in relation to the control.

The efficiency of phosphorus absorption depends on a number of factors: age, body weight of animal, physiological state, amount of consumed dry matter of the diet, calcium-phosphorus ratio, concentration of trace elements in feed, fat, pH in the intestine; source of phosphorus. Animals of the experimental groups, in comparison with their peers in the control group, deposited more calcium and phosphorus in the body. Moreover, they had higher utilization rates of these elements.

It should also be noted that bulls fed with finely dispersed forms of microelements in their diet had higher rates of phosphorus utilization from its amount received with feed. The experimental animals of group I exceeded their peers from the control by 29% in this indicator. In the bulls of group II, the phosphorus utilization rate was lower.

Thus, the mineral metabolism in the rumen of young cattle can be adjusted through the additional introduction of finely dispersed microelements in the diet, in particular an alloy of iron and cobalt and silicon dioxide.

4. Discussion

The interest in the use of finely dispersed microelements in feeding polygastric animals is currently growing. The study of the balance of the main mineral elements is important

in the regulation of metabolism in the body of polygastric animals, which makes it possible, based on the results obtained, to increase the productivity of animals.

It should be noted that the experiment showed a decrease in the concentration of iron and cobalt in ruminal fluid against the background of the introduction of FDP of FeCo alloy. Probably the reason for this is the triggering of homeostasis mechanisms, which leads to a decrease in the negative effects of excess iron in the body [10]. A similar result of a decrease in the iron content was observed in the muscles of rats upon intake of iron nanoparticles and their agglomerates [11].

Comparison of the experimental groups with each other revealed that the introduction of SiO_2 FDP promotes an increase in the concentration of silicon, phosphorus, and calcium in the ruminal fluid. Whereas the introduction of FeCo FDP was accompanied by a decrease in the concentration of iron and cobalt in the rumen fluid. This is probably due to the selective ability of bacteria to absorb trace elements and use them for their own needs [5]. The balance of calcium and phosphorus in the experimental animals was positive, which is associated with both the absence of factors aimed at increasing the elimination of trace elements from the body, and with their better assimilation. Similar results were previously obtained in studies on raising animals [12, 13].

5. Conclusion

Thus, the use of a feed additive in the form of finely dispersed microelements in the ration of animals is accompanied with an increase in the use of calcium and phosphorus by the animal's body, which is advisable for intensifying milk and meat productivity. The results obtained require further research.

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