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Effectiveness of using mixed ligand complexes of Zinc, Manganese and Cobalt in feeding dry stable cows

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ABSTRACT. The purpose of the investigation was to determine the optimal dose of mixed ligand complexes of zinc, manganese, and cobalt in the ration of dry stable cows in the first and second dry periods. To cover the deficiency of Zinc, Manganese and Cobalt, different levels of mixed ligand complexes of Zinc, Manganese and Cobalt were introduced into the premix. During the dry period, the feeding of cows undergoes changes. During the early dry stable period in cows, feed mixtures with the lowest content of biologically active substances should be used for their feeding, namely, in 1 kg of DM, mg: Zinc and Manganese - 31.5; Cobalt - 0.41 due to mixed ligand complexes. Instead, during the late dry period, they need a higher concentration of these trace elements due to mixed ligand complexes in dry matter: Zinc and Manganese - 35 mg; Cobalt - 0.49 mg. A mandatory condition is to ensure the indicated level of trace elements due to their mixed-ligand complexes. With such feeding, a decrease in the need for labor assistance, the length of the service period and the number of inseminations per successful fertilization, an increase in the productivity.

Keywords: organic compounds of trace elements; milk productivity; fertilization; service period.

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Introduction

Intensification of dairy farming is the rational use of breeding animal resources, improvement of herd reproduction, improvement of the cow feeding system, which corresponds to the modern level of knowledge about complete animal feeding, mechanization and automation of production processes.

To date, it is impossible to organize a balanced and complete feeding of cows at the expense of fodder alone. For this, it is necessary to use feed additives (Erickson & Kalscheur, 2020).

Feed additives are developed on the basis of data on the need of cows in individual nutrients and their presence in the forage of the ration. For the development of feed additives, it is necessary to have data on the chemical composition of the ration feed, determine on the type of feeding and take into account lactation periods. These are the feeding periods of dry stable cows (the first and the second), the milking period and the first 100 days of lactation, the second and third 100 days of lactation. Each of these periods is characterized by its own metabolism, has different productivity, so feed supplements are calculated for each of these periods (Erickson & Kalscheur, 2020).

When creating new or improving existing feed additives, the genotype (breed, pedigree, etc.), ecological aspect, and the natural and climatic zone of cow feeding must be taken into account.

Trace elements from organic and inorganic sources are absorbed differently in the organism of animals, particularly cows (Mion et al., 2023; El-Hamd et al., 2024). Numerous investigations indicate greater bioavailability of trace elements from organic sources (Wang et al., 2019; Yaremchuk & Farionik, 2023). This contributes to the reduction of environmental pollution with metals that have not been assimilated by the animal's organism and defecate (Paik, 2001; Beshkenadze, Klarjeishvili, Gogaladze, Chikaidze, & Gogua, 2022). At the same time, it has been experimentally proven that the better bioavailability of the element from an organic source allows reducing the amount of the additive itself for cattle (Khavturina & Bomko, 2015; Guimaraes, Wagner, Spears, Brandao, & Engle, 2022), goats (Horchanok, Kuzmenko, & Khavturina, 2019; Mayasula et al., 2021), sheep (Grešáková, Tokarčíková, & Čobanová, 2021; Eren, Güleş, Gökdal, Eren, & Aypak, 2024), pigs (Kuzmenko et al., 2021a; Biswas, Dang, & Kim, 2024), chickens (Redka, Bomko, Slomchynsky, Chernyavsky, & Babenko, 2019; Broom, Monteiro, & Piñon, 2021), rabbits (Kuzmenko et al., 2021b; Luis-Chincoya, Herrera-Haro, Pro-Martínez, Santacruz-Varela, & Jerez-Salas, 2021), feesh (Mohseni, Hamidoghli, & Bai, 2021; Meiler & Kumar, 2021).

The purpose of the investigation was to determine the optimal dose of mixed ligand complexes of zinc, manganese, and cobalt in the ration of dry stable cows in the first and second dry periods.

Material and methods

At the beginning of the scientific and economic experiment, an analysis of fodder was made, including the actual content of Zinc, Copper, Manganese, Cobalt, Iodine and Selenium in fodder and rations. The content of these trace elements was determined by spectral analysis using energy-dispersion X-ray fluorescence spectrometer 'ElvaX'. This made it possible to use the actual nutritional value of the feed and the actual content of microelements in the formulation of feed mixes.

Cows were fed with full-ration feed mixes, the nutritional content of which was the same except for the concentration of Zinc, Manganese and Cobalt (Table 1).

50 cows participated in each experiment and were divided into 5 groups of 10 cows each. The equalization period in each experiment lasted 10 days. In the course of the experiments, the consumption of feed and nutrients, the dynamics of live weight and milk productivity of cows, their reproductive qualities and postpartum indicators, as well as the weight of calves, were investigated.

For the first experiment (early dry period), cows were selected immediately after the termination of previous lactation. Cows for the second experiment (late dry period) were selected on the 20-25th day of the dry period after the second lactation. The live weight of the cows was about 600 kg, the planned milk yield was 8,000 kg. The selected cows, both in the second half of the dry period and in the first 100 days of lactation, were fed with low-component fodder mixtures, which included: 4 kg of vetch-oat hay, 10 kg of cereal and leguminous hay, 10 kg of corn silage, 2 kg of molasses and compound feed concentrate 4 kg, salt 0.19 kg, non-fluorinated phosphate 0.18 kg. The got feed mixture was deficient in Zinc, Copper, Cobalt, Manganese, Iodine and Selenium. Premix was introduced to cover the deficiency of trace elements. To cover the deficiency of Zinc, Manganese and Cobalt, different levels of mixed ligand complexes of Zinc, Manganese and Cobalt were introduced into the premix. In the premix of the 1st control group, the concentration of Zinc and Manganese was brought up to 50 mg, and Cobalt to 0.7 mg per 1 kg of DM of feed mixture. In the premixes of the experimental groups, the concentration of Zinc and Manganese ranged from 30 to 45 mg, and Cobalt from 0.42 to 0.63 mg. Copper deficiency was covered in all premixes due to Copper Sulfate, iodine - Potassium Iodide 100% to the norm, Selenium - due to Selenium Suplex, at the rate of 0.3 mg kg^{-1} DM.

Results and discussion

Effectiveness of using mixed ligand complexes of Zinc, Manganese and Cobalt in feeding high-yielding cows in the early dry period

It is known that in the first half of the dry period there is an opportunity to provide high-yielding cows with nutrients at the expense of high-quality coarse and juicy fodder with or without the addition of 1-2 kg of concentrates. At the same time, it is necessary to monitor the balance of rations not only in terms of basic nutrients, but also in terms of biologically active ones such as trace elements and vitamins. Therefore, in our research, we studied the effectiveness of using mixed ligand complexes of Zinc, Manganese, and Cobalt in the rations of high-yielding dry stable cows.

After the comparison period of the experiment, there was no difference in the feeding of the experimental cows by group, then in the main period of the experiment the use of different levels of mixed ligand complexes of Zinc, Manganese and Cobalt had different effects on the consumption of the feed mixture (Figure 1) and, accordingly, nutrients (Table 2).

So, out of 38 kg of feed mixture, animals of the 1st control group ate 34.6 kg, animals of the 2nd experimental group - 35 kg, 3rd experimental group - 35.2 kg, 4th experimental group - 35.5 kg and the 54th experimental group – 35.8 kg. The consumption of feed dry matter per 100 kg of live weight of cows was 2.43 kg in the 1st control group and 2.46–2.50 kg in the experimental groups. Cows of the 5th experimental group consumed the best amount of dry matter in their rations due to better eating of hay, silage and silage - by 3.92% compared to the control group. The consumed fodder provided cows with crude protein at the level of 14.3–14.4% of dry matter, its poorly soluble fraction at the level of 68.4% of crude protein.

Table 1. Scheme of the experiments.

A group of animals	Feeding conditions
The first scientific and economic experiment (early drought period)	
1st control	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 45; Mn – 45; Co – 0,63
2nd experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg; Zn – 40,5; Mn – 40,5; Co – 0,56
3rd experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 36; Mn – 36; Co – 0,49
4th experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 31,5; Mn – 31,5; Co – 0,41
5th experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 27; Mn – 27; Co – 0,34
The second scientific and economic experiment (period of late drought)	
1st control	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 50; Mn – 50; Co – 0,7
2nd experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 45; Mn – 45; Co – 0,63
3rd experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 40; Mn – 40; Co – 0,56
4th experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 35; Mn – 35; Co – 0,49
5th experimental	FM[1] + mixed ligand complexes Zn, Mn, Co. An 1 kg of DM[2] contain, mg: Zn – 30; Mn – 30; Co – 0,42

[1]FM – feed mixture, [2]DM – dry matter.

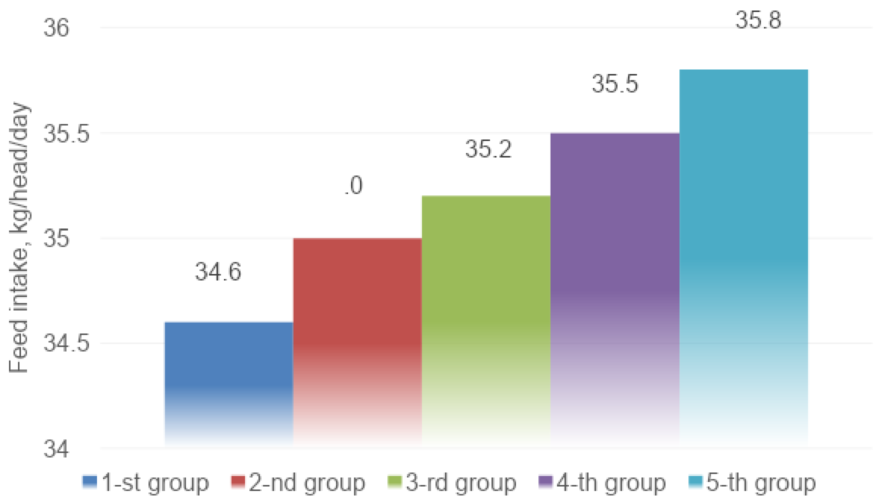

Figure 1. Consumption of feed mixture by dry stable cows on average over 30 days of the first experiment (1st phase of dry stable period).

Table 2. Consumption of nutrients by dry stable cows on average over 30 days of the experiment (1st phase of the dry stable period).

Indexes	A group of animals				
	control	experimental			
	1	2	3	4	5
The exchange energy, MJ	145.0	146.3	146.96	148.0	149.0
Dry matter, kg	14.58	14.73	14.8	14.9	15.03
Crude protein, g	2098.0	2115.5	2118.6	2137.5	2150.7
Easily soluble protein fraction, g	1434.6	1446.1	1452.2	1460.6	1469.2
Hardly soluble protein fraction, g	663.3	669.3	672.3	676.8	681.3
Digestive protein, g	1441.7	1452.5	1458.1	1466.1	1474.2
Lysin, g	92.1	92.9	93.3	93.9	94.4
Methionine, g	63.5	64.1	64.4	64.8	65.3
Tryptophan, g	36.9	37.2	37.3	37.7	37.9
Crude fiber, g	4051.2	4102.6	4127.8	4166.8	4205.3
Starch, g	721.2	738.5	746.6	743.4	746.3
Sugar, g	1679.2	1685.5	1689.8	1693.5	1698.2
Crude fat, g	701.6	709.2	713.3	718.7	724.4
Kitchen salt, g	34	34	34	34	34
Calcium, g	126.4	127.9	128.6	129.7	130.8
Phosphorus, g	41.0	41.3	41.4	41.7	41.88
Sulphur, g	25.7	25.9	26.0	26.2	26.4
Copper, mg	145	145	145	145	145
Zinc, mg	657	591.3	525.6	459.9	370
Manganese, mg	657	591.3	525.6	459.9	389.8
Cobalt, mg	9.2	8.2	7.2	6.2	5.2
Iodine, mg	10.2	10.2	10.2	10.2	10.2
Selenium, mg	0.17	0.17	0.17	0.17	0.17
Carotene, mg	875	875	875	875	875
Vitamin D, IU	17500	17500	17500	17500	17500

The cows of the experimental groups consumed 146.3-149 MJ of exchangeable energy against 145 MJ of the control group. At the same time, the % of fiber from dry matter was: in the 1st control group 27.2%, in the experimental groups 27.9–28%, which was within the normal range. The sugar-protein ratio was 1.15–1.16:1 in the experimental groups, and 1.16:1 in the control group.

Provision of crude protein, crude fat, macro- and microelements corresponded to the norm.

The entry into the organism of experimental cows of various levels of zinc, manganese and cobalt microelements in the first half of the dry period ensured the dependence of their live weight on these indicators (Table 3).

At the end of the first half of the dry period, the live weight of the experimental cows increased (Table 3). Cows of the 1st control group increased their live weight by 25.1 kg, while the live weight increase in the cows of the experimental groups was greater by 1.2-9.6% or by 0.3-2.4 kg. The difference was significant for cows of the 4th and 5th experimental groups ($p < 0.01$–$p < 0.001$).

During this period, cows consume less feed due to the decrease in the volume of the gastrointestinal tract due to the growth of the fetus and more rationally use the nutrients of the feed for its intensive growth and deposition of nutrients in the organism. Therefore, in our opinion, based on the got indicators of live weight gains, coarse, juicy and small doses of concentrated feed, as well as lower levels of Zinc, Manganese and Cobalt due to their mixed ligand complexes provide cows with the need for these trace elements in the first 30 days of the dry period. In this regard, it is necessary to review the norms of trace elements for dry fodder in the first half of the dry period.

In the second phase of the dry period, the experimental cows continued to increase their live weight due to the growth of the fetus and the deposition of nutrients in the organism. Live weight gains were somewhat smaller compared to the first phase of the dry period and amounted to: 24.8 kg in the 1st control group, 25.2 kg in the 2nd experimental group, 25.7 kg in the 3rd experimental group , in the 4th experimental group - 26.0 kg and in the 5th experimental group - 26.1 kg.

Thus, the used levels of mixed ligand complexes of Zinc, Manganese and Cobalt did not have a significant influence on the live weight gain of cows in the dry period. On the contrary, the cows of the 5th experimental group, where the need for Zinc, Manganese and Cobalt were provided by coarse, juicy and concentrated feed, and the 4th experimental group, where the levels of these microelements were the lowest due to their mixed ligand complexes, had the best results of increasing live weight.

All experimental cows calved within 10 days. At lower levels of mixed ligand complexes of Zinc, Manganese and Cobalt, the live weight of calves at birth increased by 2.6–8.6% in the experimental groups compared to the control group.

The best indicators were in cows whose rations used copper sulfate, Selenium Suplex and potassium iodide, and the need for Zinc, Manganese and Cobalt was provided by fodder, the concentration of which in 1 kg of DM feed mixture was, mg: Zinc – 27, Manganese – 27, Cobalt - 0.36.

During calvings, their progress was monitored and special attention was paid to the nature of litter separation after calving in experimental cows. The fertility rates of experimental cows are shown in Table 4.

Table 3. Live weight dynamics of experimental cows and newborn calves during the first experiment (early dry stable period), kg (M±m, n=10).

Indexes	Groups of animals				
	control	experimental			
	1	2	3	4	5
The first phase of the dry period (concentration of Zn, Mn and Co according to the scheme of the experiment)					
Live weight at the beginning	604.4±4.7	605.2±4.9	604.8±4.4	604.5±3.7	603.6±4.6
Live weight on the 30th day	629.5±3.9	630.6±3.6	630.8±2.9	631.7±2.4	630.1±2.6
Increment in 30 days	25.1±0.5	25.4±0.5	25.9±0.5	27.2±0.7	27.5±0.5
Average daily increment, g	836±15	847±14	863±16	907±11	917±14
The second phase of the dry period (the concentration of Zn, Mn and Co does not differ between the groups)					
Live weight on the 60th day	654.3±3.6	655.8±3.7	656.5±3.1	657.7±3.5	656.2±3.3
Increment in 30 days	24.8±0.5	25.2±0.5	25.7±0.5	26.0±0.4	26.1±0.5
Average daily increment, g	826.5±14.2	839.9±15.5	856.9±15.8	866.7±14.7	870.3±14.5
Increment in 60 days	49.9±0.5	50.6±0.5	51.6±0.5	53.2±0.5	53.6±0.5
Average daily increment, g	831.6±14.6	843.3±14.8	860.2±15.5	886.7±12.7	893.9±14.0
Live weight of newborn calves	30.3±0.54	31.1±0.68	31.8±0.47	32.0±0.37	32.3±0.43

Table 4. Fertility indicators of experimental cows (consumption of different levels of Zn, Mn and Co during the first dry stable period).

Indexes	A group of animals				
	control	experimental			
	1	2	3	4	5
Number of cows, heads	10	10	10	10	10
Calving took place without outside help, heads	7	9	10	10	10
Help was provided during fertility, heads	3	1	0	0	0
The placenta was separated on its own, heads	8	9	10	10	10
Placenta retention, heads	2	1	0	0	0
Separation of the placenta took place with veterinary assistance, heads	1	0	0	0	0
Endometritis, heads	1	0	0	0	0
Mastitis, heads	1	1	0	0	0

The use of different levels of mixed ligand complexes of Zinc, Manganese and Cobalt in the ration of dry stable cow in calf had a positive influence on their fertility rates. In particular, cows in the experimental groups had a better delivery process and there were no cases of placental retention.

So, out of 10 cows in the control group, 7 cows, or 70%, calved without outside help. In the 2nd and 4th experimental groups, there were 9 heads of such cows, and in the 3rd and 5th - 10 heads each, or 100%.

During parturition, three cows in control group 1 received assistance, while in experimental group 2 only one cow required such assistance, and in experimental 3, 4 and 5 such cows were not detected at all.

As for separation of the placenta, it separated in a timely manner in all cows of the 3rd, 4th and 5th experimental groups. In the 2nd experimental group of cows with independently separated placenta there were 9 heads, or 90%. In the control group, normal separation of the placenta occurred only in eight cows, which was 80% of the total number. Hence, retention of the placenta in cows of the 1st control group occurred in 20% of cases, of the 2nd experimental group in 10%. In the 3rd, 4th and 5th experimental groups, there were no cows with a disturbed mode of separation of the placenta at all.

In the 1st cow of the control group, the placenta had to be separated by a veterinary medicine worker, and in the cows of the experimental groups there were no such cows at all. In addition to the above, one cow from the 1st control group fell ill with endometritis, which had to be treated for 6 days, and one cow from the control and one cow from the 2nd experimental group had the initial stage of udder mastitis.

Therefore, the analysis of the post-partum state of experimental cows is the basis for the assertion that different levels of mixed ligand complexes of Zinc, Manganese and Cobalt contribute to a better course of parturition, reduce retention of the placenta by 2 times, and prevent the occurrence of endometritis.

For the purpose of deeper evaluation the influence of different levels of mixed ligand complexes of Zinc, Manganese and Cobalt on the organism of dry stable cows, an evaluation of their milk productivity for 100 days of lactation was carried out. The above-mentioned fodder mixture continued to be used in feeding the experimental cows, but as the average daily milk yield increased, the amount of compound feed was increased.

On average, there was 12.5 kg of compound feed in the feed mixture for 100 days of lactation. The cows of the experimental groups had better eating of the feed mixture. As a result, the concentration of microelements changed and amounted to 1 kg DM, mg: control group – Zinc and Manganese 48 each, Cobalt – 0.68; the 1st control group - Zinc and Manganese 40 each, Cobalt - 0.58; the 2nd experimental group - Zinc and Manganese 35 each, Cobalt - 0.48; the 4th experimental group - Zinc and Manganese 30 each, Cobalt - 0.38; 5th experimental group – Zinc and Manganese 25 each, Cobalt – 0.28. The concentration of Selenium, Copper and Iodine in all groups was the same and was, respectively, mg: 0.3; 9 and 0.7.

The productivity of the experimental cows for 100 days of lactation is shown in Table 5.

As shown in Table 5, the elimination of Zinc, Manganese and Cobalt deficiency in the rations of cows during the dry season due to different levels of their mixed ligand complexes had a positive influence for further milk productivity.

From each cow of the control group for 100 days of lactation, 4020 kg of natural milk was got, and from the cows of the 2nd-5th experimental groups, 120-250 kg more was got with a simultaneous increase in the content of milk by 0.01-0.05% fat. In the calculation of the gross milk yield of natural milk per milk of 4% fat content, the difference in this indicator between the cows of the 2nd experimental group and the control amounted to 195.9 kg, or 5.52% ($p < 0.01$), the 3rd experimental group - 220.4 kg, or 6.21% ($p < 0.001$), the 4th experimental group – 242.0 kg, or 6.82% ($p < 0.001$) and the 5th experimental group and control – 116.3 kg, or 3.28%.

Table 5. Milk productivity of experimental cows that consumed different levels of Zn, Mn and Co during the first dry period (M±m, n=10).

Indexes	Groups of animals				
	control	experimental			
	1	2	3	4	5
Milk yield per 1 cow for 100 days of lactation, kg	4020	4230	4210	4270	4140
Average daily milk yield of natural fat, kg	40.2	42.3	42.1	42.7	41.4
Fat content in milk, %	3.53	3.54	3.58	3.55	3.54
Milk yield of 4 % fat, kg	3547.6± 23.9	3743.6± 43.0**	3768.0± 31.4***	3789.6± 19.8***	3663.9± 35.3*
Average daily milk yield of 4% fat, kg	35.48	37.44	37.68	37.90	36.64
Protein content in milk, %	3.23	3.25	3.25	3.26	3.22

In the milk of the cows of the experimental groups, with the exception of the 5th experimental group, compared to the control, although not too noticeably, the protein content increased to 3.25-3.26% against 3.23% in the control.

Therefore, according to the data of milk productivity of cows for the first 100 days of lactation, it is possible to judge the positive effect of lower levels of mixed ligand complexes of Zinc, Manganese and Cobalt in the dry stable period and during lactation on the animal organism.

The use of different levels of mixed ligand complexes of Zinc, Manganese and Cobalt in the rations of dry stable and lactating cows during the dry stable period and during the lactation period affected their reproductive abilities (Figure 2).

From the data in Figure 2, it can be seen that the feeding of different levels of mixed ligand complexes of Zinc, Manganese and Cobalt in 1 kg of dry matter of the feed mixture to the experimental cows during the entire gestation period led to the fact that for one fertile insemination of each cow in the 1st control group, it was necessary to carry out 2, 8 fertilizations, in the 2nd, 3rd, 4th and 5th experimental groups - 2.1 each; 1.9; 1.7 and 2.3 fertilizations, which, according to the control, is 75.0; 67.9; 60.7 and 82.1%.

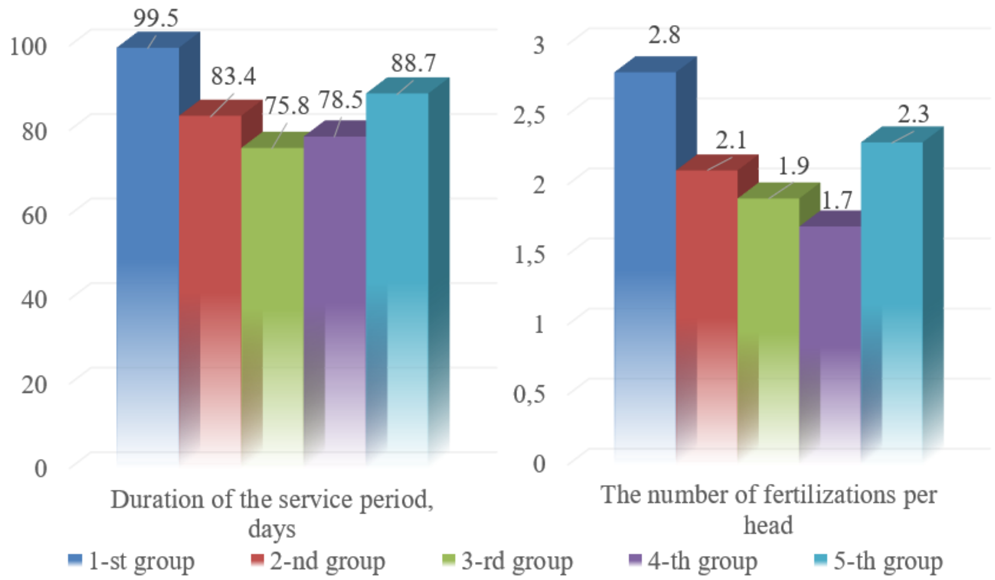

Figure 2. Reproduction indicators of cows and offspring quality.

The length of the service period was also depended on the number of fertilizations. Thus, in cows of the 1st control group, the service period averaged 99.5 days, in the 2nd – 83.4 days, in the 3rd – 75.8 days, in the 4th – 78.5 days and in the 5th – 88.7 days, which in percentage terms was 100, 83.82, 76.18, 78.89 and 89.15%, respectively.

Thus, lower levels of Zinc, Manganese and Cobalt due to their mixed ligand complexes had a positive influence on the physiological state of cows, stimulation of their desire and provided normal conditions for fertilization and embryo development in cows.

The best influence on the live weight of calves at birth, milk productivity, and reproductive functions was shown by the following levels: Zinc - 31.5 mg, Manganese - 31.5 mg and Cobalt - 0.41 mg per 1 kg of feed mixture due to mixed ligand complexes of these elements.

Effectiveness of using mixed ligand complexes of Zinc, Manganese and Cobalt in feeding of high-yielding cows in the late dry stable period

The nutritional value of 1 kg of the feed mixture was: exchangeable energy – 5.19 MJ, dry matter 0.5 kg, crude protein – 85.37 g, easily soluble protein fraction – 58.74 g, poorly soluble protein fraction – 26.65 g, digestible protein – 63.13 g, crude fiber - 128.78 g, starch - 37.55 g, sugar - 60.11 g, crude fat - 26.21 g, Calcium - 4.41 g, Phosphorus - 1.8 g, Sulfur – 0.95g, Copper – 3.37 mg, Zinc – 16.25 mg, Manganese – 17.31 mg, Cobalt – 0.18 mg, Iodine – 0.12 mg, Selenium – 0.005 mg, carotene – 21.5 mg and vitamin D 124.7 IU.

Due to the premix, one kilogram of DM feed mixture for dry stable cows contained: 1st control group Zinc and Manganese – 50 mg, Cobalt – 0.7 mg; The 2nd experimental group of Zinc, Manganese and Cobalt is 10% less than the control, the 3rd experimental group of Zinc, Manganese and Cobalt is 20% less, the 4th experimental group of Zinc is 30% and the 5th experimental group is 40% less than control

Dry stable cows were fed 35.87 kg of feed mixture during the preparatory and early research period. The consumption of the feed mixture at the beginning of the experiment is shown in Figure 3, and the nutrients in Table 6.

Consumption of the feed mixture on average during the experiment (second dry stable period) by the experimental cows is shown in Figure 4 and Table 7.

In the second half of the dry stable period, the experimental cows consumed an average of 24.0-25.5 kg of feed mixture per day (Table 7). At the same time, it should be noted that smaller doses of mixed ligand complexes of Zinc, Manganese, and Cobalt in the feed mixture stimulated better its consumption. Cows of the 4th experimental group consumed the feed mixture the most, where the concentration of Zinc and Manganese was 35 mg per 1 kg of DM, and Cobalt was 0.49 mg. In our opinion, as it was set in previous experiments, the increase in the consumption of feed mixture is associated with better digestibility of nutrients and their better assimilation by the organism of cows.

Better eating of the feed mixture by experimental cows of the 2nd, 3rd and 4th groups had a positive influence on their live weight. Table 3.38 shows data on live weight and average daily growth of experimental cows of the Ukrainian Black-Spotted Dairy breed at different levels of Zinc, Manganese and Cobalt in feed mixtures due to their mixed-ligand complexes.

From the data in Table 8, it can be seen that the live weight of all experimental cows increased during the last 30 days of the dry stable period due to their better eating of feed mixtures with lower levels of Zinc, Manganese and Cobalt, which were introduced into compound feed in the form of their mixed ligand complexes.

At different doses of mixed ligand complexes of Zinc, Manganese and Cobalt, the increase in live weight in cows of the control group was 24.3 kg, and in the experimental groups it ranged from 23.7 kg to 26.9 kg, and was statistically significant ($p < 0.05$) in comparison with the control in the 3rd and 4th experimental groups.

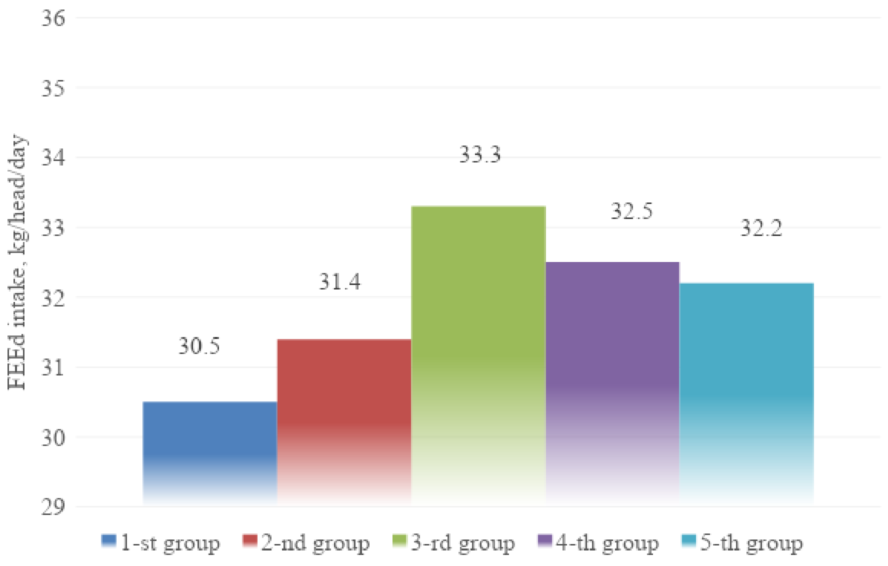

Figure 3. Consumption of feed mixture by dry stable cows at the beginning of the research period of the experiment (2nd phase of the dry stable period).

Table 6. Consumption of nutrients by dry stable cows at the beginning of the experiment (second dry stable period).

Indexes	A group of animals				
	control	experimental			
	1	2	3	4	5
The exchange energy, MJ	161.9	166.7	176.8	172.6	171.0
Dry matter, kg	14.3	14.7	15.6	15.2	15.1
Crude protein, g	2202.4	2267.4	2404.6	2346.8	2325.2
Easily soluble protein fraction, g	1316.4	1355.2	1437.2	1402.7	1389.7
Hardly soluble protein fraction, g	886.0	912.2	967.4	944.1	935.4
Digestive protein, g	1686.3	1736.5	1841.1	1796.9	1780.3
Crude fiber, g	2600.7	2677.5	2839.5	2771.3	2745.7
Starch, g	3222.6	3317.7	3518.5	3433.9	3402.2
Sugar, g	1453.3	1496.2	1586.7	1548.6	1534.3
Crude fat, g	584.7	601.9	638.4	623.0	617.3
Calcium, g	106.4	109.6	116.2	113.4	112.4
Phosphorus, g	73.2	75.4	79.9	78.0	77.3
Potassium, g	186.7	192.2	203.8	198.9	197.1
Magnesium, g	22.6	23.2	24.6	24.1	23.8
Sulphur, g	31.7	32.6	34.6	33.8	33.5
Ferrum, mg	2669.4	2748.1	2914.4	2844.4	2818.1
Copper, mg	130.1	133.8	142.0	138.3	137.4
Zinc, mg	715	662	624	532	453
Manganese, mg	715	662	624	532	453
Cobalt, mg	10.01	9.26	8.74	7.45	6.34
Iodine, mg	10.0	10.3	10.9	10.6	10.6
Selenium, mg	4.29	4.41	4.68	4.56	4.53
Carotene, mg	611.2	629.2	667.3	651.3	645.3
Vitamin D, IU	15013.9	15456.9	16392.2	15998.4	15850.8

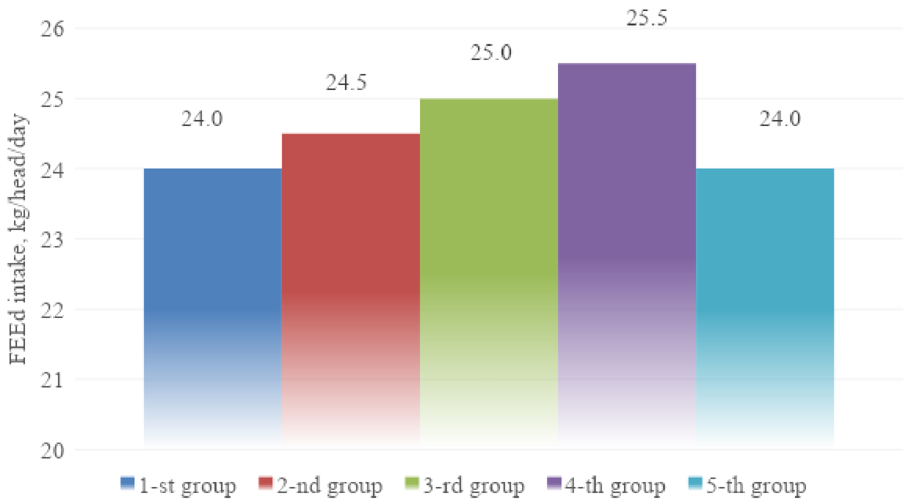

Figure 4. Consumption of feed mixture by dry stable cows on average during the experiment (2nd phase of the dry stable period).

Such a difference in live weight gains of cows of the Ukrainian Black Spotted Dairy breed of the control and experimental groups can be explained by better assimilation of Zinc, Manganese and Cobalt and better assimilation by the animal organism of their smaller doses from mixed ligand complexes. The best average daily gains in live weight were in experimental cows of 4 experimental groups.

Process monitoring of the calving of the cows confirmed that it passed normally, without placental retention, but some experimental cows were assisted during parturition (Table 9).

So, out of 10 cows in the 1st and 5th experimental groups, 9 cows, or 90%, were calved without outside help. In the 2nd, 3rd and 4th experimental groups, there were 10 such cows in each, or 100% (Table 9).

Endometritis and mastitis were not observed in experimental cows.

After calving for 10 days, the cows were fed with a complete ration forage mixture of the dry stable period, and then the separation of cows was carried out due to the increase of concentrated and juicy feeds in order to reveal the influence of mixed ligand complexes of Zinc, Manganese and Cobalt not only on the organism of dry stable cows, but also on milk productivity during the first 100 days of lactation were carried out (Table 10).

Table 7. Consumption of nutrients by dry stable cows on average during the experiment.

Indexes	A group of animals				
	control	experimental			
	1	2	3	4	5
The exchange energy, MJ	132.615	134.56	136.51	139.75	132.615
Dry matter, kg	12.54	12.75	12.96	13.25	12.54
Crude protein, g	2196.44	2226.84	2257.24	2312.11	2196.44
Easily soluble protein fraction, g	1511.57	1532.47	1553.37	1591.22	1511.57
Hardly soluble protein fraction, g	684.87	694.37	703.72	720.89	684.7
Digestive protein, g	1660.8	1680.2	1699.7	1743.39	1660.8
Lysin, g	108.3	109.65	111.0	113.8	108.3
Methionine, g	67.59	68.32	69.05	70.87	67.59
Tryptophan, g	35.77	36.11	36.45	37.44	35.77
Crude fiber, g	2702.56	2799.15	2895.9	2927.93	2702.56
Starch, g	1074.8	1079.1	1083.4	1116.65	1074.8
Sugar, g	1686.4	1696.15	1705.9	1756.26	1686.4
Crude fat, g	698.2	705.55	712.9	731.76	698.2
Kitchen salt, g	68	68	68	68	68
Calcium, g	94.1	97.29	100.48	101.7	94.1
Phosphorus, g	55.83	56.38	50.93	58.18	55.83
Sulphur, g	24.56	24.9	25.23	25.85	24.56
Copper, mg	145	145	145	145	145
Zinc, mg	730	657	584	511	438
Manganese, mg	730	657	584	511	438
Cobalt, mg	10.2	9.18	8.16	7.14	6.13
Iodine, mg	10.2	10.2	10.2	10.2	10.2
Selenium, mg	8.76	8.76	8.76	8.76	8.76
Carotene, mg	875	875	875	875	875
Vitamin D, IU	17500	17500	17500	17500	17500

Table 8. Dynamics of live weight of experimental cows in the second half of the dry stable period, (M±m, n=8).

Indexes		A group of animals				
		control	experimental			
		1	2	3	4	5
Live weight, kg	at the beginning of the experiment	627.2±4.4	628.4±5.1	628.7±5.1	627.3±4.7	628.0±3.5
	at the end of the experiment	651.5±1.7	652.1±3.9	655.1±1.8	654±2.7	653.8±1.6
Absolute growth for 30 days, kg		24.3±0.6	23.7±0.7	26.4±1.0*	26.9±0.4*	25.8±0.9
Average daily growth, g		810±21	790±28	880±34	897±31	858±27

Table 9. Fertility indicators of experimental cows.

Indexes	Groups of animals				
	control	experimental			
	1	2	3	4	5
Number of cows in a group, heads	10	10	10	10	10
Calving took place without outside help, heads	9	10	10	10	9
Help was provided during parturition, heads	1	0	0	0	1
Endometritis, heads	0	0	0	0	0
Mastitis, heads	0	0	0	0	0

Table 10. Milk productivity of experimental cows (M±m, n=10).

Indexes	Groups of animals				
	control	experimental			
	1	2	3	4	5
Milk yield per 1 cow for 100 days of lactation, kg	3190	3250	3330	3370	3280
Average daily milk yield of natural fat, kg	31.9	32.5	33.3	33.7	32.8
Fat content in milk, %	3.71±0.04	3.72±0.03	3.74±0.04	3.76±0.02	3.75±0.05
Milk yield of 4% fat, kg	2958.3	3022.5	3113.5	3167.8	3075.0
Average daily milk yield of 4% fat, kg	29.6±0.1	30.2±0.2 **	31.1±0.2 ***	31.7±0.2 ***	30.8±0.2 **
Protein content in milk, %	3.14±0.04	3.21±0.03	3.23±0.05	3.22±0.04	3.19±0.06

Reducing the concentration of mixed ligand complexes of Zinc, Manganese, and Cobalt in the rations of dry stable cows of the experimental groups by 10, 20, 30, and 40% had a positive influence on their further milk productivity (Table 10).

During the first 100 days of lactation, 3,190 kg of natural fat milk was milked from each control cow, while 60-180 kg more was milked from the cows of the experimental groups with an increase in fat by 0.01-0.05%. Due to the increase in milk fat content and the conversion of gross milk yields of natural milk into milk with 4% fat content, the difference in this indicator between the cows of the 2nd experimental group and the control will be 64.2 kg, or 2.2% ($p < 0.01$), the 3rd experimental – 155.2 kg, or 5.2% ($p < 0.001$), the 4th experimental – 209.5 kg, or 7.1% ($p < 0.001$), and the 5th experimental group and control - 116.7 kg, or 4.0% ($p < 0.01$).

Compared to the control, the protein content increased in the milk of the cows of the experimental groups (3.22-3.23 vs. 3.14% in the control).

So, according to the data on milk productivity of cows for the first 100 days of lactation, it is possible to claim the after positive effect of mixed ligand complexes of Zinc, Manganese and Cobalt on the body of cows.

During the first 100 days of lactation, the prolonged effect of mixed ligand complexes of Zinc, Manganese and Cobalt was studied not only on milk productivity, but also on their reproductive capacity (Table 11).

Table 11. Reproductive capacity of cows.

Indexes	A group of animals				
	control	experimental			
	1	2	3	4	5
Live weight of newborn calves, kg	26.1±1.3	27.7±0.8	27.9±1.2	28.4±1.1	27.8±0.9
Duration of the service period, days	87.8	84.7	82.2	80.6	83.5
Insemination index	1.5	1.4	1.3	1.2	1.4

The reproductive capacity of experimental cows was evaluated by the live weight of calves at birth, the duration of the service period and the insemination index. Live weight of calves at birth of the fourth experimental group exceeded their peers from the control group by 2.3 kg, or 8.81%, while calves got from cows of the 2nd experimental group exceeded the control by live weight by 1.6 kg, or 6.13%, the 3rd experimental group – 1.8 kg, or 6.90%, and the 4th experimental group – 1.7 kg, or 6.51%.

The duration of the service period in all experimental groups was within the recommended norms and amounted to: cows of the control group 87.8 days, and cows of the 2nd, 3rd, 4th and 5th experimental groups, respectively, 84.7 days, 82.2 days, 80 .6 days and 83.5 days and was less than the control by 3.1-7.1 days, or 3.3-8.2% less.

The insemination index in the control cows was 1.5, while in the experimental cows it was 1.2-1.4, which is 6.7-20% less. At the same time, the lowest number of inseminations per fertilization was in cows of the 4th experimental group, in the ration of which the concentration of Zinc and Manganese was 35 mg, and Cobalt was 0.49 mg kg^{-1} of dry matter. Obviously, smaller doses of Zinc, Manganese and Cobalt better contributed to extension the period of prolonged action of their mixed ligand complexes on the organism of lactating cows.

The completeness and balance of feeding dry stable cows in our experiment was directed not only at ensuring their high milk yield in the future, but also at increasing the viability of the offspring got from them.

Smaller doses of trace elements Zinc, Manganese and Cobalt in the rations of dry stable cows, due to their mixed ligand complexes, had a positive influence in the embryonic and postnatal period of their development, not only on their resistance, but on the intensity of their growth. Thus, out of 10 calves in the 1st control group, two fell ill with dyspepsia, in the 2nd experimental group there was 1 such case, in the 3rd, 4th and 5th groups they were absent. Regarding live weight, the difference was noted immediately after the birth of calves (Table 12).

Live weight of calves of the 2nd, 3rd, 4th and 5th experimental groups at birth was higher compared to the control by 1.6, respectively; 1.8; 2.5 and 1.3 kg, or 6.1; 6.8; 9.5 and 5.0%.

At the age of one month, the calves of the experimental groups were ahead of the control peers by 2.5-4.1 kg, or 5.4-9.0%, by 3.5-5.8 kg, or 5 ,3-8.7%, in 3 months - by 4.2-7.2 kg, or 4.9-8.4%.

Table 12. Dynamics of live weight of calves got from cows with different content of Zinc, Manganese and Cobalt in the ration.

Indexes		Groups of animals				
		control	experimental			
		1	2	3	4	5
Live weight at birth, kg		26.2	27.8	28.0	28.7	27.5
At the age of 1 month	Live weight, kg	45.7	48.2	48.8	49.8	48,2
	Average daily increase, g	650±8	680±7*	693±10**	703±9***	690±9***
At the age of 2 months	Live weight, kg	66.1	69.6	70.5	71.9	70,6
	Average daily increase, g	681±7	712±7	723±7*	735±12*	729±10*
At the age of 3 months	Live weight, kg	85.5	89.7	90.9	92.7	91,2
	Average daily increase, g	645±9	671±11	681±11	693±10*	686±6
Gross live weight gain for 90 days, kg		59.3	61.9	62.9	64.0	63.7
Average daily growth for three months, g		658±13	688±10	699±9*	711±11*	708±10*

According to the data of average daily growth of their live weight, the intensity of growth of calves was confirmed. Thus, in the first 30 days after birth, the calves of the experimental groups relatively increased their live weight by 680-703 g, which is 30-53 g or 4.6-8.2% more than in the control group. However, the average daily gain in live weight of the calves of the experimental and control groups decreased slightly with increasing age and was already 4.5-7.9% in the second month of life, and 4.0-7.4% in the third. Thus, we can see that the growth intensity of calves gradually decreased with age, which is obviously related to the decrease in the prolonging action of trace elements. In general, it can be noted that increasing the level of Zinc and Manganese to 35, and Cobalt to 0.49 mg kg^{-1} DM in the ration of dry stable cows helps to increase the viability and intensity of growth of calves in the first 3 months after birth by 8%.

In the first phase of the dry stable period, zinc and manganese 45 were used in 1 kg of DM, mg; Cobalt 0.63 for the 1st control group; Zinc and Manganese 40.5; Cobalt 0.56 for 2nd experimental groups; Zinc and Manganese 36; Cobalt 0.49 for the 3rd experimental group; Zinc and Manganese 31.5; Cobalt 0.41 for the 4th experimental group and Zinc and Manganese 27; Cobalt 0.34 for the 5th experimental group, cows of the 1st control group increased their live weight by 25.1 kg, while the increase in live weight in cows of the experimental groups was greater by 1.2-16.3% or by 0.3-4.1 kg, the difference was reliable for cows of the 4th and 5th experimental groups ($p < 0.01$–$p < 0.001$), and during childbirth, three cows of the 1st control group were assisted, and only one needed assistance in the 2nd experimental group of cows, and in the 3rd, 4th and 5th experimental groups such cows were not found at all. In all cows of the 3rd, 4th and 5th experimental groups, the placenta was separated in a timely manner, while in the 2nd experimental group placentas was separated independently in 9 cows or 90%, in the control group normal separation of the placenta occurred in only eight cows, which was 80% of the total amount.

The level of Zinc and Manganese – 31.5 mg, Cobalt – 0.41 mg per 1 kg of feed mixture due to the mixed ligand complexes of these elements showed the best influence on the live weight of calves at birth, milk productivity, and reproductive functions. The dose of Zinc and Manganese - 27 mg, Cobalt - 0.34 mg per 1 kg of body weight, which was provided through the feed of cows of the 5th experimental group, practically showed the same results as the cows of the 4th experimental group.

Conclusion

During the early dry stable period in cows, feed mixtures with the lowest content of biologically active substances should be used for their feeding, namely, in 1 kg of DM, mg: Zinc and Manganese - 31.5; Cobalt - 0.41. Instead, during the late dry period, they need a higher concentration of these trace elements in dry matter: Zinc and Manganese - 35 mg; Cobalt - 0.49 mg. A mandatory condition is to ensure the indicated level of trace elements due to their mixed-ligand complexes.

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