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NEW PRINCIPLES OF BALANCING DAIRY COWS MINERAL NUTRITION ACCORDING TO THE MILK PRODUCTION AND METABOLIC PROCESSES REQUIREMENTS IN THE BODY

Kulyk M.F., Doctor of agricultural sciences, corresponding member of NAAS

Didorenko T. O.

Obertiukh Y. V., Candidate of agricultural sciences, senior researcher

Institute of feed research and agriculture of Podillya NAAS

Skoromna O.I. , Candidate of agricultural sciences, assistant professor

Vinnytsia national agrarian university

Tuchyk A.V.

SE RF «Oleksandrivske» Trostyanets district, Vinnytsia region

Balancing mineral nutrition of dairy cows is done according to the mineral elements requirement for daily milk yield production by increasing the number of dividing the share of crude protein in the diet on milk protein and minerals needed for metabolic processes in the body. The requirement for mineral elements for milk production, metabolic processes in the body and general requirement and their ration content ant the elements assimilation ratio, the balance between the requirement and forage availability for assertion should be mentioned. The insertion of mineral supplements for satisfying physiological requirements should be determined.

Keywords: *macroelements, microelements, dairy cows, milk, requirement for milk and metabolism, the total requirement, minerals assertion.*

There are three main assessment methods of cows mineral nutrition balancing, they are empirical, factorial, system and kinetic, each of them has its advantages and disadvantages. The system and kinetic method is the development of the first

mentioned two methods on the tissue and cell levels taking into consideration dynamic interactions of nutrients, replacement and compensation of substratum, autoregulation effects [17, 19].

The excessive supply of animals by mineral substances causes the reducing of forage nutrients usage, their productivity, reproducible ability and their resistance to diseases [9].

The standards of cows mineral nutrition for certain elements differ greatly in various countries. In order to compare them we will give some standards for cow with body weight 600 kg, daily milk yield of 30 kg of milk fat 4% (per 1 kg dry matter of feed): Russia [5] — 6.55 g Ca; 4.72 g P; 1.6 g Mg; 6.55 g NaC1; 6.7 g K; 2.1 g S; 74 mg Fe; 10 mg Cu; 63 mg Zn, 63 mg Mn; 0.79 mg Co i 0.88 mg J; England [25] — 3.4 g Ca; 3.1 g P; 1.7 g Mg; 1.2 g Na; 7.4 g K; 40 mg Fe; 12 mg Cu; 40 mg Zn, 40 mg Mn; 0.11 mg Co; 0.5 mg J i 0.1 mg Se; the USA [23] — 5.8 g Ca; 3.7 g P; 2.0 g Mg; 1.8 g Na; 9.0 g K; 50 mg Fe; 10 mg Cu; 40 mg Zn, 40 mg Mn; 0.1 mg Co; 0.6 mg J i 0.3 mg Se; Japan [21] — 5.7 g Ca; 3.8 g P; 1.6 g Mg; 1.8 g Na; 8.0 g K; 50 mg Fe; 10 mg Cu; 40 mg Zn, 40 mg Mn; 0.1 mg Co i 0.1 mg Se; Germany [20] — 5.9 g Ca; 3.8 g P; 1.5 g Mg; 1.3 g Na; 50 mg Fe; 10 mg Cu; 50 mg Mn; 0.1 mg Co; 0.5 mg J i 0.15 mg Se; Belorussia [12] — 8.2 g Ca; 5.5 g P; 2.0 g Mg; 6.6 g NaC1; 6.7 g K; 2.8 g S; 75 mg Fe; 14 mg Cu; 75 mg Zn, 86 mg Mn; 1.3 mg Co; 1.0 mg J i 0.1 mg Se.

The unbalance of mineral nutrition of cows has characteristic clinical signs of certain diseases in experimental conditions. The pathology of mineral nutrition can be defined only by the biochemical examination of blood, organs and tissues, milk, feces, pelage and analysis of forage and water. The importance of animal diet balance by the elements that has not been researched has been experimentally proved, they are silicon, selenium, chromium, lithium, boron, aluminum and others [8].

The need for 1 kg of dry matter intake of cows for 15 mineral elements and the data about requirements in these minerals by leading countries were summarized (Table. 1 [8]) on the base of VA Kokorev others extensive research (2004).

1. The requirements of cow with body weight 600 kg, daily milk yield of 30 kg of milk fat 4% (per 1 kg dry matter of feed) in mineral elements in the leading countries

Element	USA	Germany	Denmark	France	England	Belorussia	Ukraine	Latvia
Ca (g)	6,5	6,6	3,4	5,7	5,9	8,2	7,3	6,5
P(g)	4,6	4,7	3,1	3,8	3,8	5,5	3,9	4,7
Mg (g)	1,7	1,6	1,7	1,6	1,5	2,0	2,3	1,6
Na (g)	2,5	-	1,2	1,8	1,3	-	1,6	-
CI (g)	3,0	-	-	-	-	-	-	-
NaCI (g)	6,1	6,6	-	-	-	6,6	-	6,5
K (g)	6,7	6,7	7,4	8,0	-	6,0	7,5	6,6
S (g)	1,8	2,1	-	-	-	2,8	-	2,0
Fe (mg)	83	74	40	50	50	5	-	70
Cu (mg)	10	10	12	10	10	14	11	11
Zn (mg)	49	63	40	40	50	75	38	70
Mn (mg)	43	63	40	40	50	86	52	70
Co (mg)	0,65	0,79	0,11	0,1	0,1	1,3	0,22	0,9
I (mg)	0,50	0,88	0,50	-	0,5	1,0	-	1,1
Se (mg)	0,15	-	-	0,1	0,15	од	0,1	0,20
Mo (mg)	0,33	-	-	-	-	-	-	0,37

According to Durst and Vittman research (2003) the norms of iron, copper, manganese, zinc, selenium, iodine and cobalt for cows per 1 kg dry matter are shown in the table 2 [4].

2. The norms of microelements for cattle (mg per 1 kg dry matter)

Microelement	Calves up to 150 kg body weight	Young animals	Milking Cows
Iron	100	50	50
Copper	4	10	10
Manganese	60	50	50
Zinc	50	50	50
Selenium	0,15	0,15	0,15
Iodine	0,25	0,25	0,50
Cobalt	0,10	0,10	0,10

Microelements Zn and Cu are classified as essence and heavy metals [1, 7]. However, they are positioned as biotic, atmophile or toxic depending on their concentration in various biological objects (soil, plants, and animal products) and their influence on animals and human bodies [18].

Nowadays the vitamin and mineral premixes of different structure produced by

domestic and foreign firms are used in dairy cattle-breeding to balance mineral nutrition of cows. The main aim is to increase milk productivity of the cows without taking into consideration the microelements balance that is transition of heavy metals from diet into milk [3, 13] and their discharge from the feces and urine of animals [18]. In the connection with the above mentioned to estimate the amount of removal of essential trace elements Zn and Cu from manure and chicken litter into the soil to prevent their excessive accumulation is very important [18].

Some researchers think that microelements dose in the animals diets should be limited in order to reduce surface pollution by decreasing their applying with animals manure and chicken litter. The laws on the maximum allowable concentrations of copper, iron, zinc, cobalt and manganese in the litter were adopted in EU countries in 2003 [15].

However, the balance of mineral nutrition by the norms of mineral elements per 1 kg dry matter has considerable differences. The iron requirement by the USA norms per 1 kg dry matter is 83 mg, in Denmark – 40 mg, France and England – 50 mg, cobalt requirement in the USA is 0.65 mg, Germany – 0.79 mg, Denmark, France, and England – 0.11-0.10 mg (table 1). So, the norms of mineral nutrition per 1 kg of dry matter don't have the evolution criteria; they should be the base for physiological balance of rations for milk production and metabolic processes cows that have different productivity.

The material and methods of research. The new principle of mineral nutrition balance for lactating cows is based on physiological criteria of mineral nutrition evaluation. Such principle of mineral nutrition for lactating cows is not based on the norms of mineral elements per 1 kg of dry matter of ration forage; it is based on the mineral elements requirement per daily milk yield increased by quotient of crude protein in milk and protein needed for metabolic processes cows, i.e. all the tissues, internal and biological liquids, their portion is 50% except bones, the mineral contents is taken as average in muscular tissue.

The suggested principle of mineral nutrition lactating cows balance will provide the optimal level of metabolism, milk quality and reducing of discharge from

the feces of heavy metals (copper, zinc, manganese and cobalt); it is important factor in organic crop production.

The research results. The requirement for macro- and microelements for milk production and metabolic processes that are equaled 50% of body weight according to our principle of cows mineral nutrition balance in comparison with the general requirements according to the USA and Russia norms for dry matter of ration forage is shown in the 3rd table.

The calculations were carried out as follows.

The average daily milk yield of 20 liters was taken as an example; the protein content was 3%.

Ca, its content is 1.2 g/l in milk [14], 0.012 g/kg in the muscle tissue [11]; 0,012 x 300 (50 % of body weight) = 3.6 g – the requirement for metabolic processes; 20 liters of milk x 3 % (protein content) /100 = 600 g; the quotient of crude protein in milk with daily milk yield of 20 liters per milk quantity [6]: 2325 : 600 = 3.9; 20 x 1,2 x 3,9 = 93.6 g – the requirement for milk production and general requirement is 93,6 + 3,6 = 97.2 g.

P, its content is 1.0 g/l in milk [14], 0.013 g/kg in the muscle tissue [11]; 0.013 x 300 (50 % of body weight) = 3.9 g – the requirement for metabolic processes; 20 x 1.0 x 3.9 = 78 g – the requirement for milk production and general requirement is 78 + 3.9 = 82 g.

Mg, its content is 0.12 g/l in milk [14], 0.07 g/kg in the muscle tissue [11]; 0.07 g/kg x 300 (50 % of body weight)= 21 g – the requirement for metabolic processes; 20 x 0.12 x 3.9 = 9.36 g – the requirement for milk production and general requirement is 9.36 + 21 = 30,36 g.

Cu, its content is 0.15 mg/l in milk [9], 0.3 mg/kg in the muscle tissue [11]; 0.3 mg/kg x 300 (50 % of body weight)= 90 mg – the requirement for metabolic processes; 20 x 0.15 x 3.9 = 11.7 mg – the requirement for milk production and general requirement is 11.7 + 90 = 101.7 mg.

3. The comparative evaluation of norms for macro- and microelements for cows with body weight 600 kg and different productive levels by the requirement for milk production and metabolic processes in comparison with the norms of Russia and the USA per 1 kg dry matter of ration

Mineral elements	Cows productivity, l						
	12	16	20	24	28	32	40
The requirement of Ca, g for:							
milk production	68	81	94	112	128	154	187
metabolic processes	3,6	3,6	3,6	3,6	3,6	3,6	3,6
general requirement *	72	84	97	116	131	157	191
Russian norms [6]	78	94	110	126	142	158	190
Dry matters of the USA [23]	104	114	123	134	144	154	172
The requirement of P, g for:							
milk production	57	67	78	94	106	128	156
metabolic processes	3,9	3,9	3,9	3,9	3,9	3,9	3,9
general requirement *	61	71	82	98	110	132	160
Russian norms [6]	54	66	78	90	102	114	138
Dry matters of the USA [23]	73	81	87	94	102	109	121
The requirement of Mg, g for:							
milk production	7	8	10	11	13	15	19
metabolic processes	21	21	21	21	21	21	21
general requirement *	28	29	31	32	34	36	40
Russian norms [6]	25	28	30	32	35	37	42
Dry matters of the USA [23]	27	30	32	35	38	40	45
The requirement of Cu, mg for:							
milk production	9	10	12	14	16	19	23
metabolic processes	90	90	90	90	90	90	90
general requirement *	99	100	102	104	106	109	113
Russian norms [6]	100	120	135	175	200	250	305
Dry matters of the USA [23]	159	175	189	205	221	237	264
The requirement of Zn, mg for:							
milk production	228	269	312	374	426	512	624
metabolic processes	570	570	570	570	570	570	570
general requirement *	798	839	882	944	996	1082	1194
Russian norms [6]	665	785	905	1130	1295	1575	1940
Dry matters of the USA [23]	779	857	926	1004	1083	1161	1294
The requirement of Fe, mg for:							
milk production	165	195	226	271	309	371	452
metabolic processes	2100	2100	2100	2100	2100	2100	2100
general requirement *	2265	2295	2326	2371	2409	2471	2552
Russian norms [6]	890	1050	1210	1390	1590	1800	2215
Dry matters of the USA [23]	1320	1453	1569	1702	1834	1967	2191
The requirement of Co, mg for:							
milk production	0,192	0,256	0,32	0,384	0,448	0,512	0,64
metabolic processes	6	6	6	6	6	6	6
general requirement *	6,2	6,26	6,32	6,39	6,45	6,51	6,64
Russian norms [6]	7,8	9,2	10,6	13,9	15,9	20,3	24,9
Dry matters of the USA [23]	10,3	11,4	12,3	13,3	14,4	15,4	17,2
The requirement of Mn, mg for:							

milk production	6	7	8	9	11	13	15
metabolic processes	105	105	105	105	105	105	105
general requirement *	111	112	113	114	116	118	120
Russian norms [6]	665	785	905	1130	1295	1575	1940
Dry matters of the USA [23]	684	753	813	882	950	1019	1135

Zn, its content is 4 mg/l in milk [9], 1.9 mg/kg in the muscle tissue [11]; 1.9 mg/kg x 300 (50 % of body weight) =570 mg – the requirement for metabolic processes; 20 x 4 x 3.9 = 312 mg – the requirement for milk production and general requirement is 312 + 570 = 882 mg.

Fe, its content is 2.9 mg/l in milk [9], 7 mg/kg in the muscle tissue [11]; 7 mg/kg x 300 (50 % of body weight) =2100 mg – the requirement for metabolic processes; 20 x 2.9 x 3.9 = 226 mg – the requirement for milk production and general requirement is 226 + 2100 = 2326 mg.

Co, its content is 0.004 mg/l in milk [22], 0.02 mg/kg in the muscle tissue [11]; 0.02 mg/kg x 300 (50 % of body weight) =6 mg – the requirement for metabolic processes; 20 x 0.004 x 3.9 = 0.312 mg – the requirement for milk production and general requirement is 0.312 + 6 = 6.3 mg.

Mn, its content is 0.099 мг/л [9], 0.35 mg/kg in the muscle tissue [14]; 0.35 mg/kg x 300 (50 % of body weight) = 105 mg – the requirement for metabolic processes; 20 x 0.099 x 3.9 = 7.72 – the requirement for milk production and general requirement is 7.72 + 105 = 112.7 mg.

The discussion of research results.

Calcium. Taylor M. S. and others [24] compared the rations that were differ by the Ca concentration (0.52 %, 0.78 % and 1.03 % of dry matter) at the beginning of lactation period of cows. The calcium content was changed by increasing the level of limestone in the ration. The consumption of dry matter didn't differ in the rations, but the daily dose of Ca increased from 0.52 % (125 g/cow) to 1.03% in ration dry matter, it was 248 g per cow. The milk yield and its calcium (48-49g) didn't differ among rations. The main discharge of Ca was with feces. As a rule, the calcium assimilation in the intestine is controlled process and it changes a bit because of its requirement. The Ca assimilation, as a rule, is not high; it is 15-35% of consumed.

The discharge of Ca with feces was from 88 to 168 grams per day and its assimilation was from 26.5 to 30.8% of consumed. The Ca discharge with urine was less than 1g daily at all three diets. Generally, if the Ca was 0.52% of ration dry matter during the early lactation period the Ca balance was negative and there was calcium release from the bones; two other rations had positive balances.

Phosphorus. The standards for cows P requirements in accordance with NRC (1989) is from 10 to 22%; they are higher than in previous NRC (1978) because of provided reducing its absorption efficiency [23]. The deficiency or surplus of Ca and P can cause postnatal paresis of cows. The optimal Ca and P ratio is 1.5:1-3.5:1, the best ratio is skeleton bones, it is 1,5-2:1 [7]. However, the ration should be balanced according to Ca and P requirements, but not to their ratio. The level of phosphorus assimilation is 30-40 % [16].

Copper. The difference between the US and Russian Cu standards and our Cu requirement for milk production and metabolic processes is rather considerable; it is 2.5-3 times higher. We should mention that Cu-containing enzyme ceruloplasmin restricts 95 % of changeable Cu in the cows' bodies, regulates the iron accessibility, involves in redox reactions and can regulate immune function [26]. The Cu requirement for metabolic processes in the cow body weight of 600 kg is 90 mg and for milk production with milk yield 40 l is 23 mg. The minimal horse requirement for Cu is 60 mg per head. The molybdenum excess and sulfur rate cause copper deficiency [26]. Saponite as mineral supplement is a natural source of copper for cows.

Iron. The milk production iron requirement is minimal; it cannot give the necessary amount for young organism, but such low level has one positive effect, it limits the bacteria growth in the milk, because milk is necessary for reproduction of different bacteria. The metabolic iron requirement for cows with different productive level is more substantial and larger than general requirements by the dry matters of Russia [6] and the USA [23]. The iron assimilation from roughage is about 3-4% [7].

Cobalt. In the rumen the microorganisms are used to synthesize vitamin B_{12}, its molecule (cyanocobalamin — $C_{63}H_{84}O_{14}Co$) contains one cobalt atom (4.5 weight

percent) [7]. 1 liter of milk contains 4.2 mkg of B_{12} [2], it is equal to 0.189 mkg of cobalt. According to other authors milk contains 0.002-0.003 mg/l of cobalt [9]; Malbe M. [22] thinks milk contains 0.004 mg of cobalt.

So the requirement of cobalt for milk production and metabolic processes for cows with daily milk yield 40 l is 6.63 mg, according to Russian dry matters standards [6] the requirement is 24.9 mg, according to the US dry matters standards [27] the requirement is 24.9 mg. The natural source of cobalt is saponite; it contains $0,5\text{-}4,0\cdot10^{-3}$ % [7] of cobalt. The average cobalt assimilation is 30% [7].

Manganese. The Mn requirements for milk production are minimal. If the milk yield is 40 l of milk the requirement is 15 mg for metabolic processes in the cow body weight of 600 kg is 105 mg. The Mn general requirements for cows with such productivity and body weight of 600 kg is 120mg, according to dry matters Russian standards[6] it is 1940 mg and US [23] it is 1135 mg; it is in 10-16 times more. The animal body contains about 0.2-0.3 mg of manganese per 1 kg body weight and it is distributed in such way: the skeleton has 55-57 %, liver – 17-18 %, muscles – 10-11%, skin – 5-6%, other organs – 10-13 %. About 1% of manganese is absorbed by ruminants from forage [7]. The animal Mn requirement is caused mainly by its reproductive functions but its requirement for intensive growth [10]. According to Russian norms the Mn requirement is 1940 mg and its assimilation at 1.0 % is 19.4mg, the largest part is discharged with milk and the rest is left for metabolic processes in the cow body.

The Mn requirement of cows is 20-25 mg/kg of forage, but its norms are increased in 2-3 times because of its important role in regulation of reproductive function [25, 20]. However, the increasing Mn content can suppress the immune system and reduce the lifespan of animals [9].

Conclusions

The balancing of mineral nutrition of cows according to the standards of mineral elements per 1 kg of ration dry matter has considerable differences. So, the US iron requirement per 1 kg of ration dry matter is 83 mg, it is 40 mg in Denmark, it is 50 mg in France and England; the US cobalt requirement is 0.65 g, it is 0.79 mg in

Germany, it is 0.11-0.10 mg in Denmark, France and England. So, the norms of mineral nutrition per 1 kg of ration dry matter don't have evaluation criteria, they should be base for physiological standards for milk production and metabolic processes of the bodies of cows with different productivity level.

The analysis of macro- and microelements balance for milk production and metabolic processes in the animal body and standards by dry matter ration is a confirmation that these figures shouldn't be equal. The requirements of mineral elements for milk production and metabolic processes and general requirements should be mentioned in the rations of cows with different productive level; the balance between requirements and availability of elements in the forage should be mentioned, too. The insertion of mineral elements to the ration is calculated to satisfy physiological needs.

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Нові принципи балансування мінерального живлення дійних корів за потребою на утворення молока і обмінні процеси в організмі.

Кулик М. Ф., Дідоренко Т. О., Обертюх Ю. В., Скоромна О. І., Тучик А. В.

Балансування мінерального живлення дійних корів проводиться за потребою мінеральних елементів на продукцію добового надою молока при збільшенні цієї кількості на частку ділення сирого протеїну в раціоні на кількість білка молока і потребою мінеральних елементів на обмінні процеси в організмі. У раціонах необхідно зазначити потребу мінеральних елементів на

утворення молока, обмінні процеси в організмі та загальну потребу, а також вміст у раціоні й коефіцієнта засвоєння цих елементів, їх баланс між потребою і наявністю доступних для засвоєння елементів в кормах. Після цього визначається введення до раціону мінеральних добавок для забезпечення фізіологічної потреби.

Ключові слова: макроелементи, мікроелементи, дійні корови, молоко, потреба на молоко й обмінні процеси, загальна потреба, засвоєння мінералів.

Новые принципы балансирования минерального питания дойных коров по потребности на образование молока и обменные процессы в организме.

Кулик М. Ф., Дидоренко Т. О., Обертюх Ю. В., Скоромна О. И., Тучик А. В.

Балансирование минерального питания дойных коров проводится по потребности минеральных элементов на продукцию суточного надоя молока при увеличении этого количества на долю деления сырого протеина в рационе на количество белка молока и потребностью минеральных элементов на обменные процессы в организме. В рационах необходимо отметить потребность минеральных элементов на образование молока, обменные процессы в организме и общую потребность, а также содержание в рационе и коэффициента усвоения этих элементов, их баланс между потребностью и наличием доступных для усвоения элементов в кормах. После этого определяется ввод в рацион минеральных добавок для обеспечения физиологической потребности.

Ключевые слова: макроэлементы, микроэлементы, дойные коровы, молоко, потребность на молоко и обменные процессы, общая потребность, усвоение минералов.