CATION-ANION BALANCE IN THE DIETS OF THE TRANSITIONAL COWS

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ABSTRACT

The latest findings about the importance and possibilities for control of the acid-base status of cows during the dry period and two months of lactation (transition period) was described in this paper. The most important roles of cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) and anions (P^{3-}, S^{3-} and Cl^{-}) was explained and their composition in common feeds. The equations for calculation of cation-anion balance were given and practical examples of their use. It is concluded that the problem of the acid-base of cows can be solved, although partially, using feeds with favourable cation-anion ratio. When there is no possibility to solve this problem by selection of feeds, the efficient way is to use anionic salts and zeolite both as natural and synthetic, which can bind the surplus of Ca cations. The results of the use of substances that can affect cation-anion balance was described and their effects in prevention of hypocalcaemia (milk fever), and production performances in dairy cows.

Key words: cows, minerals, cations, anions

1. INTRODUCTION

The most interesting research in the area of nutrition the high producing cows, in the world and here, in the last two decades, was that one which relates on research of the nutrition physiology problems or questions in the period of high pregnancy and early lactation, about two months before and after the calving (transition period). The reasons for that are certainly the new discoveries about the importance of transition period for reaching the high production of milk, maintaining the health, reproductive characteristic and profit, too. In the frame of that research the special importance had investigations in the area of mineral nutrition of high yielding cows, because of the importance, but also because of the complexity of researching. On that plan the attention was paid to cations and anions, especially the ones which are important for making acid-base balance in the organism. (Beede, 1992; Goff, 1987; Goff and Horst, 1997; Goff, 1999; Sattler, 2002; Thilsing-Hansen and Jorgensen, 2001; Stojanović at al., 2003, Ivanov and Šamanc 2005

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d the others). Besides these, the research about the use of the organically bonded mi-
)elements was interesting, whose characteristic is high adoptability and which contrib-
:s to improving reproduction results and increasing the immunity of animals. The aim
this work is to emphasize on the new knowledge and results of research and about
ssibilities of keeping acid-base condition of high producing cows in the dry phase and
: first two months after calving (transition period).

2. ROLE OF CATIONS AND ANIONS IN THE ORGANISM

Role of cations Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} and anions P^{3-}, S^{2-} and Cl^{-} in organism is very
iable and complex and because of that the knowledge of their role and the connec-
ns between themselves are very important. The most important activities of some
ions and anions are given in table 1.

Table 1. Most important activities of cations and anions

lement	Activity	Interaction
Ca^{2+}	Development of the bone system, production of milk, activator of enzymes, convey of nerve impulses, acid-base condition, activity of muscles	P, vitamin D_3, Fe, Mn, Zn, fats from feed
P^{3-}	Development of the bone system, production of milk, reproduction, metabolism of carbohydrates, transport of energy, acid-base condition, appetite	Ca, vitamins D_3, Fe, Mn
Mg^{2+}	Production of milk, activator of enzymes, function of nerves, , activity of muscles, acid-base condition	K, Ca, P, Zn, N from plants
K^{+}	Balance of liquids, function of the nerve system, production of milk, acid-base condition, consumption the feed, luster of hair	Mg, Na
Na^{+}	Balance of liquid, production of milk, acid-base equilibrium, appetite, quality of the hair	K
Cl^{-}	Acid-base condition, osmosis pressure, component of HCl, pancreas juice and intestinal secretes	Na
S^{2-}	Synthesis of methionine and cystine, appetite, component of secret of the gastrointestinal tract	Cu, Se

3. RECOMMENDATIONS AND SOURCES OF ANIONS AND CATIONS IN THE COWS DIETS

The latest recommendations of NRC (2001) enabled the more precisely defined
ds of cation and anion in the diet (Table 2). Needs in this components of a diet are
ified based on bigger number of data's about socket, from which the most important
he race, body mass, old, phase of lactation, stadium of pregnancy, body condition,
ike of cows, volume of the consumption of dry matter of a diet and conditions of
ping.

Table 2. Recommendations of cations and anions for the Holstein cows, % DM of diet

Element	20-60 days before calving	0-20 days before calving	0-20 days after calving	20-60 days after calving
Ca^{2+}	0.44	0.48	0.74	0.79
P^{3-}	0.22	0.26	0.38	0.42
Mg^{2+}	0.11	0.16	0.27	0.29
K^{+}	0.51	0.52	1.19	1.24
Na^{+}	0.10	0.10	0.34	0.34
Cl^{-}	0.13	0.20	0.36	0.40
S^{2-}	0.20	0.20	0.20	0.20

Knowledge of the content of cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (P^{3-}, S^{2-} and Cl^{-}) in feed has special importance for its successful balancing in diet. Variability of some elements in feed can be big and depends from more factors from which the most important are technology of fertilizing and chemistry composition of a soil, water regime of soil, time of harvest the plants and other factors. Because of that is necessary sometimes chemistry control of plants and soil.

Table 3. Content of cations and anions in feeds and additives (% DM, NRC, 2001)

Feed	Ca^{2+}	P^{3-}	Mg^{2+}	K^{+}	Na^{+}	Cl^{-}	S^{2-}
Alfalfa hay	1.40	0.23	0.35	2.51	0.03	0.59	0.35
Meadow hay	0.74	0.25	0.22	2.11	0.09	0.65	0.20
Maize plant silage	0.30	0.18	0.21	0.94	0.03	0.30	0.33
Maize ear silage	0.04	0.28	0.15	0.44	0.03	0.07	0.10
Alfalfa haylage	1.37	0.29	0.27	3.06	0.02	0.58	0.31
Wheat straw	0.32	0.10	0.12	1.42	0.14	0.60	0.19
Barley straw	0.42	0.29	0.18	2.36	0.14	0.65	0.17
Oat straw	0.40	0.22	0.20	2.01	0.28	1.00	0.14
Maize grain	0.03	0.29	0.14	0.40	0.03	0.08	0.09
Wheat grain	0.08	0.43	0.14	0.50	0.02	0.11	0.17
Barley grain	0.08	0.40	0.15	0.52	0.02	0.18	0.14
Oat grain	0.10	0.37	0.14	0.48	0.03	0.17	0.22
Wheat bran	0.15	1.12	0.51	1.26	0.04	0.18	0.24
Sunflower meal	0.44	1.18	0.77	1.40	0.04	0.13	0.32
Soybeans, extruded	0.32	0.64	0.29	1.81	0.01	0.03	0.29
Soybean meal	0.32	0.69	0.30	2.02	0.03	0.12	0.42
Brewer's grains	0.30	0.65	0.25	0.50	0.05	0.10	0.35
Dry sugar beet pulp	0.91	0.11	0.23	0.95	0.32	0.15	0.30
Limestone	39.39	0.04	0.05	0.06	0.06	-	-
Dicalcium phosphate	22.00	19.30	0.59	0.07	0.05	-	1.14
Monocalcium phosphate	16.40	21.60	0.61	0.08	0.06	-	1.22
Monoammonium phosphate	0.28	24.74	0.46	0.01	0.06	-	1.46
Salt	-	-	-	-	39.34	60.66	-

4. BALANCE OF CATIONS AND ANIONS IN THE DIET

To enable the optimal acidic-basis condition of organism is important to make balance of cations and anions of the diet (BKAO). The value of this balance expressed in miliequivalents per kg of dry matter (meq/ kg DM). Negative value BKAO is for the needs of cows in period of drying (-50 to –150). Contrary to that BKAO for cows in lactase need to be positive and much bigger (+300 to +450). Bigger values for BKAO in a frame of mentioned is recommended for fresh cows. In that sense especially important role have as cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} such an anions P^{3-}, S^{2-} and Cl^{-}, too. Cations Na^{+} and K^{+} are used because of strong alkaline effect, used to the increase the buffer capacity of blood, with increased retention of bicarbonates HCO_3^{-} and increased pH of blood. Besides that, they have very good resorption in digestive tract. Other authors, however, for researching BKAO besides cations Na^{+} and K^{+} use Ca^{2+} and Mg^{2+}, too. Anions P^{3-}, S^{2-} and Cl^{-} decrease buffer capacity of blood and how important is difference between cations and anions in the utility of anions it can came to the acidosis of blood. Because of that and during the using the additive of this kind is necessary sometimes to renewal control of pH and blood. Normal pH of urine is 7-8. During the giving of anion salts pH of urine decreases on 6-6.5 and it mustn't fall under these values. In the case that the value of pH of urine falls under the 6 comes to the damage of kidneys. Because of that it is necessary to make the control pH of urine 4 days after giving the salts (2-4 hours after the diet)

There is the bigger number of formulas for calculation the BKAO from which in this paper we instigate following:

BKAO meq/ kg DM= [(%Na: 0.023) + (%K: 0.039)] – [(%Cl: 0.0355) + (% S: 0.0016)]. (West, 1993)

BKAO meq/kg DM= [(435 x %Na) – (256 x %K)]–[(282 x %Cl) – (625 x % S)], (Beedde, 1992)

BKAO meq/kg DM= [(mEq Na^{+}) + (mEq K^{+})] – [(mEq Cl^{-}) + (mEq SO_4^{2-})], (Stojanović et al. 2003)

BKAO meq/kg DM= (0.38 mEq Ca kg+0.3 mEq Mg/kg+mEq Na/kg+mEq K/kg) – (mEq Cl/kg + 0.6 mEq S/kg), (Horst et al. 1997)

BKAO meq/kg DM= [(0.15 mEq Ca^{2+}) + (0.15 mEq Mg^{2+}) + (mEq Na^{+}) + (mEq K^{+})] – [(mEq Cl^{-}) + (0.2 mEq SO_4^{2-}) + (0.3 mEq PO_4^{3-})], (Goff et al. 1997)

Factors for translation % of cations and anions in meq are given in table 4.

Table 4. Factors for translation % of cations and anions in meq

Cation	Factor	Anion	Factor
Na^{+}	435	Cl^{-}	282
K^{+}	256	S^{2-}	624
Ca^{2+}	499	P^{3-}	968
Mg^{2+}	823		

Inadequate relation between cations and anions in some phases of productive cycle can be the cause of origin some disarrangements. The best example for that is calcium. Deficit of calcium cause parathormone production (hormone of paratoide gland) which influences no rebuilding the calcium from bones and increasing adsorption from digestive tract. During the sufficient of calcium, what is very often case, is activating leaching the calcitonin (hormone of thyroid gland) and the cause of its influence is increasing of building the calcium in bones and decreasing its resorption from digestive tract. If this sufficient lasts until the calving, the metabolism of calcium under the influence of calcetonin is keeping after the calving, and besides the bigger needs of organism for calcium it is still disposing in bone system. In such state, besides the evident sufficient of calcium in the feed, animals can't use the calcium of feed and satisfy the basic needs for maintenance and synthesis of milk. The result of that is puerperal paresis (milk fever or parturient paralysis) which is very often disarrangement of metabolism of cows. Nutrition the cows with diets with low content of calcium in last month of pregnancy is the most efficient way of preventing the puerperal paresis. However, very often, it is not possible with the available feeds. For reaching the wanted value BKAO the grass mixtures are more appropriate because they contain nearly two times less calcium then alfalfa.

By decreasing the quantity of calcium to 40-60 g/day and keeping the relation with phosphorus (1.5-2:1) two weeks before calving it is enabling activation of parathormone and by that also, directing of the metabolism of calcium in the wanted direction (increasing the resorption from digestive tract and mobilization from bones). One of the solutions, for making optimal values BKAO can be using anion salts (Santos at al., 2003, Table 5).

Table 5. Effects of using anion salts in the cow diets (Santos at al. 2003)

Indicator	With anion salts added	Without anion salts added
Quantity of milk for 305 d., kg	9376	9049
Sub clinical hypocalcaemia,%		
I and II lactation	2	16
> 3 lactation	28	66
Total	19	50
Clinical hypocalcaemia,%		
I and II lactation	0	0
> 3 lactation	5	12
Total	4	9
Gravidity,%	77	66
Service period (days of calving)	124	139
Insemination index	3	3,4

The most often sources of anion are ammonia chloride, magnesium chloride, calcium chloride, magnesia sulfate and calcium sulfate. Daily dose of anion salts is about 200 mg/day for cow in which the part of ammonia chloride is 100g (Grubic and Adamovic, 2003). Sulfates have bigger acidogenic potential, and besides that, animals have easier consumption different from chloride (Goff, 1997; Oetzel, 1991, Jovanović at al. 2002). Theoretically looking, the biggest acidogenic potential has hydrochloric acid. Including the anion salts in the diets of dried cows make possible getting needed BKAO values which has negative before sign which causes soft acidosis in blood and decreasing the

pH value of urine. It stimulates bigger mobilization of calcium from bones, increasing its esorption from digestive tract with increasing renal synthesis $1.25(OH)_2D_3$. Value of pH of the urine in the time of drying is 5.8-6.8 and in the period after calving 8-8.5. Results of testing BKAO in the cow diets, one farm in Serbia are given in tables 6 and 7.

Table 6. Composition of the cow diets

Parameter	30 days before calving BM 650 kg	30 d. after calving/ BM 570 kg; Milk 35 kg/d.
Alfalfa hay	3	4
Straw, wheat/oats/barley	3	-
Maize silage (28-32%DM)	10	15
Alfalfa haylage	4	8
Maize ear silage	2	4
Dry sugar beet pulp	0.5	2
Extruded soybeans	-	2
Additional mixture (30%CP	1.5	4.5
Dry matter, kg	12.1	21.5
NEL, MJ	66.2	153.2
Crude protein, %DM	12.1	18.3
Undegradable protein, %CP	35.82	39.69
ADF, %DM	32.33	22.6
NDF, %DM	49.08	37.16

Table 7. Content of cation and anion in the cow diet

Parameter	30 days before calving, BM 650 kg	30 days after calving, BM 570 kg; Milk 35 kg/day
Ca, %DM	0.93	1.04
P, %DM	0.43	0.56
Mg, %DM	0.28	0.31
K, %DM	1.78	1.67
Na, %DM	0.19	0.25
Cl, %DM	0.63	0.62
S, %DM	0.31	0.32
BKAO meq/kgDM		
- the diet values	+ 167	+ 162
- the optimal values	- 50 do – 150	+300 do + 450
BKAO correction		
Anionic salts[1], g/day	200	-
Mix Plus[2], g/day	-	250
Corrected BKAO values meq/kgDM	-88.13	+335

[1] Mixture:ammonium-chloride, calcium chloride, ammonia sulfate and magnesium sulfate (Cl 39%, S 7.4%).

[2] Mixture:sodium bicarbonate, organic zeolite, bentonite and magnesia oxide (Na 30%, Mg 2,7%.

If bigger correction of BKAO is needed, besides sodium bicarbonate we can use sodium carbonate, too, or potassium bicarbonate, apropos potassium carbonate. Potassium

carbonate is very efficient for increasing BKAO, with which we need to handle carefully and keep the instructions of the producers (Sattler 2002).

Last few years are done the studies in which are researched the possibilities of the prevention of milk fever by reduction of the available of calcium in the last month of pregnancy by using synthetic zeolite. According the results of Thisling-Hansen and Jorgensen (2001), Thisling-Hansen et al. (2002) synthetic zeolite successfully binds the cation of calcium. The capacity of binding in range pH from 7 to 11 is more then 110 mg Ca/g zeolite. In the research of Thisling-Hansen and Jorgensen (2001) content of Ca and P in the dry matter of the cow diet in the last month of pregnancy (the diets were identical in control and experimental group) was 0.64%, apropos 0.45%. The value of BKAO was extremely high for this category of cows and was +283 meq/kg of dry matter. Level of calcium in the blood serum of 75% cows of control group in the first two days after calving was under 2 mmol/L and the values varying from 0.7-3.3 mmol/L. In the experimental group of cows which got the synthetic zeolite (1 kg/cow/day) the value of calcium in the blood serum was to the all the cows under 2 mmol/L, and values was very equable and they were 2.1-3.2 mmol/L.

Natural zeolite, due to negative electricity and porosity of the structure find wide application as cation exchange changers). The content and kind of changeable cations in mineral zeolite can be controlled and changed depending of need. In the acid environment zeolite can be donor Ca^{2+} and in basic acceptor Ca^{2+}. The advantage of the natural zeolite in compared to synthetic is in higher acidic and thermal stability in the condition of application.

Investigations of this type have the significance because the natural zeolite, besides cation binding ability, has capability to bind the mycotoxins, toxic metals and ammonia, which is interesting property from the aspect of nutrition of high producing cows.

5. CONCLUSION

Harmonizing the balance of cations and anions of the diet (BKAO) made possible establishing the optimal acid-base condition of cows in the harmony with needs of certain phases of the producing cycle. It is especially important to the cows in the period of transition. Negative value of BKAO suites to the needs of cows in the dry period (-50-150). This value for cows in lactation needs to be positive and it is +300 to +450. Higher values for BKAO, in the frame of mentioned, are recommended for fresh cows. During the use of anion salts we must have a clear picture about actual acid-base status of cows (first pH of blood and urine, and after that the rumen fluid), also the content of cations and anions in the available feeds. On this plan it will be useful to have new investigations, which will give answers on certain specific questions.

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