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Effect of anionic salts in concentrate mixture and calcium intake on some blood and urine minerals, acid-base balance and feed intake of dry pregnant cows on grass silage based feeding

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Twelve Ayrshire and eight Friesian cows were randomly assigned to one of four prepartum diets in a 2 x 2 factorially designed experiment to determine the effect of anionic diet and calcium (Ca) intake on Ca metabolism, acid-base status and feed intake of grass silage based diets during the dry period. Four diets provided either 34 g or 74 g total dietary Ca/day, and were either anionic or cationic. Dietary cation-anion balance (DCAB), calculated as milliequivalents [$(Na^+ + K^+) – (Cl^- + S^{2-})$], was –247 mEq/kg dry matter (DM) in the low DCAB group and +34 mEq/kg DM in the high DCAB group. DCAB was formulated using NH_4Cl, $(NH_4)_2SO_4$ and $MgCl_2$ as anionic salts. Cows received grass silage (5.2 kg DM), hay (0.9 kg DM) and concentrate mixture (1.6 kg DM) until calving. Blood and urine samples were collected 4, 3, 2 and 1 week before the expected calving date, at calving, the day after calving and 1 week following calving. The results indicate that the reduction of cation-anion balance induced mild metabolic acidosis and increased the ability of the cow to maintain blood Ca concentration. However, DCAB should be higher since urinary pH decreased markedly (< 6) and so remarkable changes in some blood electrolyte concentrations were noticed.

Keywords: calcium, cows, ion balance, minerals, parturient paresis

Introduction

When prepartum dairy cows are fed rations with a low dietary cation anion balance (DCAB), a decrease in the incidence of milk fever has been observed in comparison with a high DCAB (Block 1984, Leclerc & Block 1989). Cows fed anionic salts tend to have higher plasma calcium (Ca) concentrations than cows fed without anionic salts (Oetzel et al. 1988, Goff et al. 1991). Furthermore, it has been shown that mild

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metabolic acidosis increases ionised Ca [Ca^{2+}] in the blood (Bushinsky et al. 1985). The favourable response of low DCAB diets is most likely to occur when cows have a positive Ca balance approaching parturition (Lomba et al. 1978).

The Agricultural and Food Research Council (AFRC) (1991) recommends 23 g Ca/day for dairy cows during the dry period. Dutch experiments (Breukink 1993) demonstrated that Ca intake should be limited to 25 g Ca/day for dry pregnant dairy cows. However, in countries like Finland where dairy cows are fed silage *ad libitum*, such a low dietary Ca level is difficult to achieve, particularly when the Ca content of the grass silage can be as high as 7 g Ca/kg dry matter (DM). Consequently, the daily Ca intake can vary between 50–90 g/d exceeding the Finnish feeding standard for dairy cows during the dry period (40 g Ca/d) (Tuori et al. 1995). Therefore, reducing the cation-anion balance could be a suitable method to prevent milk fever when the ration is naturally high in Ca.

Our main objective was to evaluate the effects of two different DCAB diets combined with a normal or high Ca content on the acid-base status and Ca metabolism as well as on some blood and urine minerals of pregnant cows during the dry period. This study was also used to develop a suitable anionic concentrate mixture for grass silage based diets of Finnish dry cows.

Material and methods

Experimental design and treatments

Twelve Ayrshire and eight Friesian cows (age 47±14 months) with one or more lactations and no history of parturient paresis from previous lactations were selected from the University of Helsinki research farm. Cows weighed 652±63 kg at the beginning of the trial and were randomly assigned to one of four dietary treatment groups with 5 cows per diet. Cows received grass silage (5.2 kg DM/d), hay (0.9 kg DM/d) and experimental concentrate mixture (1.6 kg DM/d). In addition, experimental cows were given vitamin and selenium supplements once a week as follows: vitamin A 200 000 IU/cow/week, vitamin D 40 000 IU/cow/week, vitamin E 400 mg/cow/wk and selenium 2 mg/cow/week. The experimental feeding period started 4 weeks before the expected calving date and ended at parturition. Immediately after parturition, cows entered the normal nutrition and management program applied at the University of Helsinki research farm.

Experimental diets were arranged 2 x 2 factorially as follows: Diet 1, high DCAB, normal Ca (0.46%, 35 g/d); Diet 2, high DCAB, high Ca (0.94%, 74 g/d); Diet 3, low DCAB, normal Ca (0.47%, 33 g/d); and Diet 4, low DCAB, high Ca (0.96%, 74 g/d). Cows were divided into two blocks according to breed. Within each block cows were randomly assigned to one of four treatments in groups of four animals according to expected calving date. The low DCAB diet contained added chlorine (Cl) and sulphur (S), supplied primarily by adding chlorides of ammonium and magnesium and ammonium sulphate. A mixture of different salts was used to avoid potential toxicity of using only one acidifying salt. Anionic salts were included in the concentrate mixture which was pelleted. The composition of the experimental diets and the concentrate mixtures are shown in Table 1. Using the formula $(Na^+ + K^+) – (S^{2-} + Cl^-)$ mEq/kg DM the high DCAB diet contained +34 mEq/kg DM, and the low DCAB diet contained –247 mEq/kg DM. Sulphur was included to avoid an excessive Cl^- content. In addition, Tucker et al. (1991) have demonstrated that the effect of S^{2-} on systemic acid-base status in lactating cows is similar to that of Cl. The high Ca level was achieved by adding 100 g/d calcium carbonate to the ration. Dietary energy content expressed as feed units (1 FU = 1 kg barley containing 11.7 MJ metabolizable energy according to MAFF 1975) was formulated to meet a moderate feed intake (i.e. 1.2 times maintenance) as recommended by van de Braak et al. (1986). Chemical analysis of the experimental diets is shown in Table 2.

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Table 1. Ingredient composition of the concentrate mixture and experimental diets[1].

Concentrate mixture Ingredient, %	High DCAB[2]		Low DCAB	
Molasses	12.62		11.11	
Wheat	22.33		22.22	
Barley	12.62		11.11	
Wheat bran	7.77		5.56	
Beet pulp	17.48		16.67	
Pelleted hay meal	17.48		16.67	
NH_4Cl	1.94		5.56	
$MgCl_2$	3.88		4.44	
$(NH_4)_2SO_4$	–		3.33	
NaH_2PO_4	3.88		3.33	
Diet **Ingredient, %**	**Normal Ca**	**High Ca**	**Normal Ca**	**High Ca**
Grass silage	67.80	67.01	69.43	67.32
Hay	11.70	11.34	12.54	11.67
Concentrate mixture	20.50	20.51	18.03	19.84
$CaCO_3$	1.14	1.17		

[1] Dry matter basis.
[2] Dietary cation-anion balance.

Table 2. Dry matter intake, energy content, chemical composition[1] and dietary cation-anion differences of experimental diets.

	High DCAB[2]		Low DCAB	
	Normal Ca	High Ca	Normal Ca	High Ca
DMI[3], kg/d	7.61	7.85	7.10	7.71
ME[4], MJ/kg DM	10.90	10.77	10.72	10.60
Crude protein, %	14.90	14.73	16.50	16.53
Crude fiber, %	25.06	24.71	25.58	24.90
ADF[5], %	28.30	24.81	25.69	25.96
NDF[6], %	46.93	46.27	47.74	46.45
Ca,%	0.46	0.94	0.47	0.96
P, %	0.51	0.51	0.49	0.50
Mg, %	0.31	0.32	0.34	0.38
K, %	2.53	2.50	2.45	2.39
Na, %	0.26	0.26	0.20	0.21
Cl, %	2.05	2.03	2.51	2.60
S, %	0.24	0.23	0.37	0.38
DCAB[7], mEq/kg DM	+35	+33	–225	–268

[1] Expressed on a dry matter basis.
[2] Dietary cation-anion balance.
[3] Dry matter intake.
[4] Metabolizable energy calculated according to MAFF (1975).
[5] Acid detergent fibre.
[6] Neutral detergent fibre.
[7] Dietary cation-anion balance calculated as milliequivalents $(Na^+ + K^+) – (Cl^- + S^{2-})$ per kg dry matter.

Cows were housed and fed in individual tie stalls with free access to drinking water. Grass silage was offered twice daily (0530 and 1400 h) and hay and concentrate once daily (1430 h). Concentrate remaining at 4–6 h postfeeding was removed and then manually mixed with silage. If feed was left until the next feeding, the amount refused was weighed and dry matter content was measured. Samples of grass silage, hay and concentrate taken weekly at the time of feeding were pooled; grass silage was combined into monthly samples and hay combined into bales and frozen. Grass silage DM was determined weekly by drying at 100°C for 24 h.

Cows were weighed and body condition was scored at the beginning of the experiment, two weeks later and after calving. Body condition was scored on a scale of 1 to 5, where 1 represented extremely thin and 5 extremely obese animals (Windman et al. 1982).

Sample collection

Blood samples were collected from the jugular vein of each cow before afternoon feeding, on 4, 3, 2, and 1 weeks prepartum, on the day of calving, and at 1 d and 7 d postpartum. Samples were placed on crushed ice immediately after sampling. One sample was taken into a heparinized vacuum tube for measurements of acid-base status. After immediate determination of gases and haemoglobin of whole blood, the remainder was centrifuged twice (3000 g for 5 min) and the plasma was stored frozen for subsequent measurement of Na, K, Cl, Ca, P and Mg. Another heparinized sample was taken into a vacuum tube for the determination of blood ionised Ca concentration within 24 hours of collection. For parathyroid hormone (PTH) blood samples were collected into a EDTA-tube, centrifuged twice and stored at –20°C prior to analysis.

Urine samples were taken before afternoon feeding on 4, 3, 2, and 1 weeks prepartum, on the day of calving, and 1 d and 7 d postpartum. Samples were obtained by vulval stimulation and stored frozen for pH, creatinine, hydroxy (OH) proline, Ca, Mg, K and Na analysis.

Laboratory analysis

Blood pH, partial pressure of CO_2 (pCO_2) and acid-base excess were measured using a blood gas analyser (ABL1 Acid-base laboratory, Radiometer A/S, Copenhagen). Measurements of pH and pCO_2 were corrected to correspond to measured body temperature and haemoglobin according to the manufacturer's instructions. The corrected pH and pCO_2 values were used to calculate the actual bicarbonate ($aHCO_3$) and standard base excess (SBE) values. Haemoglobin was determined by the cyanmethaemoglobin method. Plasma PTH concentration was determined using an immunoradiometric assay (INTACT PTH Parathyroid Hormone Kit, Nichols Institute Diagnostics, USA).

Plasma and urinary Ca and Mg were determined by an atomic absorption spectrophotometer (Model 2380, Perkin Elmer Corp., Norwalk, Conn., USA) and creatinine by an automated kinetic alkaline picrate method (Fabiny & Ertigshausen 1971). Plasma inorganic phosphorus was determined by the colorimetric method of Daly & Ertigshausen (1972). Concentrations of Na^+, K^+ and Cl^- in plasma and blood ionised Ca were assessed by using ion-specific electrodes (KONE Microlyte 3 + 2, KONE Corp., Espoo, Finland).

Urinary Na^+ and K^+ were analysed by a flame photometer (Corning 480, Ciba Corning Diagnostics Limited, Halstead, Essex CO9 2DX, England). Urinary pH was measured by a pH meter (Radiometer Copenhagen, PHM 83 Autocal pH meter). Fractional excretion (FE_x) of electrolytes (x) was calculated using the following formula: $FE_x, \% = x_u \times creatinine_p / x_p \times creatinine_u \times 100$, where u refers to urinary electrolyte concentration, and p to the corresponding concentration in plasma. Concentration of OH-proline in urine was measured to estimate bone Ca mobilisation (Black & Capen 1971) according to Prockop & Udenfriend (1960).

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Feeds were analysed according to standard procedures (Association of Official Analytical Chemists, AOAC 1984). NDF (neutral detergent fiber) and ADF (acid detergent fiber) were determined according to Goering and Van Soest (1970). Feed DM was determined by drying at 100°C for 24 h. Samples for analysis were dried under vacuum at 50°C for one to two days and ground through a 1 mm screen. Ground samples were ashed at 560°C for 4 h. After dissolving the ash in 2.5 N HCl, Ca, Mg, Na and K were determined using an atomic absorption spectrophotometer (model 5100 PC, Perkin-Elmer). P was determined colorimetrically by the vanadomolybdate procedure of Tayssky & Shorr (1953). Dietary Cl was determined by the titrimetrical method of Mohr (Welcher 1963) and sulphur using a magnesium nitrate method in a commercial laboratory (Viljavuuspalvelu, Mikkeli, Finland). *In vitro* digestibility was measured in all roughage samples (Tilley & Terry 1963). All measurements were performed in duplicate. Energy content of concentrates as feed units was calculated according to published chemical composition and digestibility coefficients (Tuori et al. 1995).

Statistical analysis

The data were analysed in two parts: 1. prepartum; from 4 weeks to 1 week before the expected calving date. 2. peripartum; from 1 week before expected calving to 1 week after calving. Plasma and urinary data were analysed by a repeated measures analysis of variance within the SAS (1985) general linear model procedure for a complete block design including the effects of breed, dietary Ca level, DCAB and their interactions in the model. Since there was no interaction between treatments and breed, this term was excluded from the model. Because preliminary analysis of raw data indicated a heterogenous of variation for OH-prolin, Ca FE% and Mg FE%, these variables were logarithmically transformed to achieve a more homogeneous variance. A one-way analysis of variance of the four treatment groups was performed for data collected at 4 weeks before the expected calving date to assess initial differences in experimental groups.

Results

Cows were fed a fixed ration throughout the experiment. Feed intake was slightly lower in the low DCAB group than in the high DCAB group due to the unpalatable anionic concentrate mixture. The low DCAB group left on average 0.34 kg DM/d of the daily total DM intake in comparison with 0.06 kg DM/d in the high DCAB group. The body condition of all cows at parturition was satisfactory (3.1), indicating that the low feeding level during the dry period had no visible adverse effects.

There were no differences ($P>0.05$) in blood or urinary analyte concentrations between the groups at the beginning of the trial, and therefore pre-treatment values were not used as covariates. A lowered cation-anion balance resulted in higher blood Ca ion concentrations both prepartum ($P<0.001$) and peripartum ($P<0.05$, Table 3). Daily Ca intake did not affect any of the blood parameters measured. None of the cows showed clinical signs of milk fever around parturition. A subclinical hypocalcaemia (Ca^{2+} < 1,00 mmol/l, Radostits et al. 1994) occurred in two cows in the high DCAB group. Concentrations of total Ca, inorganic P and Mg in plasma were unaffected either by Ca intake or DCAB during the trial, but Ayrshire cows had a higher prepartum plasma inorganic P concentration ($P<0.001$). Total Ca, inorganic P and Mg in plasma varied within the reference range (Radostits et al. 1994). Plasma K, Na and Cl concentrations were unaffected peripartum, but all of these parameters were higher prepartum in cows fed the low DCAB diets (K, $P<0.05$; Na, $P<0.05$; Cl, $P<0.01$,Table 3). Plasma PTH concentration did not differ ($P>0.10$) between treatment groups.

Blood pH, HCO_3^- and base excess were influenced ($P<0.05$) by DCAB and the breed pre-

Table 3. Effect of dietary cation-anion balance (DCAB) and Ca intake on mean plasma mineral concentrations and urinary Ca excretion.

		Time from parturition							Significance[4]	
	Factor	–4 wk	–3 wk	–2 wk	–1 wk	0	+1 d	+1 wk	Prepartum	Peripartum
Calcium[2+]	High DCAB	1.21	1.18	1.18	1.21	1.09	1.13	1.20		
mmol/l	Low DCAB	1.25	1.25	1.24	1.23	1.17	1.18	1.23		
	sem[1]	0.012	0.012	0.009	0.014	0.030	0.018	0.017		
	Normal Ca	1.22	1.20	1.22	1.22	1.17	1.16	1.23		
	High Ca	1.23	1.23	1.21	1.22	1.10	1.14	1.20		
	sem	0.012	0.012	0.009	0.014	0.030	0.018	0.017		
									DCAB[3] ***	DCAB *
Potassium	High DCAB	4.43	4.48	4.42	4.39	4.35	4.18	3.98		
mmol/l	Low DCAB	4.48	4.70	4.66	4.53	4.28	4.24	4.18		
	sem	0.086	0.091	0.063	0.096	0.107	0.087	0.123		
	Normal Ca	4.42	4.60	4.43	4.40	4.31	4.14	4.15		
	High Ca	4.49	4.58	4.65	4.52	4.32	4.28	4.01		
	sem	0.086	0.091	0.063	0.096	0.107	0.087	0.123		
									DCAB *	
Chloride	High DCAB	103.5	104.0	104.5	104.6	106.3	106.8	102.4		
mmol/l	Low DCAB	104.3	106.6	111.4	108.2	106.7	106.2	102.8		
	sem	0.43	0.83	2.35	0.91	1.03	0.42	0.34		
	Normal Ca	103.8	105.6	106.2	106.6	107.0	107.0	102.8		
	High Ca	104.0	105.0	109.7	106.2	106.0	106.0	102.4		
	sem	0.43	0.83	2.35	0.91	1.03	0.42	0.34		
									DCAB **	
Sodium	High DCAB	138.7	138.3	138.7	140.0	140.2	141.5	138.3		
mmol/l	Low DCAB	138.4	139.9	140.7	142.0	140.7	140.6	137.9		
	sem	0.303	0.537	0.454	0.543	1.033	0.645	0.462		
	Normal Ca	138.4	138.8	139.5	141.1	140.6	141.9	137.9		
	High Ca	138.7	139.4	139.9	140.9	140.3	141.1	138.3		
	sem	0.303	0.537	0.454	0.543	1.033	0.645	0.462		
									DCAB *	
Ca/creat.[2)5]	High DCAB	0.32	0.31	0.37	0.36	0.13	0.08	0.79		
	Low DCAB	1.00	2.26	1.65	1.54	0.52	0.22	0.74		
	sem	0.309	0.452	0.115	0.142	0.087	0.057	0.201		
	Normal Ca	0.63	0.84	0.90	0.74	0.23	0.15	0.73		
	High Ca	0.68	1.73	1.12	1.14	0.43	0.15	0.80		
	sem	0.309	0.452	0.115	0.142	0.087	0.057	0.201		
									DCAB ***	DCAB **
Ca FE%[5]	High DCAB	1.68	1.89	2.43	2.13	1.04	0.58	4.00		
	Low DCAB	5.46	12.66	10.51	9.72	3.20	1.41	3.73		
	sem	1.557	2.352	0.813	0.687	0.500	0.378	1.086		
	Normal Ca	3.76	5.23	5.93	5.09	1.66	1.04	3.64		
	High Ca	3.38	9.32	7.01	6.75	2.58	0.95	4.09		
	sem	1.557	2.352	0.813	0.687	0.500	0.378	1.086		
									DCAB ***	DCAB **

[1] sem = standard error of means

[2] Ca/creatinine, mmol/mmol

[3] DCAB = high DCAB vs low DCAB

[4] P < 0.05 *, P < 0.01 **, P < 0.001 ***

[5] These peripartum means were based on nine rather than ten observations and the sem given should be multiplied by 1.061 when making comparisons with other values.

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Table 4. Effect of dietary cation-anion balance (DCAB) and Ca intake on mean blood and urinary pH.

		Time from parturition							Significance[4]	
	Factor	–4 wk	–3 wk	–2 wk	–1 wk	0	+1 d	+1 wk	Prepartum	Peripartum
Blood pH	High DCAB	7.36	7.36	7.38	7.38	7.36	7.37	7.38		
	Low DCAB	7.36	7.28	7.35	7.36	7.36	7.38	7.38		
	sem[1]	0.010	0.015	0.015	0.014	0.009	0.008	0.009		
	Normal Ca	7.36	7.34	7.37	7.36	7.36	7.38	7.39		
	High Ca	7.36	7.30	7.36	7.36	7.36	7.37	7.37		
	sem	0.010	0.015	0.015	0.014	0.009	0.008	0.009		
									DCAB[2] *	
pH in urine[3]	High DCAB	8.44	8.40	7.98	8.07	8.14	8.40	7.91		
	Low DCAB	8.40	6.00	5.90	6.09	6.77	7.72	7.66		
	sem	0.049	0.188	0.254	0.286	0.220	0.232	0.221		
	Normal Ca	8.42	7.35	6.92	7.08	7.58	8.07	7.68		
	High Ca	8.42	7.06	6.96	7.08	7.34	8.05	7.90		
	sem	0.049	0.188	0.254	0.286	0.220	0.232	0.221		
									DCAB ***	DCAB***

[1] sem = standard error of mean.
[2] DCAB = cationic vs. anionic.
[3] These peripartum means were based on nine rather than ten observations and the sem given should be multiplied by 1.061 when making comparisons with other values.
[4] $P < 0.05$ *, $P < 0.01$ **, $P < 0.001$ ***

partum. Five cows from the low DCAB group experienced metabolic acidosis (Radostits et al. 1994) after one week from the start of the experiment. However, they could compensate for it within a week (Table 4).

Urinary calcium excretion was markedly higher ($P<0.001$, Table 3) and urinary pH significantly lower ($P<0.001$) in cows fed the low DCAB diet than for cows fed the high DCAB diet (Table 4). Neither urinary excretion of Mg, K and Na, nor urine FE% of Mg, K and Na were significantly influenced by treatments. Urinary OH-proline/creatinine excretion tended to increase with increasing Ca prepartum (–3 wk: 0.018 vs. 0.032) but otherwise they were unaffected by treatments.

Discussion

The results of this trial demonstrated that the low DCAB diet had a beneficial influence on Ca metabolism during the periparturient period. This result agrees with previous reports of the effect of dietary Cl^- and SO_4^{2-} anions on hypocalcaemia in cows at parturition (Abu Damir et al. 1994, Phillippo et al. 1994). Feeding the high or normal Ca ration had no significant effect on the concentrations of selected elements in plasma. This observation is in agreement with the results of the studies by Schonewille et al. (1994). On the other hand Goff and Horst (1997) demonstrated in a recent study that K was more important risk factor for milk fever than dietary Ca.

The DCAB in experimental groups was lower than expected due to higher contents of S and Cl in silage and hay during the trial than found in the preliminary analysis. Our experiment showed that cows can tolerate moderately low DCAB without any detrimental effects. However, the proportion of anions can also be lower and anion feeding period shorter than in the current study to demonstrate the beneficial effect on dairy cow Ca metabolism (Oetzel et al. 1988).

The pH of blood was reduced ($P<0.05$) and acid-base status was changed in cows fed the low

DCAB group. According to Phillippo et al. (1994) this is possibly a result of absorption of Cl^-, because plasma Cl^- levels were increased before parturition. The low DCAB diet increased blood ionised Ca ($P<0.001$). This observation has also been noted by many other authors (Oetzel et al. 1988, Oetzel et al. 1991, Abu Damir et al. 1994). Probably the result is due to mild metabolic acidosis as Bushinsky et al. (1985) showed with rats. The intracellular movement of hydrogen in exchange for K helps to prevent an excessive increase in extracellular fluid hydrogen concentration in the acid load. This can result in hyperkalemia. In our study it was noticed that in two out of ten cows in the low DCAB group the blood concentration was raised to over 5.0 mmol/l after one week of feeding the experimental diet. Thus, the DCAB was too low. Considerable changes in blood electrolyte concentrations have been noticed even when the DCAB has not been as low as in the current trial (Fredeen et al. 1988).

Actual HCO_3^- tended to be lower and blood pH was ($P<0.05$) lower for Ayrshire than Friesian cows prepartum. However, urinary pH was higher for Ayrshires than for Friesians. Ayrshire cows consumed more DM in relation to their body weight; this may be attributed to the higher metabolic acid production by Ayrshire cows. Another explanation could be that Friesian cows have a better ability to conserve aHCO_3^- ions by reabsorption in the kidney, which affects acid-base balance.

Plasma inorganic P was not affected by diet. This is in agreement with the results of other studies (Oetzel et al. 1988, Gaynor et al. 1989, Tucker et al. 1992). In the present study, with a dietary Mg content of 3.4 g/kg DM, there were no differences in plasma Mg concentration between treatments. Oetzel et al. (1988) reported that feeding a low DCAB increased plasma Mg immediately prepartum when the feed Mg level was 2.2 g Mg/kg DM. Our assumption is that the higher level of Mg in the current experiment prevented the changes in plasma. Under normal conditions, renal antagonism between Ca and Mg may account for increased plasma Mg associated with decreased plasma total Ca (Halse 1984). In this experiment urinary Mg excretion tended to increase with a low DCAB. Similar effects were observed by Gaynor et al. (1989) and Oetzel et al. (1988).

In general, the bovine kidney is highly efficient in conserving Ca. In our study, about 98% of Ca filtered by the kidney was reabsorbed in the high DCAB group prepartum. Cows in the low DCAB diet excreted 5 to 8 times more Ca in urine than cows fed the high DCAB diet. In addition, about 11% of filtered Ca was excreted by cows fed the low DCAB diet compared with less than 3% for the high DCAB diet. These findings are in agreement with many other studies (Gaynor et al. 1989, Oetzel et al. 1991, Wang & Beede 1992, Mosel van et al. 1993). The level of Ca intake did not influence the amount of Ca excreted in the urine. Stacy & Wilson (1970) reported that the renal tubules are sensitive to acid-base status and that they respond to a lowering of blood pH by decreasing tubular reabsorption of filtered calcium. Thus, renal Ca excretion appears to depend on DCAB rather than Ca intake. However, acidification in the low DCAB group was excessive since urinary pH decreased to below six when feeding was continued for two weeks. According to Jardon (1995) urinary pH should be 6–7 to ensure the effect but avoiding excessive acidification.

In the current study the measured amount of OH-proline in the urine was assumed to originate from bone matrix. The low DCAB diet did not affect the ratio of urinary OH-proline to creatinine excretion although a minor increase was noticed after one week from the start of the trial. In experiments where OH-proline excretion has been reported (Gaynor et el. 1989, Goff et al. 1991), sample collection had been carried out more frequently and closer to parturition and may explain discrepancies with the current data.

Concentration of plasma PTH was not affected by the treatments although plasma Ca^{2+} concentration was higher in the low DCAB group. This observation is in agreenment with earlier studies (Abu Damir et al. 1994, Goff et al. 1991, Phillippo et al. 1994) and implies that groups (low vs. high DCAB) have a difference in sensitivity to PTH as Goff et al. (1991) demonstrated.

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Current results indicate that the anionic salt can maintain blood Ca^{2+} level during puerperium at different Ca intakes and may therefore decrease the risk of parturient paresis on grass silage based diets. However, clinical deficiencies could have been shown even more clearly if cows had been older. Because of a lack of facilities animal material was rather young. Dairy farmers could also successfully use salts of Cl^- and SO_4^{2-} in the feed to control hypocalcemia when the Ca content of grass silage or hay is moderately high. Furthermore the additives must be carefully formulated to achieve sufficient effects but avoid excessive acidification. The DCAB should probably be higher than in this experiment (–247 mEq/kg DM). In this trial the experimental diet was not palatable enough. It is necessary to develop more palatable concentrate mixtures in order to feed an anion-containing supplement separately from grass silage.

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References

Abu Damir, H., Phillippo M., Thorp, B. H., Milne, J. S., Dick, L. & Nevison, I. M. 1994. Effects of dietary acidity on calcium balance and mobilisation, bone morphology and 1,25 dihydroxyvitamin D in prepartal dairy cows. *Research in Veterinary Science* 56: 310–318.

Agricultural and Food Research Council (AFRC) 1991. Technical Committee on Responses to Nutrients, Report No 6. A Reappraisal of the calcium and phosphorus requirements of sheep and cattle. *Nutrition abstracts and reviews, Series B, Livestock Feeds and Feeding.* Vol. 61. p. 573–612.

AOAC 1984. *Official methods of analysis.* Association of Official Analytical Chemists, Inc. Arlington. Virginia. 1141 p.

Black, H. E. & Capen, C. C. 1971. Urinary and plasma hydroxyproline during pregnancy, parturition and lactation in cows with parturient hypocalcemia. *Metabolism* 20: 337–344.

Block, E. 1984. Manipulating dietary anions and cations for prepartum dairy cows to reduce incidence of milk fever. *Journal of Dairy Science* 67: 2939–2948.

Braak, A. E. van de, Klooster, A. Th van't & Malestein A. 1986. Influence of prepartum calcium intake on calcium mobilisation rate around parturition in dairy cows fed at a high prepartum feeding level. *Veterinary Quarterly* 8: 24–37.

Breukink, H. J. 1993. Dutch experiments related to milk fever prevention. *Acta Veterinaria Scandinavica Supplementum* 89: 125–128.

Bushinsky, D. A., Riera, G. S., Favus, M. J. & Coe, F. L. 1985. Response of serum $1,25(OH)_2D_3$ to variation of ionised calcium during chronic acidosis. *American Journal of Physiology* 249 (Renal Fluid Electrolyte Physiology 18): F361–F365.

Daly, J. A. & Ertigshausen, G. 1972. Direct method for determining inorganic phosphate in serum with the "CentriChem". *Clinical Chemistry* 18: 263–265.

Fabiny, D. L. & Ertigshausen, G. 1971. Automated reaction rate method for determination of serum creatinine with Centrifichem. *Clinical Chemistry* 17: 696–700.

Fredeen, A. H., DePeters, E. J. & Baldwin, R. L. 1988. Characterisation of acid-base disturbances and the effects on calcium and phosphorus balances of dietary fixed ions in pregnant or lactating does. *Journal of Animal Science* 66: 159–173.

Gaynor, P. J., Mueller, F. J., Miller, J. K., Ramsey, N., Goff, J. P. & Horst, R. L. 1989. Parturient hypocalcemia in Jersey cows fed alfalfa haylage-based diets with different cation to anion rations. *Journal of Dairy Science* 72: 2525–2531.

Goering, H. K. & Van Soest, P. J. 1970. Forage fibre analysis. *U. S. D. A. Agricultural Handbook* 379. Washington. p. 20.

Goff, J. P., Horst, R. L., Mueller, F. J., Miller, J. K., Kiess, G. A. & Dowlen, H. H. 1991. Addition of chloride to a prepartal diet high in cations increases 1,25-dihydroxyvitamin D response to hypocalcemia preventing milk fever. *Journal of Dairy Science* 74: 3863–3871.

– & Horst, R. L. 1997. Effects of the addition of potassium and sodium, but not calcium, to prepartum rations on milk fever in dairy cows. *Journal of Dairy Science* 80: 176–186.

Halse, K. 1984. Calcium effects on renal conservation of magnesium in cows. *Acta Veterinaria Scandinavica* 25: 213–227.

Jardon, P. W. 1995. Using urine pH to monitor anionic salt programs. *Compendium on Continuing Education for the Practicing Veterinarian Food Animal* 17: 860–862.

Leclerc, H. & Block E. 1989. Effects of reducing dietary cation-anion balance for prepartum dairy cows with specific reference to hypocalcemic parturient paresis. *Canadian Journal of Animal Science* 69: 411–423.

Lomba, F., Chauvaux, G., Teller, E., Lengels, L. & Bienfet, V. 1978. Calcium digestibility in cows as influ-

enced by the excess of alkaline ions over stable acid ions in their diets. *British Journal of Nutrition* 39: 425–429.

MAFF 1975. Energy allowances and feeding systems for ruminants. Ministry of Agriculture, Fisheries and Food. London, HMSO. *Technical Bulletin 33.* 79 p.

Mosel, M. van, Klooster, A. Th. van't, Mosel, F. van & Kuilen, J van der. 1993. Effects of reducing dietary $(Na^+ + K^+)–(Cl^- + SO_4^-)$ on the rate of calcium mobilisation by dairy cows at parturition. *Research in Veterinary Science* 54: 1–9.

Oetzel, G. R., Fettman, M. J., Hamar, D. W. & Olson, J. D. 1991. Screening of anionic salts for palatability, effects on acid-base status and urinary calcium excretion in dairy cows. *Journal of Dairy Science* 74: 965–971.

–, Olson, J. D., Curtis C. R. & Fettman, M. J. 1988. Ammonium chloride and ammonium sulphate for prevention of parturient paresis in dairy cows. *Journal of Dairy Science* 71: 3302–3309.

Phillippo, M., Reid, G. W. & Nevison, I. M. 1994. Parturient hypocalcaemia in dairy cows, Effects of dietary acidity on plasma minerals and calciotrophic hormones. *Research in Veterinary Science* 56: 303–309.

Prockop, D. J. & Udenfriend, S. 1960. A specific method for the analysis of hydroxyproline in ttissues and urine. *Analytical Biochemistry* 1: 228–239.

Radostits, O. M., Blood, D. C. & Gay, C. G. 1994. *Veterian Medicine*. 8th ed. Bailliere Tindal. London. p. 1315, 1319, 1727.

SAS 1985. *SAS User's Guide, Statistics*. 5th ed. SAS Institute Inc. Cary, NC USA. 956 p.

Schonewille, J. Th., Klooster, A. Th. van't & Beynen, A. C. 1994. The addition of extra calcium to chloride-rich ration does not affect the absolute amount of calcium absorbed by non-pregnant, dry cows. *Journal of Animal Physiology and Animal Nutrition* 72: 272–280.

Stacy, B. D. & Wilson, B. W. 1970. Acidosis and hypercalciuria: renal mechanisms affecting calcium, magnesium and sodium excretion in the sheep. *Journal of Physiology* 210: 549–564.

Tayssky, H. H. & Shorr, E. 1953. A microcolorimetric method for the determination of inorganic phosphorus. *Journal of Biology Chemistry* 202: 675–685.

Tilley, J. & Terry, R. 1963. A two-stage technique for *in vitro* digestion of forage crops. *Journal of British Grassland Society* 18: 104–111.

Tucker, W. B., Hogue, J. F., Adams, G.D., Aslam, M., Shin, I.S. & Morgan, G. 1992. Influence of dietary cation-anion balance during the dry period on the occurrence of parturient paresis in cows fed excess calcium. *Journal of Animal Science* 70: 1238–1250.

–, Hogue, J. F., Waterman, D. F., Swenson, T. S., Xin, Z., Hemken, R. W., Jackson, J. A., Adams, G. D., & Spicer, L. J. 1991. Role of sulfur and chloride in the dietary cation-anion balance equation for lactating dairy cattle. *Journal of Animal Science* 69: 1205–1213.

Tuori, M., Kaustell, K., Valaja, J., Aimonen, E., Saarisalo, E. & Huhtanen, P. 1995. *Rehutaulukot ja ruokintasuositukset*. Helsinki. 99 p.

Wang, C. & Beede, D. K. 1992. Effects of ammonium chloride and sulphate on acid–base status and calcium metabolism of dry Jersey cows. *Journal of Dairy Science* 75: 820–828.

Welcher, F. J. (ed). 1963. *Standard methods of chemical analysis*. 6th ed. D.Van Nostrand company, Inc. (Canada), Ltd. USA. p. 254–256.

Windman, E. E., Jones, G. M., Wagner, P. E., Boman, R. L., Troutt, H. F. Jr & Lesch, T. N. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. *Journal of Dairy Science* 65: 495–501.

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SELOSTUS

Kationi-anionitasapaino ja kalsiumin saanti ummessaolevien lypsylehmien säilörehuruokinnassa

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Kokeessa selvitettiin kationi-anionitasapainon ja kalsiumin saannin vaikutusta ummessaolevien lehmien tiettyihin verestä ja virtsasta mitattuihin kivennäisarvoihin sekä happo-emästasapainoon säilörehuvaltaisella ruokinnalla. Tarkoituksena oli testata, voidaanko anionisten suolojen lisäämisellä ennen poikimista vaikuttaa poikimisen aikaiseen kalsiumaineenvaihduntaan. Lisäksi tutkittiin, onko kalsiumin saannilla vaikutusta anionisten suolojen tehoon. Kationi-anionitasapaino laskettiin [$(Na^+ + K^+) – (Cl^- + S^{2-})$] mEq/kg kuiva-ainetta (ka). Se oli joko –273 tai +34 mEq/kg ka. Kalsiumin saanti oli joko 34 g tai 74 g kalsiumia päivässä. Suoloina käytettiin magnesiumkloridia, ammoniumkloridia ja -sulfaattia. Lehmät saivat säilörehua (5.2 kg ka), heinää (0.9 kg ka) ja täysrehua (1.4 kg ka) neljä viikkoa ennen odotettua poikimista poikimispäivään saakka. Veri- ja virtsanäytteitä otettiin 4, 3, 2 ja 1 viikkoa ennen odotettua poikimista sekä poikimispäivänä, 1 vrk ja 1 viikko poikimisen jälkeen. Lehmien, joiden kationi-anionitasapaino oli säädetty negatiiviseksi, veren ionisoitunut kalsium säilyi poikimisen aikaan vakaana verrattuna lehmiin, joiden kationi-anionitasapaino oli positiivinen. Kationi-anionitasapaino –247 mEq/kg ka osoittautui kuitenkin liian negatiiviseksi, koska se aiheutti muutoksia lehmien veren happo-emäsarvoihin sekä alensi liikaa virtsan pH-arvoa (<6). Lisäksi koerehun maittavuus oli huono. Kalsiumin saannilla ei ollut vaikutusta mitattuihin parametreihin.