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Effect of anionic salts and potassium intake on some blood and urine minerals and acid-base balance of dry pregnant cows on grass silage based feeding *

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ABSTRACT

Twenty-one Ayshire cows were randomly assigned to one of three diets to determine the effect of an anionic diet and high potassium (K) intake on mineral metabolism, acid-base status and feed intake of dairy cows fed grass silage based diets during the dry period. Dietary cation-anion balance (DCAB), calculated as milliequivalents [$(Na^+ + K^+) - (Cl^- + S^{2-})$], for high DCAB (control), high DCAB + K-supplement (added as $KHCO_3$) and low DCAB treatments were +298, +571 and +107 mEq/kg DM, respectively. Dietary magnesium (Mg) content, equivalent to a daily Mg intake of 33 g, was on average 0.4% (in a DM basis). Cows received grass silage (5.2 kg DM), hay (0.9 kg DM) and concentrate mixture (2.7 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 and 1 week after calving. Only urinary pH was significantly affected by a low DCAB prepartum. K supplementation decreased fractional excretion of Mg and Na in the urine and significantly increased prepartum urinary K excretion. A dietary K concentration of 34 g/kg DM coupled with a high Mg intake of 4 g/kg DM in the prepartum diet may negatively effect Mg metabolism after parturition.

KEY WORDS: calcium, cows, ion balance, minerals, parturient paresis, potassium

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INTRODUCTION

Acidic diets have been successfully used to prevent parturient hypocalcaemia in dairy cows (Block, 1984; Oetzel et al., 1988; Goff et al., 1991). When a low dietary cation anion balance (DCAB) has been fed to dry cows, the blood calcium (Ca) concentration has remained more stable around parturition relative to high DCAB diets (Wang and Beede, 1992; Abu Damir et al., 1994; Phillippo et al., 1994). In most studies of DCAB feeding, diets have been formulated as a total mixed ration (TMR) (Block, 1984; Goff et al., 1991; Goff and Horst, 1997). However, in Finland concentrates and forages are traditionally fed separately, and the use of low DCAB diets has not been used for the prevention of parturient hypocalcaemia. In previous studies (Tauriainen et al., 1998a,b,c) a concentrate mixture which contained anionic salts for dry cows has been evaluated in cows fed a grass silage based diet with a relatively high potassium (K) content (mean 30 g/kg dry matter, DM). It appears that the development of a suitable concentrate mixture which would balance the high cationic load of grass silage, having a high palatability, and also would be effective and safe is difficult.

Goff and Horst (1997) found that dietary K concentration of 21 g and 31 g/kg DM increased the incidence of parturient hypocalcaemia compared with diets containing 11 g/kg DM. On this basis, it was suggested that dietary Ca concentration is not a major risk factor for parturient hypocalcaemia, but reactive cations such as K could induce metabolic alkalosis in the prepartum dairy cow, which has a detrimental influence on Ca homeostasis. Between 1996 and 1999 the mean K content of grass silage and pre-wilted grass silage in Finland has been 21 and 25 g/kg DM, respectively (Nousiainen, 2000). In some farms the K content of grass silage, particularly after wilting, can be as high as 50 g/kg DM, corresponding to a total dietary K concentration of between 35 and 45 g/kg DM. Cows fed such diets could be predisposed to hypocalcaemia and parturient hypocalcaemia.

Udder oedema has been reported postpartum, when 15 g/kg DM of $CaCl_2$ was offered compared to 22 g/kg DM of limestone 3 weeks before expected calving date to Holstein heifers (Lema et al., 1992). Dietary inclusion of NaCl or $KHCO_3$ from 45 d prepartum to 10 d postpartum has been shown to increase the severity of udder oedema, but addition of both salts had no influence (Nestor et al., 1988). Supplemental NaCl (227 g/d), KCl (227 g/d) or both 30 days prepartum resulted in a greater incidence of oedema than non-supplemented diets (Randall et al., 1974). Reports on the possible relationship between udder oedema and DCAB are limited and tended to be conflicting. According to Kiess et al. (1987), the incidence of udder oedema was not significantly correlated with DCAB. However, Tucker et al. (1991) found that udder oedema regressed postpartum more rapidly in cows previously fed a low DCAB (-30 mEq/kg DM) relative to cows

fed a high DCAB (+90 mEq/kg DM). In an earlier study (Tauriainen et al., 1998a) severe udder oedema was unexpectedly observed in a high proportion of cows when the DCAB was -247 mEq/kg DM, but the incidence was not routinely evaluated and as such these findings were not documented.

The current experiment was conducted in order to assess the effect of anionic salts and high dietary K content on some blood and urinary mineral concentrations. Since earlier studies (Tauriainen et al., 1998bc) have indicated that recommended magnesium (Mg) intakes (14 g/d) for dry cows may be too low, Mg intakes in the current study were increased to a higher level (33 g/d). The potential influence of anionic salts in the concentrate mixture or supplemental K in the diet on the degree of udder oedema was also monitored.

MATERIAL AND METHODS

Experimental design and treatments

Twenty-one multiparous Finnish Ayrshire cows (age 48±14 months) and no history of parturient paresis from previous lactations were selected from the research herd of the University of Helsinki. Cows weighed 638±58 kg at the beginning of the trial, and were randomly allocated to one of three dietary treatments with 7 cows per diet. Cows were fed grass silage (5.2 kg DM/d), hay (0.9 kg DM/d) and concentrate treatments (2.7 kg DM/d). The experimental feeding period started 4 weeks prior to expected calving date of each cow and ended at parturition. Immediately after calving, cows entered the routine nutrition and management program adopted at the research farm of the University of Helsinki.

Experimental diets were: Diet 1, high DCAB (control), Diet 2, high DCAB and K supplement fed as $KHCO_3$, and Diet 3, low DCAB. Cows were divided into two blocks according to age (2nd parity and >2nd parity). Within each block cows were randomly assigned to one of three treatments in groups according to the expected calving date. The low DCAB diet contained additional chlorine (Cl) and sulphur (S), supplied primarily by adding chlorides of ammonium and magnesium, and magnesium sulphate. Anionic salts were included in the concentrate mixture that was subsequently pelleted (diameter 5 mm). Composition of experimental diets and concentrate mixtures are shown in Table 1. Using the formula $(Na^+ + K^+) - (Cl^- + S^{2-})$ mEq/kg DM, the control, high DCAB and low DCAB diets contained +298, +571 and +107 mEq/kg DM, respectively. Sulphur was included to avoid an excessive Cl^- content, since the effect of S^{2-} on the systemic acid-base status in lactating cows has been reported to be similar to that of Cl^- (Tucker et al., 1991). The high K level was achieved by dietary inclusion

TABLE 1

Formulation of experimental diets[1]

Ingredient, %	Concentrate		
	control	high DCAB[2]	low DCAB
Oat	27.77		
Wheat-protein	20.85	19.88	17.95
Oat bran	16.06	13.70	17.42
Barley	14.59	9.74	12.08
Wheat molasses	7.24	7.15	7.33
$CaCO_3$	4.85	4.79	4.14
$MgPO_4$	3.55	3.62	-
NaCl	0.65	0.64	0.65
$KHCO_3$	-	10.62	-
$CaPO_4$	-	-	2.14
NH_4Cl	-	-	2.18
$MgCl_2$	-	-	1.84
$MgSO_4$	-	-	1.95
Flavour premix	2.98	3.93	4.73
Plant oil	0.56	0.55	0.57
Selenium mix	0.50	0.49	0.51
Vitamin mix	0.20	0.20	0.20
Trace element mix	0.20	0.20	0.20
Dietary inclusion, %			
grass silage	59.16	59.00	59.12
hay	10.35	10.36	10.35
concentrate mixture	30.49	30.64	30.53

[1] dry matter basis

[2] dietary cation-anion balance

of $KHCO_3$. According to Schonewille et al. (1999) added and intrinsic K have the same effects at least on ruminal K concentrations and Mg absorption from the rumen. Chemical composition of experimental diets is documented in Table 2.

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 concentrates once daily (1430 h). In case of refused feed, refusals were weighed and the dry matter content was determined. Samples of grass silage, hay and concentrate collected each week were pooled; grass silage was combined into monthly samples and hay 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 assessed on a scale from 1 to 5, where 1 represented extremely thin and 5 represented extremely obese animals (Windman et al., 1982).

TABLE 2

Dry matter intake, energy content, chemical composition[1] and cation-anion balance of experimental diets

	Control	High DCAB[2]	Low DCAB
DMI[3]kg/d	8.79	8.79	8.79
ME[4]MJ/kg DM	9.70	9.71	9.46
Crude protein, %	14.22	14.08	14.61
Crude fibre, %	25.11	24.67	24.85
ADF[5]%	31.33	24.02	24.18
NDF[6]%	47.03	45.91	45.89
Ca, %	0.78	0.86	0.85
P, %	0.43	0.44	0.42
Mg, %	0.38	0.41	0.34
K, %	2.37	3.42	2.52
Na, %	0.14	0.16	0.14
Cl, %	0.67	0.68	1.34
S, %	0.29	0.29	0.35
DCAB[7]mEq/kg DM	+298	+571	+107

[1] expressed on a dry matter (DM) 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 DM

Udder oedema was evaluated by measuring the vertical height from the hind udder attachment to the root of the hind teat and the horizontal width from the outer edge of the udder to the central ligament and marking a cross at the intersection of these lines. Measurements were performed from the centre of the cross to the central ligament and the root of rear teat of each side of the udder. Evaluation was done in the beginning of the experiment, two weeks later, at parturition and one week after calving.

Sample collection

Blood from jugular vein and urine samples were collected before afternoon feeding, 4, 3, 2, and 1 week prepartum, on the day of calving, and 1 and 7 days postpartum. Two samples were collected into 5 ml evacuated heparinized tubes (Venoject VT-050 SHL ,Terumo Europe N.V., Leuven, Belgium). The first was centrifuged (1000 g for 8 min) immediately after sampling and the resultant plasma was stored frozen (-20°C) for Na^+, K^+, Cl^-, total Ca, Mg, P and creatinine deter-

minations. The second was stored frozen (-20°C) for haemoglobin measurements. An additional sample was collected into a 2-ml syringe containing Ca-stabilized heparin (Pico 50, Radiometer Copenhagen) for measurements of acid-base status. Syringes were placed on ice after sampling. After an immediate determination of blood gases in whole blood, the remainder of the sample was used for measurements of ionized Ca and Mg concentrations. Cow body temperature was measured before each blood sampling with a metal thermometer.

Urine samples were collected by manual stimulation of the vulva and were frozen prior to pH, creatinine and P determinations. Five ml of urine were transferred into a tube containing 0.5 ml of 12 N HCl and frozen for subsequent of total Ca, Mg, K and Na determinations.

Analyses

Blood pH, partial pressure of CO_2 (pCO_2) and acid-base excess were measured using a blood gas analyser (ABL3 Acid-Base Laboratory, Radiometer A/S, Copenhagen, Denmark). Measurements of pH and pCO_2 were corrected for measured body temperature for each cow according to the manufacturer instructions. Corrected pH and pCO_2 values were subsequently used to calculate true bicarbonate ($aHCO_3$) and base excess (BE) values.

Plasma and urinary Ca and Mg concentrations were assessed by an atomic absorption spectrophotometer (Model 2380, Perkin Elmer Corp., Norwalk, Conn., USA), and creatinine concentrations were determined using an automated kinetic alkaline picrate method (Fabiny and Ertigshausen, 1971). Inorganic phosphorus in plasma was determined based on the colorimetric method of Daly and Ertigshausen (1972). Concentrations of Na^+, K^+ and Cl^- in plasma (KONE Microlyte 3 + 2, KONE Corp., Espoo, Finland) and ionized Ca and Mg in whole blood (Microlyte 6 Ion Selective Analyser, Konelab Corp., Espoo, Finland) were analysed using ion-specific electrodes.

Concentrations of Na and K in urine were determined using a flame photometer (Corning 480, Ciba Corning Diagnostics Limited, Halstead, UK). Urinary pH was measured with a pH meter (Radiometer Copenhagen, PHM 83 Autocal pH meter). Fractional excretion (FE_x) of electrolytes (x) was calculated as:

$$FE_x, \% = x_u \times creatinine_p / x_p \times creatinine_u \times 100$$

where u refers to urinary electrolyte concentration, and p to the corresponding concentration in plasma.

The Cl content of grass silage was determined according to standard procedures (AOAC, 1984). Chemical composition of feeds was measured according to previously reported methods (Tauriainen et al., 1998a).

Statistical analysis

Experimental data was analysed in two parts; prepartum from 4 weeks to 1 week before the expected calving date and peripartum from 1 week before expected calving to 1 week after calving. Plasma and urinary data was analysed by repeated measures analysis of variance using the SAS (1985) general linear model procedure for a complete block design that included the following model:

$$Y_{ij,} = \mu + T_i + P_j + e_{ij}$$

where μ is the general mean, T_i is the effect of treatment *i*, P_j is effect of parity *j* and e_{ij} the error term.

Because there was no interaction between treatments and parity, this interaction term was subsequently excluded from the model. Treatment differences were evaluated using the Tukey test. Residuals of all data within dietary treatments were assessed for normality (Shapiro-Wilk test). Because preliminary analysis of raw data indicated heterogeneous variance for urinary Ca/creatinine and P/creatinine rations and fractional Na and Mg excretion, these variables were logarithmically transformed to achieve a more homogeneous variance. An one-way analysis of variance of the three treatment groups was performed for data collected at 4 weeks before the expected calving date to assess initial differences between experimental groups. Due to significant ($P<0.05$) differences between Mg/creatinine at the start of the trial, pre-treatment values were used as covariates. Udder oedema data was analysed by week using least squares analysis of variance, following the general linear models procedure. The statistical model was:

$$Y_{ij,} = \mu + T_i + P_j + e_{ij}$$

where μ is the general mean, T_i is the effect of treatment *i*, P_j is effect of parity *j* and e_{ij} the error term.

For the vertical height measures of udder oedema, initial values were used as a covariate. For all analysis $P<0.05$ was considered to reflect significant differences.

RESULTS

Cows were fed a fixed ration throughout the experiment. Palatability of all experimental concentrates was good with no refusals, leading to similar intake between treatments (Table 2). The mean body condition of all cows at parturition was 3.3, indicating that the slightly lower feeding level than that recommended in Finland during the dry period (Tuori et al., 1996) had no visible adverse effects on the cows. No significant udder oedema was identified during the entire trial for any of the treatment groups.

A lowered cation-anion balance had no effect on measured blood parameters (Table 3). One of the cows in K-supplement group showed clinical signs of parturient hypocalcaemia around parturition and was treated with a Ca infusion after blood sampling (Ca^{2+} 0.74 mmol/l). Two cows in the low DCAB group and one cow in the K-supplement group had a low blood Ca level (Ca^{2+} < 1.00 mmol/l) at parturition. Cows calving for the second time had a significantly lower ($P<0.05$) plasma Ca concentration prepartum compared with multiparous cows, although at parturition the mean value for older cows was lower. Total plasma Mg and blood ionized Mg were not affected by treatments, but five cows from the K-supplement group and one cow in the low DCAB group were found to have subclinical hypomagnesaemia one week after parturition indicated by a plasma Mg below 0.85 mmol/l (Samson et al., 1983). The lowest mean plasma Mg concentration (0.80 mmol/l) was observed for the K-supplement group one week after calving (Table 3). Concentrations of total Ca, inorganic P, Na and Cl in plasma were unaffected by K-supplementation during the trial, but plasma K concentrations tended to be higher prepartum and lower on the day of calving than that of other treatment groups. Blood Ca^{2+} and plasma inorganic P, Na^{+}, K^{+} and Cl^{-} did not differ between treatment groups. Blood pH, HCO_3^{-} and base excess were not affected by experimental diets indicating that all cows were acid-base balanced.

Urinary pH was significantly lower ($P<0.01$) in the low DCAB diet prepartum than other treatments and its was lower ($P<0.05$) for second parity than older cows (Table 4). All other parameters measured from urine were unaffected by age. In the K-supplemented group, urinary pH was lower than in the other treatment groups after parturition, although the difference was not statistically significant. Urinary FE% of Mg and Na were markedly lower ($P<0.01$) prepartum in cows fed K-supplement compared with cows fed the other experimental diets. Urinary K excretion was higher ($P<0.05$) and urinary FE% of K tended to be higher in the K-supplement group relative to other treatment groups prepartum (Table 4). Neither urinary excretion of Ca, P and Na, nor urinary FE% of Ca and P were significantly influenced by treatments prepartum. All parameters measured from urine peripartum were unaffected by treatments.

DISCUSSION

Current results imply that a high dietary K content during the dry period may have a negative effect on Mg metabolism in the beginning of lactation when Mg secretion in milk rapidly increases. High dietary concentrations of K are known to inhibit Mg utilization in ruminants (Greene et al., 1983; Khorasani and Armstrong, 1990; Schonewille et al., 1997). In the current study five cows from se-

TABLE 3

Effect of dietary cation-anion balance (DCAB) and K intake on mean plasma mineral concentrations

	Factor	Time from parturition							Significance[2]	
		-4 wk	-3 wk	-2 wk	-1 wk	0	+1 d	+1 wk	prepar-tum	peripar-tum
Calcium[2+] mmol/l	Control	1.31	1.29	1.31	1.31	1.12	1.15	1.28		
	K-suppl	1.33	1.29	1.34	1.29	1.05	1.16	1.35		
	Anionic	1.30	1.28	1.29	1.32	1.05	1.15	1.28		
	SEM[1]	0.020	0.011	0.021	0.013	0.041	0.039	0.032	ns	ns
	2nd parity	1.30	1.28	1.30	1.30	1.13	1.17	1.29		
	>2nd parity	1.32	1.29	1.32	1.30	1.02	1.14	1.31		
	SEM	0.014	0.0074	0.014	0.010	0.031	0.030	0.024	ns	ns
Calcium[ion] mmol/l	Control	2.63	2.54	2.55	2.64	2.20	2.23	2.58		
	K-suppl	2.54	2.42	2.54	2.43	1.89	2.09	2.55		
	Anionic	2.55	2.45	2.47	2.56	1.94	2.18	2.53		
	SEM	0.084	0.064	0.070	0.073	0.130	0.092	0.118	ns	ns
	2nd parity	2.43	2.38	2.44	2.46	2.05	2.14	2.44		
	>2nd parity	2.71	2.56	2.60	2.63	1.97	2.19	2.67		
	SEM	0.064	0.048	0.054	0.056	0.099	0.070	0.090	parity*[3]	ns
Magnesium[ion] mmol/l	Control	1.00	1.04	0.99	0.99	1.06	1.14	0.98		
	K-suppl	0.93	1.02	1.01	0.99	1.00	1.02	0.80		
	Anionic	0.97	1.00	0.97	0.94	1.01	1.02	0.90		
	SEM	0.026	0.028	0.026	0.032	0.038	0.046	0.051	ns	ns
	2nd parity	0.95	1.00	0.96	0.94	1.01	1.09	0.88		
	>2nd parity	0.98	1.04	1.02	1.00	1.04	1.03	0.91		
	SEM	0.019	0.021	0.020	0.024	0.029	0.035	0.039	ns	ns
Potassium mmol/l	Control	4.25	4.45	4.30	4.13	4.00	4.11	3.87		
	K-suppl	4.09	4.64	4.46	4.56	3.80	4.22	3.97		
	Anionic	4.01	4.32	4.36	4.03	4.10	3.81	3.90		
	SEM	0.145	0.102	0.148	0.089	0.126	0.146	0.112	ns	ns
	2nd parity	4.14	4.50	4.39	4.20	4.00	4.11	3.92		
	>2nd parity	4.09	4.45	4.35	4.29	3.93	3.98	3.91		
	SEM	0.110	0.078	0.113	0.068	0.096	0.111	0.085	ns	ns

[1] SEM = standard error of means, due to unbalanced data standard errors vary. Lower value is given. Maximum deviated at most from lower value 9.6%

[2] $P < 0.05$*, $P < 0.01$**, $P < 0.001$***

[3] parity = 2nd parity vs >2nd parity

TABLE 4

Effect of dietary cation-anion balance (DCAB) and K intake on mean urinary pH and mineral excretion

	Factor	Time from parturition							Significance[2]	
		-4 wk	-3 wk	-2 wk	-1 wk	0	+1 d	+1 wk	prepar-tum	peripar-tum
pH in urine	Control	8.24	8.39	8.33	8.29	8.31	8.20	8.29		
	K-suppl	8.25	8.41	8.41	8.38	8.30	7.97	7.81		
	Anionic	8.24	8.20	7.99	8.07	8.07	8.06	8.21		
	SEM[1]	0.064	0.042	0.079	0.056	0.063	0.117	0.169	anionic**[3]	ns
	2nd parity	8.27	8.25	8.18	8.16	8.24	8.20	8.24		
	>2nd parity	8.22	8.42	8.32	8.33	8.22	7.95	7.96		
	SEM	0.048	0.032	0.060	0.043	0.048	0.089	0.129	parity*[4]	ns
Ca/creat.[6]	Control	0.49	0.11	0.10	0.05	0.06	0.03	0.09		
	K-suppl	0.22	0.14	0.05	0.04	0.03	0.06	0.37		
	Anionic	0.43	0.22	0.13	0.22	0.03	0.02	0.25		
	SEM	0.155	0.060	0.031	0.030	0.018	0.012	0.145	ns	ns
K/creat.	Control	38.9	43.2	44.3	45.6	35.6	57.6	56.0		
	K-suppl	42.6	59.3	63.1	64.2	51.1	52.0	62.6		
	Anionic	59.3	46.8	46.5	51.8	36.7	61.7	60.5		
	SEM	8.79	4.18	4.13	3.74	5.62	5.38	7.63	K-suppl*[5]	ns
Ca FE%[7]	Control	1.96	0.48	0.46	0.26	0.37	0.14	0.41		
	K-suppl	0.96	0.60	0.17	0.20	0.17	0.27	1.12		
	Anionic	1.49	0.96	0.59	1.08	0.17	0.10	0.92		
	SEM	0.590	0.280	0.142	0.161	0.116	0.055	0.437	ns	ns
Mg FE%	Control	6.85	11.41	11.47	9.89	6.60	9.18	4.67		
	K-suppl	4.45	7.48	6.26	6.23	2.45	3.50	7.00		
	Anionic	9.08	12.05	10.62	11.74	4.54	4.76	5.69		
	SEM	1.195	1.287	1.440	1.729	1.209	1.098	1.374	K-suppl.**	ns
K FE%	Control	89.1	102.7	119.6	135.0	112.4	162.1	155.5		
	K-suppl	102.3	128.5	146.0	165.9	158.4	127.2	142.2		
	Anionic	128.6	105.0	108.4	142.7	102.1	168.1	136.0		
	SEM	16.42	9.13	8.39	12.37	13.07	12.18	18.72	parity*	ns
Na FE%	Control	6.85	11.41	11.47	9.89	6.60	9.18	4.67		
	K-suppl	4.45	7.48	6.26	6.23	2.45	3.50	7.00		
	Anionic	9.08	12.05	10.62	11.74	4.54	4.76	5.69		
	SEM	1.195	1.287	1.440	1.729	1.209	1.098	1.374	K-suppl.**	ns

[1] SEM = standard error of means, due to unbalanced data standard errors vary. Lower value is given. Maximum deviated at most from lower value 9.6%

[2] $P < 0.05$ *, $P < 0.01$ **, $P < 0.001$ ***

[3] Tukey; anionic salts vs other treatments

[4] parity = 2nd parity vs >2nd parity

[5] Tukey; K-supplement vs. other treatments

[6] = mmol/mmol

[7] = fractional excretion

ven had subclinical hypomagnesaemia one week after parturition in the K-supplemented group. Such an observation was unexpected since the K-supplement had already been removed at parturition and the Mg content of prepartum diets was relatively high (4.1 g Mg/kg DM). In addition, all cows received the same feeds after calving which composed of a commercial concentrate and mineral mix fed according to milk yield and grass silage *ad libitum*. However, K is the most abundant intracellular cation, and it is possible that during supplementation, K was transiently stored intracellularly. After calving when the feeding was changed, it is likely that there is a lag time associated with the redistribution of K between extracellular and intracellular fluid.

One cow in the K-supplement group showed clinical signs of parturient hypocalcaemia and another had low Ca^{2+} status since blood Ca^{2+} concentrations were below 1.00 mmol/l (Radostits et al., 1994). These findings are consistent with the study of Goff and Horst (1997) who demonstrated that dietary K intake was associated with a predisposition to parturient hypocalcaemia. In the current experiment dietary content of control, K-supplemented and anionic treatments were 24, 34 and 25 g/kg DM, respectively. According to Goff and Horst (1997) the level of K in the control group should have lead to a predisposition to hypocalcaemia, but no incidences were observed. These findings cannot be explained by age, a factor known to increase the risk of hypocalcaemia (Radostits et al., 1994), since all experimental animals were relatively young.

Cows in the K-supplemented group tended to have higher plasma K concentrations during the study and excreted significantly ($P<0.05$) more K in the urine than the other groups. Supplementation with K caused a significant ($P<0.01$) renal conservation of Mg and Na, since FE% of Mg and Na was lower relative to other treatment groups. It is likely that Na is conserved by the secretion of aldosterone and that the subsequent increase in tubular reabsorption of Na in the kidney leads to an increase in K excretion. Increased diuresis has been observed in cows fed KCl at the rate of 1.5 g/kg body weight (Deetz et al., 1982).

Urinary pH was significantly lower ($P<0.01$) for cows fed the low DCAB prepartum compared with the other treatments, indicating a rapid renal recognition of the excessive dietary acid load. This finding is consistent with earlier studies where the acid-base status of dry cows could be modified even within the positive DCAB range, although no effects on urinary mineral excretion were observed (Delaquis and Block, 1995). Acidification must be stronger since no changes in blood Ca^{2+} were noticed. In the present study, urinary pH decreased for the K-supplemented group after parturition compared with other treatment groups, but the reason for this phenomena remains unclear.

In the current study we offered cautiously anionic salts not to modify the palatability of experimental diets. As a result, even the low DCAB remained positive (+107 mEq/kg DM) and ionized Ca in blood, total Ca in plasma and

urinary Ca excretion were unaffected. Futhermore, two from seven cows had low ionized Ca concentrations at parturition. DCAB should be under -30 mEq/kg DM to affect acid-base status and subsequently improve Ca metabolism (Tucker et al., 1992). Using a daily dose of 3 Eq of anionic salts per cow as recommended by Oetzel (1993), the DCAB would have been -67 mEq/kg DM.

Poor palatability is a potential problem with anionic concentrate mixtures. In the current study a daily intake of 1.8 Eq of anionic salts was shown to have no detrimental effects on intake. According to Oetzel et al. (1991), the amount of anionic salts (Eq/day) could be higher since an intake of anionic salts (2 Eq/d) maintained intake, but at higher levels of 2.3 Eq/day a dramatic decrease in the acceptability of the concentrate mixture was noticed (Oetzel and Barmore, 1993). However, anionic salt intake does not fully explain the effects on intake, since a daily intake of 3.2 Eq has in some (Tauriainen et al., 1998a) but not all cases (Tauriainen et al., 1998b,c) had detrimental effects. It is likely that there are factors other than the amount anionic salt equivalents that effect the palatability of a concentrate mixtures. In the present study, palatability could be improved by the inclusion of wheat molasses in the concentrate mixture to disguise the bitter taste of anionic salts. Futhermore, the odorous substance of coconut also encouraged the cows to eat.

Udder oedema has been evaluated using a subjective categorical scoring from 1 to 5 (Randall et al., 1974; Dentine and McDaniel, 1983; Nestor et al., 1988). We tested a quantitative method to measure udder oedema. It appears that this approach requires simultaneous evaluation with the subjective method, since in some cows the oedema appeared to spread cranially under the abdomen, a phenomena which could not be taken into account in quantitative measurements. Two weeks before the expected calving date would be a more suitable time to start the evaluation of udder oedema since 4 weeks before expected parturition was too early.

In conclusion, the palatability of concentrate mixtures was not depressed by the presence of anionic salts, although their inclusion had no effect on Ca metabolism of dry cows. The target for effective DCAB should be below -30 mEq/kg DM. Increases in Mg intake from recommended levels of 17 g/d to 33 g/d appeared to be beneficial since only one cow had a plasma Mg concentration below 0.85 mmol/l at parturition. However, a dietary K concentration of 34 g/kg DM coupled with a high Mg intake of 4 g/kg DM in the prepartum diet may negatively effect Mg metabolism after parturition. This phenomenon should be noted under practical conditions whenever K intake of cows is changed.

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STRESZCZENIE

Wpływ podania soli anionowych i potasu na zawartość niektórych składników mineralnych w krwi i moczu oraz równowagę kwasową u zasuszonych cielnych krów żywionych kiszonką z traw

Dwadzieścia jeden krów Ayshire podzielono losowo na 3 grupy żywieniowe celem zbadania wpływu soli anionowych oraz pobrania wysokich dawek potasu (K) na przemianę mineralną, równowagę kwasową i pobranie paszy przez zasuszone krowy otrzymujące kiszonkę z traw jako paszę podstawową. Bilans kationowo-anionowy (DCAB), obliczony w milirównoważnikach [$(Na^+ + K^+) - (Cl^- + S^{2-})$] przy wysokim DCAB (kontrola), wysokim DCAB z dodatkiem K (jako $KHCO_3$) oraz niskim DCAB wynosił +298, +571 i +107 mEq/kg s.m., odpowiednio. Zawartość magnezu (Mg) w dawce, odpowiadająca 33 g dziennego pobrania Mg, wynosiła średnio 0,4% w s.m.. Krowy otrzymywały kiszonkę z traw (5,2 kg s.m.), siano (0,9 kg s.m.) i mieszankę treściwą (2,7 kg s.m.) aż do ocielenia. Próby krwi i moczu pobierano 4, 3, 2 i 1-go tygodnia przed spodziewaną datą wycielenia, przy wycieleniu oraz 1-go dnia tydzień po wycieleniu. Podawanie dawki z niskim bilansem DCAB wpłynęło istotnie tylko na pH moczu przed wycieleniem. Dodatek K obniżał wydalanie w moczu Mg i Na, a istotnie zwiększał wydalanie K do czasu wycielenia. Dzienna dawka K, 34 g/kg s.m., w połączeniu z wysokim pobraniem Mg, 4 g/kg s.m., w okresie przed wycieleniem, wpłynęła ujemnie na przemianę Mg po wycieleniu.