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INFLUENCE OF INCREASING DIETARY CATION-ANION BALANCE ON THE PERFORMANCE OF LACTATING DAIRY CATTLE

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ABSTRACT

Twelve mid-lactation Holstein cows were blocked according to milk production and assigned to diets containing +12, +29, +54, or +64 meq [$(Na^+ + K^+) - Cl^-$] 100^{-1} g diet dry matter (DM). The objective of this study was to examine diets having cation-anion balances spanning a range wider than had been examined previously. Diets were mixed to contain a 60:40 concentrate to corn silage ration (DM basis). Treatment periods were 3 wk with the first 2 wk serving as an adaptation period. Feed intake, actual milk yield, milk fat, fat yield, and 3.5% FCM increased as dietary cation- anion balance increased to +54 meq 100^{-1} g DM. Blood pH, PCO2 and HCO_3^- increased with increasing dietary cation-anion balance. Plasma Na^+, K^+, and Mg^{2+} levels were unaffected by the dietary treatment. Urinary pH was lower for cows fed the +12 diet than for those fed all other diets. Urinary Na^+, K^+

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and Cl^- tended to reflect dietary concentration of these minerals. Cows fed the +12 diet excreted more Cl^- and Ca^{2+} in urine compared with those fed all other treatments. Ruminal pH was not affected by the dietaary treatment. Fermentation patterns were only slightly affected by the dietary cation-anion balance. The results suggest that dietary cation-anion balance may become a useful tool when examining the overall performance of lactating dairy cattle.

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تا ثیر افزایش موازنه کاتیون-آنیون برتولید شیر گاوهای شیری

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چکیده

دوا زده گاو هولشتین که در اواسط دوره شیردهی بودند براساس تولید شیر برای تغذیه با جیره های حاوی ۱۲+ ۵۴+ و ۶۴+ میلی اکی والان موازنه مجموع (سدیم و پتاسیم نسبت به کلر)

در ۱۰۰ گرم ماده خشک، گروه بندی شدند. هدف ا زاین مطالعه آ زمایش کردن جیره های حاوی تعادل های کاتیون-آنیونی بود که طیف وسیعتری نسبت به آن چه که بیشتر آزمایش شده بود داشتند. جیره های غذائی، ۶۰٪ کنسا نتره و ۴۰٪ سیلوی ذرت براساس ماده خشک داشتند. دوره های آ زمایش (تیمار) سه هفته بود که ا ز دوهفته اول بعنوان دوره اداپته شدن (عادت به جیره) استفاده شد. میزان مصرف غذا، تولید شیر واقعی، چربی شیر، تولید چربی و شیر تصحیح شده با ۳/۵٪چربی با افزایش تعادل کاتیون-آنیون تا۵۴ +میلی اکی والان افزایش یافت pH خون باافزایش موازنه کاتیون -آنیون افزایش یافت میزان منیزیم پتاسیم وسدیم پلاسما تحت تاثیر تیمارها قرا رنگرفت. pH ادرا ر برای گاوهائی که ا ز جیره ۱۲+ تغذیه شدند کمتر از آنهائی بود که دیگر جیره ها را مصرف کردند. مقدار کلر، پتاسیم وسدیم ادرا ر تقریبا منعکس کننده غلظت آنها در جیره بود. گاوهائی که جیره ۱۲+ را مصرف کردند در مقایسه با گاوهای دیگر کلر وکلسیم بیشتری را از طریق ادرا ر دفع کردند. pH شکمبه تحت تاثیر تیمارها قرار نگرفت. الگوهای تخمیر به مقدار کمی تحت تاثیر تعادل کاتیون-آنیون قرارگرفت. نتایج نشان می دهند که موازنه کاتیون-آنیون میتواند وسیله ای مفید به هنگام ارزیابی عملکرد کل گاوهای شیرده باشد.

INTRODUCTION

Dietary cation-anion balance (DCAB), the balance of positively and negatively charged ions in the diet, has been shown to be useful in predicting performance in non-ruminant species (4,12,15). The importance of cation-anion balance in the ruminant diet is well recognized. Although different views are expressed as to which minerals should and should not be included in the DCAB calculation, the two equations used most often are meq (Na^+ +

K^+)-$C1^-100^{-1}$ g diet DM and meq ($Na^+ + K^+$)- ($C1^- + S^-$) 100^{-1} g diet DM. Manipulation of the dietary cation-anion balance during the dry period appears to reduce the problems associated with parturient paresis in the postpartum cow. Dishington (9) observed a reduction in the incidence of parturient paresis in postpartum cows when the diet contained an excess of anions during the latter part of the dry period. Block (3) reported a 47% incidence of parturient paresis in cows fed diets containing +44.9 meq 100^{-1} g diet while those fed diets containing -17.2 meq 100^{-1} g diet had a zero incidence, supporting the observation of Dishington (9) Block (3) and Dishington (9) used the equattion meq ($Na^+ + K^+$)-($C1^- + S^-$). Results of Tucker *et al.* (19) indicate that S^- should be included when calculating cation-anion balance. Sulfur was found to be 0.6 time as effective as $C1^-$ as a urine acidifier. Sulfur, depending on the source, has a relative absorbance of about 0.6 that of $C1^-$ which may account for the observed difference in effectiveness.

While anionic diets may be helpful in reducing parturient paresis, a cationic diet appears to support higher milk production. Tucker *et al.* (18) observed an 8.6% increase in actual milk yield of cows when the DCAB was +20 meq when compared with those fed a -10 meq 100 g^{-1} diet DM. Blood, urine and rumen pH increased linearly with increasing DCAB.Coppock *et al.* (8), when interpreting data after the fact as it related to heat stress, suggested that manipulating the DCAB between +10 and +40 meq 100^{-1} g diet DM should cause little differences in intake and production responses. The objective of this sutdy was to examine the effects of DCAB on acid-base physiology and production in lactating dairy cows when diets contain DCAB from +10 to +70 meq 100^{-1} g diet.

MATERIALS AND METHODS

Twelve lactating Holstein cows (4 ruminally fistulated and 8 non-fistulated) ranging from 4 to 7 mo postpartum were assigned to 3 blocks of four cows each according to milk production (16-45 kg d^{-1}). A replicated 4x4 Latin square design with 3 wk periods was employed to compare DCAB treatments of: 1+10, 2+30, 3+50, and 4+70 meq$[(Na^+ + K^+) - Cl^-]$ 100^{-1} g diet DM. All diets contained 40% corn silage and 60% concentrate (DM basis). The trial was conducted from October to December of 1988. Treatment periods were 3 wk with the first 2 wk serving as an adaptation period and wk 3 serving as the data collection period for all parameters except DM intake, milk production, and milk constituents where the experimental period was the 3 wk treatment period. Diets were formulated to meet established nutrient requirments of dairy cattle (16) ; however fiber content was lower than recommended. Concentrations of Na^+, K^+,and Cl^- were manipulated to achieve the various dietary balances. Upon analysis, diets were found to contain +12, +29, +54, and +64 meq$[(Na^+ + K^+) - Cl^-]100^{-1}$ g diet DM which will be referred to as such throughout This anticle. Accounting for S^- in the DCAB calculation the diets were +1, +17, +42, and +52 meq $[(Na^+ + K^-) - (Cl^- + S^-)]100^{-1}$ g diet DM, respectively. Ingredient and chemical composition of diets are presented in Tables 1 and 2.

Cows were individually fed their respective diet twice at 0700 and 1700 h while housed in individual tie stalls. Daily measurements included milk production and feed intake. Milk samples were collected once weekly during consecutive morning and evening milkings and analyzed for milk fat and protein. Means reported for these parameters represent the 3 wk trial period. Concentrate mixes were sampled upon mixing and stored at -20 °C for subsequent analysis. The corn silage was sampled weekly for DM determination by toluene distillation, and concentrate DM was determined by

Table 1. Dietary composition of concentrates for different dietary cation-anion balances.

	Dietary cation-anion balance			
Ingredient	+12	+29	+54	+64
	% as fed basis			
Cracked corn	68.80	68.10	66.30	48.20
Soybean meal, 44%	28.40	28.30	27.30	29.65
Limestone	1.15	2.40	2.30	2.30
Calcium chloride, 95%	1.30	0.00	0.00	0.00
Sodium bicarbonate	0.00	0.85	3.75	4.50
Dry molasses	0.00	0.00	0.00	15.00
Selenium premix†	0.20	0.20	0.20	0.20
Vitamin ADE premix§	0.15	0.15	0.15	0.15

† Selenium 90

§ Contains 10,008,818 IU Vitamin A kg^{-1}, 2,204 586 IU vitamin D. and 1,102 IU vitamin E kg^{-1}.

oven drying for 48 h at 60 °C. Chemical analysis of the diets (Table 2) was determined according to the methods of AOAC (1) by Northeast Dairy Herd Improvement Association, Ithaca, NY.

Blood and urine samples were collected at 4 h postfeeding (during wk 3) Ruminal fluid was collected (via rumen fistula) from the four rumen fistulated cows at 4 h postfeeding (wk 3). Aliquots of milk samples from two consecutive milkings were combined. Minerals were extracted from milk by adding 10 ml of 9:1 concentrated nitric/perchloric acid to 1.0 ml of the sample. The flask was covered and heated overnight until digestion was completed. The mixture was carried to dryness over heat. Minerals were dissolved in 10.0 ml of 1.0 N HCl and stored frozen for subsequent mineral analysis. Thirty-ml blood samples were collected via jugular venipuncture and transferred into evacuated heparinized tubes. The blood was placed on

Table 2. Chemical composition of concentrate diet mix and corn silage[†]

Item Measured[§]	$[(Na^+ + K^+) - Cl^-,]$ meq 100^{-1} g diet				
	+12	+29	+54	+64	Corn silage
Dry matter, %	90.90	90.80	90.00	90.40	31.70
Crude protein, %	21.30	19.90	20.80	20.90	9.10
ADF, %	3.90	4.20	3.70	7.30	26.20
NDF, %	13.40	11.30	11.60	14.40	45.20
Calcium, %	1.33	0.97	1.02	1.29	0.34
Phosphorus, %	0.42	0.40	0.41	0.37	0.30
Magnesium, %	0.17	0.16	0.16	0.16	0.16
Sulfur, %	0.23	0.21	0.22	0.23	0.16
Sodium, %	0.02	0.19	1.03	1.30	0.02
Potassium, %	1.06	0.95	1.00	1.48	1.35
Chloride, %	0.88	0.06	0.05	0.15	0.32
Total diet balance[¶]	+11.90	+28.60	+54.0	+64.20	-
Total diet balance[††]	+ 0 .80	+16.70	+41.80	+51.60	-

[†] Dry matter basis.

[§] ADF=acid detergent fiber, NDF=neutral detergent fiber.

[¶] Calculated as $[(Na^+ + K^+) - Cl^-]$meg 100^{-1} g diet DM.

[††] Calculated as $[(Na^+ + K^+) - (Cl^- + S^-)]$ meq 100^{-1} g diet DM.

crushed ice and analyzed within 1 h for blood pH and PCO2 (Corning 150 pH/ion analyzer, Scientific Instruments, Medfield, MA). Blood bicarbonate was calculated from PCO2 and blood pH by fitting the data into the Henderson-Hasselbalch equation. Venous blood samples were centrifuged, plasma was transferred into clean glass tubes, and frozen (-20 °C) until subsequent mineral analysis. Urine samples were collected via manual stimulation of the vulva, analyzed for pH,and were acidified, and frozen (-20 °C) for subsequent mineral analysis.

Ruminal fluid was collected via rumen fistula with a stomach tube pump (with an attached strainer, 1-mm pores) and analyzed for pH. Ruminal fluid was then centrifuged at 7× 103 *g* for 10 min and 8 ml supernatants were transferred into glass tubes with 1.6 ml metaphosphoric acid (25% w/v). The tubes were stored frozen (-20 °C) for later volatile fatty acid (VFA) analysis (5880A Series Gas Chromatograph, Hewlett Packard, Avondale, PA). The remaining supernatant was frozen (-20 °C) for subsequent mineral analysis. Blood plasma, urine, milk, and ruminal fluid were analyzed for Na^+ and K^+ by flame photometry, Ca^{+2} and Mg^{+2} by atomic absorption spectrophotometry (Perkin-Elmer, Model 560 Norwalk, CT), Cl^- by spectrophotometry (Autoanalyzer, II, Technician Instruments Corporation, Tarrytown, NY), and phosphate by spectrophotometry (Spectronic 1001, Mitton Roy Company, Linden, NJ).

One cow turned dry and was removed during the last period of the study due to closeness of calving, with her results calculated as a missing plot. Statistical analysis was performed by SAS General Liner Models procedures (17) with the statistical model including square, cow (square), period, period*square, and treatment. The least squares difference test was used to compare treatment means with significant F values.

RESULTS AND DISCUSSION

Feed

Cows fed +12 DCAB diet had lower ($P<.05$) average daily DM intake (Table 3) when compared with cows fed the other diets and cows fed the +29 balance has lower ($P<.05$) DM intake than cows fed the +54 and +64 balance diets. This lower intake could be due to inadequate Na^+ levels in +12 diet. Even though lower DM intake of lactating cows fed a lower DCAB balance diet with adequate Na^+ has been observed previously (8, 18,21), Tucker *et al.*

Table 3. Feed intake, milk yield, and milk composition for cows fed diets of varying cation-anion balance.

	$[(Na^+ + K^+) - Cl^-]$ meq 100^{-1} g				
Items	+12	+29	+54	+64	SEM
Dry matter intake, kg	17.3^{a}	19.3^{b}	20.3^{c}	20.4^{c}	1.0
Actual milk yield, kg	23.6^{a}	24.1^{ab}	24.4^{ab}	25.1^{b}	.52
3.5 % FCM, kg	23.6^{a}	25.2^{b}	26.0^{bc}	26.8^{c}	.59
Fat, %	3.6^{a}	3.81^{b}	3.94^{c}	3.96^{c}	.09
Fat, kg	$.83^{a}$	$.91^{b}$	$.96^{c}$	$.99^{c}$	.03
Protein, %	3.4^{a}	3.42^{a}	3.42^{a}	3.33^{b}	.06
Protein, kg	$.79^{a}$	$.82^{ab}$	$.83^{b}$	$.82^{ab}$	.02
Cl^-, meq l^{-1}	33.1^{a}	28.4^{c}	26.4^{b}	29.1^{c}	.9
$Ca^{2+,}$ meq l^{-1}	53.8	55.0	57.5	54.8	1.8
$Mg^{2+,}$ meq l^{-1}	12.3	11.5	11.9	12.2	.6
p, meq l^{-1}	27.7	29.0	27.6	28.9	.8

a,b,c Means in the same row with different superscripts differ ($P<.05$).

d,e,f Means in the same row with different superscripts differ ($P<.01$).

(18) and West *et al.* (21) observed a linear increase in voluntary feed intake as DCAB increased. It is interesting that in this study, the intake was maintained in cows fed the +64 meq diet. Few studies with ruminants have examind diets with DCAB above +50 meq 100^{-1} g DM and researchers have postulated that little advantage would be achieved with dietary DCAB above the +50 meq 100^{-1} g diet DM content. One study with chickens (15) resulted in depressed feed intake and body weight gain when DCAB was above or below 25 meq 100^{-1} g diet DM .

Milk

Mean milk yield and composition values are summarized in Table 3. Actual milk yield was lower for cows fed +12 DCAB ($P<.05$) when compared with those fed +64 DCAB, potentially a result of the lowered feed intake in this group. Milk yields of cows fed +29 and +54 DCAB were not statistically different from those fed the +12 or +64 DCAB diets.

It must be mentioned that dietary fiber content was below NRC recommendations (16) which may affect interpretion of milk fat data. Milk fat percentage tended to increase with increasing DCAB, possibly a result of dietary buffer ($NaHCO_3$) addition to those marginal fiber diets . Milk fat percentage and yield were lower ($P<.01$) for cows fed +12 DCAB than all other treatments. Cows fed +29 DCAB had lower ($P<.05$) milk fat percentage when compared with those fed +54 and +64 DCAB diets. Consequently 3.5% fat corrected milk (FCM) yield was lower ($P<.01$) in cows fed +12 DCAB than all other treatment groups. These results support those of Tucker *et al.* (18) and West *et al.* (21) where milk production increased linearly as DCAB increased. Cows fed the +29 DCAB had lower 3.5% FCM yields than those fed the +54 and +64 DCAB diets.

Milk protein percentage was lower ($P<.05$) for cows fed the +64 DCAB when compared with those fed all other treatments. Actual milk protein yield was higher ($P<.05$) in cows fed the +54 DCAB as compared with those fed the +12 DCAB diet.

Milk mineral concentrations are summarized in Table 3. Milk Ca^{2+}, Mg^{2+}, and P^- levels were not significantly affected by DCAB; however, milk Cl^- differed significantly among groups. Cows fed the +12 DCAB had higher milk Cl^- concentrations when compared with other treatments. Cows fed +29 and +64 DCAB had higher ($P<.05$) milk Cl^- concentrations than cows fed the +54 DCAB diet. Mean milk Cl^- concentration tended to change in association with dietary Cl^- concentration; however, Kirchgessner *et al.* (14) concluded that dietary Cl^- was not correlated with milk Cl^- concentrations.

Blood

Blood pH, bicarbonate (HCO_3^-), and PCO_2 (Table 4) reflected the DCAB of the diet being fed. Recent studies (7, 18) show an association between excess dietary Cl^- and acidosis in dairy cattle. The tendency for blood pH, and HCO_3^- to be lower on +20 balance can presumably be attributed to the inverse relationship of plasma Cl^- (11), or it is likely that the mechanism by which DCAB affects blood is via altering blood HCO_3^- concentration (18).

Plasma Na^+ and K^+ levels were not significantly by affected DCAB (Table 4). Variation in plasma Na^+ and K^+ levels was slight, even when the diet contained high concentrations of these minerals. Excess Na^+ and K^+ was excreted via kidneys (Table 4). Plasma Na^+ and K^+ levels have been reported to remain unchanged (18) in response to DCAB. Plasma Cl^- level was higher ($P<.01$) in cows fed the +12 DCAB compared with all other treatment groups. Plasma Cl^- level is the variable mostly affected by changes in DCAB.This response has been also observed in poulty (5).

Plasma Ca^{2+} level was higher ($P<.01$) in cows fed the +12 DCAB than those fed the +54 DCAB. Several factors may have influenced this response. The Ca^{2+} source of cows fed the +12 DCAB was supplied by more available $CaCl_2$ as opposed to limestone in the remaining diets (11). It has been suggested (3) that diets containing acid forming ions cause greater Ca^{2+} uptake by decreasing intestinal pH. This observation is also in keeping with the reported data (2) where diets with low DCAB appeared to mobilize bone Ca.

Plasma P^- level (Table 4) was lower ($P<.05$) for cows fed the +12 DCAB as compared with those fed the +54 DCAB diet. Cows fed the +29 and +64 DCAB diets had plasma P^- concentrations which were not significantly different from those fed the +12 and +54 DCAB balances. Other researchers (7, 9) have noted an increase in phosphate excretion during acidosis produced by a high Cl^- diet. Beighle *et al.* (2), examines the effects of

Table 4. Acid-base status, pH, and mineral composition of blood and urine for each balance.

	$(Na^+ + K^+) - Cl^-$, meq 100^{-1} g				
Items	+12	+29	+54	+69	SEM
Blood					
pH	7.437^{c}	7.447^{cd}	7.457^{cd}	7.466^{d}	0.007
PCO_2, mm Hg	35.640^{a}	37.780^{ab}	40.080^{b}	38.960^{b}	0.800
HCO_3^-, meq l^{-1}	23.250^{a}	25.230^{a}	27.350^{b}	27.150^{b}	0.700
Plasma Na^+, meq l^{-1}	139.20	122.50	131.80	134.40	7.100
Plasma K^+, meq l^{-1}	6.640	7.250	7.600	6.950	0.500
Plasma Cl^-, meq l^{-1}	131.90^{c}	118.10^{d}	116.10	118.10^{d}	2.200
Plasma Ca^{+2}. meq l^{-1}	6.360^{c}	5.850^{cd}	5.660^{d}	6.110^{cd}	1.100
Plasma Mg^{+2}, meq l^{-1}	1.540^{ab}	1.4700^{ab}	1.630^{a}	1.350^{b}	0.040
Plasma P^-, meq l^{-1}	2.090^{c}	2.460^{cd}	2.760^{d}	2.420^{cd}	0.100
Plasma $[(Na^+ + K^+) - Cl^-]$ meq 100^{-1} ml	1.500	1.200	2.300	2.300	0.800
Urine pH	6.900^{e}	8.550^{f}	8.670^{f}	8.670^{f}	0.100
Urine Na^+, meq l^{-1}	11.870^{e}	45.340^{e}	183.70^{f}	195.20^{f}	14.30
Urine K^+, meq l^{-1}	410.60^{ab}	495.90^{b}	404.9^{ab}	379.0^{a}	35.80
Urine Cl^-, meq l^{-1}	120.20^{e}	6.800^{f}	5.200^{f}	5.400^{f}	7.300
Urine Ca^{+2}, meq l^{-1}	15.30^{e}	1.80^{f}	1.480^{f}	1.040^{f}	2.500
Urine Mg^{+2}, meq l^{-1}	6.60^{a}	8.80^{b}	6.800^{a}	5.200^{a}	0.600
Urine P^-, meq l^{-1}	9.00^{a}	10.10^{a}	11.100^{a}	5.400^{b}	1.100
Urine $[(Na^+ + K^+) - Cl^-]$ meq 100^{-1} ml	30.20^{e}	53.40^{f}	58.300^{f}	56.900^{f}	3.200
Urine creatinine, meq 100^{-1} ml	81.66^{a}	85.38^{a}	68.45^{ab}	53.74^{b}	6.400

a,b Means in the same row with different superscripts differ ($P<.05$).

c,d Means in the same row with different superscripts differ ($P<.01$).

e,f Means in the same row with different superscripts differ ($P<.001$).

varying DCAB on P^- requirement in calves and observed an increase in serum inorganic P^- at low dietary DCAB content in P^- deficient calves. No differences in plasma Mg^{2+} levels were detected (Table 4). These results are in agreement with those observed by other researchers (9).

Urine

Urinary creatinine an indicator of urine volume, was higher in cows fed the +12 and +29 meq diets when compared with those fed the +64 meq diet (Table 4). Cows fed the +54 meq diet had creatinine concentrations which were not significantly different from all other treatment groups.

Urinary minerals presented are actual values. Urinary pH, Na^+, and Cl^- (Table 4) were very responsive to changes in DCAB. Cows fed +12 DCAB had a lower pH and higher Cl^- than cows fed all other diets.. A previous study by Tucker *et al.* (19) found S^- to be 0.6 time as effective as Cl^- as a urine acidifier. The difference in effectiveness is thought to be due to differences in absorption. Results also indicated that S^- should be included in the equation when calculating cation-anion balances. Sulfur was maintained constant in this study. However, when S- is included in the calculations the balances are +1, +17, +42, and +51 for the +12,+29, +54, and +64 meq 100^{-1} g diet DM treatments, respectively.

Urinary K^+ concentration was higher ($P<.05$) for +29 DCAB diet than those fed the +64 DCAB. Cows fed the +12 and +54 DCAB diets had urinary K+ concentration not significantly different from cows fed the +29 and +64 DCAB diets. Under alkali conditions, the kidneys increase alkali excretion and simultaneously suppress H^+ excretion in order to maintain normal blood pH, and as a result, urine pH increases (6). These data demonstrated this capability with low and high dietary Cl^- and Na^+, respectively. These responses would be expected in view of the kidney's role in electrolyte homeostasis. Urinary Ca^{2+} concentration was higher for cows fed the +12 DCAB than those fed all other DCAB treatments. This may be due to increased Ca^{2+} mobilization at the lower DCAB and would coincide with higher plasma Ca^{2+} observed for the same treatment group. Urinary Mg^{2+} concentaration was higher ($P<.05$) for cows fed the +29 DCAB diet when compared with all other diets. No direct relationship of DCAB with urinary Mg^{2+} is readily apparent. Urinary P^{-} concentration was lower ($P<.05$) for cows fed the +64 DCAB than cows fed all other diets.

Rumen

Ruminal fluid pH tended to be lowest for cows fed the +12 DCAB diet; however, no significant differences were detected among treatments. (Table 5) Ruminal fluid VFA profile was largely unaffected by DCAB, except for butyrate, and total volatile fatty acids (Table 5). Cows fed +12 DCAB had lower ($P<.05$) ruminal butyrate concentration than those fed the +54 DCAB. Cows fed the +29 and +64 treatment had butyrate concentrations not significantly different from those of the +12 and +54 DCAB treatment groups. Ruminal isovalerate level was lower ($P<.05$) in cows fed +64 DCAB than those fed the +29 and +54 DCAB. Total VFA concentrations followed the same trend as did butyrate concentration. Cows fed +12 DCAB had lower ($P<.05$) total VFA concentrations than cows fed +54 which could be due to lower DMI and lower pH of the rumen (20). Cows fed the +29 and +64 DCAB diets had similar total VFA concentrations as did cows fed the +12 and + 54 DCAB diets.

Cows fed +12 balance had significantly lower rumen Na^{+} than those fed +54 balance. Cows fed +29 and +64 DCAB had rumen Na^{+} contents similar to those fed +12 and + 54 DCAB. Rumen K^{+} content was higher ($P<.05$) for cows fed +12 when compared with those fed +29 DCAB. Rumen + 54 and +64 balances were not different from those of cows fed K^{+} concentration of cows fed +12 and +29 DCAB. Cows fed +12 balance had higher ($P<.05$) rumen Cl^{-} when compared with those fed all other balances. Rumen Mg^{2+} was lower ($P<.01$) for cows fed +12 DCAB than those fed other diets. Tucker

Table 5. Ruminal fluid volatile fatty acids, pH, and mineral composition for cows fed diets of varying cation-anion balance.

	[(Na^{+} + K^{+}) - Cl^{-}] meq 100^{-1} g				
Composition	+12^{a}	+29^{a}	+54^{a}	+64^{a}	SEM
Ruminal pH	5.92^{a}	5.99^{a}	6.10^{a}	6.18^{a}	.2
VFA, mol 100^{-1} mol					
Acetate	65.5^{a}	69.0^{a}	74.3^{a}	72.4^{a}	3.3
Propionate	25.3^{a}	27.0^{a}	27.8^{a}	27.8^{a}	2.2
Isobutyrate	2.7^{a}	2.8^{a}	2.9^{a}	2.5^{a}	.5
Butyrate	15.4^{a}	18.8^{ab}	19.5^{b}	18.3^{ab}	1.3
Isovalerate	2.3^{ab}	2.5^{b}	2.7^{b}	2.1^{a}	.2
Valerate	2.2^{a}	2.6^{a}	2.4^{a}	2.2^{a}	.3
Total VFA, mmol l^{-1}	113.4^{a}	122.8^{ab}	129.6^{b}	121.9^{ab}	6.5
Acetate:propionate, ratio	2.7^{a}	2.6^{a}	2.8	3.0^{a}	.2
Ruminal Na^{+}, meq l^{-1}	90.3^{c}	120.6^{cd}	142.9^{d}	120.1^{cd}	13.0
Ruminal K^{+}, meq l^{-1}	79.1^{b}	46.9^{a}	50.0^{ab}	48.0^{ab}	10.8
Ruminal Cl^{-}, meq l^{-1}	17.4^{b}	10.1^{a}	12.6^{a}	11.9^{a}	1.5
Ruminal Ca^{2+}, meq l^{-1}	7.6^{a}	6.0a	4.7^{a}	6.1^{a}	9.3
Ruminal Mg^{2+}, meq l^{-1}	13.0^{c}	17.9^{d}	17.2^{d}	16.7^{d}	1.1
Ruminal P^{-}, meq l^{-1}	9.6^{a}	15.4^{a}	14.5^{a}	11.5^{a}	2.1
Ruminal [(Na^{+}+K^{+})-Cl^{-}], meq 100^{-1} ml	15.2^{a}	15.7^{a}	18.0^{a}	15.6^{a}	1.7

a,b Means in the same row with different superscripts differ ($P<.05$).

c,d Means in the same row with different superscripts differ ($P<.01$).

e,f Means in the same row with different superscripts differ ($P<.001$).

et al. (18), when examining diets containing -10 to +20 DCAB, reported that rumen parameters were largely unaffected by DCAB. Our results would support this conclusion

CONCLUSIONS

Dry matter intake, actual milk yield, FCM, milk fat percentage and blood and urinary pH increased with increasing DCAB. Of the electrolytes analyzed, blood Cl^- appeared to be the most profoundly affected by changes in DCAB and may be primarily responsible for the observed alterations in acid-base physiology, lower feed intake, and decreased milk production as a result of homeostatic adjustment to maintain acid-base balance.

Although information available at this time is inconclusive, defining the range of dietary electrolytes resulting in maximum performance by lactating cows where fiber may be limited, appeared to be between 29 and 54 meq $[(Na^+ + K^+) - Cl^-]$ 100^{-1} g diet DM in our study. Although increasing the balance to + 64 had no depressing effect on DM intake and milk production, no further increase was noted above that of the +54 diet.

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