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IMPACT OF DIETARY CATION ANION BALANCE ON WATER INTAKE AND PHYSIOLOGICAL MEASUREMENTS OF FEEDLOT CATTLE

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Authors:

A.F. La Manna, F.N. Owens, S. Janloo, Y.H. Ahmad and S.D. Welty

Story in Brief

Nine ruminally cannulated heifers (510 kg) in three Latin squares were given ad libitum access to 80% concentrate feedlot diets based on cracked corn. Diets were modified by addition of either .46% ammonium chloride (NH_4Cl), .50% white salt (NaCl) or .61% sodium sulfate (Na_2SO_4) to achieve dietary cation-anion balances (DCAB) of 98, 186 and 270 mEq/kg DM for NH_4Cl, NaCl and Na_2SO_4, respectively. Although water intake was not significantly altered by any of the treatments, the ratio of water intake to dry matter intake increased as DCAB increased. As DCAB increased partial pressure of carbon dioxide and bicarbonate in arterial blood increased. Although serum chloride decreased linearly as DCAB was increased, none of the other macromineral concentrations in serum were affected. Increasing DCAB increased urine pH. NH_4Cl addition to the diet increased ruminal fluid concentrations of chloride and potassium when compared with the other two treatments. Sodium concentration in ruminal fluid was increased linearly by increasing DCAB. Total weight and liquid weight of ruminal contents were increased by the NaCl treatment when compared with the other two treatments. Lower dietary DCAB decreased blood base excess.

Key Words: DCAB, Intake, Minerals, Beef Cattle

Introduction

Altering the dietary cation anion balance has been shown to alter milk yield of dairy cows (Tucker et al., 1988), average daily gain of steers (Wheeler, 1981; Ross et al., 1994a,b), and gain:feed ratio of growing steers (Ross et al., 1994a).

Presumably, modifying the dietary cation anion balance has an effect on animals through altering blood acid-base balance and mineral status. Most of the studies on DCAB in ruminants have involved dairy cattle, mainly preparturient cows. Research has been limited with other ruminants.

The objectives of this experiment were 1) to test the impact of DCAB concentration on intake of water and feed by feedlot cattle, 2) to examine the impact of DCAB in ruminal parameters and mineral concentrations, and 3) to measure physiological responses in urine and blood (venous and arterial) to DCAB.

Materials and Methods

Nine (510 kg) ruminally cannulated heifers in individual pens were assigned to three 3 x 3 Latin squares. These animals were given ad libitum access to a concentrate diet (Table 1) with fresh feed added daily (8.30 a.m.) in each 21-d period of each Latin Square (14 d adaptation, 7 d for sampling and measurement). The dietary modifications included addition of either .46% ammonium chloride (NH_4Cl), .61% of sodium sulfate (Na_2SO_4) .50% of salt (NaCl) of Kansas rock salt #4 containing at least 96% NaCl . The first two diets contained equal amounts of dietary chloride while the second and third diets contained equal amounts of dietary sodium. Chemical compositions of these diets are shown in Table 1.

Total amount of feed provided and orts were weighed daily. Water was provided free choice in large barrels and water intake was measured daily.

Animals were dosed with Co-EDTA at 8:00 a.m. on d 20 and ruminal contents were sampled at 2, 5, 7 and 24 h later using a vacuum pump.

Within 2 h after being drawn, a 10 ml sample of arterial blood was analyzed in a Critical Blood Analyte for pH, partial pressure of carbon dioxide (pCO_2), partial pressure of oxygen (pO_2), bicarbonate (HCO_3), base excess (BE), sodium (Na^+), ionic calcium (Ca^{++}) and potassium (K^+). Urine samples were collected twice a day for three consecutive days using a procedure of stimulating urination by massaging the ventral commissure of the vulva. Urinary pH was measured immediately.

On d 21 total ruminal contents were removed mechanically using a vacuum device. Ruminal contents were screened twice (.63 x .63 and .31 x .31 cm square pore mesh) manually to separate ruminal particulates from liquid contents. Ruminal fluid pH was measured immediately. Energy charge (EC) was calculated as (2 x butyrate)/acetate. The non-glucogenic ratio (NGR) was calculated as (acetate + 2 x butyrate)/propionic.

Period, animal and treatment were used as sources of variation and the statistical analyses were performed using the GLM procedure of SAS (1990). Linear and quadratic effects of DCAB (calculated as meq/kg DM of $Na^+ + K^+ - Cl^-$) were tested using contrast statements. Treatments with equal dietary amounts of Na (NaCl and Na_2SO_4) were tested vs the treatment with different Na (NH_4Cl) level using contrast statements. Treatments with equal dietary amounts of Cl (NaCl and NH_4Cl) were contrasted with the treatment with less Cl (Na_2SO_4) level using contrast statements.

Results and Discussion

Dry Matter and Water Intake. Supplementation did not significantly (P=.32) alter DMI, although DMI for heifers fed the NH_4Cl diet (7.9 kg) tended to be lower than for heifers fed the NaCl and Na_2SO_4 diets (9.0 and 8.5 kg, respectively). Water intake (WI) also was not significantly different (P=.49) among treatments. The ratio WI/DMI decreased (P<.10; Table 2) as DCAB was increased. On the average, animals fed the NH_4Cl diet drank 24 to 28% more water per kg of DM of feed DM than those fed Na supplemented diets.

Ruminal Parameters. Ruminal pH was not affected by the treatments. Total weight of ruminal contents and liquid ruminal contents responded quadratically to increasing DCAB (P=.05; Table 3). Total weight of ruminal contents (kg) was higher (P<.10) for the NaCl treatment (35.7) than NH_4Cl (29.7) and Na_2SO_4 (28.8).

Total volatile fatty acids in the ruminal samples and their molar proportions are presented in Table 3. Neither total VFA□s, acetate, propionate, butyrate nor the acetate to propionate ratio (A:P) was affected by the treatments but the molar proportion of valerate responded quadratically (P<.05) to increasing DCAB.

Soluble minerals in the rumen for the three treatments are presented in Table 4. Sodium increased linearly (P<.05) as DCAB increased, primarily because sodium concentration in the rumen was lower (P<.05) for the NH_4Cl treatment than for the NaCl and Na_2SO_4 treatments, perhaps a result of sodium intake being greater with the NaCl and Na_2SO_4 diets. Ruminal potassium concentration was higher (P<.05) for the NH_4Cl treatment when compared with the other two treatments.

The ruminal concentration of chloride was lower (P<.05) for heifers fed the NaCl (280 ppm) treatment than in the NH_4Cl (358 ppm) treatment but no clear response to DCAB was noted. The higher concentration of potassium and the higher chloride intake with low sodium diet might explain the higher chloride concentration observed with the NH_4Cl diet.

There were no effects (P>.10) of dietary alteration on ruminal concentrations of Ca, P, S and Mg. Ruminal calcium in ruminal fluid was highly correlated with ruminal pH (r=-.835; p<.01) reflecting a higher degree of ionization. Also magnesium concentration in ruminal fluid was highly correlated with ruminal pH (r=-.79; p<.01). Neither linear nor quadratic responses to DCAB were observed (Table 4). The ratio of Na:K decreased (P<.05) as DCAB increased.

Arterial Blood Parameters. Arterial blood pH tended to increase as DCAB was increased. Base excess also tended to increase (P=.12) as DCAB increased.

Partial pressure of carbon dioxide was significantly lower (P<.10) in the

NH_4Cl diet when compared with the Na_2SO_4 diet. Blood concentration of HCO_3 also increased (P<.10) as DCAB increased.

No differences (P>.10) in arterial concentrations of Na, K or ionized Ca were detected (Table 5).

Serum Minerals. Concentration of Cl in the serum decreased with increasing DCAB (Table 6). Serum Cl was higher (P<.05) with the NH_4Cl treatment than the Na_2SO_4 treatment. Differences in chloride concentrations in blood serum among treatments in our experiment presumably can be explained by DCAB and chloride intake.

No differences were detected in serum concentrations of Na, K, Mg, Ca, and P among treatments (Table 6).

Urinary pH. Urinary pH increased markedly as DCAB increased (Table 7), but fecal pH was not altered.

Lower DCAB tended to acidify arterial decreased blood bicarbonate and partial pressure of oxygen and urinary pH. Chloride concentration of venous serum decreased as DCAB was increased. For this experiment DCAB was more closely correlated with urinary pH (r=.46; p<.02) than with either BE, arterial pH or cation anion balance in the rumen (r=.31; .23; .30, respectively). This suggests that urinary pH was responding more readily or repeatable to DCAB than other acid-base status indicators to DCAB. Furthermore, DCAB was more closely related to these indices of acid-base balance than DCABS; therefore DCAB appears to be a better index of acid base status than DCABS. Addition of ammonium chloride to the diet to decrease DCAB increased ruminal concentrations of both potassium and chloride. Replacing ammonium chloride with salt or sodium sulfate linearly increased ruminal concentrations of sodium. Whether this reflects an effect of DCAB or deficiency of Na in the NH_4Cl diet is not certain.

Literature Cited

Ross, J.G. et al. 1994a. J. Anim. Sci. 72:1842.

Ross, J.G. et al. 1994b. J. Anim. Sci. 72:1600.

Tucker, W.B. et al. 1988. J. Dairy Sci. 71: 346.

SAS. 1990. SAS Programming Guide (Version 6, 3rd Ed.). SAS Inst. Inc., Cary, NC.

Wheeler, W.E. 1981. Proc. Georgia Nutr. Conf. p 17.

Table 1. Ingredients and chemical composition of diets (DM basis)

Ingredient (%)	NH_4C1	NaC1	Na_2SO_4
Dry rolled corn	63.11	63.08	63.01
Cottonseed hulls	14.69	14.69	14.67
Soybean meals (44 %)	10.14	10.14	10.13
Dehydrated alfalfa pellets	6.14	6.14	6.13
Cane molasses	4.23	4.23	4.22
Salt	--	.50	--
Ammonium chloride	.46	--	--
Sodium Sulfate	--	--	.61
Ground limestone	.57	.57	.57
Dicalcium phosphate	.55	.55	.55
Urea (46%)	.11	.11	.11
Total	100.00	100.00	100.00
Composition (%)			
Sodium	.02	.22	.22
Potassium	.83	.83	.82
Chloride	.43	.43	.13
Calcium	.55	.55	.55
Phosphorus	.32	.32	.32
Magnesium	.13	.13	.13
Sulfur	.15	.15	.29
DCAB mEq/Kg DM[1]	98.1	185.8	270.2
DCABS mEq/Kg DM[2]	6.5	92.5	90.9

[1]DCAB mEq/Kg DM = mEq(Na + K)-mEqCl.

[2]DCABS mEq/Kg DM = mEq(Na + K)-mEq(Cl-S)

Table 2. Dry matter intake (DMI), water intake (WI) and ratio for heifers receiving ammonium chloride (NH_4Cl), NaCl and sodium sulfat (${Na_2SO_4}$).

	Treatments			
	NH_4Cl	NaCl	Na_2SO_4	
DMI, kg	7.90	8.99	8.51	
WI, lt	35.97	33.19	33.09	

WI/DMI	4.95	3.88	4.00	L*	Na**
L=Linear effects of DCAB; **P<.05; *P<.10. Na= (NaCl and Na_2SO_4) vs NH_4Cl; Cl= (NaCl and NH_4Cl) vs Na_2SO_4.					

Table 3. Ruminal VFA, pH and liquid and solid contents for heifers receiving ammonium chloride (NH_4Cl), salt (NaCl) and sodium sulfate (Na_2SO_4).

	Treatments			
	NH_4Cl	NaCl	Na_2SO_4	
VFA (molar %)				
Acetate	51.02	54.67	53.30	
Propionate	31.64	28.33	29.73	
Butyrate	12.54	12.60	12.57	
Isovalerate	2.49	2.86	2.58	
Valerate	2.31	1.53	1.82	Q** Na**
A/P	1.81	2.01	2.04	
Total VFA mmol/L	118.3	117.9	129.3	
NGR	2.66	2.92	3.02	
EC	.51	.46	.47	
Rumen pH	5.82	5.81	5.79	
Rumen contents				
Total kg	29.69	35.65	28.81	Q*
Solids kg	4.65	5.35	4.24	
Liquids kg	25.04	30.30	24.57	Q**
Co-EDTA dilution rate	3.93	3.62	3.35	

Q=quadratic effects of DCAB; **P<.05;*P<.10.

Na= (NaCl and Na_2SO_4) vs NH_4Cl; Cl= (NaCl and NH_4Cl) vs Na_2SO_4

Table 4. Centrifuged ruminal fluid parameters for heifers receiving ammonium chloride (NH_4Cl), salt (NaCl) and sodium sulfate (Na_2SO_4).

	Treatments				
	NH_4Cl	NaCl	Na_2SO_4		
Ruminal fluid					
Na, ppm	1129	1723	1638	L**	Na**
K, ppm	3053[c]	2237[d]	2355[d]		Na**
Cl, ppm	358[a]	280[b]	305[ab]		Na**
Ca, ppm	81	86	110		
P, ppm	972	1060	985		
Mg, ppm	153	159	165		
S, ppm	60	67	61		
Ratio Na/K, ppm/ppm	.45	.99	.92	L*	Na**

[a,b]Means with different superscripts within row P<.05. L=Linear effects of DCAB.

[c,d]Means with different superscripts within row P<.10; **P<.05; *P<.10.

Na= (NaCl and Na_2SO_4) vs NH_4Cl; Cl= (NaCl and NH_4Cl) vs Na_2SO_4.

Table 5. **Arterial blood parameters in heifers receiving ammonium chloride (NH_4Cl), salt (NaCl) and sodium sulfate (Na_2SO_4).**

	Treatments				
	NH_4Cl	NaCl	Na_2SO_4		
pH	7.409	7.422	7.430		
pCO_2 mmHg	34.57	35.91	37.63	L*	Cl*
pO_2 mmHg	106.7	104.5	102.8		
Ca^{++}	4.80	4.88	4.74		
Na mmol/L	139.39	140.10	140.38		
K mmol/L	4.24	4.30	4.30		
BE mmol/L	-1.33	.12	1.58		

HCO_3 mmol/L	22.00	23.43	24.99	L*	
*P<.10. Na= (NaCl and Na_2SO_4) vs NH_4Cl; Cl= (NaCl and NH_4Cl) vs Na_2SO_4. L=Linear effects of DCAB.					

Table 6. Serum macrominerals in heifers receiving ammonium chloride (NH_4Cl), salt (NaCl) and sodium sulfate (Na_2SO_4).

	Treatments				
	NH_4Cl	NaCl	Na_2SO_4		
Cl mmol/L	113.1	111.5	109.0	L**	Cl*
Na mmol/L	145.3	146.4	144.7		
K mmol/L	4.18	4.32	4.29		
Ca mg/dl	9.26	9.14	9.20		
P mg/dl	5.65	5.83	5.71		
Mg meq/L	2.03	2.07	1.98		

L=linear effects of DCAB, **P<.05.

Na= (NaCl and Na_2SO_4) vs NH_4Cl; Cl= (NaCl and NH_4Cl) vs Na_2SO_4.

Table 7. Urine and fecal pH in heifers receiving ammonium chloride (NH_4Cl), salt (NaCl) and sodium sulfate (Na_2SO_4).

	Treatments			
	NH_4Cl	NaCl	Na_2SO_4	

Urine pH	5.95	6.53	6.91	L**	Na**
Fecal pH	5.67	5.91	5.73		

L=linear effects of DCAB, **P<.05.

Na= (NaCl and Na_2SO_4) vs NH_4Cl; Cl= (NaCl and NH_4Cl) vs Na_2SO_4

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