DIETARY SODIUM BICARBONATE AND POTASSIUM METABOLISM IN DAIRY CALVES

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Story in Brief

We evaluated the influence of supplemental dietary $NaHCO_3$ on K metabolism of young dairy calves. Thirty-two Holstein and Jersey male and female calves were blocked at 56 to 70 days after birth according to breed, sex and age, and assigned randomly to a 2x2 factorial arrangement of dietary treatments for 8 weeks: .4% K with 0% $NaHCO_3$, .4% K with 2% $NaHCO_3$, .6% K with 0% $NaHCO_3$, and .6% K with 2% $NaHCO_3$. Feed intake was not affected by dietary KCl or $NaHCO_3$ supplementation, but average daily gain increased with increasing K and tended to be reduced by dietary $NaHCO_3$. Plasma K was elevated by increased dietary K, but generally was unaffected by $NaHCO_3$. Urinary Ca excretion appeared to be reduced by $NaHCO_3$; urine pH increased with supplemental $NaHCO_3$. Our results indicate: 1) that the K requirement of the growing calf is between .40 and .55% of diet dry matter, 2) that because urinary K excretion was elevated by dietary $NaHCO_3$, the K requirement may be increased when the diet is supplemented with $NaHCO_3$, and 3) average daily gain and plasma K are sensitive indicators of dietary K in the growing calf.

(Key Words: Dairy Calf, Potassium, Sodium Bicarbonate.)

Introduction

Young calves may not produce enough saliva to adequately buffer ruminal acid production. The ability of dietary buffers to meet this deficit has been investigated (Hart and Polan, 1984). In nonruminants, high dietary Na intakes increase renal K excretion by increasing the flow rate in the late distal tubules and cortical collecting ducts of renal nephrons, thus creating a larger gradient for the diffusion of K into the tubular lumen (Valtin, 1983). Because dietary Na increases with $NaHCO_3$ addition, the objective of this trial was to evaluate the effects of dietary $NaHCO_3$ on K metabolism in growing dairy calves.

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Materials and Methods

Twenty-four Holstein (8 male, 16 female) and 8 Jersey female calves were weaned at 6 wk of age and offered a calf starter concentrate. After intake of the starter reached .9 kg/d (56 to 70 d of age), calves were blocked according to breed, sex and age, and assigned randomly to a 2x2 factorial arrangement of dietary treatments: .4% K with 0% $NaHCO_3$ (LK0), .4% K with 2% $NaHCO_3$, .6% K with 0% $NaHCO_3$, and .6% K with 2% $NaHCO_3$. After an initial 1-wk adaptation period in which all calves were offered LK0, experimental diets (Table 1) were fed for 8 wk. Individual feed intake was recorded daily and averaged by week; BW were recorded weekly. Urine was collected at wk 0, 2, 4, 6 and 8. Blood was collected at 0900 h at 0 d and every 14 d thereafter.

Results and Discussion

Feed Intake and Weight Gain

Feed intake (Table 2) was not affected by dietary K or $NaHCO_3$ concentration during any individual week, or as the average response during the last 4 wk weeks of the study. In our study, covariate-adjusted BW (Table 2) were greater for increased dietary K during wk 4 to 8 of the study; BW tended to be reduced by supplemental dietary $NaHCO_3$ throughout the study. As a result, ADG (Table 2) increased as dietary K was increased from .4 to .6%, but ADG tended to decrease with supplemental $NaHCO_3$. Weil et al. (1988) indicated that the K requirement of the growing dairy calf is in the range of .34 to .58% of diet DM. They reported increased ADG as dietary K increased from .34 to .58% of diet DM; but in a separate experiment, they observed no growth response to increasing dietary K from .55 to .84%. The faster growth observed in our study in response to increasing dietary K from .4 to .6%, when contrasted with the lack of growth response to increasing dietary K from .55 to .84% (Weil et al., 1988) indicates that the K requirement for growth of young calves is between .4 and .55% of DM. In both studies, ADG appeared to be more useful than feed intake as an indicator of the adequacy of K.

Plasma and Urine Minerals, and Urine pH

Plasma Na (Table 3) averaged across the final 3 sampling times was greater when dietary K was supplemented, but no effect of K on urinary Na excretion was observed. Urinary Na excretion increased with increasing dietary $NaHCO_3$ concentration.

Table 1. Ingredient and nutrient composition of experimental diets.

Ingredient:	Diet .4% K 0% $NaHCO_3$	.4% K 2% $NaHCO_3$	.6% K 0% $NaHCO_3$	.6% K 2% $NaHCO_3$
	(% DM)			
Shelled corn, cracked	35.00	34.30	34.83	34.14
Dried brewers grain	34.10	33.42	33.94	33.26
Oat grain, dry rolled	15.00	14.70	14.93	14.63
Cottonseed hulls	9.40	9.21	9.36	9.17
Soybean meal	4.60	4.51	4.58	4.49
Limestone	1.13	1.09	1.10	1.05
Dicalcium phosphate	.40	.39	.40	.39
Potassium chloride	....	.02	.50	.51
Dynamate[a]	.07	.06	.07	.06
Sodium chloride	.16	.16	.16	.16
Magnesium oxide	.07	.06	.07	.06
Vitamin ADE premix[b]	.06	.05	.06	.05
Sodium bicarbonate	....	2.00	....	2.00
Calcium chloride[c]	.03	.03	.03	.03
Nutrient[d]:				
DM	91.60	91.60	92.40	91.60
CP	17.40	14.40	17.00	16.00
NE_m (Mcal/kg)	1.73	1.70	1.73	1.73
NE_g (Mcal/kg)	1.11	1.09	1.11	1.11
ADF	18.00	19.60	17.40	17.50
NDF	41.50	37.50	35.70	26.30
Ca	.69	.46	.55	.43
P	.48	.43	.47	.42
Mg	.19	.17	.19	.17
Na	.08	.30	.08	.31
K	.35	.42	.61	.53
Cl	.18	.17	.34	.38
S	.24	.20	.23	.21
(Na+K)-Cl (meq/100 g diet DM)	12.21	23.34	11.02	20.16

[a]Double sulfate of K and Mg.

[b]Contains 4,540,000 IU Vitamin A, 1,000,000 IU Vitamin D_3 and 500 IU Vitamin E per .454 kg.

[c]Product contains 95% calcium chloride.

[d]Composition from laboratory analyses.

Table 2. Least squares means and orthogonal contrasts for feed intake, BW and average daily gain.

	.35% K 0% $NaHCO_3$	.42% K 2% $NaHCO_3$	.61% K 0% $NaHCO_3$	.53% K 2% $NaHCO_3$	SE	K Low	K High	SE	$NaHCO_3$ Low	$NaHCO_3$ High	SE	Effect, P
Feed intake[a], kg												
Wk[b]												
4-8	4.41	3.96	4.32	4.33	.24	4.19	4.32	.17	4.36	4.14	.17	
Body weight, kg												
Wk												
0	78.9	77.0	69.9	77.6	3.6	77.9	73.7	2.5	74.4	77.3	2.5	
2	88.4	87.1	89.1	88.7	1.2	87.8	88.9	.8	88.7	87.9	.8	
4	97.4	97.3	100.5	99.0	1.4	97.4	99.8	1.0	99.0	98.2	1.0	K,.11
6	111.6	108.2	115.4	113.1	1.7	109.9	114.3	1.2	113.5	110.7	1.2	K,.02 Na,.10
8	122.9	121.0	130.1	128.0	2.2	121.9	129.0	1.5	126.5	124.5	1.5	K,.005
4-8	117.3	114.6	122.7	120.6	1.7	115.9	121.6	1.2	120.0	117.6	1.2	K,.004
ADG, kg												
Wk												
0												
2	.90	.81	.95	.92	.08	.85	.93	.06	.92	.86	.06	
4	.64	.73	.82	.74	.10	.69	.78	.07	.73	.73	.07	
6	1.02	.78	1.06	1.01	.10	.90	1.03	.07	1.04	.89	.07	Na,.15
8	.81	.91	1.05	1.06	.13	.86	1.06	.09	.93	.99	.09	
4-8	.91	.84	1.05	1.03	.08	.88	1.04	.05	.98	.94	.05	K,.04

[a]As-fed basis.
[b]Week of study.

Table 3. **Least squares means and orthogonal contrasts for plasma and urine response to experimental diets during wk 4 to 8 of study.**

	.35%K 0%$NaHCO_3$	.42%K 2% $NaHCO_3$	.61% K 0% $NaHCO_3$	.53% K 2% $NaHCO_3$	SE	K Low	K High	$NaHCO_3$ Low	$NaHCO_3$ High	SE	Effect, P
Plasma (meq/L):											
Na	137.6	138.2	140.5	141.2	1.3	137.9	140.9	139.1	139.7	.9	K,.03
K	5.13	5.27	5.48	5.60	.15	5.20	5.54	5.31	5.44	.10	K,.04
Cl	96.0	95.7	98.5	99.4	1.2	95.8	98.9	97.2	97.5	.8	K,.02
Ca	5.39	5.49	5.34	5.50	.11	5.44	5.42	5.37	5.49	.08	
Mg	1.86	1.77	1.75	1.86	.05	1.82	1.81	1.81	1.82	.03	KxNa,.04
Urine mineral excretion (mg urine mineral/mg urine creatinine):											
Na	.019	.271	.010	.157	.049	.145	.083	.014	.214	.035	Na,.001
K	.064	.107	.123	.142	.017	.086	.133	.094	.125	.012	K, .01 Na, .08
Cl	.020	.019	.065	.047	.006	.020	.056	.042	.033	.004	K, .001 Na, .11 NaxK,.14
Ca	.0034	.0006	.0039	.0004	.0011	.0020	.0021	.0036	.0005	.0008	Na, .01
Mg	.049	.041	.043	.032	.005	.045	.037	.046	.036	.004	Na, .08
Urine pH	6.234	7.730	6.447	7.916	.199	6.982	7.182	6.341	7.823	.140	Na, .001

Plasma K (Table 3) was increased by supplemental dietary K during wk 4 to 8 of the study; this elevation (5.71 vs. 5.24 meq/L, SE=.136) was evident by wk 2. Both dietary K and $NaHCO_3$ increased urinary K excretion, a response which was evident by wk 4 of the study for K, and by wk 8 for $NaHCO_3$. Increased urinary K excretion in response to dietary $NaHCO_3$ supplementation likely can be attributed to the diuretic effect of excess Na.

Plasma Cl (Table 3) was elevated by supplemental dietary KCl during wk 4 to 8, and tended to be increased throughout the study. Urinary Cl excretion was increased by dietary KCl, but tended to be reduced (P=.11) by dietary $NaHCO_3$.

Plasma Ca (Table 3) was generally not affected by diet, although supplemental K increased plasma Ca (5.43 vs. 5.21 meq/L, SE=.076) during wk 2 of the study. Urinary Ca excretion was not affected by dietary K, but it was decreased by supplemental dietary $NaHCO_3$ throughout the study. However, this effect is confounded by the dietary Ca concentrations, which were unintentionally lower for the 2 vs. 0% $NaHCO_3$ diets. A reduction in urinary Ca excretion is a typical response to elevated dietary Na or K.

Plasma Mg (Table 3) was increased by supplemental dietary $NaHCO_3$ for calves receiving the low-K diets, but was reduced by supplemental dietary $NaHCO_3$ for calves receiving the high-K diets during wk 4 to 8. Dietary K concentration did not affect plasma Mg or urinary Mg excretion. In contrast to our study, Deetz et al. (1982) reported that ruminal infusion of KCl increased plasma Mg; they detected no effect on urinary Mg excretion. In our study, urinary Mg excretion tended to be reduced by supplemental dietary $NaHCO_3$.

Urine pH (Table 3) was not increased by the addition of supplemental dietary KCl. However, it was increased by supplemental dietary $NaHCO_3$ throughout our study. Similarly, Tucker et al. (1988) reported that urine pH increased as dietary cation-anion balance increased.

In conclusion, ADG of calves increased as dietary K from KCl was increased from .4 to .6%. In contrast, ADG tended to be depressed by adding 2% $NaHCO_3$ to the diet. Within the range of .4 to .6% K, $NaHCO_3$ supplementation may be detrimental to ADG of 8 to 16 wk old calves. Plasma K and ADG served equally well as indicators of K status, but responsiveness of plasma K to dietary K has not been unanimously supported. We suggest that: 1) the K requirement of the young, growing calf is between .40 and .55% of diet DM, 2) the response of growing calves to supplemental dietary $NaHCO_3$ will vary, perhaps related to effects on K and Ca, 3) K and Ca status of the growing calf should be considered when supplementing the diet with $NaHCO_3$, and 4) in our study, ADG and plasma K appeared to be sensitive and reliable indicators of the adequacy of a diet in meeting K requirements of young, growing calves.

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