THE EFFECT OF DIETARY CATION-ANION BALANCE ON MINERAL BALANCE IN THE ANAEROBICALLY EXERCISED HORSE

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Story in Brief

Four mares and four geldings were used to study the effects of dietary cation-anion balance on mineral balance and dry matter digestibility in anaerobically exercised horses. Calcium chloride, ammonium chloride, potassium citrate, and sodium bicarbonate were added to the diets to achieve the desired dietary cation-anion balance (Low=27, Medium Low=130, Medium High=223, High=354) calculated as: meq (Na+K)-Cl/kg diet dry matter. Dry matter digestibility was lower and thus fecal output was greater in those horses consuming the low versus the high diet. Sodium balance was higher in those horses consuming the high diet versus the medium low and low diets. Potassium and sulfur balances were not significantly affected by dietary cation-anion balance. Chloride balance was higher while magnesium and phosphorus balances were lower in horses consuming the low diet. Calcium balance was significantly higher in horses consuming the high versus the low diet. Depending on the level of mineral intake, horses cosuming highly anionic diets may experience negative calcium, phosphorus, and magnesium balances. If prolonged, an osteoporotic weakening of the skeletal system might occur.

(Key Words: Equine, Exercise, Mineral, Dietary Cation-Anion Balance.)

Introduction

Current recommendations on mineral requirements for most classes of horses are not well defined. Potassium, sodium, and chloride are involved in acid-base balance and osmotic regulation of body fluids. These three ions are the main components of the equation used to express dietary cation-anion balance (DCAB), calculated as meq((Na + K) - Cl)/kg diet DM. Diets fed to most exercising horses have calculated DCAB near 150 meq/kg of dry matter and may

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be as low as 50-100 meq/kg dry matter. Those levels would be considered as marginal to deficient for poultry and dairy cattle rations in terms of maintaining optimum blood pH and calcium retention.

Materials and Methods

Four geldings and four mares of Quarter Horse and Thoroughbred breeding were used to study the effects of DCAB on mineral balance. Diets consisted of a pelleted concentrate of corn, soybean meal and cottonseed hulls. The concentrate was fed with bermudagrass hay in a 60:40 ratio. Treatments with calculated DCAB of +27 (Low,L), +130 (Medium Low,ML), +223 (Medium High,MH) and +354 (High,H) were formed by supplementing diet L with calcium chloride and ammonium chloride, diet ML with calcium chloride and diet H with sodium bicarbonate and potassium citrate (Table 1). All diets were calculated to contain 2.7 Mcal/kg DM and 10.4% CP. Further, the diets were analyzed and determined to contain equilivant amounts of calcium, phosphorus, magnesium, and sulfur (Table 2).

Eight mature horses were aerobically conditioned 6 d/wk by galloping 3.2 km/d at a heart rate of 150 beats/min for 6 wk. During the experiment, the horses were subjected to a combined exercise regimen alternating the LSD work with interval training 6 d/wk. The interval training program consisted of two .4 km sprints eliciting heart rates of 200-220 beats/min. Heart rate was allowed to recover to below 110 beats/min between sprints.

Table 1. Composition of treatments, dry matter basis.

	Treatment			
Ingredient (%)	L	ML	MH	H
Corn	33.20	33.20	33.20	33.20
Soybean Meal	6.90	6.90	6.90	6.90
Cottonseed Hulls	14.80	15.10	15.00	13.70
Dicalcium Phosphate	.21	.21	.19	.20
Limestone, ground	----	.22	.78	.78
Trace Mineral Salt	.55	.55	.55	.55
Calcium Chloride	.78	.54	----	----
Ammonium Chloride	.30	----	----	----
Potassium Citrate	----	----	----	.89
Sodium Bicarbonate	----	----	----	.61
Molasses, syrup	2.00	2.00	2.00	2.00
Bermuda Grass Hay	40.00	40.00	40.00	40.00
DCAB, meq((Na+K)-Cl)/kg	+27	+130	+223	+354

Table 2. Dietary treatment analysis, dry matter basis.

Constituent	Treatment L	ML	MH	H
DE, Mcal/kg	2.7	2.7	2.7	2.7
Crude Protein, %	10.4	10.4	10.4	10.4
Calcium, %	.50	.53	.52	.54
Phosphorus, %	.28	.29	.28	.28
Magnesium, %	.15	.16	.15	.15
Potassium, %	1.12	1.14	1.13	1.39
Sulfur, %	.11	.12	.11	.13
Sodium, %	.29	.27	.30	.43
Chloride, %	1.38	1.00	.69	.68
DCAB meq((Na+K)-Cl)/kg	+27	+130	+223	+354

Total urine collection was taken for 72 hr from geldings using urine harnesses and for 24 hr from mares by catheterizing the bladder. Fecal grab samples were also taken over the 72 hr period to represent every 2 hr during the post feeding interval. Feed, fecal, and urine samples were analyzed for Na, K, Ca, P, S, Mg, and for Cl.

Results and Discussion

The effect of DCAB on dry matter digestibility and fecal output is shown in Table 3. An increase in fecal output and thus a decrease in dry matter digestibility was observed for those horses consuming diet L versus diet H. Fecal output increased from 2709 g/d on diet H to 3134 g/d for those horses consuming diet L. Accordingly, dry matter digestibility decreased from 66.82% to 61.63%.

Table 3. The effect of dietary cation-anion balance on dry matter digestibility in the anaerobically exercised horse.

	Treatment L	ML	MH	H	S.E.
DM Digestibility %	61.63^{a}	65.41^{ab}	63.54^{ab}	66.82^{b}	1.05
Fecal Output g/d	3134^{a}	2825^{ab}	2978^{ab}	2709^{b}	85.99

^{a,b} Means in rows with different superscripts differ ($P < .05$).

The effect of DCAB on mineral balance is shown in Table 4. No differences in fecal sodium excretion were detected between the four treatments. However, urinary sodium excretion paralleled intake. Sodium excretion was similar for diets L, ML, and MH The increased daily sodium intake for those horses consuming diet H resulted in an increase in daily urinary sodium excretion. This increase in daily urinary excretion did not offset the increased intake as those horses consuming diet H had higher sodium balances.

Those horses consuming diet L had higher fecal excretion of potassium as compared to the other treatments. Daily urinary excretion of potassium paralleled intake with horses consuming diet L having increased urinary potassium excretions. The increase in urinary excretion in diet H and the decrease in intestinal absorption in diet L did not produce significant differences in potassium balance.

No difference was detected in fecal chloride excretion across treatments. However, decreasing the DCAB resulted in increased urinary chloride excretion in diets L and ML as compared to diets MH and H. Apparently, the increase in urinary chloride excretion and the loss of chloride in the sweat was sufficient to offset the increased chloride intake in diet ML as daily chloride balance was similar for diets ML, MH, and H. However, these chloride elimination pathways were not adequate in removing the excess chloride in diet L as those horses had higher chloride balances. These results agree with other data demonstrating increased urinary chloride excretion in horses consuming diets with a lower DCAB (Topliff et al., 1989).

DCAB affected magnesium and phosphorus in the same manner. Those horses consuming diet L had increased fecal excretions compared to the other diets. It appears that urinary excretion of magnesium and phosphorus was not affected by DCAB. Due to the increased fecal excretion, magnesium and phosphorus balances were lower for those horses consuming diet L compared to the other treatments.

DCAB did not appear to affect sulfur balance as values for urinary and fecal sulfur excretion were similar across treatments. Although no significant differences were detected, the sulfur balance was slightly negative across treatments. In this study, the sulfur content of the feedstuffs was overestimated resulting in sulfur concentrations slightly below the requirement. Therefore, these horses consumed about 2 to 3 g/d below the suggested 12.25 g/d. This could be the likely explanation for the negative sulfur balances.

Fecal calcium excretion was higher for those horses consuming diet H versus diet ML. This effect is basically opposite those of the other minerals, but may be explained by the calcium homeostatic control mechanisms. These horses also had decreased urinary calcium excretion versus those horses consuming diet L. These findings agree with published data demonstrating increased urinary calcium excretion in horses (Topliff et al., 1989). These changes in fecal and urinary calcium metabolism resulted in an increase in calcium balance of those

Table 4. The effect of dietary cation-anion balance on mineral balance in the anaerobically exercised horse.

	Treatment				
MINERAL	L	ML	MH	H	S.E.
SODIUM					
Intake g/d	24.02	22.36	24.33	35.38	
Urine g/d	8.57[a]	8.61[a]	5.94[a]	14.03[b]	.96
Fecal g/d	11.97[a]	11.67[a]	13.06[a]	12.48[a]	.99
Balance g/d	3.47[a]	2.08[a]	5.36[ab]	8.86[b]	1.18
POTASSIUM					
Intake g/d	91.85	93.37	92.37	113.78	
Urine g/d	50.74[a]	49.38[a]	50.33[a]	73.95[b]	4.31
Fecal g/d	22.29[a]	17.52[b]	17.35[b]	17.46[b]	1.06
Balance g/d	18.82[a]	26.46[a]	24.69[a]	22.38[a]	4.53
CHLORIDE					
Intake g/d	112.40	81.36	56.62	55.17	
Urine g/d	67.17[a]	56.14[a]	33.05[b]	35.39[b]	4.13
Fecal g/d	7.58[a]	8.22[a]	6.49[a]	7.74[a]	.86
Balance g/d	37.65[a]	17.00[b]	17.07[b]	12.04[b]	4.13
MAGNESIUM					
Intake g/d	12.41	12.69	12.51	12.48	
Urine g/d	3.88[a]	3.70[a]	3.78[a]	3.70[a]	.31
Fecal g/d	7.59[a]	6.34[b]	6.45[b]	6.47[b]	.24
Balance g/d	.94[a]	2.65[b]	2.28[b]	2.31[b]	.34
SULFUR					
Intake g/d	9.20[a]	9.49[a]	9.26[a]	10.39[a]	
Urine g/d	7.91[a]	9.03[a]	8.34[a]	8.73[a]	1.93
Fecal g/d	2.54[a]	2.35[a]	2.31[a]	2.23[a]	.14
Balance g/d	-1.25[a]	-1.89[a]	-1.39[a]	-0.56[a]	1.91
PHOSPHORUS					
Intake g/d	22.77	23.95	22.86	22.94	
Urine g/d	.07[a]	.06[a]	.06[a]	.06[a]	.01
Fecal g/d	21.6[a]	17.74[b]	17.18[b]	17.20[b]	.42
Balance g/d	1.0[a]	6.16[b]	5.62[b]	5.68[b]	.42
CALCIUM					
Intake g/d	40.82	42.98	42.35	44.22	
Urine g/d	20.11[a]	15.71[ab]	12.16[ab]	10.33[b]	2.12
Fecal g/d	17.45[ab]	15.66[a]	19.53[ab]	21.01[b]	.97
Balance g/d	3.26[a]	11.61[ab]	10.66[ab]	12.88[b]	2.29

[a,b] Means in rows with different superscripts differ ($P < .05$).

horses consuming diet H as compared to those on diet L. These results do suggest that as DCAB decreases calcium balance also decreases, predisposing those animals to a negative calcium balance. When prolonged, this condition could lead to an osteoporotic weakening of the skeletal system as seen in poultry (Edwards, 1984 , Halley et al. 1987).

Conclusions

Horses consuming diets with low DCAB experienced mineral balances similar to that seen in other species. Depending on the level of intake, these horses may experience negative calcium, phosphorus, and magnesium balances. Whereas, an increase in calcium balance was seen in those horses consuming the high DCAB diet. Thus, feeding diets with higher DCAB may improve performance by minimizing potential skeletal disorders in the exercised horse.

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