EFFECT OF DIETARY CATION-ANION BALANCE ON MINERAL BALANCE IN HORSES

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Story In Brief

Four mature sedentary geldings were used in a 4x4 Latin square designed experiment to study the effects of dietary cation-anion balance on mineral balance in the non-exercised horse. Four diets were fed with a Low, Medium Low, Medium High and High Dietary Cation-Anion Balance (calculated as meq $((Na^{+} + K^{+}) - Cl^{-}$/kg of diet dry matter) for a 21 day adjustment period followed by a 72 hour collection period. Diets consisted of a pelleted base concentrate of corn, soybean meal and cottonseed hulls fed with native prairie grass hay. Feed, fecal and urine samples were composited and analyzed for mineral content. Daily sodium balance was higher in those horses consuming the Medium High diet as compared to those horses consuming the Medium Low and Low diets. Daily potassium balance was higher in those horses consuming the High diet as compared to those horses consuming the Medium Low diet. No differences were seen in daily chloride or magnesium balances. Daily phosphorus balance was different between all treatments, however, balances were reflective of phosphorus intake. Daily calcium balance decreased significantly as the Cation-Anion Balance of the diet decreased between all treatments. These data indicate that horses consuming diets with lower Dietary Cation-Anion Balance's may be in a net negative calcium balance which could lead to an osteoporotic weakening of the skeleton.

(Key Words: Equine, Mineral, Nutrition.)

Introduction

Sodium, potassium and chloride are the most influential ions involved in the regulation of osmotic pressure in body fluids, as well as the maintenance of acid-base balance. The equation used to calculate dietary cation-anion balance (DCAB) in this study is meq $((Na^{+} + K^{+}) - Cl^{-})$/kg of diet dry matter. Feeding

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diets with lower DCABs has been shown to have an adverse effect on the acid-base status, growth, dry matter digestibility, bone physiology, milk yield and mineral balance in other animal species, namely poultry, swine, dairy cattle and horses. Recent studies in horses have demonstrated that exercising horses consuming diets with a lowered DCAB have increased urinary excretion of both chloride and calcium, and that this increased calcium excretion could lead to a net loss of calcium from the body (Topliff et al. 1989; Wall et al. 1992). Furthermore, it has been demonstrated that non-exercised horses consuming a diet with a lowered DCAB have lowered arterial and venous blood pH, bicarbonate and pCO_2 levels, as well as a lowered urinary pH, indicative of metabolic acidosis. It was the objective of this trial to study the effects of varied DCAB's on total mineral balance in non-exercised horses.

Materials and Methods

Four mature geldings were used in a 4x4 Latin square designed experiment to study the effects of DCAB on daily mineral balance in the non-exercised horse. Diets consisted of a pelleted base concentrate of corn, soybean meal and cottonseed hulls and was fed in a 60:40 ratio with native prairie grass hay in amounts to maintain a constant body weight. Each period consisted of a 21 day adjustment period followed by a 72 hour collection period. Treatments with DCAB's of +21 (Low, L), +125 (Medium Low, ML), +231 (Medium High, MH) and +350 (High, H) were formed by supplementing diet L with ammonium chloride and calcium chloride, diet ML with calcium chloride and diet H with potassium citrate and sodium bicarbonate. Diet MH received no additional Na^+, K^+ or Cl^- supplementation and served as the control diet (Table 1). Diets were calculated to contain equivalent amounts of digestible energy and crude protein across treatments. Diets were analyzed and determined to contain approximately equal amounts of calcium, phosphorus, magnesium and sulphur. Furthermore, after supplementation, diet H contained 1.25% potassium and .40% sodium, while diet ML contained 1.04% chloride and diet L contained .73% chloride (Table 2). Horses were exercised for 30 minutes daily on a mechanical walker. Horses were individually stalled and were given routine health care throughout the trial.

Total urine collection was taken for 72 hours using urine harnesses. Composited urine samples were immediately acidified and frozen for later mineral analysis. Fecal samples were taken to represent every two hours post feeding, and samples were immediately frozen for mineral analysis. Feed samples were also taken at various times throughout the trial and samples were analyzed for mineral content.

Table 1. Composition of diets, as fed basis.

Ingredient (%)	L	ML	MH	H
Ground corn	36.80	37.30	37.30	35.90
Soybean meal	6.00	6.00	6.00	6.00
Cottonseed hulls	15.00	15.00	15.00	15.00
Dical	.50	.50	.50	.50
Trace mineral salt	.50	.50	.50	.50
Limestone	---	---	.50	.50
Chromic oxide	.20	.20	.20	.20
Calcium chloride	.50	.50	---	---
Ammonium chloride	.50	---	---	---
Sodium bicarbonate	---	---	---	.40
Potassium citrate	---	---	---	1.00
Prairie grass hay	40.00	40.00	40.00	40.00
Total	100	100	100	100
DCAB	+21	+125	+231	+350

Table 2. Diet analysis (dry matter basis).

Ingredient	L	ML	MH	H
DE, Mcal/kg	2.54	2.56	2.56	2.50
Crude protein %	9.60	9.70	9.70	9.50
Calcium %	.52	.54	.50	.58
Phosphorus %	.29	.34	.28	.33
Magnesium %	.15	.16	.15	.15
Potassium %	.57	.57	.57	1.25
Sodium %	.22	.27	.32	.40
Sulphur %	.13	.13	.11	.14
Chloride %	1.04	.73	.40	.38

Results and Discussion

Daily mineral balance data are shown in Table 3. Those horses consuming diets L and H excreted more sodium in the urine as compared to those consuming diets ML and MH. Also, those horses consuming diet L excreted less sodium in the feces when compared to those consuming all other diets. These urinary and fecal excretions resulted in daily sodium balances that

Table 3. Effect of dietary cation-anion balance on daily mineral balance in horses.

	Treatment			
Mineral, g/d	L	ML	MH	H
Sodium				
Intake	18.03	21.59	24.50	30.13
Urine	13.50[a]	6.20[b]	5.32[b]	11.53[a]
Fecal	5.66[a]	13.03[b]	13.71[b]	16.56[b]
Balance	-0.76[a]	3.71[ab]	7.90[b]	5.04[ab]
Potassium				
Intake	69.10	67.01	67.01	95.48
Urine	34.85[a]	46.55[a]	41.52[a]	68.47[b]
Fecal	24.05[b]	18.19[a]	16.98[a]	15.28[a]
Balance	12.27[ab]	6.42[a]	12.66[ab]	20.47[b]
Chloride				
Intake	84.23	57.26	30.29	29.29
Urine	70.59[a]	57.53[a]	31.34[b]	31.43[b]
Fecal	4.60[a]	5.58[a]	5.78[a]	3.52[a]
Balance	13.16[a]	-2.35[a]	-3.82[a]	-3.16[a]
Calcium				
Intake	41.50	42.25	38.26	44.75
Urine	39.81[a]	31.80[b]	13.99[c]	3.99[d]
Fecal	15.35[a]	15.76[a]	19.11[b]	15.92[a]
Balance	-12.20[a]	-2.65[b]	8.31[c]	28.51[d]
Phosphorus				
Intake	23.67	26.46	20.97	24.96
Urine	.15[a]	.13[a]	.14[a]	.16[a]
Fecal	19.05[a]	19.10[a]	18.97[a]	17.32[b]
Balance	5.31[a]	8.73[b]	3.86[c]	9.98[d]
Magnesium				
Intake	12.17	12.30	11.30	11.80
Urine	6.02[a]	6.74[a]	6.47[a]	6.44[a]
Fecal	7.95[a]	7.42[ab]	6.76[bc]	6.68[c]
Balance	-1.31[a]	-1.01[a]	-1.08[a]	-0.48[a]

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

were similar for those horses consuming diets L, ML and H, although daily sodium balance was higher in those horses consuming diet MH when compared to those consuming diet L. Daily intake of potassium was increased to 104 g/d in those horses consuming diet H, as compared to 73, 71 and 71 g/d for diets L, ML and MH, respectively. Those horses consuming diet H had higher concentrations of potassium in the urine when compared to those consuming all other diets. Furthermore, those consuming diet L had greater amounts of potassium in the feces as compared to those consuming all other diets. Potassium balances were similar among diets L, ML and MH, however, potassium balance was higher in those horses consuming diet H as compared to those consuming ML diet. Daily intake of chloride was approximately 60 g/d for the ML diet, and 89 g/d for the L diet. Horses consuming diets L and ML excreted more chloride in the urine than horses consuming diets MH and H. Daily fecal chloride excretions were similar across all treatments. No differences were seen in daily chloride balance across treatments, however, only those horses consuming the L diet had a positive balance. There were no differences in daily magnesium balance across treatments. No differences were observed in daily urinary phosphorus excretion between any treatment, and daily fecal excretion was similar between diets L, ML and MH, while those consuming diet H had lower daily fecal excretion as compared to all other diets. Although there were significant differences in daily phosphorus balance between all treatments, balances tended to reflect intake, and since all daily balances were positive, these differences are not thought to be of any practical significance.

Daily fecal excretion of calcium was similar in those horses consuming diets L, ML and H, however, those horses consuming diet MH excreted more calcium in the feces as compared to all other diets. Daily urinary excretion of calcium increased significantly between all treatments as the DCAB decreased. These urinary and fecal excretions of calcium resulted in marked differences in daily calcium balance between all diets. Daily calcium balances ranged from +28.51 g/d for those horses consuming the H diet, to -12.20 g/d for those horses consuming the L diet.

Feeding highly anionic diets has been shown to induce a state of nutritionally induced metabolic acidosis (Baker et al. 1992, Wall et al. 1992, Stutz et al. 1992). A chronic state of acidosis has also been shown to have a marked effect on mineral metabolism and the urinary excretion of certain minerals (Wall et al., 1992). Urinary excretion of minerals such as sodium and potassium is sensitive to the intake of those minerals by the animal. Urinary sodium excretion has been shown to be directly related to intake, however, the reason for the increased sodium excretion in horses consuming diet L in this study is most likely due to the fact that the excess chloride being excreted in those horses consuming the L diet is being accompanied by a sodium ion. Urinary potassium excretion is also directly related to dietary intake. The kidney is also the main route of chloride excretion. In a state of chronic metabolic acidosis, one of the routes of excretion of excess hydrogen ions is through the combination of these hydrogen ions with chloride in the tubule lumen. This forms the strong acid HCl which quickly combines with ammonia to form ammonium chloride (NH_4Cl) which is a much weaker acid and much less damaging to the kidney tubules. The increase in calcium excretion in the urine is not completely understood, however, it may be due to the action of parathyroid hormone (Goff et.al. 1991) which causes an increase in intestinal absorption of calcium and also an increase in resorption of bone calcium. It is also known that as the pH of the plasma decreases, the amount of ionized, or free calcium in the plasma increases, due to the release of this bound calcium from plasma proteins. This free, or ionized calcium is then able to be excreted by the kidney.

The results from this study suggest that non-exercising horses consuming a diet with a lowered cation-anion balance may be in a negative calcium balance. If prolonged, this could lead to an osteoporotic weakening of the skeletal system, which has been demonstrated in other species. On the other hand, those horses consuming the H diet had the largest positive daily calcium balance, therefore, feeding diets with a high DCAB could result in fewer injuries to exercising horses and less developmental orthopedic diseases in young growing horses due to a more desirable mineral balance in the body.

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