EFFECTS OF DIETARY CATION-ANION BALANCE ON BLOOD PARAMETERS AND MINERAL METABOLISM IN EXERCISING HORSES

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Story in Brief

Four geldings and four mares of primarily Thoroughbred and Quarter Horse breeding were grouped by sex and randomly assigned to one of four experimental treatments to test the effects of dietary cation-anion balance (DCAB) on exercising horses. Treatments were formed by supplementing the corn-soybean meal-cottonseed hull supplement to provide a DCAB of -50 (Low, L), +50 (Medium Low, ML), +150 (Medium High, MH) and +250 (High, H) meq((Na+K)-Cl)/kg diet dry matter. Calcium chloride and ammonium chloride were added to diet L and ML and sodium bicarbonate and potassium citrate were added to diet H to achieve the desired DCAB. Horses were subjected to a six week conditioning period, consisting of long slow distance (LSD) aerobic work. During the experimental periods horses were subjected to a combined exercise regimen alternating LSD with an interval training protocol 6 days/week. The effect of treatment was highly significant for acid base parameters in horses at rest, although acid-base parameters, heart rate and plasma glucose concentrations were not significantly different in horses performing anaerobic work. Horses consuming diet L excreted significantly more calcium and chloride and less sodium than those consuming diet H. Results of this trial suggest that DCAB has a significant effect on acid-base status and mineral excretion in resting horses, although the buffering effect of excess cations in the diet did not protect blood pH during the exercise bout itself.

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

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Introduction

Little research pertaining to the effect of DCAB on the exercising horse is available. Potassium, sodium and chloride are the major ions involved with acid-base balance and the osmotic regulation of body fluids. The equation that is used to determine the DCAB is meq((Na+K)-Cl)/kg diet dry matter. The effects of DCAB on acid-base physiology have been investigated in many species. In dairy cattle it has been shown that increasing the level of DCAB from -10 to +20 meq/100g DM increased milk yield in lactating Holsteins by 8.6 percent (Tucker et al., 1988). Altering the DCAB of rations fed to swine and poultry has been shown to affect blood pH and calcium balance and suggests to predispose the development of bone disease (Austic, 1984; Patience et al. 1987). Low DCAB due to chloride has been shown to depress blood pH, bicarbonate and decrease pCO_2 levels (Tucker et al., 1988).

Horses performing extensive amounts of physical exercise may lose large quantities of some minerals from the body through sweat (Schryver et al., 1978; Kerr and Snow, 1983). Young et al. (1989) showed that horses fed a diet that contained 4.32 Mcal/d during the rest period and 7.93 Mcal/d during the exercise period to have increased fecal outputs of sodium, potassium, chloride, and phosphorus. There was also a decrease in the urinary output of all the above ions except potassium which increased 31.3 mg/kg body weight. Topliff et al. (1988) showed that there is a significant increase of calcium in urine ($p<.05$) of horses consuming a diet with a low DCAB. Those horses also had higher concentrations of chloride ($p<.05$) in the urine.

Sodium and potassium are frequently absorbed from the gastrointestinal tract in exchange for the secretion of a proton. Also, as chloride is absorbed from the gastrointestinal tract, a bicarbonate ion is secreted. Altering these ions in the diet may help to delay the onset of fatigue in performance horses. It was therefore the objective of this experiment to investigate the effect of varying levels of DCAB on blood acid-base status and mineral balance in horses performing strenuous work.

Materials and Methods

Four geldings and four mares of primarily Thoroughbred and Quarter Horse breeding were used in two simultaneous 4x4 Latin square experiments. Horses were subjected to a six week conditioning period, consisting of LSD aerobic work. During the experimental periods horses performed a combined exercise regimen alternating LSD with an interval training protocol consisting of alternating sprints with a slow gallop 6 days/wk. Four diets

(Table 1) with DCAB's (calculated as meq((Na+K)-Cl)/kg diet dry matter) of -50 (L), +50 (ML), +150 (MH) and +250 (H) were fed for a 21 day adjustment period followed by a 96 hour collection period. The concentrate was fed with bermuda grass hay in a 60:40 ratio in amounts required to maintain constant body weight. Calcium chloride and ammonium chloride were added to diet (L), calcium chloride was added to the diet (ML), and potassium citrate and sodium bicarbonate were added to the diet (H) to achieve the desired DCAB. The diet (MH) served as the basal diet. The horses were maintained in individual stalls with free access to water. The horses were immunized and dewormed prior to the initiation of the trial and received standard animal health care throughout the trial.

Beginning with the morning feeding on the 22nd day of each experimental period, venous blood samples were drawn hourly for 17 hours. The blood samples were analyzed immediately for blood pH and blood gases. A total urine collection was taken beginning at the same time for 72 hours on the geldings by urine collection harnesses and for 24 hours on the mares by catheterizing the bladder. Fecal grab samples were taken over 72 hours to represent every two hours during the post feeding interval. Composited urine and fecal samples were stored for later mineral analysis. The last day of each experimental period, horses were subjected to a standard exercise

Table 1. Composition of concentrate diets, DM basis.

	Diet			
Ingredient (%)	L	ML	MH	H
Ground Corn	33.2	33.2	33.2	33.2
Soybean Meal	6.9	6.9	6.9	6.9
Cottonseed Hulls	14.8	15.1	15.0	13.7
DiCal	.21	.21	.19	.20
Limestone	----	.22	.78	.78
Trace Mineral Salt	.55	.55	.55	.55
Calcium Chloride	.78	.54	----	----
Ammonimum Chloride	.30	----	----	----
Potassium Citrate	----	----	----	.89
Sodium Bicarbonate	----	----	----	.61
Liquid Cane Molasses	2.0	2.0	2.0	2.0
Bermuda Grass Hay	40	40	40	40
Total	100	100	100	100

test (SET) approximately two hours before the morning feeding. The SET consisted of a 1.6 km sprint at speeds sufficient to elicit a target heart rate of 200 beats/min. Blood samples were drawn via jugular venipuncture preexercise, at the end of exercise and at 1, 2, 3, 4, 5, 10, 20 and 30 minutes postexercise. Blood samples were analyzed immediately for blood pH, blood gases and plasma glucose concentration. Heart rates were recorded using an on board heart rate monitor. All data were analyzed using a general linear model procedure for repeated measures and least square means calculated for each parameter. The pDiff procedure was used to detect significant differences between means (SAS, 1985).

Results and Discussion

Least square means for blood pH and blood gases for horses at rest and exercising horses are shown in Figures 1-5. Blood pH (Figure 1) for horses at rest was reduced ($p<.001$) by the (L) diet versus the basal diet (MH). Effect of treatment was also significant for HCO_3 (26.95(L)-31.43(H)mmol/L) (Figure 2). These results are in agreement with Tucker et al. (1988) who reported a decrease in venous blood pH, bicarbonate and pCO_2 in dairy cows fed diets with low DCAB's.

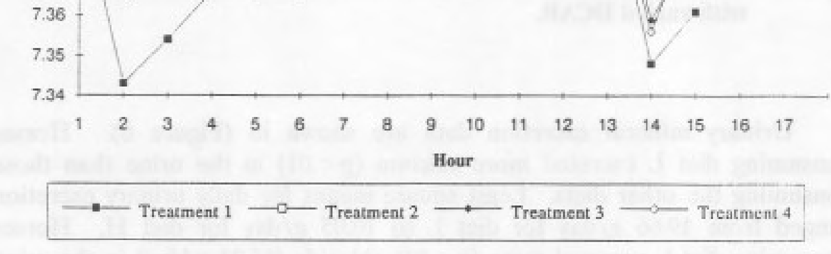

Figure 1. Venous blood pH in horses at rest consuming diets with varied DCAB.

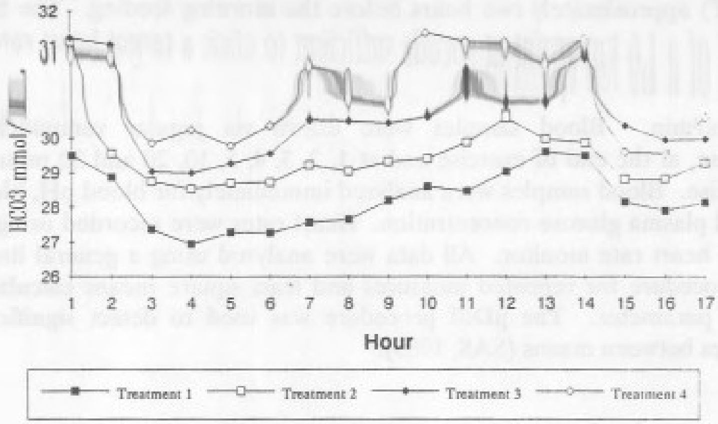

Figure 2. Venous bicarbonate in horses at rest consuming diets with varied DCAB.

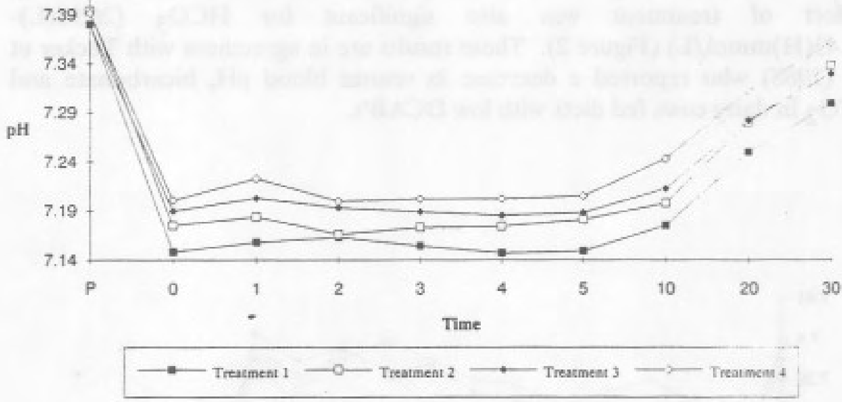

Figure 3. Venous pH of anaerobically exercised horses consuming diets with varied DCAB.

Urinary mineral excretion data are shown in (Figure 6). Horses consuming diet L excreted more calcium ($p<.01$) in the urine than those consuming the other diets. Least square means for daily urinary excretion ranged from 19.66 g/day for diet L to 10.05 g/day for diet H. Horses consuming diet L excreted more ($p<.01$) chloride (65.31 g/day) in the urine when compared to the other treatments (ML-48.51; MH-32.30; H-34.86 g/day). These results are in agreement with Topliff et al. (1989) who

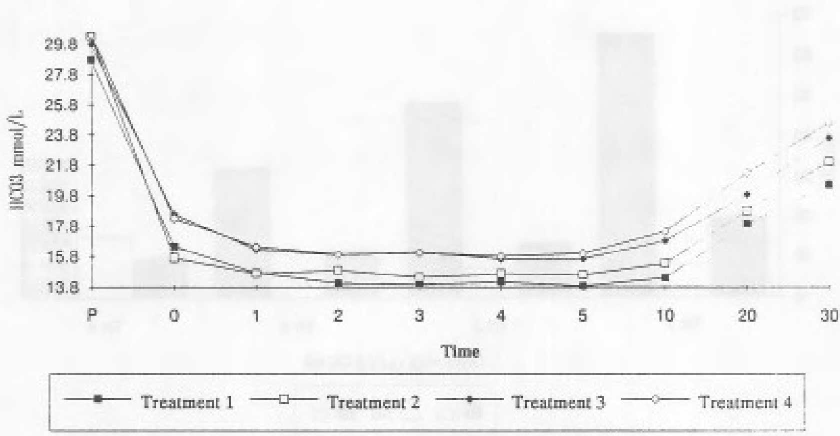

Figure 4. Venous bicarbonate in anaerobically exercised horses consuming diets with varied DCAB.

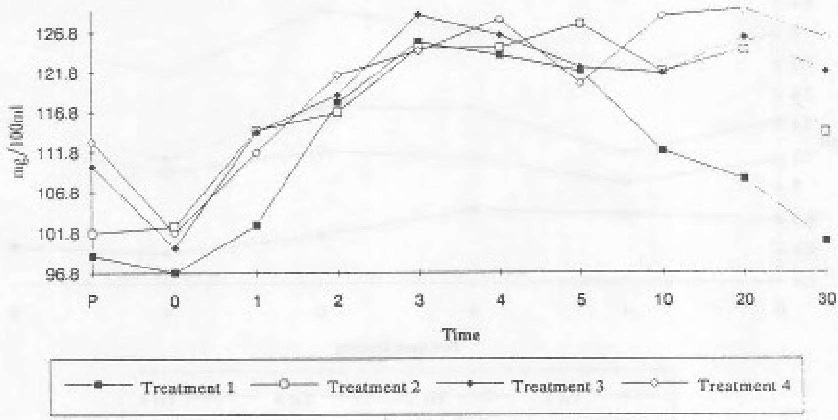

Figure 5. Plasma glucose in anaerobically exercised horses consuming diets with varied DCAB.

reported an increase in urinary calcium and chloride excretion in exercising horses consuming diets of low DCAB. Daily urinary sodium excretion (15.21 g/day) for horses consuming diet H was greater ($p < .01$) as compared to the other three diets (L-8.24; ML-7.25; MH-5.75). No significant differences were detected in daily urinary K, Mg, P, or S excretion. Urine pH data are shown in Figure 7. There was a significant Time x Treatment interaction with an average pH across time of 6.74, 7.18, 7.39 and 7.94 for diets L, ML,

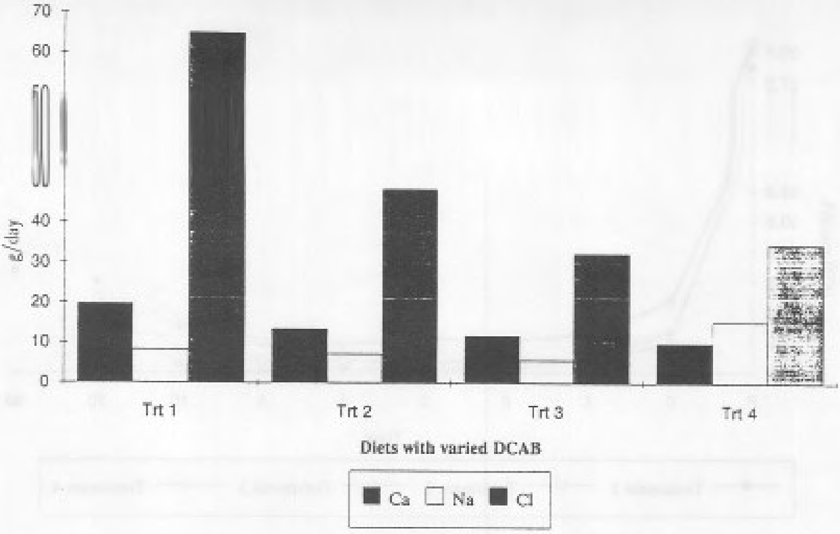

Figure 6. Urinary mineral excretion of exercising horses consuming diets with varied DCAB.

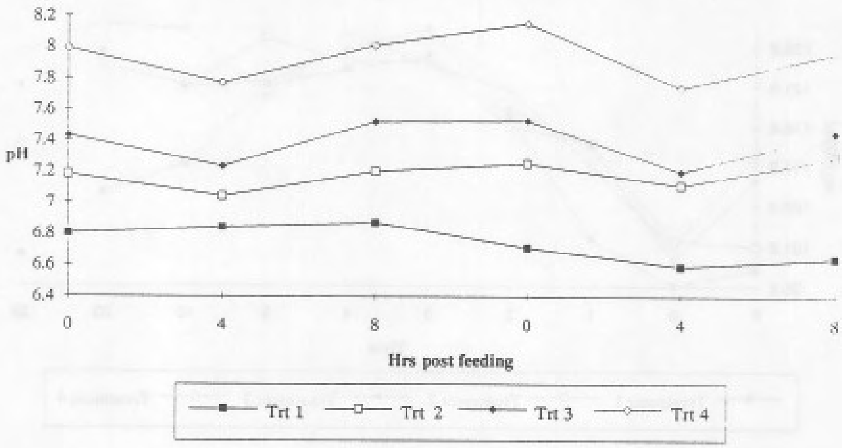

Figure 7. Urine pH of exercising horses consuming diets with varied DCAB.

MH and H respectively. Although the cause of the increased calcium excretion is not fully understood, these results indicate that exercising horses consuming diets of lower DCAB may be in a net negative calcium balance. Under prolonged situations, this could lead to an osteoporotic weakening of the skeletal system as seen in swine and poultry (Patience et al., 1987; Austic, 1984).

When cations such as Na^+ and K^+ are absorbed, systemic base generation will increase. In addition, when anions such as Cl^- are absorbed, acid generation will also increase. From this information the conclusion can be drawn that the ratio of cations to anions in the diet (DCAB) could influence blood acid-base status as previously shown by Tucker et al. (1988). Effects of treatment were not significant for the measures of acid-base status in horses performing anaerobic work. However, the data concerning exercise blood pH (Figure 3) and bicarbonate (Figure 4) demonstrate a trend toward a difference between treatment L and treatment H. During strenous exercise blood pH will drop due to respiratory and metabolic effects along with a concurrent drop in bicarbonate. Diets that are high in DCAB may buffer these responses. No difference was detected in heart rate during exercise or recovery. There were no significant differences in plasma glucose concentrations (Figure 5) in all four dietary treatments until 10 minutes post exercise, where there was a difference ($p<.05$) between diets L and H. At 20 minutes post exercise, there was a significant difference between diets L and ML, and diets MH and H. At 30 minutes post exercise, there were significant differences between the L diet and the ML, MH and H diets. These data indicate that horses consuming diets with a low DCAB may experience a metabolic acidosis. No buffering effect of diets MH and H was apparent post exercise. However, that may be attributed to the time exercise was performed in relation to feeding. In a pretrial study, we observed a buffering effect on blood pH in horses exercised within four hours post-feeding. Additional research is needed to clarify the effect of DCAB on acid-base status post-feeding.

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