EFFECTS OF DIETARY CATION-ANION BALANCE ON ACID BASE BALANCE AND BLOOD PARAMETERS IN ANAEROBICALLY EXERCISED HORSES

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Story in Brief

Four mature geldings were used in a 4 X 4 Latin square experiment to study the effect of dietary cation-anion balance (DCAB), calculated as meq (Na+K)-(Cl+S)/kg of diet dry matter, on urine pH, arterial and venous blood pH, blood gases, blood lactate concentration and recovery heart rates in horses performing anaerobic work. Diets consisted of a pelleted concentrate (corn, soybean meal and cottonseed hulls) fed in a 60:40 ratio with native prairie grass hay. The four treatments were formed by supplementing the concentrate with calcium chloride, ammonium chloride, sodium bicarbonate or potassium citrate to provide treatment cation-anion balances of 10, 95, 165 and 295. On the final day of each 15 day experimental period, horses performed a standard exercise test within 4 hrs after feeding. The standard exercise test consisted of a 1.64 km sprint at speeds sufficient to maintain heart rates above 200 bpm. Seventy-two hours prior to the standard exercise test, total urine was collected every four hours using urine harnesses. Arterial and venous blood samples were taken via indwelling catheters pre-exercise (P), immediately after exercise (0), and at 1, 2, 3, 4, 5, 10, 30, and 60 minutes of recovery. Results from this trial further demonstrate that horses ingesting highly anionic diets experienced a nutritionally induced metabolic acidosis. Moreover, when exercised within 4 hours of feeding, horses consuming highly cationic diets achieved greater work output and recovered more quickly due to the buffering effect of the diet.

(Key Words: Horse, Exercise, Blood pH, Lactate.)

Introduction

Dietary cation-anion balance (DCAB) has begun only recently to be investigated in the exercising horse. DCAB can be defined quantitatively as meq [(Na+K)-(Cl+S)]/kg dry matter (Tucker et al., 1991). Sodium,

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potassium and chloride are the major ions involved in the maintenance of acid-base balance and the osmotic pressure of body fluids. Because sulfur has been shown to have similar effects as chloride on acid-base status in lactating dairy cows (Tucker et al., 1991), it was included in the equation .

The effects of DCAB on acid-base physiology has been studied in many species. Tucker et al. (1988) found that milk yield in lactating Holsteins was increased 8.6% by increasing DCAB from -100 to +200 meq/kg DM. Patience et al. (1987) showed that sodium bicarbonate supplementation in swine diets increased growth and feed intake. Conversely, lowering DCAB in poultry and swine diets predisposes animals to metabolic bone disorders (Austic, 1984, Patience et al., 1987). Baker et al. (1992) observed that in sedentary horses blood pH, pCO_2 and HCO_3 decreased as DCAB decreased. This concurs with results reported by Stutz et al. (1991) who showed that strenuously exercised horses experience a nutritionally induced metabolic acidosis when fed highly anionic diets. Furthermore, such diets have been shown to lower urine pH and increase calcium excretion (Baker et al., 1992, Topliff et al., 1989 and Wall et al., 1992).

When sodium and potassium ions are exchanged in the gastrointestinal tract for intracellular fluid hydrogen ions this results in a net systemic base generation. Chloride is also absorbed from the gastrointestinal tract in exchange for a bicarbonate ion, resulting in systemic acid generation. Hence, raising the level of cations in the diet may retard the drop in blood pH during strenuous exercise and thereby delay the onset of fatigue. The objective of this experiment was to study the performance, recovery heart rates, acid base status, blood lactate concentrations and blood gases in horses performing anaerobic work.

Materials and Methods

Four mature geldings were used in a 4 X 4 Latin square experiment designed to study the effects of DCAB on the acid-base status, work performance, blood lactate concentration and recovery heart rates in anaerobically exercised horses. Four diets providing a DCAB of 10 (L), 95(ML), 165(MH) and 295(H) calculated as $[(Na^+ + K^+) - (Cl^- + S^-)]$/kg diet DM were rotated among the four 15 day experimental periods. Diets consisted of a pelleted concentrate (corn, soybean meal and cottonseed hulls) fed in a 60:40 ratio with native prairie grass hay at 12 hour intervals in amounts to maintain constant body weight throughout the experiment. The four treatments were formed by the addition of calcium chloride and ammonium chloride to diet L, calcium chloride to diet ML and potassium citrate and sodium bicarbonate to diet H. Diet MH received no supplementation and served as the control ration (Table 1).

Table 1. Composition of diets on a dry matter basis.

	Diet			
Ingredient (%)	L	ML	MH	H
Corn	37.10	37.10	37.10	37.00
Soybean Meal	6.30	6.50	6.80	6.80
Cottonseed Hulls	14.90	15.10	15.10	13.00
Dicalcium Phosphate	.50	.50	.50	.40
Limestone, ground	---	---	.50	.40
Trace Mineral Salt	.50	.50	.50	.50
Calcium Chloride	.30	.30	---	---
Ammonium Chloride	.40	---	---	---
Potassium Citrate	---	---	---	1.20
Sodium Bicarbonate	---	---	---	.70
Native Grass Hay	40.00	40.00	40.00	40.00
Total	100	100	100	100
DCAB	10	95	165	295

Horses were aerobically conditioned 6d/wk for 4 weeks prior to the beginning of the experiment using a long slow distance (LSD) training regimen which consisted of a 3.28 km gallop at target heart rates of 160 bpm. During the experimental periods, horses were exercised 6d/wk alternating LSD with 2d/wk sprint training. Sprint training consisted of one .8 km sprint at a heart rate above 200 bpm. On the last day of each 14 day experimental period, horses performed a standardized exercise test (SET) approximately two hours after the morning feeding. The SET consisted of a 1.64 km sprint at speeds sufficient to elicit target heart rates between 200 and 210 bpm. Heart rates were recorded using a digital onboard heart rate monitor (UNIQ Computer Instruments Corp., Hempstead, NY).

Arterial (A) and venous (V) blood samples were taken via indwelling catheters pre-exercise (P), immediately after exercise (0), and at 1, 2, 3, 4, 5, 10, 30, and 60 minutes of recovery (REC). Samples for analysis of blood lactate concentration were immediately deproteinized in 10% w/v trichloroacetic acid, centrifuged and the supernatant was decanted and stored. Lactic acid concentrations were determined using an enzymatic assay (Sigma Lactate Procedure No. 826-UV). A portion of each sample was immediately analyzed for pH, HCO3, pCO2, total CO2, pO2, base excess (extracellular fluid) and base excess (blood) on a blood gas analyzer (Instrumentation Laboratory Model 1304, Lexington, Ma.). Seventy two hours prior to the SET, total urine was collected every four hours using urine harnesses. Urine pH was determined and samples were immediately frozen for later mineral analysis. All data were analyzed using a general linear model for repeated measures, with horse, period and treatment as main effects and time as a repeated variable. Treatment least squares means over time were calculated and tested for significance (SAS, 1985).

Results and Discussion

Urine pH was lower ($P < .001$) for horses consuming diet L and higher ($P < .01$) for horses on diet H when compared to treatments ML and MH. The effect of treatment over time on urine pH is shown in Table 2. These differences concur with that of Baker et al. (1991), Wall et al. (1991) and Tucker et al. (1988), demonstrating the systemic acid generation of anions, and the systemic base generation of cations. The effect of treatment on A and V blood pH and HCO3 values pre and post-exercise are shown graphically in Figures 1 and 2. No significant differences between A and V blood were detected for any parameters measured except pCO2 and pO2 indicating that venous blood was representative of central circulation with respect to acid-base status. For all blood gas values, treatment L was different from treatment H at times P and 60 but not at other times. Furthermore, blood gas parameters increased with increasing DCAB at times P and 60. Conversely, no consistent significant differences between blood gas parameters were detected at times 0, 1, 2, 3, 4, 5, 10 and 30 REC. Recovery heart rates were significantly lower at times 3, 4, 5, 10 and 30 REC for diet H, and in addition SET times were significantly higher for horses consuming diet

Table 2. Effect of dietary cation-anion balance on urine pH post feeding in anaerobically exercised horses.

	Treatment			
Time	L	ML	MH	H
11am*	5.88^a	7.41^b	7.51^b	7.91^c
3pm	6.03^a	7.23^b	7.55^b	8.02^c
7pm	5.89^a	7.29^b	7.30^b	7.83^c
11pm*	5.97^a	7.28^b	7.47^b	8.03^c
3am	6.01^a	7.51^b	7.54^b	7.97^c
7am	6.14^a	7.26^b	7.32^b	7.93^c

* Indicates feeding time.

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

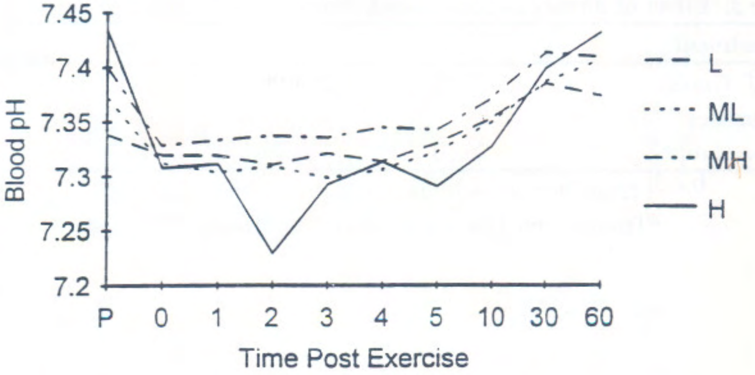

Figure 1. Effect of dietary cation-anion balance on blood pH in anaerobically exercised horses.

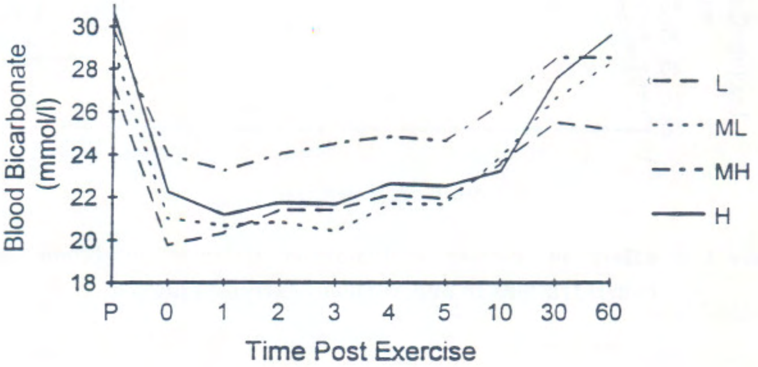

Figure 2. Effect of dietary cation-anion balance on blood HCO3 in anaerobically exercised horses.

L as compared to diet H (Table 3). Blood lactate concentrations (Figure 3) were lower for diet L at times P and 60 REC than for diets ML, MH and H and were highest at all times for diet H.

Because the ratio of cations to anions in the diet influences acid-base balance, horses consuming diets with a low DCAB may experience a nutritionally induced metabolic acidosis. Moreover, there appeared to be a buffering effect of diet H post exercise, which resulted in faster recovery of

Table 3. Effect of dietary cation-anion balance on SET times.

Treatment	L	ML	MH	H
SET Times (min:sec)	2:55^{b}	2:37^{bc}	2:31^{cd}	2:26^{d}
(Speed,mph)	20.60	22.90	23.80	24.70

^{b,c,d}Means in rows with different superscripts differ (p<.10).

^{a}Time to run 1.64 km at heart rate of 200 to 210 bpm.

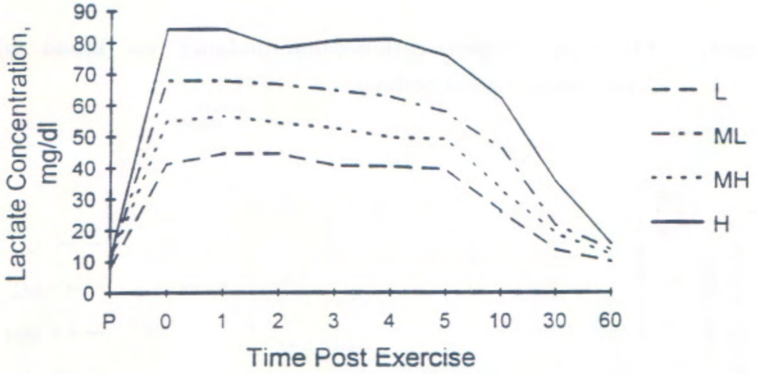

Figure 3. **Effect of dietary cation-anion balance on blood lactate concentrations in anaerobically exercised horses.**

heart rate even though blood lactate concentrations were greater. These data demonstrate that anaerobic performance can be enhanced through the feeding of highly cationic diets when exercise is performed within 4 hours after feeding.

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