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EFFECT OF VARYING DCAD ON THE ACID-BASE STATUS OF MATURE SEDENTARY HORSES WITH VARYING STARCH SOURCE AND LEVEL OF INTAKE

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Story in Brief

Six mature horses were used in a 6 x 6 Latin Square design to determine the effects of varying dietary cation anion difference (DCAD) on the acid-base status of horses consuming varying amounts and types of starch. Rolled corn, whole oats, or dehydrated alfalfa meal were used to make up the concentrate portions of the diets. Three diets had a DCAD above 300 meq/kg DM, and three below 160 meq/kg DM. This trial consisted of 11-d adjustment periods followed by 72-h experimental collection periods. During that time venous blood samples were drawn for analysis of pH, pCO_2, HCO_3^-, pO_2, and lactate concentrations. Total urine was collected and measured for pH and mineral content. Blood lactate concentration showed no variation among treatments. Urine pH, blood pH and blood HCO_3^- concentrations were significantly lower for horses consuming diets with a low DCAD as compared with diets with a high DCAD regardless of starch source or intake. Thus, it may be possible to reverse any metabolic acidosis caused by high starch intake by increasing the DCAD of the diet.

Key Words: Dietary Cation Anion Difference, Starch, Metabolic Acidosis

Introduction

Many studies conducted with many species from this laboratory have shown the correlation of the dietary cation anion difference (DCAD) with the acid-base status of the animal (Tucker et al., 1991; Baker et al., 1992; Popplewell et al., 1993; Stutz et al., 1992; Wall et al., 1992; Baker et al., 1993). Researchers have developed an equation to quantify this balance: meq $(Na^+ + K^+) - (Cl^- + S)$ /kg of dry matter (Popplewell et al., 1993; Tucker et al., 1991). Many researchers have shown that diets with a low DCAD can result in decreased blood and urine pH as well as depressed bicarbonate levels. Several studies have also shown that grains fed in high concentration tend to cause a metabolic acidosis (Roby et al., 1987; Abu Damir et al., 1990; Ralston, 1994).

Some researchers have speculated that this metabolic acidosis is due to lactic acid production from the digestion of starch irrespective of the DCAD. The present hypothesis, however, is that the acidosis is due to the low levels of cations typically found in cereal grains and thus a low DCAD, particularly compared with forages. Thus the focus of this study was to determine if the metabolic acidosis that can occur when horses are fed diets high in starch can be prevented by increasing the DCAD.

Materials and Methods

Three mares and three geldings were used in a 6 x 6 Latin Square designed experiment at the Oklahoma State University Equine Farm in Stillwater, OK. During each of the six experimental periods, horses were fed one of the six experimental diets during an 11-d adjustment period followed by a 72-h, experimental collection period. The six diets were formulated utilizing one of three energy sources combined with one of two DCADs.

All diets were formulated so that each resulted in similar daily intakes of energy, protein, calcium and phosphorus (Table 1). The treatments were as follows: 1) rolled corn with a

DCAD of +318 meq/kg DM (HC), 2) rolled corn with a DCAD +124 meq/kg DM (LC), 3) whole oats with a DCAD of +304 meq/kg DM (HO), 4) whole oats with a DCAD of +154 meq/kg DM (LO), 5) dehydrated alfalfa with a DCAD of +333 meq/kg DM (HH), and 6) dehydrated alfalfa with a DCAD of +152 meq/kg DM (LH) (Table 2). Sodium bicarbonate was used to increase DCAD values and ammonium chloride was added to decrease the DCAD values. Native prairie grass hay was fed at 30% of daily intake for the four grain diets and 50% of daily intake on the alfalfa diets (Table 3). Horses were fed at 7:00 a.m. and 7:00 p.m. and supplied with fresh water at all times.

During the 72-h collections total urine production was collected via an urinary harness. Urine was collected at the time of urination, immediately measured for volume and analyzed for pH. On the last morning of the collection period, blood samples were drawn via jugular venapuncture at feeding and at 2, 4, and 6 h post-feeding. Samples for blood gas analyses were collected in lithium heparin syringes, immediately placed in ice, and analyzed within 15 to 30 min on a Ciba-Corning 288 Blood Gas Analyzer. Samples for blood lactate analyses were drawn into lithium heparin vacutainers, placed on ice, and measured using a YSI Lactate Analyzer.

Statistical analysis was performed using the GLM procedure of SAS (1990). Orthogonal contrasts were developed to compare high vs low DCAD, corn vs oats, corn vs hay, oats vs hay, and corn and oats vs hay. Statistical significance was declared at an alpha level of $P<.05$. For blood data, least squares means were calculated and used to determine any effects over time.

Results and Discussion

Blood lactate concentrations were not significantly different between the six diets at any time interval. Thus, it is unlikely that any acid-base response could be attributed to lactic acidosis from a starch overload in the cecum. Horses consuming low DCAD (LC, LO, and KH) diets had a lower ($P<.01$) blood pH than the horses on the high DCAD (HC, HO, and HH) diets (Table 4). There was no significant difference in blood pH between starch sources or starch intake levels. These findings are in contradiction to Ralston et al. (1993) who found a decrease in blood pH due to starch intake while holding DCAD constant. Blood [HCO_3^-] was higher ($P<.0001$) when horses consumed diets with a high DCAD than when horses consumed diets with a low DCAD (Table 4). Starch intake or source had no significant effect on blood [HCO_3^-]. No significant differences were detected in pCO_2 concentrations among treatments (Table 4).

Urine pH was higher ($P<.0001$) for the horses on the high DCAD diets. Horses consuming diets LC, LH, and LO had mean urine pH values of 7.13, 6.93 and 7.11, respectively. Horses on diets HC, HH, and HO had mean urine pH values of 7.75, 7.67 and 7.94, respectively. No significant difference in urine pH was detected between the corn- and oat-based diets (HC and LC vs HO and LO), or between the corn- and hay-based diets (HC and LC vs HH and LH). However, there was a difference when comparing the high starch diets (HC, LC, HO, and LO) with the low starch diets (HH and LH), with a higher urine pH on the high starch diets. However, the urine pH values of the LH diet were considerably lower than all other readings, which could account for this difference.

These data indicate that the depression in urine and blood pH and HCO_3^- is due to the DCAD of the diet and not the starch source or amount. Therefore, by correcting the low cation-anion difference of cereal grains, producers can overcome the potential negative effects of feeding high grain diets to their horses.

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Table 1. Daily nutrient intake, DM basis.

Nutrient	HC	LC	HO	LO	HH	LH
DE (mcal/d)	23	24	24	24	22	22
CP (g/d)	1127	1147	1435	1461	1240	1355
Ca (g/d)	132	128	144	143	100	88
P (g/d)	23	25	30	32	22	22
Mg (g/d)	12	12	15	16	24	23
K (g/d)	68	67	78	82	190	180
S (g/d)	10	12	15	15	15	16
Na (g/d)	26	15	27	10	23	32
Cl (g/d)	10	43	14	35	69	144

Table 2. Nutrient analysis of diets, DM basis.

	HC	LC	HO	LO	HH	LH
CP (%)	15.1	15.4	17.4	17.7	11.4	12.4
DE (Mcal/kg)	3.11	3.26	2.88	2.89	2.0	2.0

Ca (%)	1.78	1.72	1.75	1.74	.92	.81
P (%)	.31	.35	.37	.38	.2	.2
Mg (%)	.16	.16	.19	.2	.22	.21
K (%)	.92	.9	.94	.99	1.75	1.66
S (%)	.14	.16	.18	.18	.14	.14
Na (%)	.34	.2	.33	.13	.21	.29
Cl (%)	.14	.58	.17	.42	.64	1.32
DCAD (meq/kg DM)	+318	+124	+305	+154	+333	+152

Table 3. Diet composition, as fed basis.

Ingredient %	HC	LC	HO	LO	HH	LH
Starch sources						
Rolled corn	45.5	45.5	--	--	--	--
Whole oats	--	--	48	48	--	--
Pellet supplement						
Dehydrated alfalfa	--	--	--	--	49.1	48.1
Soybean meal	18.7	19.5	16.8	17.5	--	--
Cottonseed hulls	1.2	1.2	1.1	1.1	--	--
Limestone	2.9	2.9	2.6	2.7	--	--
DiCal	.12	.12	--	--	.15	.15
TM premix	.06	.06	.06	.06	.06	.06
Feed flavor	.02	.02	.02	.02	.02	.02
Sodium bicarbonate	1.2	--	1.3	--	--	--
Ammonium Chloride	--	.24	--	.25	--	1.0
Salt		.24		.23	.50	.50
Prairie hay	30	30	30	30	50	50

Table 4. Urine pH, blood pH, blood pCO_2, and HCO_3^- means.

Item[a]	HC	LC	HO	LO	HH	LH	S.E
Lactate Mmol/L	.75[bd]	.75[bd]	.75[bd]	.75[bd]	.81[bd]	.77[bd]	.0216
pH	7.38[bd]	7.36[cd]	7.37[bd]	7.36[cd]	7.37[bd]	7.37[cd]	.00379
PCO_2 Mm Hg	53.0[bd]	52.3[bd]	53.6[bd]	52.4[bd]	51.7[bd]	51.9[bd]	1.0805
HCO_3^- Mmol/L	31.4[bd]	29.9[cd]	31.1[bd]	29.9[cd]	30.3[bd]	30.0[cd]	.25551

[a]Values are least squares means. [b,c]Means within a row with different superscripts differ ($P<.05$) with respect to DCAD. [d,e]Means within a row with different superscripts differ ($P<.05$) with respect to source or intake of starch.

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