Apparent Mineral Absorption by White-tailed Deer

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Abstract: Two completely randomized design studies were conducted from May 1986 through June 1987 with white-tailed deer (*Odocoileus virginianus*) to determine seasonal mineral absorption patterns of guajillo (*Acacia berlandieri*) and a pelleted diet. The pelleted diet contained 0.56% phosphorus (P), 2.57% calcium (Ca), 0.31% magnesium (Mg), 2.25% sodium (Na), 1.63% potassium (K), 9.6 ppm copper (Cu), 45.0 ppm zinc (Zn), and 314.8 ppm iron (Fe). Calcium and P from the pelleted diet were absorbed in a 2:1 ratio. There were no seasonal differences in mineral absorption of the pelleted diet. The data indicate mineral absorption patterns of white-tailed deer eating a pelleted diet are not different from cattle. Mineral concentrations of guajillo varied seasonally. Absorption of P, Ca, Mg, Na, K, Cu, Zn, and Fe from guajillo also varied seasonally. Phosphorus concentrations in guajillo followed active plant growth patterns but were below recommended levels for proper white-tailed deer growth. Phosphorus and Zn absorption were negative in all seasons indicating absorption problems or the difficulty of balancing metabolic P and Zn losses with a forage containing small amounts of these 2 minerals.

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The importance of trace and macro-minerals for animal maintenance, growth, and reproduction is well documented; however, the mineral nutrition of white-tailed deer is poorly understood. Some quantitative information is available on trace or macro-mineral concentration of deer and livestock forages (Everitt and Gonzalez 1979, Jones and Weeks 1985, Barnes et al. 1990). Other studies have focused on mineral requirements for white-tailed deer (Pletscher 1987), but most of the requirement studies have focused solely on Ca and P (French et al. 1955, 1956; Magruder et al. 1957; Ullrey et al. 1973, 1975).

Nutrient quality and availability are believed to be major factors affecting white-tailed deer habitat carrying capacity. Most studies emphasize energy or protein as the nutritionally important variables, although some studies have shown macro-minerals, usually Na or P, may be limiting factors in deer habitat (Varner et al. 1977, Jones and Weeks 1985, Pletscher 1987). Blair et al. (1977) reported P to be the major limiting nutrient for deer in the Southeast. Because limited P occurs in the soil (Fisher 1974) and vegetation in south Texas (Varner et al. 1977), numerous authors have recommended P supplementation in this region (Everitt and Gonzalez 1981, Meyer and Brown 1985). See Barnes et al. (1990) for a contrary opinion.

There are problems with evaluating habitat based on mineral concentrations in the soil or vegetation. These analyses provide proximate mineral concentrations. McDowell (1985) reviewed the literature and discussed problems of evaluating the mineral status of an animal based on soil or forage analyses. Digestible nutrients, not proximate nutrient concentrations, are the important factor in meeting animal requirements. There is limited quantitative data available on trace or macro-mineral absorption or digestion by white-tailed deer. To complement previous research on food habits and food quality (Varner et al. 1977, Varner and Blankenship 1987, Barnes et al. 1989, Barnes et al. 1991), we investigated the in vivo absorption of 5 macro- and 3 trace minerals by white-tailed deer consuming guajillo and a pelleted ration.

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Methods

Guajillo was selected for study because it is eaten by white-tailed deer during all seasons and may constitute up to 37% of white-tailed deer diets in south Texas (Varner and Blankenship 1987). Guajillo leaves growing on stems <2 mm in diameter were collected in the field. Only the current year's growth was collected to mimic deer browsing. Leaves were stripped by hand and fed to confined deer fresh, or stored overnight under refrigeration and fed the following morning. We conducted 5 seasonal, completely randomized trials using guajillo from June 1986 to April 1987.

Because many ranchers in south Texas feed deer a supplemental pelleted diet year-round, we also investigated the mineral absorption of a nutritionally complete pelleted ration. The composition of the pelleted ration is reported by Barnes et al. (1991). We conducted 3 completely randomized balance trials using the pelleted diet during the winter, spring, and summer 1986. We did not conduct a trial during the fall because this is not a nutritionally stressful period for deer (Barnes et al. 1991).

Deer ($N = 6$ per trial) were confined in individual $1.2 \times 1.2 \times 1.2$-m metabolism crates housed in a climate controlled room for each trial using guajillo and the pelleted diet. A mixture of adult male and female animals, previously conditioned to the metabolism crates, were randomly selected for each guajillo trial. A mixture of adult and yearling male and female deer were used for the pelleted diet trials. Male deer were allowed to grow antlers throughout the study. Once the antlers were hardened they were removed prior to the fall and winter trials. Female deer were not pregnant or lactating during the experimental periods.

Temperatures closely approximated outdoor conditions except summer when daytime temperatures never exceeded 27 C. Animals were weighed prior to each trial. Trials consisted of a 5-day adjustment period followed by a 5-day total fecal and urine collection period. While 7-day adjustment periods are recommended for reduction of variance in the data, Schneider and Flatt (1975) reviewed the literature and concluded a 5-day pretrial period for cattle was adequate if all that is necessary is to change residual plant materials. At worst, a 5-day pretrial period would result in decreased precision and failure to detect the relationships that exist with a decreased possibility of bias (Holloway et al. 1981). Longer collection trials can result in more precision, but may increase bias due to animal sickness, feed refusal, or a variety of other factors (Schneider and Flatt 1975).

Feed was offered *ad libitum* during the pretrial period and fed at maximal pretrial consumption levels during the collection period. Deer were fed in the morning. Feed remained available to the animals throughout the day. Water was provided *ad libitum* for all experiments.

Feed, orts and fecal collections were taken daily for each animal, oven-dried at 60 C, composited for each animal over the entire sample period, ground through a 1-mm screen in a Wiley mill, and subsampled for analysis. Urine was collected in opaque plastic containers, filtered to remove hair or other debris, acidified with 20% HCL, subsampled and frozen until analyzed.

Feed and fecal samples were wet-digested with perchloric acid and hydrogen peroxide (Adler and Wilcox 1985). Phosphorus was determined colorimetrically (Kallner 1975). All remaining mineral concentrations were determined using AOAC approved atomic absorption spectrophotometry techniques. Mineral concentrations in urine were determined on undiluted urine samples. Absorption was calculated using the following formula:

$$\frac{\text{Mineral intake—fecal mineral—urinary mineral}}{\text{mineral intake}} \times 100$$

Unbalanced one-way analysis of variance and the least significant differences mean comparison tests were used to detect seasonal differences in mineral absorption of the guajillo and pelleted diets. The use of an unbalanced design was necessary because during each trial except for the fall trial, 1 individual went off feed and had to be removed from the metabolism crate. Significance was evaluated at the 0.05 level.

Results and Discussion

Mean deer weight (39.4 kg) was not different among any comparisons (Table 1). Yearling deer consuming the pelleted diet had higher daily dry matter intake

Table 1. Number, mean body weight (BW) and dry matter intakes (DMI) of south Texas white-tailed deer used in metabolism studies from winter 1986 through summer 1987.

Diet	*N*	Weight (kg)	SE	DMI/ kgBW (g/day)	SE
Guajillo					
Spring	5	43.7	2.1	11.7A[a]	1.4
Early summer	5	49.3	2.4	13.0A	1.9
Late summer	5	30.5	1.0	19.6B	2.5
Fall	6	36.8	1.0	13.3A	1.8
Winter	5	41.1	2.0	20.0B	1.5
Pelleted	7 (A)[b]	43.7	1.3	21.0	0.6
	4 (Y)	25.1	0.7	32.4	1.3

[a]Values within a column followed by different letters are different ($P \leq 0.05$).
[b]Indicates a difference ($P \leq 0.05$) in DMI/kgBW between adult (A) and yearling (Y) white-tailed deer.

(DMI) per unit body weight (BW) than adults (Table 1). This is to be expected because young deer can meet higher nutritional requirements by increasing intake. Deer consumed less guajillo during the spring, early summer and fall periods (Table 1). Daily dry matter intake of adult deer eating guajillo averaged 15.5g/kg BW. Intake is determined by a variety of morphological, physiological, and behavioral mechanisms; hence, differences in voluntary intake were expected. Intake rates reported in our study are similar to levels reported in other studies (Mautz et al. 1976). The proximate nutrient content of guajillo varied seasonally and contained an average of 18% crude protein, 1.9 Kcal/g digestible energy, 104.2 mg/g condensed tannins, and 54.4% neutral detergent fiber (Barnes et al. 1989). The diet also averaged 40.9% in vivo dry matter digestibility.

There were no seasonal differences in mineral absorption between pelleted diet trials. Consequently, data were pooled and tested for differences attributed to age or sex. There were no differences in mineral absorption attributed to age or sex, consequently, data were pooled for a total sample size of 11.

Although mineral element requirements for white-tailed deer are unknown, mineral concentrations in the pelleted diet were equal to or greater than National Research Council (1984) recommended requirements for beef cattle (Table 2). Sodium and K levels were high but within tolerable levels (Natl. Res. Counc. 1984). High Na was due to salt added during diet formulation to limit intake.

Calculation of apparent assimilation (absorption × concentration) indicates Ca and P were assimilated in a 2:1 ratio (Table 2). This is considered optimum for proper nutrition of ruminant animals (Maynard et al. 1979). The high absorption of Na and K on this diet was expected because these elements function in maintaining osmotic pressure and water metabolism. Since they are not stored, there is a regular dietary turnover of Na and K. Apparent absorption patterns of the 8 minerals examined in the pelleted diet were similar to reported values for beef cattle (Maynard

Table 2. Concentration and apparent absorption of 5 macro- and 3 trace minerals of a pelleted diet fed to 11 South Texas white-tailed deer in digestion studies conducted during the winter, spring and summer 1986. Results are presented on a 100% dry matter bases.

Mineral	Concentration in feed	Apparent absorption (%)	SE
P	0.56%	43.7	1.9
Ca	2.57%	6.5	2.5
Mg	0.31%	30.4	3.1
Na	2.25%	96.1	0.2
K	1.63%	93.5	0.4
Cu	10 ppm	18.8	2.3
Zn	45 ppm	5.0	2.7
Fe	315 ppm	27.4	2.9

et al. 1979). This indicates white-tailed deer eating a concentrated diet have mineral absorption patterns similar to other ruminants.

Phosphorus concentrations followed active plant growth patterns and were below National Research Council (1984) recommended guidelines for cattle in guajillo every season except spring (Table 3). Copper also was below National Research Council (1984) recommended requirements for beef cattle during every season except winter, although concentrations were within reported acceptable tolerance levels. Zinc concentrations fell below National Research Council (1984) recommended requirements for beef cattle during the early and late summer. All other minerals met or exceeded National Research Council (1984) recommended requirements for beef cattle.

Apparent absorption of minerals from guajillo diet varied by element and season (Table 4). The strongly negative absorption of P may reflect the difficulty of balancing metabolic fecal P losses with a forage containing low levels of P. Negative

Table 3. Seasonal mineral concentration (100% dry matter basis) of guajillo fed to South Texas white-tailed deer in digestion studies conducted from June 1986 through April 1987.

Season	P (%)	Ca (%)	Mg (%)	Na (%)	K (%)	Cu (ppm)	Zn (ppm)	Fe (ppm)
Spring	0.25	0.85	0.20	0.21	1.33	6	29	112
Early summer	0.19	1.48	0.25	0.28	1.53	7	17	151
Late summer	0.12	1.83	0.26	0.28	1.22	6	15	203
Fall	0.15	1.75	0.25	0.28	1.25	7	21	170
Winter	0.17	1.50	0.23	0.29	1.09	8	29	214

Table 4. Mean seasonal mineral absorption of guajillo fed to South Texas white-tailed deer in digestion studies conducted from June 1986 through April 1987.

	P		Ca		Mg		Na	
Season	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Spring	−43B[a]	9.2	0A	1.1	29A	2.0	46B	2.4
Early summer	−99AB	17.0	24D	3.4	43B	2.8	43AB	3.0
Late summer	−131A	8.6	9B	1.4	29A	3.3	37A	1.8
Fall	−89AB	21.7	15C	1.4	32A	3.6	38A	2.6
Winter	−87AB	9.4	−5A	1.7	32A	2.6	38A	1.0

	K		Cu		Zn		Fe	
Season	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Spring	70A	4.6	−17A	5.0	−67BC	9.2	−7AB	2.7
Early summer	73A	2.3	10BC	2.9	−126A	11.9	3BC	2.4
Late summer	83B	1.9	2B	3.1	−97AB	19.5	15D	3.3
Fall	70A	3.0	1B	5.9	−44C	9.6	11CD	4.3
Winter	71A	2.1	14BC	1.1	4C	3.4	−11A	3.4

[a]Values within columns followed by different letters are different ($P \leq 0.05$).

P absorption also may reflect negative interactions with other cations particularly Ca (Maynard et al. 1979). The Ca:P ratio of guajillo varied from 3:1 to 15:1. High dietary Ca has been shown to interfere with P absorption in cattle, sheep and goats (Maynard et al. 1979). Gallagher (1990) observed similar P absorption values for white-tailed deer consuming 4 different south Texas brush species. These strongly negative absorption values should concern managers in south Texas because deer diets are dominated by browse during most seasons except spring (Arnold and Drawe 1979, Kie et al. 1980, Varner and Blankenship 1987). Deer are probably adapted to chronic recurring mineral deficiencies and select high P containing forbs whenever available. This would offset a negative P balance on a browse-dominated diet. Deer also may have a mechanism for conserving and transferring P in a manner similar to known mechanisms of Ca transfer (Stephenson and Brown 1984).

Sodium and K absorption values (Table 4) were lower than expected, but apparently were sufficient since deer absorb as much Na and K as is required and immediately excrete excess concentrations (Maynard et al. 1979). Lower Na and K absorption values may be attributed to stress or the presence of condensed tannins (Freeland et al. 1985) which accounted for approximately 1% dry matter of guajillo. Magnesium absorption was similar in both the guajillo and pelleted diets and is similar to Mg absorption in cattle (Maynard et al. 1979).

Low absorption values for Fe (Table 4) were expected because feed values were high and once body stores are filled, Fe is effectively conserved and the animal regulates iron absorption in accordance to what it needs (Maynard et al. 1979). Thus, unless an animal losses blood or has some pathological condition, ruminants need little iron. A mean Cu absorption of 2% was not surprising since ruminants only absorb 1% to 3% of available copper (McDowell 1985). Zinc absorption was strongly negative during every season except winter (Table 4). The negative absorption of Zn may reflect the difficulty of balancing metabolic Zn fecal losses with a forage containing small amounts of Zn. McDowell (1985) suggested the most important factor affecting Zn absorption was the concentration of Zn in the feed, supporting the above idea.

It is important to recognize that a variety of factors including the amount of mineral in the diet, the mineral status of the animal and interrelationships between minerals and organic compounds, influence mineral uptake and absorption. In addition, since most minerals are excreted in the feces, it is difficult to differentiate between endogenous sources of mineral and minerals which have escaped absorption (Maynard et al. 1979). This makes data interpretation complex and relationships difficult to define.

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