Evaluation of Eight Species of Native Texas Browses as Suitable Forage Substitutes for Black Rhinoceros *(Diceros bicornis*)

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ABSTRACT

Duplication of natural foodstuffs for animals in captivity can be a difficult task. While it may not be possible to provide food sources normally available in an animal' s natural habitat, a prospective goal might be to provide similar nutrients from locally available foods. Eight species of native Texas browse were studied for adequacy as a source of browse for black rhinoceros *(Diceros bicornis)* in captivity. Samples of browse were analyzed for moisture, crude and bound protein, neutral (NDF) and acid detergent fiber (ADF), lignin, vitamin E, ash, macrominerals and selected microminerals. Texas browse samples (whole plants) contained 42.5%-77.8% water, 7.5-24.8% protein, 0.81-2.43% bound protein, 30.1-61.6% NDF, 16.2-42.7% ADF, 5.8-22.5% lignin, 4.8-21.3% ash and 94.1-509.0 IU/kg vitamin E (all on a dry matter basis except water). Leaves contained significantly ($P<0.05$) higher protein and vitamin E than twig portions of the same plants. Twigs contained significantly higher NDF, ADF and lignin than leaves. Twig and leaf fractions did not differ in water or ash concentrations. Texas browses were compared to previously published values for black rhino browses from Zimbabwe and found to have similar concentration of nutrients. Overall, available Texas browses appear to be nutritionally adequate substitutes for the plants that black rhinos consume in nature, at least for the constituents evaluated.

Key words: Browse, rhino, fiber, minerals, vitamin E

INTRODUCTION

The black rhinoceros *(Diceros bicornis),* an extremely endangered browser, consumes a wide variety (often >100 species) of herbs, succulents, and woody plants throughout the year. [Goddard, 1970; Mukinya, 1977; Hall-Martin et al., 1982; 0100 et al., 1994]. Grasses are not generally consumed except when accidentally taken with other browse items [Goddard, 1970; Mukinya,1977]. Most captive rhinos are housed in settings where natural browse acquisition is limited, thus are generally sustained on a diet consisting of hay (grass, alfalfa or mixed) with herbivore pellets, produce and occasional browse [AAZK, 1988]. The AZA Rhino Taxonomic Advisory Group (TAG) dietary recommendations [Dierenfeld, 1996] for browsing black rhinos are to feed mixed grass:legumes hays and/or a mixture of legume hay and less digestible browse (rather than straight legume hay) as the forage source(s), with water and salt blocks available at all times.

With a few exceptions [Joubert & Eloff, 1971; Loutit et al., 1987; Ghebremeskel et al., 1991; Dierenfeld et al, 1995] , published literature on the dietary habits of rhinos has either focused exclusively on proximate composition, or included no nutritional analyses, of browses consumed by black rhinos (either free-ranging or captive). Without more detailed information, substitution of locally available browses to meet nutritional needs of this species can be risky at best. As a result of this lack of information, the adequacy of diets for animals consuming browse may be estimated solely from dietary components that have known composition, thus are incomplete.

Providing browse to rhinos in captivity can also play an important role in behavioral enrichment. Many animals will spend considerable time selecting and picking at leaves and twigs, supplying both nutrition as well as activity.

Based solely on digestive anatomy, the domestic horse is considered the most relevant model from which to extrapolate the nutritional requirements of the rhinoceros. Even using modified horse information, the amounts and types of fiber and other nutrients that are required for optimal health in these animals is unknown. Since such a wide variety of plants is consumed in the wild, complete analysis of the natural diet components could be prohibitive. Nonetheless, identifying and filling data gaps should remain a priority in understanding nutrition of the black rhinoceros. This study was initiated as part of a larger project to better evaluate the chemical composition of browses consumed by black rhinoceros.

METHODS

Samples from eight species of available browses *(Acacia farnesiana, Acacia roemeriana,* unknown *Acacia* sp., *Cassia fasciculata, Celtis pallida, Condalia obovata, Opuntia leptocaulis, Prosopis juliflora)* were collected during June 1990 at El Coyote Ranch in southern Brooks County, Texas. Samples were randomly selected from 3 to 5 different plants, cut, frozen and shipped on ice to the Wildlife Nutrition Laboratory at the Wildlife Conservation Society for analysis. All samples (except *Opuntia leptocaulis)* were separated into leaf and twig fractions for the determination of leaf:twig ratio (L:T) by weight (as-fed basis). Leaves and twigs were analyzed separately and chemical composition of total browse was determined using weighted L:T ratios. Tocopherols were immediately extracted using fresh plant tissue and vitamin E concentrations were calculated as detailed by Dierenfeld et al. [1995]. Vitamin E activity was calculated from tocopherol portions using the formula listed in Table 1. Samples were then dried to a constant weight at 60(C before being ground in a Wiley mill to pass through a 2 mm screen. Moisture, crude and bound protein, neutral (NDF) and acid detergent fiber (ADF), sulfuric acid lignin and total ash were determined as described by Dierenfeld et al. [1995]. Leaf and twig portions were mixed together at the ratio for that plant and submitted for selected macro- and micromineral concentrations (Dierenfeld et al., 1995). Paired comparisons of nutrient concentrations in leaf versus twig fractions were performed using the statistical package in Microsoft Excel [Microsoft Corporation, 1993].

RESULTS

Proximate composition of browse samples is summarized in Table 1. Texas browse samples (whole plants) contained 42.5%-77.8% water, 7.5-24.8% crude protein (CP), 0.81-2.43% bound protein, 30.1-61.6% NDF, 16.2-42.7% ADF, 5.8-22.5% lignin, 4.8-21.3% ash and 94.1-509.0 IU/kg vitamin E (all on a dry matter (DM) basis except water). On average, leaves contained significantly ($P<0.05$) higher protein and vitamin E concentrations than twig portions of the same plants. Twigs contained significantly higher NDF, ADF and lignin values than leaves. Twig and leaf fractions did not differ in water or ash content.

Mineral analyses of are included in Table 2. Plants (whole) contained an average of 2.4% Ca, 1.5% K, 0.45% Mg, 0.14% Na, 0.11% P, 7.3 IU/kg Cu, 122.5 IU/kg Fe, 34.6 IU/kg Mn, 27.4 IU/kg Zn. Ranges for native browses collected in the Zambezi Valley, Zimbabwe, are also included in Table 2 for comparison.

DISCUSSION

Using horse and pony NRC [1989] dietary nutrient recommendations as a guide, protein requirements for maintenance of mature rhinos should be met with diets containing 8% CP (DM basis). Other physiological states (growth, pregnancy or lactation) would require higher-protein diets ranging from 10 to 15%. Leaves of the seven species analyzed contained considerably higher crude protein levels (14.3 to 43.7%, average = 22.7%), with <3.0% as chemically bound protein for any single species. Twigs contained less protein (9.9 (3.8%; mean (SD), but were generally similar in CP content to many grass hays by comparison (6.4-12.9 % CP) [NRC, 1989]. Bound protein fractions were considerably higher (as a percentage of total CP assayed) in twig fractions versus leaves (7% bound in leaves compared with 25% in twigs); as much as 67% of protein measured in mesquite browse twigs was chemically bound, thus presumably unavailable from the diet.

Whole browses (leaves plus twigs) averaged approximately 15% available CP (CP less bound protein) in this study (range 9.0 to 22.4%), comparable to values reported from other studies (4 to 22% of DM) [see summary in Dierenfeld et al. , 1995] .Although browses can be high in CP , particularly leaf fractions, diets consumed by black rhinoceros in nature appear, in general, to contain a protein concentration similar to that of equid dietary recommendations [NRC, 1989].

Texas browses were rather fibrous and highly lignified, with leaves containing significantly lower levels of all fiber fractions evaluated than twigs. Despite these differences in total fiber content, the degree of lignification (lignin/NDF; approximately 30%) did not differ between leaves and the woodier twig samples. Because lignin constitutes a theoretically indigestible fiber fraction, cell wall lignification can be an indicator of the degree of fiber digestibility. From these data, both leaves and twigs may have limited digestibility. As with browses from Zimbabwe [Dierenfeld et al., 1995], the total fiber in these Texas samples was higher overall, and more highly lignified, than forages (hays) commonly fed to black rhinos in captivity. Despite the lower fiber and higher protein content of leaves in browses, leaves are not necessarily preferentially consumed by rhinos, with twigs up to approximately 3 cm in diameter completely consumed. Both total amount and type of dietary fiber may have important health consequences, as diets which are too digestible have been implicated as a possible cause underlying gastrointestinal problems in captive rhinos [Dierenfeld, 1996] .

All browse species (whole) examined here exceeded equid requirements for dietary vitamin E (50-80 IU/kg), and in general contained considerably higher concentrations of this nutrient than dried forages and most concentrate feeds utilized in zoos. These data substantiate the high levels of this nutrient previously measured in native browses in Kenya [Ghebremeskal et al., 1988] and Zimbabwe

[Dierenfeld et al., 1995]. Thus fresh browse may be an important natural source of vitamin E for captive rhinos, particularly if consumed as a significant portion of the diet.
Texas browses contained levels of Ca (2.41 (2.23), K (1.49% (0.52), and Mg (0.45% (0.27) which are adequate to supply the needs of rhinos at maintenance, based on data derived from values for domestic equids (0.3, 0.3 and 0.1% DM for Ca, K, and Mg, respectively) [NRC, 1989]. Phosphorus in these browses (0.11 (0.04%) , however, may be marginal to low compared with suggested levels (0.3% of dietary DM). In addition, only one browse *(Prosopis juliflora)* contained Na above recommended amount (0.1% of dietary DM). Native plants from Zimbabwe were also low in Na as compared to horse requirements [Dierenfeld et al., 1995]. Copper, manganese and zinc levels in these browse samples were, in general, lower than equid dietary recommendations, while iron content appeared adequate. Trace mineral metabolism of rhinoceros has not been investigated in detail, but these browses may not provide adequate mineral nutrition; therefore, mineral contributions must be considered in association with other dietary components.

Rhinos offered the browses sampled in this study appear (observational evaluation) to prefer *Acacia farnesiana* and the unknown *Acacia* species. The latter, however, while common in the Texas environment, is a small plant not productive enough to be harvested in large quantities. In winter months, when the huisache *(A. farnesiana)* loses its leaves, a greater proportion of the other browse species are offered and consumed along with leafless twigs of huiscahe. Huisache collected in August and September (considered a period of lower nutritive content) was previously reported by Ruthven and Hellgren [1995] to have a CP content of 26.8 (0.69%, and NDF content of 37.4 (0.6%. While protein content was lower than that reported here, fiber value was similar to results reported here. Similar protein and fiber values for identical parts of the same species of Texas browses have been previously documented (assumed to be on a DM basis): *Celtis pallida* (leaves and undesignated plant parts) CP 16-31.3%,26.7-29.0%; *Condalia obovata* (leaves and undesignated plant parts) CP 8.6-15.2%, NDF 27.5%; *Opuntia leptocalcius* CP 7-11.3%; *Prosopis juliflora* (leaves) CP 23.9%, NDF 38.2% [Varner et al., 1977; Everitt and Gonzalez, 1979 and 1981; Meyer and Brown, 1985; Ruthven and Hellgren, 1995]. However, the browsing herbivores considered in these other studies (primarily white-tailed deer, *Odocoileus virginanus)* are generally more selective feeders than the black rhinoceros appears to be; thus, plant parts analyzed were heavily skewed towards leaves and less lignified plant components than browses examined here.

During summer months, at peak browse production, individual adult black rhinos at El Coyote Ranch consume approximately 14.3 kg of huisache (leaves plus twigs) daily in addition to the staple diet comprising: a small amount of red top cane hay (1.6 kg; *Agrostis alba),* 1.8 kg commercially available elephant supplement pellets (HMS, Bluff ton, IN), 7.3 kg alfalfa hay, a small amount of produce (i.e. apple, sweet potato), and 30 cc liquid vitamin E supplement (77.4 IU/g; TPGS, PMI Feeds, St. Louis, MO), with access to a salt block free choice. This diet (DM intake approximately 1.4% of body mass), by calculation, contains 23% CP, 47% NDF, 34% ADF, 14% lignin, 308 IU/kg vitamin E and adequate minerals compared with equine recommendations.

Depending upon habitat and season, black rhinos consume a wide variety of plants in nature. It is impossible to duplicate this type of diversity in most captive management situations, but nutrients contained within those dietary ingredients can be reproduced. The browses analyzed in this study contained concentrations of protein, fiber, vitamin E, and some macrominerals similar to those in plants which black rhinos consume in their native environments; however, other nutrients (Na, some microminerals) were limiting in these single samples, and must be supplied through other dietary ingredients. Nonetheless, significant nutritional contributions from available browses, provided as a staple ingredient in diets of browsing species, should not be discounted. Although not quite half of DM intake, browse contributed >55% of the protein and fiber, and about 25% of total vitamin E to the diet, accentuating the absolute need for more detailed investigations of the nutrient composition of browses in managed feeding programs.

CONCLUSIONS

1. Texas browses contained protein, vitamin E, calcium, potassium and magnesium concentrations which would meet dietary recommendations for domestic equids, and may be nutritionally adequate for the browsing black rhinoceros.
2. However, these same browses contained low levels of phosphorus, sodium, copper, manganese and zinc when compared to domestic equid requirements, and may be unsuitable as these nutrients for black rhinos.
3.Rhinoceros diets should be evaluated based on, and balanced in relation to, composition of and other dietary components.

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Table 1. Proximate composition of native Texas browses fed to black rhinoceros at El Coyote Ranch.

Species	Common name	Part or ratio[a]	Water	CP	AD-CP	NDF	ADF	Lignin	Ash	Vit E[b]
				< ------------- Dry Matter Basis					------------ >	
			< ----------			%			---------- >	IU/kg
Acacia farnesiana	Huisache	L	59.7	43.7	2.03	40.6	23.9	15.2	6.2	236.1
		T	49.1	8.1	2.83	69.7	49.6	21.1	5.9	47.6
		47:53	54.1	24.8	2.40	56.3	37.7	18.4	6.0	103.4
Acacia roemeriana	Catclaw	L	43.5	15.1	2.85	48.1	32.3	18.8	7.0	295.1
		T	41.4	7.7	2.00	75.0	53.2	26.2	2.5	34.0
		50:50	42.5	11.4	2.43	61.6	42.7	22.5	4.8	164.5
Acacia spp		L	59.7	25.6	1.07	28.9	13.6	6.5	6.0	155.2
		T	67.8	17.6	1.40	50.9	35.8	9.3	6.0	72.5
		48:52	63.9	21.4	1.24	40.3	25.1	8.0	6.0	112.3
Cassia fasciculata	Partridge Pea	L	60.5	18.3	0.96	22.7	10.1	6.4	11.2	249.4
		T	52.2	9.9	1.63	65.3	40.5	14.0	3.5	30.7
		73:27	58.3	16.0	1.14	34.3	18.4	8.5	9.1	189.7
Celtis pallida	Spiny Hackberry	L	66.7	24.0	1.10	25.6	9.6	3.7	22.4	272.6
	Granjeno	T	51.4	11.2	1.52	78.9	53.1	17.9	4.2	32.1
		72:28	62.4	20.5	1.22	40.6	21.9	7.7	17.3	204.8
Condalia obovata	Brazil	L	56	14.3	1.25	33.4	22.7	13.8	12.9	144.4
	Bluewood condalia	T	43.6	6.1	2.17	77.6	54.3	24.1	1.9	38.6
		61:39	51.2	11.1	1.61	50.8	35.1	17.8	8.6	102.8
Opuntia leptocaulis	Prickly Pear		77.8	7.5	0.81	30.	16.2	5.8	21.3	94.1
Prosopis juliflora	Mesquite	L	55.9	18.0	1.64	43.4	27.4	11.6	5.2	550.0
		T	32.9	9.0	6.06	76.0	55.9	30.3	4.5	74.5
		91:9	53.8	17.3	2.03	46.3	29.9	13.2	5.1	509.0
Leaf Average			57.4	22.7	1.6	34.7	19.9	10.9	10.1	271.8
			±7.1	±10.2	±0.7	±9.6	±8.9	±5.5	±6.1	±135.1
Twig Average			48.3	9.9	2.5	70.5	48.9	20.4	4.1	47.1
			±10.9	±3.8	±1.6	±9.9	±7.7	±7.3	±1.6	±18.9
Whole Average			58.0	16.3	1.6	45.0	28.4	12.7	9.8	185.1
			±10.5	±5.9	±0.6	±10.8	±9.6	±6.2	±6.2	±128.8
L:T paired comparisons[c]			n.s	*	n.s.	***	***	*	n.s.	***

CP = crude protein; AD-CP = bound protein; NDF = neutral detergent fiber; ADF = acid detergent fiber

[a] L = Leaf; T = Twig; L:T=leaf:twig ratio of whole plant sample as consumed by rhinoceros.

[b] Vit E = vitamin E activity calculated as [(α-tocopherol x 1.49) + (γ-tocopherol x 0.1) + (δ-tocopherol x 0.015)]

[c] P levels: *** = <0.001; * = <0.05

Table 2. Mineral composition of whole native Texas browses fed to black rhinoceros at El Coyote Ranch (dry matter basis).

Plant	L:T ratio	Ca	K	Mg	Na	P	Cu	Fe	Mn	Zn
		< ----------	----------	%	----------	---------- >	< -------	IU/kg	------- >	
Acacia farnesiana	47:53	1.40	0.81	0.22	0.07	0.12	3.8	145	20.0	12.0
Acacia roemeriana	50:50	-	-	-	-	-	-	-	-	-
Acacia spp	48:52	0.79	1.71	0.2	0.01	0.15	16.1	100	33.5	18.6
Cassia fasciculata	73:27	-	-	-	-	-	-	-	-	-
Celtis pallida	72:28	4.15	2.04	0.66	0.03	0.13	6.1	104	38.2	13.1
Condalia obovata	61:39	1.40	1.50	0.47	0.04	0.05	3.2	100	21.7	5.1
Opuntia leptocaulis		6.13	1.95	0.88	0.04	0.08	3.2	141	54.7	96.3
Prosopis juliflora	91:9	0.61	0.90	0.29	0.65	0.13	11.6	145	39.4	19.2
Average		2.41	1.49	0.45	0.14	0.11	7.3	122.5	34.6	27.4
SD		2.23	0.52	0.27	0.25	0.04	5.4	23.3	12.8	34.2
SSP recommendations[a]										
Growing		0.6	0.3	0.1	-	0.3	-	-	-	-
Mature		0.3	0.3	0.1	0.1	0.2	10	50	40	40
Pregnant/lactating		0.4	0.4	0.1	-	0.3	-	-	-	-
Zambezi native browse samples[b]		0.55-4.27	0.28-1.77	0.12-0.65	0.001-0.094	0.06-0.19	3.0-12.2	29.0-215	10.8-269	2.5-67.4

[a] Modified from NRC [1989] for horses and ponies
[b] From Dierenfeld et al. [1995]