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CHAPTER 83

Rhinoceros Feeding and Nutrition

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Because of similarities in digestive tract morphology and digestive physiology,[1, 2] the domestic horse probably represents the most suitable nutritional model for all rhinoceros species. As such, a diet comprising good quality forage should provide primary nutrients for captive rhinoceroses, with low-energy density grain concentrate feeds used to balance identified energy, protein, mineral, or vitamins needs. General feeding guidelines as detailed in the *AZA Rhinoceros Husbandry Resource Manual*[4] appear suitable for maintenance of rhinoceroses in captivity. Until nutrient requirements are more specifically detailed for rhinoceroses, diets should be formulated according to National Research Council[12] recommendations for horses of various physiologic stages (Table 83–1).

Rhinoceros feeding behavior, however, ranges from rather unselective grazing by white rhinoceroses (*Ceratotherium simum*) to selective browsing by black rhinoceroses (*Diceros bicornis*), Sumatran rhinoceroses (*Dicerorhinus sumatrensis*), and greater one-horned rhinoceroses (*Rhinoceros unicornis*) on a wide diversity of plants. Whereas gastrointestinal problems contribute substantially to mortality in all captive rhinoceros species,[9] health disorders linked with possible nutrient imbalances appear limited to browsing rhinoceros species maintained on predominantly legume-based diets (either forages or concentrates, or both), at least in North America.[3, 10, 11] Thus, numerous areas of rhinoceros nutrition are currently under investigation, with implications for formulating more appropriate captive diets.

DIETARY HUSBANDRY

Rhinoceroses typically consume 1% to 3% (as-fed basis) or 1% to 2% (dry matter [DM] basis) of body mass

TABLE 83–1. Nutrient Concentrations in Total Diets for Horses and Ponies

Nutrient	Growth	Mature/ Maintenance	Pregnancy/ Lactation
Digestible energy Mcal/kg	2.45–2.90	2.0	2.25–2.60
Crude protein, %	12–15	8.0	10–13
Ca, %	0.6	0.3	0.4
P, %	0.3	0.2	0.3
Mg, %	0.1	0.1	0.1
K, %	0.3	0.3	0.4
Vitamin A, IU/kg	2000	2000	2000
Vitamin D, IU/kg	800	300	600
Vitamin E, IU/kg	80	50	80

Concentrations of Na, S, Fe, Mn, Cu, Zn, Se, I, and Co should be provided at the following levels, respectively: 0.1%, 0.15%, 50 mg/kg, 40 mg/kg, 10 mg/kg, 40 mg/kg, 0.1 mg/kg, 0.1 mg/kg, and 0.1 mg/kg.
Table to be used as a guideline in developing captive rhinoceros diets (dry matter basis, modified from reference 12).

daily. The larger, grazing rhinoceroses should be fed high-quality grass hays, whereas browsing species should be fed mixed grass: legume hays and/or a mixture of hay and less digestible browse. High-quality legume hay appears too digestible for rhinoceroses and may result in diarrhea, colic, and mineral imbalances, whereas poor quality, very fibrous hay has been implicated in torsion and impaction. Clearly, forage quality must be a prime consideration in feeding rhinoceroses. Hay and clean water should always be available; the concentrate portion of a ration should contribute no more than approximately one third of total calories, offered in at least two feedings per day for better utilization. Larger pellets (>1.0 cm diameter) can be easily manipulated and consumed by all rhinoceros species.

Particularly for the browsing rhinoceros species, the addition of fresh or frozen browse to diets may be essential to health, contributing as yet unquantified nutrients. Table 83–2 lists a number of browse species that have been successfully fed to rhinoceroses in North America. Fresh red maple (and possibly other maple species) and oak browse have been associated with hemolytic anemia in other species, as have a number of high-S containing plants including brassicas, rape, and onions. These should be avoided in rhinoceros browse.

Dietary supplements should not be necessary if rations are properly formulated. If forage is grown in an area of known mineral imbalances, hay and browse should be tested routinely for determination of mineral content to adequately address any potential problems. A possible vitamin E deficiency has been suggested but not confirmed in zoo rhinoceroses; current recommendations based on natural browse composition[6, 7] suggest that diets should contain between 150 and 200 IU of vitamin E/kg dry matter. Salt blocks should always be available.

NUTRIENTS IN FORAGES

Many of the health problems identified[10, 11] in browsing captive rhinoceroses fed legume forages may be linked to nutritional factors, as opposed to a much lower reported incidence of disease in the white or greater one-horned rhinoceroses fed primarily a grass hay–based diet. The black rhinoceros, in particular, has been shown to have unique enzyme activity that may predispose it to oxidative damage,[13] but a number of these syndromes including hemolytic anemia, ulcerative dermatitis, and encephalomalacia may also be linked with imbalances in membrane stability (fatty acids or vitamin E status) that could be nutritionally mediated. Overall, the browsing rhinoceros consumes a diet in nature that is highly lignified, poorly digested, relatively low in available protein, and marginally adequate in some minerals.

Proximate Composition

Comparison of nutrient composition in browses consumed by free-ranging black and Sumatran rhinoceroses[3] suggests that a mixture (50:50) of grass and legume forages better duplicates digestibility, hemicellulose (a potentially valuable energy source), dietary protein, and fatty acid[7, 15] profiles of native browse than either hay fed separately as a substitute forage for the browsing rhinoceros species. The soluble carbohydrate content of grass (25% of DM) compared to alfalfa (11%) hay differs considerably, which may also be important for this hindgut fermenter, although the soluble sugar content of native browses has not been quantified for comparison. Even fewer data are available to evaluate the nutritional suitability of locally available browses for feeding rhinoceros species in zoos. Palatability ranking and nutrient composition of browses consumed by rhinoceroses in zoos, with correlations to animal health and physiologic responses, have been initiated through the AZA Rhino Taxonomic Advisory Group.

Minerals

Although availability and form of minerals in dietary items significantly influence utilization by herbivores,

TABLE 83–2. North American Browse Species Eaten by Rhinoceros

Acacia farnesiana	Huisache	*Malus* species	Crabapple
Acacia roemeriana	Catclaw	*Morus alba*	White mulberry
Acer saccharum	Sugar maple	*Musa acuminata*	Banana
Alnus species	Alder	*Opuntia engelmannii*	Prickly pear
Celtis occidentalis	Hackberry	*Phaeoamerica* species	Torch ginger
Celtis pallida	Granjeno	*Phyllostachys aurea*	Golden bamboo
Condalia obovata	Brazil	*Populus alba*	White poplar
Eugenia species	Eugenia	*Prosopis juliflora*	Mesquite
Fagus granifolia	American beech	*Robinia pseudoacacia*	Black locust
Ficus benjamina	Weeping fig	*Salix babylonica*	Weeping willow
Forsythia species	Forsythia	*Salix nigra*	Black willow
Gymnocladus diocus	Kentucky coffee tree	*Viburnum* species	Fragrant honeysuckle
Hibiscus rosa	Hibiscus	*Vitis vinifera*	Grape
Liquidambar styraciflua	Sweetgum		

From Dierenfeld ES: Nutrition. *In* Fouraker M, Wagener T (eds): AZA Rhinoceros Husbandry Resource Manual. Fort Worth, Cockerell Printing Company, pp 52–53, 1996.

TABLE 83–3. Macromineral (n = 42 Species) and Trace Element (n = 39) Concentrations in Browses Eaten by Black and Sumatran (n = 44 Species) Rhinoceros Compared with Nutrient Requirements for Horses

Component (Dry Weight Basis)	Range in Native Browses: Black Rhinoceros	Range in Native Browses: Sumatran Rhinoceros	Equid Requirements
Calcium, %	0.7–6.1	0.04–6.76	0.3–0.6
Copper, mg/kg	3.0–16.1	3.4–13.3	10
Iron, mg/kg	29–215	47.9–116.0	50
Magnesium, %	0.1–0.9	0.2–1.3	0.1
Manganese, mg/kg	4.0–269	45–1940	40
Phosphorus, %	0.05–0.26	0.03–0.37	0.2–0.3
Potassium, %	0.3–2.0	0.1–6.3	0.3–0.4
Selenium, mg/kg	0.02–0.04	NA	0.1
Sodium, %	0.001–0.65	<0.01–0.45	0.1
Zinc, mg/kg	2.5–96.3	7.1–25.6	40

(Data from reference 3.)

examination of natural foodstuffs may provide some guidelines for diet development. Sodium appears limiting in native rhinoceros browses (Table 83–3), but can be obtained from natural salt licks soils or water, both of which are reportedly used by both Sumatran and black rhinoceroses. Phosphorus also appears to be limiting in natural rhinoceros browse; hypophosphatemia has been associated with hemolytic and dermatitis problems in captive black rhinoceroses,[9, 10, 13] warranting supplementation of zoo rhinoceroses with both dietary (routine) and parenteral phosphorus (in marked deficiencies). Selenium and zinc status in zoo black rhinoceroses has been suggested to be marginal based on limited blood samples,[7] and browses sampled appear to contain low levels of these nutrients in relation to equid requirements.[3] In addition, hemosiderosis, possibly linked with dietary mineral interaction, has been reported in captive but not free-ranging, black rhinoceroses.[8, 10] Iron metabolism in rhinoceroses is under investigation,[14] as is captive dietary mineral content evaluation. Mineral stressors (both deficiencies and toxicities) can impact in vivo oxidative status and should not be considered unrelated to the health syndromes noted. However, physiologic baseline data for evaluation of mineral status in the rhinoceros, or even determination of the most suitable domestic model for comparison, have not yet been compiled, remaining a high priority research issue.

Vitamin E

The vitamin E content of native browses consumed by rhinoceroses (50 to 200 mg/kg DM)[6, 7] is considerably higher than found in most zoo-based diets without supplementation. Current recommendations for supplementation (150 to 200 IU/kg DM) derive from native forage analyses but are dependent upon the form of supplement used and should also be considered with respect to other dietary fat-soluble vitamin concentrations (see Chapter 12). Currently, no data support the hypothesis that the rhinoceros has inhibited absorption or transport mechanisms for this nutrient, but research is ongoing.

Physiologic Assessment of Status

Plasma vitamin E (measured as *d*-alpha-tocopherol) concentrations in North American zoo rhinoceroses do not differ significantly across species (Table 83–4), and mean values for the black rhinoceros have increased

TABLE 83–4. Alpha Tocopherol Concentrations in Tissues Collected from Rhinoceros Held in North American Zoological Facilities (Mean ± SD)

Tissue	Black (n)	White (n)	Greater One-Horned (n)	Sumatran (n)
Plasma (μg/ml)	0.71 ± 0.88 (224)	0.56 ± 0.49 (63)	0.69 ± 0.60 (17)	1.07 ± 0.99 (7)
Liver (μg/g wet)	19.67 ± 18.85 (21)	9.84 ± 9.11 (9)	17.75 ± 19.87 (6)	19.48 ± 1.70 (3)
Skeletal muscle (μg/g wet)	6.64 ± 5.63 (20)	4.98 ± 4.04 (8)	13.08 ± 20.39 (3)	16.57 ± 8.25 (3)
Heart (μg/g wet)	15.95 ± 14.56 (19)	11.78 ± 10.09 (8)	18.22 ± 25.57 (4)	34.71 ± 8.60 (3)
Adipose (μg/g wet)	5.41 ± 4.87 (13)	12.81 ± 12.53 (8)	5.34 ± 7.54 (4)	8.14 ± 4.13 (3)

Horse normals: plasma, 2 μg/ml; liver, 5 μg/g; muscle, 5 μg/g; adipose 25 μg/g.
Data source: Wildlife Conservation Society Nutrition Laboratory, 1997.

(from 0.2 μg/ml, n = 11) with dietary supplementation over the past several years.[3] By comparison, apparently healthy free-ranging black rhinoceroses display geographic (and presumably dietary concentration) variability, ranging from 0.23 μg/ml (Kenya, n = 7) to 0.80 μg/ml (Namibia, n = 3), but average approximately 0.6 μg/ml (n = 129 from South Africa and Zimbabwe). Plasma vitamin E concentrations in rhinoceroses are one third to one tenth lower than in other herbivores, possibly because of a lack of high-density carrier lipoproteins.[5]

Circulating concentrations of alpha tocopherol can be useful in assessing availability of vitamin E from diets; as with most biologic systems, however, coefficient of variation around a single sample should be considered plus or minus approximately 15%. In addition, storage tissue fluxes of this nutrient in response to body needs can make blood values particularly tenuous in assessing status. Tissue (liver, skeletal muscle, heart, adipose) vitamin E concentrations quantified in 39 individual rhinoceroses representing four species (see Table 83–4) provide more detail for evaluating metabolism of this nutrient both within and between species. Although widely variable, concentrations measured in liver and muscle tissues of the browsing rhinoceroses tend to be higher than those of the white rhinoceros, possibly because of higher dietary supplementation in the browsers. Normal tissue alpha tocopherol concentrations in domestic horses do not appear to provide useful comparative indicators for tissue vitamin E status in rhinoceroses, perhaps because of differences in fat storage and metabolism between the temperate-evolved horse and tropical rhinoceros. Alpha tocopherol concentrations in free-ranging rhinoceros tissues have not been measured, but may be essential to understand optimal captive animal nutrition. It is possible that antagonistic nutrients (pro-oxidant minerals, vitamins, fats) are being supplied in excess of animal requirements, leading to a necessity for elevated antioxidant vitamin supplementation in captive animals.

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