CHEMICAL COMPOSITION OF SOUTHEAST ASIAN COLOBINE FOODS

Joeke Nijboer, Ellen S. Dierenfeld, Carey P. Yeager, Elizabeth L. Bennett, William Bleisch, and Arthur Ho. Mitchell

Rotterdam Zoo, Rotterdam, **THE NETHERLANDS** (J.N.), Wildlife Conservation Society, Bronx, New York, USA (E.S.D., E.L.B., W.B.), Fordham University, Bronx, New York, USA (C.P .Y.) and Yale University, New Haven, Connecticut, USA (A.H.M.)

Expanded Abstract

Digestive disturbances have been considered a major health issue among captive colobines [Janssen, 1994; Calle et al., 1995]. Inadequate or inappropriate fiber sources may underlie some of these problems. Apart from maintaining normal gastrointestinal function [Van Soest, 1994], one critical issue in husbandry of these species is the necessity of providing a suitable diet for supporting pregastric [Stevens, 1988] fermentation for microbial degradation of plant cell wall constituents as an energy source [Bauchop and Martucci, 1968; Bauchop, 1978; Waterman, 1984]. Alternatively, suitable microbial populations may provide important detoxification mechanisms for coping with secondary compounds identified in leaves and seeds consumed in nature [Freeland and Janzen, 1974; Hladik, 1977; Oates et al., 1977; Lebreton, 1982; Waterman, 1984]. Furthermore, both excessive soluble carbohydrate [Goltenboth, 1976; Waterman, 1984] and protein [Davies et al., 1988] concentrations in diets fed to captive colobines have been implicated in health disorders.

This report summarizes data on the chemical composition of foods eaten by proboscis monkeys *(Nasalis larvatus),* Hose's langurs *(Presbytis hosei),* and the Guizhou snub-nosed monkey *(Rhinopithecus brelichi).* Feeding observations and sampling of plants eaten follow standardized methodologies as reported by studies of primate foraging [see, for example, Bennett and Sebastian, 1988; Yeager, 1989]. Plant materials consumed by the proboscis monkeys were collected in Samunsam Wildlife Sanctuary , Sarawak, Malaysia or Tanjung Puting National Park (Talimantan Tengah), Indonesia, over a 10-yr period. Those eaten by Hose's langurs were collected in Silabukan Forest Reserve and Tabin Wildlife Reserve, Sabah, Malaysia, over an 18-mo period [Mitchell, 1994], and the plant samples eaten by the Guizhou snub-nosed monkey were collected over a 2-yr field study in the Fanjing mountains of southwestern China (Bleisch and Xie, 1994].

Leaf (n=92), fruit (n=16), flower (n=15) and seed (n=31) samples were air- or oven-dried to a constant weight, and water content determined in the field before shipment to the Nutrition Laboratory at the Wildlife Conservation Society, Bronx, NY .All samples were ground to pass a 2 mm screen, and analyzed according to AOAC methods for animal feeds (1996). Crude protein (CP) values were determined as total nitrogen X 6.25 using a macro-Kjeldahl method with a copper catalyst; acid detergent nitrogen X 6.25 (AD-CP) was evaluated as a measure of unavailable protein (Goering and Van Soest, 1970).
Neutral detergent fiber (NDF), acid detergent fiber (ADF), and sulfuric acid lignin values were quantified using the methods of Goering and Van Soest [1970] with no pretreatments or enzymes. Crude fat extractions (fruits, flowers, and seeds only) were performed using petroleum ether. Total ash content was

obtained by heating samples to 550° C overnight in a muffle furnace. Mineral concentrations were determined in triplicate by atomic absorption spectroscopy after dry ash digestion [Perkin Elmer, 1982].

Proximate and mineral data are reported in Tables 1 and 2. For all three species, chemical composition of plants was included in averages if the plant occurred in the diet. No weighting of foods (i. e. by percent of diet) was attempted for this broad summary .The food choices of Asian colobines vary seasonally in the wild. When available, fruits and seeds are a frequent component of the diet; during times of low fruit availability, these primates typically switch to eating leaves [Yeager, 1989; Kool, 1993]. Results of this survey suggest chemical similarities among items in these broadly different food categories.

Overall, protein content in foods eaten by these primates averaged between 12.9 ± 4.4% (mean ± S.D.) of dry matter, of which almost 50% analyzed as AD-CP, or nutritionally unavailable, protein. Bound protein comprised 31-52% of crude protein in leaves, 54-84% in flowers, and 44-53% in seeds. While crude protein levels are identical to the concentration recommended by the National Research Council [NRC, 1978] for feeding nonhuman (and noncolobine) primates (16.3% of dietary dry matter), available protein (CP less AD-CP) in native plants appears considerably lower than both the NRC recommendation and the protein content reported in a survey of diets fed to colobines (15.0 ± 3.0) in European and North American zoos [Nijboer and Dierenfeld, 1996]. Available protein levels measured in preferred plants approached minimums required for the maintenance of microbial populations in ruminant herbivores [Van Soest, 1994], and ruminant nutrient requirements may better model the dietary protein needs of colobine monkeys, but has not been investigated in detail.

All food categories were highly fibrous, with even leaves containing >50% NDF. The degree of lignification (Lignin/NDF) in leaves (41-45%) did not differ from that measured in fruits (37-42%; n = 16); lignification in flowers averaged 52 ± 2% (n=12). These values contrast markedly with the low fiber (12.5 ± 4.6%), and very low lignin (1.0 ± 1.1%) diets evaluated for zoo colobines [Nijboer and Dierenfeld, 1996). Physical as well as chemical components of fibrous constituents of herbivore diets are known to influence gut motility and function, as well as play an important role in fecal integrity [Van Soest, 1994], and may underlie current health problems noted for these species in captivity. Temperate browses fed in many zoos appear to provide suitable chemical substitutes for native browses for some of these species [Nijboer and Dierenfeld, 1996], but effects on digestive physiology have not yet been quantified in controlled studies.

Seeds and fruits would appear to be a variable source of dietary fat for colobines, possibly providing significant energy, but effects of dietary fats upon either colobine monkeys, or their gastrointestinal microbes, have not been investigated. Regarding the mineral content of plants evaluated in this study, both Ca and Fe may be limiting compared with primate recommendations; again, ruminant dietary requirements may provide a more suitable model. Calcium in flowers and seeds eaten by langurs and proboscis monkeys was higher than in many leaf samples. This finding was unexpected, as cultivated seeds and nuts are known to contain low Ca content as a rule, whereas leaves are often considered a primary Ca source.

Implications for Captive Feeding Programs

Although wild proboscis monkeys and langurs tend to select foods higher in protein and lower in fiber than nonpreferred plant species [Yeager, 1989; Kool, 1993; Yeager et al., 1997], the natural foods eaten

by these primates are not high in protein, and contain much higher levels of indigestible fiber than most zoo dietary ingredients. The lack of mineral data for most browses (either native or those substitutes fed in zoos) limits their assessment as feeds, and needs to be addressed. Detailed analysis and comparison of natural feedstuffs may provide useful information for the development of optimal diets for managed populations of colobines.

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Table 1. Chemical Composition of native food plants (mean ± s.d.) eaten by three southeast Asian colobines. All nutrients on a dry matter basis except water.

Primate Species	Plant Part (n)	Water ←--------	CP ----------	AD-CP ----------	NDF %	ADF ----------	Lignin ----------	Fat -------→	Field Site[a]
Nasalis larvatus (Proboscis monkey)	Leaves (n=13)	31.7 ±19.0	11.7 ± 5.5	6.1 ± 1.9	57.2 ± 14.1	46.3 ± 13.3	25.8 ± 10.0	NA	1
	(n=20)	NA	9.9 ± 3.4	3.4 ± 1.8	43.7 ± 11.3	30.5 ± 12.1	14.5 ± 8.8	NA	2
	Fruits (n=13)	78.3 ± 11.7	5.2 ± 1.6 (n=22)	3.8 ± 0.9	66.7 ± 15.3	52.3 ± 15.1	28.3 ± 14.4	7.4 ± 6.9	2
	Flowers (n=10)	37.2 ± 19.3	10.4 ± 4.0 (n=13)	5.6 ± 2.3 (n=9)	50.7 ± 7.3	41.6 ± 19.3	26.7 ± 15.8	3.4 ± 0.5 (n=3)	1,2
	Seeds	68.4 ± 17.7 (n=14)	8.1 ± 2.5 (n=22)	3.6 ± 2.0 (n=9)	NA	NA	NA	13.0 ± 11.2 (n=11)	1,2
Presbytis Hosei (Hose's langur)	Leaves (n=10)	NA	16.0 ± 4.0	7.4 ± 3.7	54.6 ± 19.6	42.2 ± 19.2	24.4 ± 13.1	NA	3
	Flowers (n=2)	NA	10.0 ± 3.4	8.4 ± 2.2	52.2 ± 6.7	39.7 ± 8.1	26.8 ± 9.3	NA	3
	Seeds (n=9)	NA	10.9 ± 4.7	5.8 ± 3.8	NA	NA	NA	17.0 ± 15.2	3
Rhino-pithecus brelichi (Guizhou snub nose monkey)	Leaves (n=49)	NA	14.0 ± 4.1	5.3 ± 2.4	47.8 ± 12.4	37.8 ± 12.8	19.5 ± 8.1	NA	4
	Fruits (n=5)	NA	5.7 ± 2.1	1.5 ± 1.2	51.3 (n=1)	40.6 (n=1)	18.9 (n=1)	11.4 ± 11.9	4

CP= crude protein; AD-CP= bound protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; NA= not analyzed

1=Bennett and Sebastian, 1988; 2= Yeager, 1989; 3=Mitchell 1994; 4=Bleisch and Xie, 1994

Table 2.Mineral Composition of native food plants (mean ± s.d.) eaten by three southeast Asian colobines compared with the recommended dietary levels for non human primates [NRC, 1978]. All nutrients on a dry matter basis.

Primate Species	Plant Part (n)	Ash	Ca %	Mg	Cu	Fe	Mn	Zn	Field Site
Nasalis larvatus (Proboscis monkey)	Leaves (n=23)	6.3 ± 2.8	0.3 ± 0.2	0.2 ± 0.1	7.2 ± 6.6	34.0 ± 14.4	55.7 ± 52.7	17.8 ± 11.7	2
	Fruits (n=17)	3.5 ± 1.4	0.2 ± 0.1	0.15 ± 0.04	5.2 ± 2.3	43.9 ± 22.9	26.8 ± 31.8	10.9 ± 4.9	2
	Flowers (n=6)	5.7 ± 2.7	0.5 ± 0.3	0.3 ± 0.1	7.0 ± 4.1	29.5 ± 18.1	127.0 ± 176.2	10.8 ± 6.4	1,2
	Seeds (n=19)	3.3 ± 1.2	0.2 ± 0.3	0.2 ± 0.1	9.0 ± 3.6	33.6 ± 12.8	20.9 ± 18.9	18.9 ± 11.4	1,2
Presbytis hosei (Hose's langur)	Leaves (n=3)	7.8 ± 4.9 (n=10)	0.4 ± 0.1	0.3 ± 0.1	13.0 ± 3.7	70.4 ± 30.0	579.5 ± 535.9	31.0 ± 12.0	3
	Seeds (n=8)	7.9 ± 12.2	0.5 ± 0.7	0.1 ± 0.1	10.3 ± 3.0	65.6 ± 50.4	174.4 ± 150.7	28.7 ± 28.4	3
Rhinopithecus brelichi (Guizhou snub-nosed monkey)	Leaves (n=7)	8.3 ± 3.5 (n=49)	1.6 ± 0.5 (n=6)	0.3 ± 0.1	9.1 ± 3.4	154.5 ± 48.0	708.5 ± 817.8	58.2 ± 59.2	4
Non-human primate recommendation		none	0.54	0.16	none	196	None	11	

1=Bennett and Sebastian, 1988; 2= Yeager, 1989; 3=Mitchell 1994; 4=Bleisch and Xie, 1994