CHEMICAL COMPOSITION OF FOODS EATEN BY AFRICAN COLOBINES COMPARED WITH SOUTHEAST ASIAN COLOBINES

Jenna Lawrence[1], MS, Colleen McCann[2], PhD, and Ellen S. Dierenfeld[3]*, MS, PhD

[1]Department of Ecology, Evolution, and Environmental Biology, Columbia University, New York, NY USA; [2]Department of Mammalogy, Wildlife Conservation Society, Bronx, NY USA; [3]Department of Animal Health and Nutrition, Saint Louis Zoo, St. Louis, MO USA

Extended Abstract

Nutritional analyses of foods eaten by wild colobine populations can be useful for understanding colobine nutritional needs, crucial for successful maintenance of captive populations. A previous report by Nijboer *et al*.[16] summarized the mineral and proximate data for browse composition of three species of Southeast Asian colobines. The authors noted that the diets of these wild colobines contained substantially more fiber and less protein than the diets of captive colobines.[15]

This report summarizes nutritional data from field studies of six species and two subspecies of African colobines: *Colobus angolensis*, *C. guereza*, *C. satanas*, *C. polykomos*, *Procolobus badius tephrosceles*, *P. b. rufomitratus*, and *P. verus*. Data from multiple studies on feeding records and nutritional analyses were grouped by field site, and data from identical analyses at the same site but in different studies were averaged. Plant parts were differentiated when the information was provided, and all data were averaged for each site and colobine taxon. If necessary, crude protein was calculated from reported nitrogen values. Individual plant composition data from each published study will be available through the Forager's Source online browse database (http://www.foragerssource.org). The summary statistics most likely do not accurately reflect true dietary composition; data from all food plant species were counted equally despite the fact that, in most studies, a few preferred plant species dominated the diet. Moreover, the analyses performed differed greatly among studies, resulting in small sample sizes and consequently large standard deviations. Results are summarized in Tables 1-3, with references listed in Table 4. All percentages are averages based on a dry matter basis.

Inadequate dietary fiber may represent a considerable threat to the health of captive folivorous primates.[6] As with Asian colobines, African colobine browse contained high proportions of fiber, although the acid detergent fiber (ADF) for most species was slightly lower (African: 22.8-42.3%; Asian: 30.5-52.3%). However, the diet of *Colobus satanas* at Douala-Edea Forest Reserve in Cameroon, a site known for sandy, acidic soils and vegetation high in tannins and fiber[4,10], contained the greatest amount of ADF (mature leaves: 64.7%; young leaves: 50.7%). Only one study calculated neutral detergent fiber (NDF), a better indicator of total fiber. The results were comparable to, if a bit lower than, those of the Asian colobine study (African: mature leaves: 47.3%, young leaves: 35.6%; Asian: 43.7-57.2% for all leaves). In pubished studies, young leaves appear to be preferred over mature leaves for both primate groups, although chemical data do not necessarily predict preference. Averages for fiber content of young leaves were lower than mature leaves except for *C. guereza* at Kanyawara, Kibale, Uganda. Lignin was also somewhat lower, but the sample size was small (African: 5.8-19.8%;

Asian: 14.5-28.3%). Pepsin/cellulase digestibility (CDIG), an estimate of dry matter digestibility, was substantially lower in Douala-Edea than other sites.

The simple average and range of total crude protein values were slightly, though perhaps not significantly, higher for African than Asian colobines (African: 16.9 ± 7.3%, 5.7-37%; Asian: 12.9 ± 4.4%, 5.2- 16.0%). However, 50% of all protein in the Asian colobine diets was bound, and therefore nutritionally unavailable. None of the African studies tested for bound protein. Seeds in the diets of African colobines contained more crude protein than those for Asian colobines (African: 9.1, 20.6, 22.4%; Asian: 8.1, 10.9%). Young leaves contained more crude protein than mature leaves at all African sites except Douala-Edea, and the protein in young leaves and seeds were comparable. Crude protein at Douala-Edea was far lower than at other sites.

Regarding minerals, Nijboer *et al*.[16] suggested that calcium and iron might be limiting for colobines. Although iron was not measured in any African study, calcium was slightly lower in the Asian colobine study (African: 0.2-1.6%; Asian: 0.5-3.6%), not counting one mature leaf sample from Kanyawara for *Procolobus badius tephrosceles* (9.9%). While relatively high calcium was found in flowers and seeds for Asian colobines, none was tested for African colobines. Magnesium was the only other mineral assay in common for both African and Asian colobine studies, but for African colobines there was only one sample from one site. Relatively large amounts of potassium were measured in browse at Kanyawara (1.4-9.8%). The amounts of ash measured in African studies (2.1-16.7%) indicate a large presence of unidentified minerals.

Nijboer *et al*.[16] did not consider secondary compounds. Data for African colobines revealed a pattern of higher condensed tannins in young leaves than mature leaves. The highest levels were found in flowers and leaves at Mcheleo, Tana River Reserve, Kenya. There was no consistent pattern in total phenolics; values varied for leaves and flowers, from 0.1 and 0.2% for *Colobus guereza* at Kanyawara[22] to 21.2-34.1% for *Procolobus badius rufomitratus* at Mcheleo.[14]

Clearly, more data, preferably standardized, from additional species and field sites are needed both for comparisons among African colobines and between African and Asian colobines, especially if the wild studies are to be truly informative for captive nutrition. Interestingly, all the immature leaf data in this summary encompass ranges measured in browse leaves (n=4 spp.) consumed by black and white colobus at the Central Park Zoo in a recently published paper[21], so we believe these summary data are not misleading but do in fact reflect ranges that are consumed and tolerated by African colobines - both in nature and in captivity. Currently, mineral, bound protein, carbohydrate, and lignin data are particularly lacking.

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Table 1. Chemical composition of native foods eaten by African colobus monkeys, summarized from published literature; all nutrients on a dry matter basis.

Primate Taxon	Plant Part	CP[1] (6.25N)	ADF[2]	NDF[3]	CDIG[4]	Lignin	Field Site
		% dry matter					
Colobus angolensis	**Mature Leaves**	**20.7 ±6.6 (n=16)**	**24.9 ±6.8 (n=16)**			**10.45 (n=16)**	Nyungwe
Colobus guereza	**Mature Leaves**	**16.8 (n=2)**	**19.1 ±21.9 (n=2)**		**64.2 (n=1)**	**10.7 ±1.2 (n=2)**	Kanyawara
	Mature Leaves	**18.4 ±4.0 (n=9)**	**34.5 ±8.9 (n=9)**	**47.3 ±9.3 (n=9)**			Kakamega
	Young Leaves	**29.9 ±14.5 (n=3)**	**30.0 ±9.1 (n=3)**		**77.5 (n=1)**	**12.3 ±3.7 (n=3)**	Kanyawara
	Young Leaves	**24.1 ±5.6 (n=9)**	**29.4 ±8.2 (n=9)**	**35.6 ±5.6 (n=9)**		**5.8 (n=1)**	Kakamega
Colobus satanas	**Mature Leaves**	**7.9 ±7.5 (n=5)**	**64.7 ±8.7 (n=4)**		**20.9 ±5.0 (n=4)**		Douala-Edea
	Young Leaves	**5.7 ±8.4 (n=6)**	**50.7 ±15.2 (n=6)**		**33.9 ±16.7 (n=6)**		Douala-Edea
	Seeds	**9.1 ±6.4 (n=7)**					Douala-Edea
Colobus polykomos	**Mature Leaves**	**12.4 ±1.2 (n=5)**	**40.3 ±7.0 (n=5)**				Tiwai
	Young Leaves	**22.3 ±8.2 (n=6)**	**26.9 ±10.4 (n=6)**				Tiwai
	Unripe Seeds/Fruits	**22.4 ±9.4 (n=6)**	**24.9 ±20.8 (n=6)**				Tiwai
Procolobus tephrosceles	**Mature Leaves**	**18.4 ±3.8 (n=11)**	**35.1 ±10.3 (n=11)**		**54.2 ±10.6 (n=7)**	**19.8 ±11.7 (n=3)**	Kanyawara
	Mature Leaves	**16.4 ±3.0 (n=7)**	**33.0 ±7.1 (n=7)**				Dura River
	Mature Leaves	**18.3 ±3.8 (n=9)**	**35.0 ±9.8 (n=9)**				Mainaro

Table 1. cont.

	Mature Leaves	**17.0 ±6.6 (n=7)**	**36.4 ±5.6 (n=7)**				Sebatoli
	Mature Leaf Petioles	**10.9 ±2.0 (n=3)**	**42.3 ±9.5 (n=2)**			**14.0 ±14.5 (n=3)**	Kanyawara
	Young Leaves	**37.0 ±2.9 (n=2)**	**22.8 ±6.4 (n=4)**		**54.3 ±32.9 (n=2)**	**7.6 ±3.0 (n=2)**	Kanyawara
	Young Leaf Petioles	**12.3 ±1.2 (n=2)**	**40.5 (n=1)**			**12.3 ±3.6 (n=2)**	Kanyawara
Procolobus badius rufomitratus	**Mature Leaves**	**13.3 ±3.9 (n=12)**	**29.6 ±8.4 (n=13)**				Mcheleo
	Young Leaves	**20.1 ±6.1 (n=14)**	**23.8 ±10.1 (n=14)**				Mcheleo
	Mature Fruit	**6.9 (n=1)**	**50.7 (n=1)**				Mcheleo
	Immature Fruit	**7.3 ±5.2 (n=3)**	**57.4 ±2.4 (n=3)**				Mcheleo
	Flowers	**16.3 ±8.8 (n=4)**	**24.2 ±9.0 (n=4)**				Mcheleo
Procolobus verus	**Mature Leaves**	**13.5 ±4.4 (n=6)**	**51.9 ±11.0 (n=6)**				Tiwai
	Young Leaves	**22.1 ±6.7 (n=6)**	**22.0 ±19.2 (n=6)**				Tiwai
	Seeds	**20.6 (n=1)**	**50.7 (n=1)**				Tiwai

[1]CP = crude protein; [2]ADF = acid detergent fiber; [3]NDF = neutral detergent fiber; [4]CDIG = pepsin/cellulase digestibility.

Table 2. Mineral composition of native foods eaten by African colobus monkeys, summarized from published literature; all nutrients on a dry matter basis.

Primate Taxon	Plant Part	Ash	P	Ca	K	Mg	Na	Field Site
		% dry matter						
Colobus guereza	**Mature Leaves**	16.7 ±2.1 (n=2)	0.2 (n=1)	0.9 (n=1)	1.4 (n=1)		0.3 (n=1)	Kanyawara
	Mature Leaves	8.3 ±3.5 (n=9)						Kakamega
	Young Leaves	9.7 (n=1)	1 (n=1)	1.8 (n=1)	7.5 (n=1)		0.1 (n=1)	Kanyawara
	Young Leaves	7.3 ±3.2 (n=9)	1.4 (n=1)	0.5 (n=1)	5.5 (n=1)	0.2 (n=1)	0.1 (n=1)	Kakamega
Colobus satanas	**Mature Leaves**	4.9 ±3.8 (n=3)	0.1 ±0.0 (n=3)					Douala-Edea
	Young Leaves	4.3 ±1 (n=3)	0.5 ±0.2 (n=3)					Douala-Edea
	Seeds	2.1 ±1.0 (n=5)	0.2 ±0.0 (n=5)					Douala-Edea
Procolobus badius tephrosceles	**Mature Leaves**	14.8 ±6.9 (n=7)	0.2 ±0.1 (n=5)	9.9 (n=1)	1.4 (n=1)		0.3 (n=1)	Kanyawara
	Mature Leaf Petioles	9.9 (n=1)	0.4 ±0.2 (n=2)	3.6 ±3.0 (n=1)	6.0 (n=1)		0.2 (n=1)	Kanyawara
	Young Leaves	7.8 (n=1)	0.8 ±0.3 (n=2)	1.5 ±1.0 (n=2)	5.2 (n=1)		0.1 (n=1)	Kanyawara
	Young Leaf Petioles	5.8 (n=1)	0.6 ±0.5 (n=2)	1.3 ±0.2 (n=2)	9.8 (n=1)		0.1 (n=1)	Kanyawara

Table 3. Secondary compounds in native foods eaten by African colobus monkeys, summarized from published literature; all nutrients on a dry matter basis.

Primate Taxon	Plant Part	FD[1]	V[2]	PA[3]	HT[4] (mg/g)	Field Site
		% dry matter				
Colobus guereza	**Mature Leaves**	1.9 (n=1)	0.0 (n=1)	0.2 (n=1)		Kanyawara
	Young Leaves	2.5 ±0.6 (n=2)	0.0 (n=1)	0.1 ±0.0 (n=2)		Kanyawara
Colobus satanas	**Mature Leaves**	6.6 ±3.2 (n=5)	2.7 ±1.8 (n=5)	4.2 ±2.6 (n=5)		Douala-Edea
	Young Leaves	8.5 ±4.8 (n=6)	4.7 ±6.3 (n=6)	7.3 ±5.4 (n=6)		Douala-Edea
	Seeds	2.8 ±2.8 (n=7)	0.4 ±0.6 (n=7)	1.2 ±1.0 (n=7)		Douala-Edea
Colobus polykomos	**Mature Leaves**			9.7 ±7.8 (n=3)		Tiwai
Procolobus badius tephrosceles	**Mature Leaves**	3.3 ±2.6 (n=8)	1.6 ±2.3 (n=8)	2.9 ±5.6 (n=8)		Kanyawara
	Young Leaves	7.4 ±2.5 (n=3)	3.2 ±4.1 (n=2)	4.6 ±5.3 (n=4)		Kanyawara
Procolobus badius rufomitratus	**Mature Leaves**	1.4 ±1.1 (n=13)		34.1 26.9 (n=13)	4.3 ±2.2 (n=13)	Mcheleo
	Young Leaves	2.0 ±2.8 (n=14)		28.9 34.3 (n=14)	4.8 ±2.5 (n=14)	Mcheleo
	Mature Fruit	0.0 (n=1)		0.3 (n=1)	1.1 (n=1)	Mcheleo

	Immature Fruit	0.0 ±0.0 (n=3)		0.2 ±0.1 (n=3)	0.6 ±0.1 (n=3)	Mcheleo
	Flowers	2.4 ±2.0 (n=4)		21.2 ±23.8 (n=14)	21.4 ±21.4 (n=4)	Mcheleo
Procolobus verus	**Mature Leaves**			15.6 ±11.0 (n=6)		Tiwai
	Young Leaves			5.2 ±7.7 (n=6)		Tiwai
	Seeds			0.5 (n=1)		Tiwai

Test Methodology: [1]FD = Folin-Denis; [2]V = Vanillin; [3]PA = Proanthocyanidin; [4]HT = hydrolysable tannins.

Table 4. Reference sources used to summarize nutrient composition of native foods consumed by African colobines, categorized according to field site and primate taxon.

Field Site	Primate taxon	Literature Cited
Douala-Edea Reserve, Cameroon	*Colobus satanas*	Choo *et al*. 1981, Gartlan *et al*. 1980, McKey *et al*. 1981, McKey and Waterman 1982, Waterman *et al*. 1980
Dura River, Kibale, Uganda	*Procolobus badius tephrosceles*	Chapman *et* al. 2002
Kakamega, Kenya	*Colobus guereza*	Fashing 2001, unpub data
Kanyawara, Kibale, Kenya	*Colobus guereza*	Baranga 1982, 1983; Choo *et al*. 1981,
	Procolobus badius tephrosceles	Baranga 1982, 1983; Chapman *et* al. 2002; Choo *et al*. 1981, Gartlan *et al*. 1980, Struhsaker 1975, Waterman *et al*. 1980
Mainaro, Kibale, Kenya	*Procolobus badius tephrosceles*	Chapman *et* al. 2002
Mcheleo, Tana River Reserve, Kenya	*Procolobus badius rufomitratus*	Marsh 1981, Mowry *et al*. 1996
Nyungwe Forest Reserve, Rwanda	*Colobus angolensis*	Fimbel *et al*. 2001
Sebatoli, Kibale, Kenya	*Procolobus badius tephrosceles*	Chapman *et* al. 2002
Tiwai Island, Sierra Leone	*Colobus polykomos*	Dasilva 1994, Oates 1990
	Procolobus verus	Dasilva 1994, Oates 1988