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Comparison of Diets Fed to Southeast Asian Colobines in North American and European Zoos, With Emphasis on Temperate Browse Composition

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In May and June 1994 a survey of diets fed to captive southeast Asian colobines in European (n = 12) and North American (n = 9) zoos was conducted. Most diets were very complex, comprising an average of 25 ingredients; 149 different foods were listed in responses. Comparison of diets fed showed that European zoos feed a greater variety of fruits and vegetables, and fewer browse plants, than North American zoos. No standardized diet recommendations, based on ingredient or nutrient composition, are currently available for colobines in captivity. Foods eaten by these primates in nature appear to contain higher amounts of fiber and lower protein and soluble carbohydrates than current zoo diets. Temperate browse plants (n = 11 spp.; leaves plus twigs) sampled in New York in summer and autumn contained higher fiber and lower protein levels than diets fed in this survey, and may approximate the nutrient content of food items selected by free-ranging colobines. Fast-growing roses grown in greenhouses, fed primarily in Europe, contained substantially less fiber and higher protein concentrations than other browses offered, and may not be an appropriate substitute for native foods. © 1996 Wiley-Liss, Inc.

Key words: browse composition, diet survey, colobine nutrition

INTRODUCTION

As of June 30, 1994, 40 zoos recorded 14 species or subspecies of southeast Asian colobines in worldwide collections, comprising a total of 321 animals. Nineteen young were born in captivity over the past 12 months, with 15 belonging to only three species or subspecies [ISIS, 1994]. Populations of these primates both in zoos and in nature are threatened, and require focused attention.

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Colobines have a highly specialized digestive system [Kuhn, 1968; Ohwaki et al., 1974; Kay and Davies, 1994]. Digestive disturbances have been identified as a major health problem in captivity [see Janssen, 1994; Calle et al., 1995], which may be related to an inappropriate diet. Based on survey data from 12 European and nine North American zoos, representing 48% (n = 160) of the extant zoo population at the time (ISIS, 1993], diets offered in captivity contained substantially more soluble carbohydrate and available protein, and less fiber than plants consumed by free-ranging colobines [see Kay and Davies, 1994; Waterman and Kool, 1994] (Nijboer et al., unpublished observations).

Limited information is available on the nutrient composition of temperate browse plants fed to these primates in zoos for comparison with natural forages. This paper focuses on specific differences between diet ingredients in European and North American zoos, and further documents seasonal differences in chemical constituents of selected browses commonly used in North American facilities. Such information, when combined with data from natural diets and feeding observations, may be integral in the development of optimal diets for managed populations of these species.

MATERIALS AND METHODS

Diet Comparison

A survey was sent to 15 European and 17 North American zoos holding southeast Asian colobines in their collections. Respondents provided dietary information (ingredients and amounts offered), which was entered into a commercial software program (Animal Nutritionist, N2 Computing, Silverton, OR) for initial evaluation.

Chemical Analysis of Browse

Samples of 11 temperate browses (sampled from 3 - 5 individual trees) commonly fed in North American facilities and rose browse from The Netherlands were analyzed in the Nutrition Laboratory, Wildlife Conservation Society, Bronx, NY. Fresh weights of leaves and twigs were taken, and samples dried at <60ºC to obtain moisture content; leaf:twig ratios were determined on an as-sampled (wet) weight basis. Dried plant samples were ground in a Wiley laboratory mill through a 2 mm screen, and analyzed according to AOAC methods for animal feeds [Jones, 1984].

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 sulphuric acid lignin (Lig) values were quantified through sequential analysis using the methods of Goering and Van Soest [1970], with no pretreatment or enzymes. Total ash content was obtained by burning samples (0.5 g) at 550°C overnight in a muffle furnace.

Paired comparisons of nutrient concentrations in leaf vs. twig fractions, or species x season, were performed using the SYSTAT computer software package [Wilkinson, 1987].

RESULTS

Captive Diet Survey

Twelve of 15 European zoos (80%) and nine of 17 North American zoos (5 3%) replied to the survey; data represent diets offered to 48% of the captive southeast Asian colobine

TABLE 1. Distribution of southeast Asian colobines comprising diet survey results*

	Europe		N. America	
Species	Total # zoos	Total # animals	Total # zoos	Total # animals
Thrachypitecus auratus sp.	4	31	—	—
T. obscura sp.	3	27	3	14
T. cristatus sp.	3	34	2	21
T. francoisi	1	3	3	14
Nasalis larvatus	1	2	1	5
Pygathrix nemaeus	1	11	—	—

*Survey results represent 48% of total captive population (in these continents).

population at the time (n = 160 animals). Table 1 shows the different species of southeast Asian colobines distributed in European and North American zoos that were involved in this project.

Zoo Diets

One hundred and forty-nine different diet ingredients were fed among the surveyed zoos, including 50 browses, 35 commercial products, concentrates and/or vitamin/mineral supplements, 22 vegetables, 18 fruits, 18 greens, and six animal-based products (Nijboer et al., unpublished). A summary of foods most frequently fed (n = 28) in the 21 responding zoos can be found in Table 2. Because many zoos did not know the exact quantity of browse fed, browse as a percentage of the diet in relation to the total amount of other food categories could not be calculated for most facilities. Response frequency for various food items was selected as a relative modal statistic for comparison of differences in diets offered between European and North American zoos.

Foods listed by >1 but < 4 zoos included: kiwi, melon, mulberry, and orange (fruits); aubergine, avocado, beets, cauliflower, corn (sweet), leeks, peas, potato (sweet), and zucchini (vegetables); cottage cheese, curd, and honey (animal products); peanuts, rolled oats, rice, sunflower seeds, and wheat bran (concentrates, grains, nuts); endive and parsley (greens); apple tree leaves, bamboo, beech, black currant, birch, cotoneaster, coprosma, grape vine, hawthorn, hazel, honeysuckle, lime, lilac, oak, plane tree, and privet (browses); and fennel tea (miscellaneous).

Most European zoos feed a greater variety of fruits (especially bananas and grapes) and vegetables, compared to North American zoos (note differences in response frequencies in Table 2). In Europe, six groups of colobines are fed eggs, compared with only one group in North America. Different types of green produce are fed with equal frequency in Europe and North America, although in North America spinach and kale are preferred, compared with fennel and lettuce in Europe. European zoos feed a greater variety of browse, especially rose, willow, and poplar.

Browse Composition

Water, crude and bound protein, and cell wall constituents of temperate browse plants cultivated as food for captive animals, sampled in July and September 1994, can be found in Tables 3 and 4.

Paired comparisons within species demonstrated that leaves are higher in water,

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TABLE 2. Most frequently used foodstuffs in colobine diets at European and North American zoos (used in >4 facilities)

	Europe		N. America	
	# Zoos responding	Response frequency[a]	# Zoos responding	Response frequency[a]
Fruits:		0.6		0.3
Apple	7	0.6	5	0.5
Banana	10	0.8	4	0.4
Grape	7	0.6	1	0.1
Pear	4	0.3	1	0.1
Vegetables:		0.5		0.2
Bean, green	1	0.1	4	0.4
Carrot	8	0.7	5	0.5
Celery	9	0.8	2	0.2
Cucumber	7	0.6	0	0.0
Onion	5	0.4	2	0.2
Pepper, green	6	0.5	1	0.1
Potato	6	0.5	1	0.1
Tomato	6	0.5	1	0.1
Yam	0	0.0	6	0.6
Animal products:		0.5		0.1
Egg	6	0.5	1	0.1
Concentrates/vitamins:		0.5		0.5
Bread	6	0.5	0	0.6
Primate pellet	8	0.7	6	0.6
Vitamins	4	0.3	2	0.2
Greens:		0.4		0.4
Broccoli	3	0.3	3	0.3
Cabbage	4	0.3	1	0.1
Fennel	8	0.7	0	0.0
Kale	1	0.1	6	0.6
Lettuce	7	0.6	2	0.2
Spinach	1	0.1	6	0.6
Browse:		0.4		0.2
Elm spp.	3	0.3	2	0.2
Maple spp.	4	0.3	2	0.2
Poplar spp.	4	0.3	1	0.1
Rose	6	0.5	0	0.0
Willow spp.	7	0.6	3	0.3

[a]Response frequency (total # responses/total # zoos surveyed).

protein, and ash ($P < 0.01$), and lower in all fiber fractions than twigs ($P < 0.05$). AD-CP differences were not significant. Paired comparisons by species showed that only NDF and ADF differed seasonally ($P < 0.01$), with fiber fractions higher later in the growing season. Leaf percentage in September was also significantly lower ($P = 0.01$) compared to July.

Diet Analysis

Diets did not differ among colobine species within zoos; unfortunately, however, diet information detailed enough for reliable nutrient summary calculations (amounts actually consumed vs. those offered) was obtained from only seven of the 21 responding facilities. The nutrient composition of representative diets eaten by five colobine species in six European and

TABLE 3. Chemical composition of common browses fed in the Wildlife Conservation Park, Bronx, NY (July 1994 samples)

Family/species	L:T[a] %	Water	Crude protein	AD-CP[b]	NDF	ADF	Lig	Ash
			- - - - - - - - - - % of dry matter - - - - - - - - - - - - - - - - -					
Aceraceae Acer *negundo*	L	72.9	15.6	1.8	30.9	21.6	6.7	8.4
Box Elder	T	59.0	8.1	1.5	67.9	54.0	19.2	4.4
	57:43	66.9	12.4	1.7	46.8	35.5	12.1	6.7
A. saccharinum	L	50.9	15.4	1.0	19.8	14.7	6.0	7.1
Silver Maple	T	49.0	4.3	1.5	63.8	46.8	12.5	4.3
	57:43	50.1	10.7	1.2	38.7	28.5	8.8	5.9
A. saccharum	L	57.8	13.3	2.3	29.0	20.8	8.1	8.2
Sugar Maple	T	45.5	4.3	2.9	62.7	51.1	20.8	7.0
	47:53	51.3	8.5	2.7	45.9	36.8	14.9	7.6
FagaceaeFagussp.	L	64.5	15.8	5.7	61.1	32.4	10.9	6.5
Beech	T	54.1	3.3	1.6	84.0	79.2	25.1	2.8
	39:61	58.1	8.2	3.4	75.1	61.0	19.6	4.3
Hamamelidaceae Liquidambar sp.	L	64.6	11.6	3.4	40.0	35.4	19.9	2.7
Sweet Gum	T	54.6	3.6	2.6	64.1	51.1	19.9	5.2
	54:46	60.0	7.9	3.0	51.1	42.7	19.9	3.8
MoraceaeMorussp.	L	65.9	18.9	1.1	21.3	14.4	4.5	15.1
Black Mulberry	T	55.8	5.9	2.0	60.3	48.7	18.0	7.1
	42:58	60.0	11.3	1.6	44.0	34.3	12.3	10.4
Salicaceae Popular alba	L	68.0	17.4	2.7	41.7	27.0	11.0	13.0
White Poplar	T	64.2	5.3	1.8	61.2	59.2	26.0	7.6
	63:37	66.6	12.9	2.4	48.9	38.9	16.5	11.0
Salix babylonica	L	63.5	18.0	2.1	29.6	24.8	14.6	12.8
Weeping Willow	T	50.0	2.8	1.9	69.7	60.2	20.4	3.8
	64:36	58.6	12.5	2.0	44.1	37.6	16.7	9.6
Salix nigra	L	62.6	18.3	2.8	38.7	27.0	13.4	8.9
Black Willow	T	53.4	6.6	2.2	61.4	50.5	20.1	5.6
	62:38	59.1	13.9	2.6	47.3	35.9	16.0	7.7
UlmaceaeCeltis occidentalis	L	62.6	16.1	1.3	36.1	20.4	7.5	8.7
Hackberry	T	40.4	5.0	2.1	74.5	53.0	16.9	7.0
	54:46	52.4	11.0	1.7	53.8	35.4	11.8	8.0
Vitaceae Vitis sp.	L	79.1	16.7	0.6	19.9	14.7	5.5	11.2
Grapevine	T	84.8	3.0	2.3	70.2	55.2	16.7	5.6
	50:50	80.4	9.9	1.5	45.1	35.0	11.1	8.4

aL = leaf; T = twig; leaf:twig proportions (% wet weight) of whole plant sample as offered.
bAD-CP = acid detergent crude protein (bound protein); NDF = neutral detergent fiber; ADF = acid detergent fiber; Lig = sulphuric acid lignin.

one North American zoo is compared with literature values of natural foods, and 12 temperate browses fed to these primates in captivity, in Table 5

In general, zoo diets contained much less fiber and higher protein levels than foods consumed by these primates in nature. Temperate browse plants (n = 11 spp.; leaves plus twigs) sampled in New York in summer and autumn contained higher fiber, and lower protein levels, than diets fed in this survey, and may approximate the nutrient content of food items selected by free-ranging colobines. Fast-growing roses grown in greenhouses, fed primarily in Europe, contained substantially less fiber and higher protein concentrations than other browses offered,

TABLE 4. Chemical composition of common browses fed in the Wildlife Conservation Park, Bronx, NY (September 1994 samples)

Family/species %	L:T[a]	Water	Crude protein	AD~CPb	NDF	ADF	Lig	Ash
			----------%of dry matter ----------					
Aceraceae Acer negundo	L	74.8	19.1	1.0	28.5	23.4	5.9	1.8
Box Elder	T	50.4	5.7	1.7	83.0	68.3	22.2	3.4
	29:71	57.4	9.5	1.5	67.4	55.3	17.5	8.9
A. saccharinum	L	70.1	18.4	3.3	50.1	35.6	8.9	9.9
Silver Maple	T	67.8	5.4	1.7	79.2	65.1	22.4	4.6
	44:56	73.9	11.1	2.4	66.4	52.1	16.5	6.9
A. saccharum	L	46.2	14.4	1.6	38.6	24.1	3.5	4.3
Sugar Maple	T	41.5	4.9	1.9	75.3	60.8	19.5	3.0
	48:52	43.8	9.4	1.8	57.8	43.3	11.9	3.6
FagaceaeFagussp.	L	55.0	16.0	3.2	72.8	39.8	14.4	7.0
Beech	T	40.4	3.8	1.9	82.7	68.0	23.9	1.1
	39:61	37.8	8.6	2.4	78.9	57.0	20.2	3.6
Hamamelidaceae Liquidambar sp.	L	82.3	10.6	3.1	39.6	32.5	15.5	6.0
Sweet Gum	T	47.9	2.9	1.6	68.3	57.9	21.6	7.5
	25:75	56.6	4.8	2.0	61.1	51.5	19.9	7.2
MoraceaeMorussp.	L	55.0	19.0	1.1	32.6	21.4	4.1	20.7
Black Mulberry	T	46.8	4.7	1.4	75.9	61.0	17.7	5.2
	43:57	50.4	10.9	1.3	57.2	43.9	11.8	11.9
Salicaceae Populus alba	L	60.6	16.8	4.6	51.8	28.7	12.2	13.6
White poplar	T	50.4	4.6	1.9	68.7	56.5	25.2	7.0
	42:58	49.9	9.7	3.0	61.6	44.8	19.7	9.8
Salix babylonica	L	59.9	19.5	1.5	37.5	24.2	9.2	9.4
Weeping Willow	T	63.3	4.3	2.4	72.7	67.8	20.0	3.5
	48:52	61.7	11.6	2.0	55.9	47.0	14.9	6.3
Salix nigra	L	63.9	18.5	4.4	56.8	34.3	17.0	8.2
Black Willow T		51.6	7.7	2.7	72.3	58.5	24.0	4.2
	26:74	45.8	10.5	1.9	71.8	47.5	17.7	8.7
Ulmaceae Ceitis occidental/s	L	51.8	10.1	1.5	44.5	28.7	8.0	15.6
Hackbeny	T	31.9	5.4	2.0	81.4	54.1	21.1	6.3
	26:74	37.1	6.6	1.9	71.8	47.5	17.7	8.7
Vitaceae Vitis sp.	L	66.0	19.2	14.2	40.7	25.0	22.4	15.4
Grapevine	T	87.1	9.3	2.2	70.3	59.1	14.4	8.9
	59:41	74.7	15.1	9.2	52.9	39.1	19.1	12.7

L = leaf; T= twig; leaf:twig proportions (% wet weight) of whole plant sample as offered.
ADF = acid detergent crude protein (bound protein); NDF = neutral detergent fiber; ADF = acid detergent fiber; Lig = sulphuric acid lignin.

and may not be an appropriate substitute for native foods.

DISCUSSION

Many diets in this survey were very complex and were probably developed through experience, rather than applied research. One hundred and forty-nine different ingredients indicates that there is no agreement as to what foods should be fed to these primates. In European zoos, a greater diversity of foods are offered. Only one-third of responding zoos knew the exact

TABLE 5. Comparison of nutrient levels in zoo diets, native foods eaten, and temperate browses fed to south-east Asian colobines in European and North American zoos.

	Zoo diets[a] (n = 7) mean SD	Native foods[a] (n = 154) (range)	Temperate browse (n = 11) (range)	Rose leaves (n = 1)
Water, %	75.4 ± 2.4	31.7—78.3	37.8 - 80.4	73.9
CP, % DM[c]	15.0 ± 3.0	5.2—21.1[b]	4.8 - 15.1	20.8
NDF, % DM	12.5 ± 4.6	43.7—66.7	44.0 - 78.9	32.3
ADF, % DM	6.3 ± 2.8	26.1—52.3[b]	34.3 - 61.0	17.7
Lig, % DM	1.0 ± 1.1	14.5—28.3	8.8 - 20.2	3.9

[a]Modified from Nijboer et al. (unpublished).
[b]Additional data from Kay and Davies [1994].
CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; Lig = H2S04 lignin; DM = dry matter.

quantities fed or consumed; all zoos fed some quantity of browse, but responded without any quantification or estimates of intake levels. More detailed intake studies are needed on southeast Asian colobines, particularly relative to browse consumption.

Comparison of zoo diets to natural food composition can be one method of approaching a nutritionally appropriate diet (see Table 5*)*. Chemical fractions of the native foods are listed as ranges only, because available studies in the literature do not provide feeding rates such that weighted averages for native diets could be calculated. Many temperate browse plants offered (leaf plus twig fractions) contain higher amounts of NDF (32.3 - 78.9%), ADF (17.7 - 61.0%), and lignin (3.9 - 20.9%) than current zoo diets. Primates in zoos consume both leaves and twigs of browse plants (leaf consumption alone was not reported), including the bark (personal observation); however, the proportions of actual leaf:twig intake have not been documented extensively in zoo collections, making nutrient intake difficult (or impossible) to accurately calculate. It is possible that animals in zoos are eating twig fractions to increase the fiber content of the overall diet; however, in browses for which only bark is stripped, primates are eating the more nutritious and relatively less fibrous part of the twig. In these cases, bark should be analyzed separately.

Quantification of intake in zoo collections (amounts as well as plant parts), along with estimates of consumption in the wild, are needed for more detailed assessment.

Nonetheless, important potential nutrient contributions to diets of zoo colobines are apparent from temperate browse plants cultivated for use in captive feeding programs. Leaves provided 10 - 20% crude protein, regardless of season sampled, while twigs contained about half that level. Browse fiber levels (NDF and ADF) increased in September in both leaves and twigs, but lignin did not. Thus, fiber present could be potentially more fermentable later in the growing season, but remains to be tested. Of the 11 species evaluated, beech contained notably higher fiber concentrations than other browses. Based strictly on chemical composition, this species (and possibly hackberry) would appear least nutritious. Grape vine (not leaves) might also be considered to be of lower nutritive value for southeast Asian colobines, due to the potential for

fibrous intestinal blockage [Calle et al., 1994]. The mineral content of two, of the species examined - mulberry and white poplar - should be investigated in detail, due to the high ash content of leaves in this report.

Inclusion of these (or other) browses may be useful in duplicating the natural diet composition of Asian colobines, particularly fiber and protein levels. In contrast, rose browse, which is widely utilized in European facilities, is often grown rapidly under artificial (greenhouse) conditions, and thus is not exposed to the environment of other browses in this report. Clearly the composition of rose browse is more different, compared with native foods or the other temperate browses described here, and should possibly not be considered the best nutritional substitute to native foods.

More extensive analyses of seasonal variability in browse composition, and the occurrence and physiological effects of secondary plant compounds, are needed. Zoos considered in this survey are not situated in tropical or subtropical areas with fresh browse available year-round; thus, harvesting followed by freezing [Koontz et al., 1988] and/or drying [Walter and Perschke, 1994] is often employed. Additional information would provide a better indication of optimal harvesting periods, and most suitable browse species. In particular, palatability trials correlated with nutritive content of these browses might provide the best insight into feeding management applications.

It must be noted that the very high lignin values indicated here for native foods as well as temperate browses (Table 5*)* include cutin fractions, due to the analytical methods used. Although indigestible (as is lignin), cutin is a wax and has a very different texture than lignin, being soft rather than harsh. Duplication of chemical fractions in captive diets must take into account such factors since they may affect palatability.

Currently, zoo diets do not appear to duplicate the very high fiber levels described in either temperate browses or native foods eaten by these primates. We propose utilizing these data as a baseline for diet development, and suggest feeding trials using locally available browses, and/or that a commercial product (or products) be advanced such that southeast Asian colobine nutritional management may be more standardized across worldwide zoological institutions.

CONCLUSIONS

1. There is currently no standardized diet fed to south-east Asian colobines in captivity.

2. European zoos feed a greater diversity of fruits and vegetables compared with North American facilities, and diets offered by zoos contain less fiber (NDF, ADF, and lignin) and more protein than natural foods eaten by these primates. Browses comprised a variable but important fraction of zoo diets.

3. Leaves plus twigs of elm, maple, poplar, and willow trees and commercially cultivated roses were most frequently reported as browses used in feeding southeast Asian colobines in northern hemisphere zoos.

4. Temperate browse plants cultivated for zoo feeding programs may provide essential nutrients and duplicate chemical constituents (particularly fiber) of natural diet items for colobines. Trees analyzed contained fiber and protein levels within ranges reported for native foods; rose browse, used extensively in European facilities, had less fiber and more protein, and may not be as suitable.

5. The leaf:twig ratio of browses analyzed decreased in September, compared with July samples; consequently, fiber content (NDF and ADF) was higher later in the growing season.

More detailed studies of browse intake and additional information on chemical composition (including potential toxins) would provide a better indication of optimal harvesting periods, and most suitable browse species for zoo feeding programs.

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