Gorilla Nutrition

D. G. Popovich, Ph.D. and E. S. Dierenfeld, Ph.D., C.N.S.

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Literature Review

Gorillas (*Gorilla gorilla*) pose an interesting and challenging dietetic study. Some differences exist among the diets of the three subspecies, probably due to habitat variation; unfortunately, most work has focused on the subspecies not represented in zoos.

Mountain gorillas are primarily folivores (Harcourt & Fossey, 1977; Watts, 1984). Their diets consist primarily of foliage of herbs and vines, with leaves making up 68% of intake, stem 25%, pith 2.5%, epithelium from roots 1.4% and the remaining 4% from bark, roots, flowers and fruit. The western lowland gorilla apparently consumes more fruit (Tutin and Fernandez, 1993; Williamson, 1990; Nishihara, 1992); however, green plant material remains the majority of the diet. Calvert (1985) concluded that, of the plant species consumed by western lowland gorillas (*Gorilla gorilla gorilla*) in Cameroon, 23% of the species were vines, 38% herbs, 24% saplings, and 15% trees. Western lowland gorillas in Gabon consume slightly different proportions of food than do mountain gorillas, with leaves and stems accounting for twice the intake of fruit (Tutin and Fernandez, 1993). Tutin also reports that many fruits consumed overlap with that of common chimpanzees occupying the same range. Gorillas seem to shift their food intake according to seasonal variations and food availability (Tutin and Fernandez, 1993; Nishihara, 1992). Calvert (1985) found no evidence of animal matter being either consumed or found in the feces. The eastern lowland gorilla diet appears to be closer to that of the western lowland gorilla than that of the mountain gorilla, but little literature exists.

Free-ranging gorillas consume a wide variety of plant species, with 50 to 300 species reported (Calvert, 1985; Rogers et al., 1990). However, they are very selective, choosing only certain parts of the vegetation at certain times of the year (Rogers and Williamson, 1987; Williamson et al., 1988, 1990). As an example, only the base and tips of young leaves may be selected, although mature leaves are also eaten (Rogers et al., 1990). *Aframomum* seems to be an important genus to gorillas in all study locations. Even captive gorillas are selective feeders, with particular species and plant parts preferred by individuals and groups (San Diego Zoo, J. Ogden, unpublished data).

Gorillas generally select immature leaves over the mature ones, which usually contain less fiber, more protein, and less secondary components such as tannins (Hladik, 1978; Milton, 1979; Rogers et al., 1990). Shoots, flowers, and fruit are also preferred over mature leaves (Clutton-Brock, 1975; Casmir, 1975). Woody vegetation species are not avoided (Calvert, 1985). Rogers et al. (1990) conducted the most complete chemical analysis of the diet of the western lowland gorilla diet in the Lope Reserve, Gabon. The gorillas in Lope Reserve do not appear to select food based on any anti-nutritional properties (i.e., phenolic compounds), and consume a wide variety of fruit from highly proteinaceious unripe seeds to sugary fruit. They seem to avoid unripe and higher-fat fruit.

Fruits consumed by gorillas are much more fibrous than our traditional idea of cultivated fruits commercially available in the west. Thus, from a nutritive perspective, caution must be used to interpret wild dietary data based on percentages of vegetation and fruit intake. Fruit consumed by the gorilla typically can have the same or higher levels of dietary fiber as leaves (as shown in Table 1; data from Calvert, 1985; Rogers et al., 1990).

Table 1. Range of nutrient composition of food categories consumed by western lowland gorillas in Cameroon and Gabon (adapted from Calvert, 1985; Rogers et al., 1990; values except water on a dry matter basis).

	Water (%)	Crude Protein	Crude Fat	WSC	NDF	ADF
Leaves (n=24)	50.0-88.5	10.6-32.2	0.6-13.5	0.2-8.0	21.3-72.6	16.5-58.0
Shoots (n=5)	85.7-92.4	8.4-13.8	2.1-3.8		63.3-80.4	48.4-54.1
Stems/Bark (n=23)	54.4-94.9	2.6-17.1	0.4-5.7	0.5-31.0	34.7-81.9	34.8-61.8
Fruit (n=18)	34.0-88.9	0.9-13.8	0.2-20.9	13.1-62.4	55.1-82.3	4.8-66.5
Seeds (n=9)	43.1-78.6	4.1-18.4	0.3-12.0	2.3-25.7		43.1-78.6

WSC = water soluble carbohydrate; NDF = neutral detergent fiber; ADF = acid detergent fiber

Native gorilla vegetation has an extremely high fiber content, which cannot be digested in the stomach or small intestine but mat be fermented in the large intestine by gut microbes to produce short chain fatty acids (SCFA), carbon dioxide, and methane. Gorillas have an enlarged hindgut for harboring such bacteria (Stevens, 1988), and SCFAs are likely used by gorillas and even humans for energy production and colonic health. However, no metabolic studies have been conducted.

The Diet Survey

A total of 37 zoos responded to food frequency questionnaires. The diet varied considerably from zoo to zoo, with over 115 distinctive food items fed regularly, occasionally, seasonally, or as a treat. Ten of the zoos (27%) offered between 11 and 15 different food items daily; 10 (27%) offered between 16 to 20 items daily; 3 zoos (8%) offered more than 20 different items daily. The remaining zoos offered 10 or less items daily.

Overall, the zoos fed an average of three meals per day, which was usually scattered in the exhibit. The majority of zoos (n=27, 73%) use commercially prepared diets in addition to produce, while 10 zoos (27%) prepared their own staple diet. Six zoos fed meat on a regular or occasional basis.

Twenty different vegetables were fed on a regular basis. The majority of zoos fed carrots (79% of the zoos), sweet potatoes/yams (71%), green beans (38%), onions (29%), white potatoes (29%), corn on the cob (12.5%), and leeks (12.5%). Twenty-three different fruits were fed on a regular basis with the majority of zoos feeding apples (96%), bananas (89%), oranges (85%), grapes (48%), fruit juices (22%), raisins (19%), and tomatoes (11%). Twenty-five different types of greens/browse were fed, including celery (89%), lettuce (71%), spinach (54%), kale (46%), broccoli (43%), cabbage (25%), willow browse (21%), parsley (14%), escarole (14%), and cauliflower (14%). Eighteen different types of cereals/grains were fed, with a majority of zoos feeding bread (86%), sunflower seed (79%), peanuts (57%), mixed nuts (29%), popcorn (29%), and white rice (14%).

Nineteen different commercial products were fed, with the primary staple comprising Mazuri Old World Primate (fed by 32% of the zoos), Purina (Lab Diet) High Protein (20%), Marion Leaf Eater Biscuit (20%), Spectrum Primate Pro-Plus (16%), HMS High Fiber Primate (16%), Mazuri Leaf Eater (12%), Zu/Preem Primate Dry (8%), and Purina Lab Diet (8%).

Animal products including meat, eggs, milk, and yogurt were fed to gorillas with frequencies as shown in Table 2.

Table 2. Frequency of Animal Products Fed to Gorillas in North American Zoos (surveyed 1995).

Animal Products	# zoos feeding	Regularly (daily)	Occasionally (1-2 times/wk)	Treat (1-2 times/mo)
Meat	6	1	5	0
Eggs	19	3	6	10
Milk	18	10	3	3
Yogurt	21	4	9	8

Macronutrient profile was developed using a modified computerized USDA database with modification for dietary fiber values and included limited preliminary analysis of some browse (Wildlife Conservation Society) and commercial primate mixtures.

Evaluation of Adequacy

Information from the surveys described diets offered, not consumed, by captive gorillas. Adequate detail for assessing nutrient composition of offered diets was available from 18 adult male, 18 adult female, and 14 juvenile diets. The calorie content of food items was calculated based on metabolizable energy (ME) values for humans (Watt and Merrill, 1975) or, in the case of commercial products, from energy estimations provided by manufacturers. Metabolizability of browses was estimated at 50%. Metabolic studies have not been published for gorillas; values for produce items based on humans may underestimate actual caloric contributions for gorillas due to the increased complexity of the gorilla hindgut. Nonetheless, values provide some interesting speculation on diet composition.

Caloric needs of the gorilla can be estimated from the general energetic equation of Kleiber (1947), where basal metabolic rate (BMR) = 70 kcal X (body mass in kg) $^{0.75}$. Adult maintenance energy would then be estimated as 2 X BMR, and growing animals 3 X BMR. Thus for captive gorillas ranging from approximately 20 kg (juvenile) to 220 kg (adult male), energy needs would theoretically be met with 1990 to 8000 kcal/day. Body mass estimates used throughout this report include 150 kg for an adult male, 100 kg for an adult female, and 50 kg for a growing juvenile gorilla. Although ranges were wide (± 50%), diets offered to zoo animals in this survey appeared to provide adequate energy (Table 3); some surveys noted obese animals.

Table 3. Calculated metabolizable energy content of diets offered to gorillas in North America, compared with theoretical requirements based on metabolic body size.

	Body	# Diets	Amount	Amount	Mean kcal in	Estimated

	Mass (kg)	Evaluated	offered kg (as-fed)	offered kg (dry)	diet offered	kcal reqt.
Adult male	150	17*	7.05	1.98	7100	6000 (2 X BMR)
Adult female	100	18	4.17	1.24	5600	4430 (2 X BMR)
Juvenile	50	14	3.25	0.86	4420	3930 (3 X BMR)

* Outlier excluded from analysis

Dietary amounts offered to gorillas in the survey ranged from 4.7% of body mass (adults; as-fed sis) to 6.5% for juveniles. On a dry matter basis, amounts ranged from 1.0 (adult males) to 1.3 % (adult females) of body mass. Herbivorous mammals typically consume 1 to 2.5% of dry matter on a daily basis. On an as-fed basis, diets offered comprised the following ingredient categories (Table 4):

Table 4. Dietary ingredients (by category) offered to gorillas in North American zoos, expressed as percentages on an as-fed basis (results of survey, 1995).

	% Fruit	% Vegetables	% Greens / Browse	% Commercial Products	% Cereals, Nuts & Seeds	% Animal
Adult male	27.9	26.9	24.6	14.7	3.1	2.6
Adult female	26.6	27.6	27.6	11.0	3.6	3.0
Juvenile	27.3	25.2	25.3	11.0	3.0	8.0

Young growing animals were offered more animal-based foods (eggs, milk, yogurt, meat) than adults, but mean overall percentages of food groups did not vary dramatically among age/sex groups. Diets, however, varied considerably depending upon the facility surveyed. Percent fruit in the diet varied from 10 (all groups) to 51% (adult males) of food offered. Vegetables (including tubers, roots, legumes, and stalks) ranged from 6 (adult males and juveniles) to 50% (adult males) of diet, whereas dark green leafy vegetables and browse ranged from 0 (adults) to as much as 60% (males) of diet. Commercial products comprised as little as 2% of diet as offered, up to a maximum of 55%; seeds, nuts and cereal grains equaled 0 to 17% of total diets as-fed. Animal based products composed up to 33% of total diet offered to some juveniles. Browses fed to gorillas in this survey are identified in Table 5.

Table 5. List of browses offered to and consumed by gorillas in North American zoos (surveyed 1995).

Scientific Name	Common Name	Scientific Name	Common Name
Acer spp.	Maple, Pal frond	Lonicera sp.	Honeysuckle, White ash
Salix spp.	Willow	Prunus spp.	Kaffir plum, Passion vine
Liquidambar spp.	Sweetgum	Rosa sp.	Roses
Fiscus spp.	Ficus	Helianthus annuus	Sunflowers, Sweet potato vine
Celtis spp.	Hackberry	Hemerocallis sp.	Day lilies, Herbs
Musa spp.	Banana, Daikon	Vitis vinifera	Grape
Diosporos spp.	Persimmon	Eugenia spp.	Eugenia

Acacia spp.	Acacia	Hibiscus spp.	Hibiscus
Malus spp.	Apple	Morus spp.	Mulberry
Pitosporum spp.	Pitosporum	Brassica spp.	Rape
Myrica cerifera	Wax myrtle, Malviscus	Sorghum vulgare	Sorghum
Phaeoameria sp.	Ginger	Poa spp.	Pea plants, Bean plants
Sambucus spp.	Elderberry	Zea mays	Corn stalks
Ulmus sp.	Elm	Delonix sp.	Royal poinceinna
Ligustrum sp.	Privet	?? numerous	Bamboo
Quercus sp.	Oak	?? numerous	Mesquite

Composition of diets offered was calculated using a commercial software program (Animal Nutritionist, N-Squared Computing, Silverton, OR) based on amounts and ingredients in the survey. Macronutrient profile was developed using a computerized USDA database with modifications for dietary fiber values, preliminary analyses of browses (Wildlife Conservation Society), and commercial primate mixtures. Intake was not measured; nutrient profile estimates in Table 6 are based on diets provided.

Table 6. Mean macronutrient profile in diets offered to gorillas in North American zoos.

	Water %	Crude Protein	Crude Fat	NDF	Ca	P	Protein	Fat	Carbohydrate
		% of dry matter					% of energy provided by		
Male	71.9	16.4	5.8	14.1	0.69	0.43	16	13	71
Female	73.6	15.7	6.3	14.7	0.67	0.40	15	14	71
Juvenile	73.4	16.6	7.0	13.7	0.63	0.41	16	15	68

Zoo diets contained one-half to one-fifth the fiber level analyzed in native foods eaten by lowland gorillas, and about twice the fat content. Digestion data were not available for zoo gorillas, but passage has been estimated at 36 to 38 hours (Milton, 1984). Diets consumed by free-ranging animals were estimated to be no more than 50% digestible (weighed mean, individual plants ranged from 4.6 to 81.3% digestibility using a cellulose / pepsin in vitro digestion technique; Calvert, 1985). Data reported here suggested a much higher diet digestibility, and relatively unchallenged fiber fermentation capabilities.

Health Risks Linked to Diet

Captive gorillas can be compared with westernized humans; they are both displaced from their natural diet and lifestyle and are thus at risk for specific diseases. Gorillas are vegetarians, consuming no animal products. This may be essential for health, as elevated cholesterol levels (281 to 311 mg/dL, McGuire et al., 1989) have been reported in zoo gorillas, leading to premature cardiovascular disease. Human subjects with the same values would be considered hypercholesterolemic and at risk for heart disease. Cardiac arrest associated with a poor diet and lack of exercise has been cited as a significant cause of adult gorilla deaths in zoos (Cousins, 1979).

Gorillas on relatively low fiber diets may also be prone to ulcerative colitis, an intestinal disorder (Scott and Kemer, 1975). These intestinal disorders may be prevented by a fiber-derived short chain fatty acid, butyrate, which is a preferred energy substrate for colonic mucosal cells and has been shown to have antineoplastic properties (Roediger, 1982; Weaver et al., 1988). Vegetables, and to

some extent, fruits, have many components that may play a major role in the prevention of diseases including dietary fiber, folic acidm antioxidant vitamins (vitamin C, vitamin E, carotenoids), flavenoids, and vegetable protein. In terms of coronary heart disease risk reduction, vegetarian diets and high fiber have been shown to be protective in various human studies. High fiber diets appear to decrease the risk of intestinal disorders such as colon cancer and vegetables are a rich source of folate, which may also play a role in reducing risk of cancer and cardiovascular disease. Components of vegetables and fruits are not mutually exclusive; to achieve full benefit from these foods, whole foods must be consumed rather then simply nutrient supplements.

Recommendation for Feeding

Clean potable water should be available at all times. Because gorillas are selective vegetarians in nature, whenever possible whole vegetation or produce items including the stalk and peels should be fed to at least mimic wild conditions. There appears to be little need to feed gorillas any type of animal products including eggs (except, of course, nursing young). Gorillas do not consume animal products to any extent in the wild. Although they have been reported to consume a variety of insects, the overall nutritional impact appears quite limited and extremely difficult to quantify. Human dietary trials have demonstrated that primates can survive and thrive eating diets composed solely of vegetables, fruits, and nuts (Jenkins et al., 1995).

Commercial products are a readily available source of nutrition for these animals; however, no systematic comparative evaluation of these products has been conducted. Over 19 different commercial products are fed to gorillas in North American zoos. Selection of a commercial feed should be based on high vegetable fiber content (>25% ADF based on native diet) and low fat (<8% total fat, virtually no saturated fat). Using natural food composition as a basic guide, no animal or dairy products should be in the formulation of diets provided to gorillas. Until gorilla nutrient requirement data are established, vitamin and mineral requirements of humans – perhaps doubled due to the size of gorilla – should be used as a guideline for diet formulation at all stages of development (see Table 7). While units for human requirements (amounts) differ from those typically expressed for animal nutrients (concentrations), diets and ingredients offered in amounts and proportions suggested from this survey would meet all the human requirements listed in Table 7 (two- to ten-fold). It may be suitable to feed a higher protein concentration diet to young animals; however, in general diets selected by gorillas in nature are not particularly high in protein.

Insert Table 7 here.

From the limited assays available in the literature, cultivated fruits are generally lower in protein and fiber, and higher in moisture and simple sugars than native fruits eaten by gorillas. Vegetable produce would, in general, appear to contain a more suitable nutrient composition than fruits for lowland gorillas, and provide an economic alternative to fruit. While current diets contain fruit and vegetable produce equaling about 50% of total food offered, it is suggested that the proportion of fruit in diets be reduced, and vegetable produce increased. A general guideline for feeding adult gorillas might be to aim for a total daily quantity not to exceed 4.5% of body mass (as-fed basis) or approximately 1.25% of body mass (dry matter basis) comprising (on an as-fed basis) 10% fruits (3-4 types), 40% vegetables (4-5 types), 25% dark green leafy produce and/or palatable browses (aim for 10% green

produce, 15% browse), 23% dry high-fiber primate biscuits, and up to 2% of the total quantity as whole, cracked, or rolled grains, nuts or seeds (the latter category fed as occupational food).

Diets offered to juvenile gorillas would follow the same general category proportions (50% produce – 15% fruit, 35% vegetable for increased palatability when introducing solid foods), 25% green leafy produce and/or browse, approximately 18% high-fiber primate biscuit, 2% cereal grains, nuts or seeds, and up to 5% animal-based products including milk. Total amounts offered to young gorillas can be increased to approximately 6.5% of total body mass (as-fed basis). In all cases, green plant materials and/or high-fiber biscuits can be fed in relative excess, but other items should be limit-fed. A minimum of about 20% of the diet should comprise nutritionally balanced primate diet(s), with possible substitutions/variety provided throughout the week in other food categories.

While browse may supply adequate levels of some of these nutrients, availability is seasonal in many locations. Nonetheless, browse should be considered an essential component of captive gorilla diets, both physiologically and psychologically. More data and improved dietary recording of browse must be undertaken by each zoo. With suitable browse composition data, it may be possible to reduce alliance on other dietary components through nutrient substitutions with browse, at least seasonally.

Future research needs

Much information needs to be collected in a systematic manner in order to truly evaluate diets for captive gorillas, and should receive priority status. Detailed intake, digestion, and passage trials would provide baseline digestive physiology data with which to supplement current speculations using humans as a model. Trials designed to compare digestibility and palatability of various commercial primate biscuits would assist in making finite product recommendations. Finally, intake data, nutrient composition and palatability of various browses consumed by gorillas in zoos is essential to develop and provide optimal diets for this species in captivity.

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