American Journal of Primatology 75:860–871 (2013)

RESEARCH ARTICLE

Foods Eaten by the Sichuan Snub-Nosed Monkey (*Rhinopithecus roxellana*) in Shennongjia National Nature Reserve, China, in Relation to Nutritional Chemistry

XUECONG LIU[1], CRAIG B. STANFORD[2], JINGYUAN YANG[3], HUI YAO[3], AND YIMING LI[4]*
[1]*Department of Biological Sciences, Jane Goodall Research Center, University of Southern California, Los Angeles, California*
[2]*Departments of Biological Sciences and Anthropology, Jane Goodall Research Center, University of Southern California, Los Angeles, California*
[3]*Shennongjia National Nature Reserve, Shennongjia, Hubei Province, P. R. China*
[4]*Institute of Zoology of the Chinese Academy of Sciences, Beijing, P. R. China*

The diet of *Rhinopithecus roxellana* is characterized by lichens, which are available year-round and an uncommon food source for nonhuman primates, supplemented by seasonal plant foods. We present the first study of foods eaten by *R. roxellana* in relation to nutritional chemistry in Shennongjia National Nature Reserve, Hubei Province, China. We analyzed the nutrients (crude protein, crude fat, and water soluble carbohydrate [WSC]) and feeding deterrents (crude fiber, condensed tannin [CT], and total phenolic [TP]) of 111 parts from 53 plant species and of 6 lichen species. Results showed that lichens were a good choice for *R. roxellana* living in habitats with limited and seasonally available plant foods. They contained higher concentrations of WSC than foliage, fat concentrations equivalent to those in plant parts (except fruits/seeds), and lower concentrations of fiber than mature leaves, flowers, and fruits. Although lichens were lower in protein than plant parts (except fruits), the monkeys could likely meet their protein requirement by eating seasonal plant foods rich in protein, including foliage, flowers, buds, and seeds. The monkeys were not observed to select foliage higher in protein, but appeared to select mature leaves higher in WSC and lower in fiber. Fruits were a good source of WSC and fat, and seeds were a good source of fat. Neither CT nor TP content showed negative effects on the selection of mature leaves or lichens. Am. J. Primatol. 75:860–871, 2013.

Key words: ***Rhinopithecus roxellana*; diet; lichen; nutritional chemistry**

INTRODUCTION

Food selection by nonhuman primates is influenced by a range of ecological, morphological, and physiological factors, including specializations of the digestive system [Chivers, 1994; Milton, 1998] and food quality [Mowry et al., 1996; Remis et al., 2001], as well as feeding competition [Stanford & Nkurunungi, 2003], body size [Milton, 1984; Nakagawa, 2003], and food availability [Dasilva, 1994; Dela, 2007].

Colobines have morphological adaptations in the digestive system, among which are their enlarged and multi-chambered stomachs containing microorganisms to ferment ingested foods [Chivers, 1994]. Microbial fermentation in the forestomach helps colobines break down the indigestible building blocks (including cellulose) of plant cell walls; therefore, colobines are generally more folivorous than most other primates [Sayers & Norconk, 2008; Stanford, 1991; Struhasker & Leland, 1987]. Evidence suggests that the fermentative digestion has the capability to detoxify or inactivate some secondary compounds that may reduce digestibility or be toxic [Gartlan et al., 1980; Hagerman & Butler, 1991].

Food choice in relation to nutritional chemistry has been studied extensively in colobines [Baranga, 1983; Dasilva, 1994; Fashing et al., 2007; Kool, 1992; Mowry et al., 1996; Oates et al., 1977]. Most studies have shown that foliage eaten by colobines contains higher concentrations of protein, lower concentrations of fiber, or higher ratios of protein to fiber than

---

Contract grant sponsor: National Basic Research Program of China; contract grant number: 2007CB411600; contract grant sponsor: National Nature Science Foundation of China; contract grant number: 30670354; contract grant sponsor: L.S.B. Leakey Foundation; contract grant sponsor: Primate Conservation, Inc.; contract grant sponsor: Integrative and Evolutionary Biology Summer Interdisciplinary Grant of the University of Southern California.

*Correspondence to: Yiming Li, Key Laboratory of Animal Ecology and Conservation Biology, Institute of Zoology, Chinese Academy of Sciences, 1 Beichen West Road, Chaoyang District, Beijing 100101, P.R. China. E-mail: liym@ioz.ac.cn

Received 19 August 2012; revised 21 February 2013; revision accepted 24 February 2013

DOI: 10.1002/ajp.22149

foliage that is not eaten [Fashing et al., 2007; Wasserman & Chapman, 2003; Yeager et al., 1997]. Protein concentrations decrease and fiber concentrations increase with leaf maturity; therefore, young leaves are usually preferred to mature leaves [Baranga, 1983; Mowry et al., 1996]. Whether plant secondary compounds affect colobine food choice is controversial, however. Some species, for example, were found to eat foods with low tannin concentrations [*Colobus satanas*: McKey et al., 1981; *Procolobus verus*: Oates, 1988], while no correlation was found between tannin (or phenol) concentrations and food choice in several other species [*Piliocolobus rufomitratus*: Mowry et al., 1996; *Piliocolobus tephrosceles*: Chapman & Chapman, 2002; *Presbytis rubicunda*: Davies et al., 1988]; this confusion may be in relation to the methods used [Rautio et al., 2007; Rothman et al., 2009].

The Sichuan snub-nosed monkey (*Rhinopithecus roxellana*) is a China-endemic endangered colobine species. It lives in temperate forests at the elevations of 1,000–4,100 m in the isolated mountainous areas on the eastern edge of the Qinghai-Tibet Plateau [Kirkpatrick & Grueter, 2010; Li et al., 2002a; Ren et al., 1998]. Its diet is diverse and strongly seasonal; flowers, young leaves, mature leaves, fruits, seeds, and buds become available and become main dietary components subsequently [Guo et al., 2007; Li, 2006; Li et al., 2010]. Lichens, an uncommon food source for nonhuman primates and other mammals, compose an important part of its diet, especially in winters with limited availability of plant foods [Guo et al., 2007; Li, 2006].

This article presents the results of the first systematic study of foods choice in relation to nutritional chemistry in a group of *R. roxellana* in Shennongjia National Nature Reserve, Hubei Province, China. We hypothesized that foods eaten by *R. roxellana* were higher in nutrients and lower in feeding deterrents than those uneaten. The nutritional basis of food choice is of great importance to understand its other ecological aspects, and to apply conservation and management strategies.

METHODS

Study Site

This study was conducted in the Qianjiaping area (about 60 km^2) of Shennongjia National Nature Reserve (110°03′–110°34′ E, 31°22′–31°37′ N), Hubei Province, China. This area has a rugged topography with an elevational range of 1,500–2,663 m. The climate is highly seasonal. There is a conservation station at the elevation of 1,700 m, where the monthly mean temperature was highest in July (16.3°C) and lowest in January (−5.5°C) during the study period [Liu et al., unpublished data]. Snowfalls lasted from early November to middle March. The annual rainfall was approximately 1,800 mm, with the rainy season between July and September. The vegetation is characterized by deciduous broadleaf and evergreen conifer mixed forest. There were 75 woody plant species (evergreen: seven species) and 12 arboreal lichen species (four species of fruticose: branched and beard-like; eight species of foliose: leaf-shaped with lobes, the whole body tightly attached to the substrate) in the forest [Liu et al., unpublished data].

Study Group

The study group had been semi-habituated and studied periodically since 1999 [Li, 2006, 2007; Li et al., 2002b]. The monkeys sometimes (often in summer) ranged to the area of two other counties adjacent to the study site. Group size was counted eight times during the study period, when the monkeys crossed open areas or rivers, or during winters when the leaves of deciduous plants fell. On average, the group contained 236 ± SD 38 individuals (N = 8), including 106 ± SD 12 adult males, 77 ± SD 18 adult females, 35 ± SD 10 juveniles, and 18 ± SD five infants [age sex class definition: Li, 2007].

Data Collection

We followed the group from August 2006 to July 2008 (except December 2006–February 2007 and February 2008) to collect behavioral data via instantaneous scans at 30-min intervals with the naked eyes or with a binocular (27–151 scans on 6–28 days per month; 1,489 scans on 317 days in total). We could approach the group within 20–30 m. For each visible individual (excluding infants) in each scan, the behavior was determined and recorded in 10 sec. If the monkey was eating (defined as plucking or manipulating food items by hands or month, or chewing food items), food species and food part were noted. If the animal was eating lichens, food part was assumed as the whole body, and lichen form (i.e., fruticose or foliose) was also recorded. The proportions of eating records on food species or parts represented dietary composition.

Samples of plant parts (i.e., mature leaves, young leaves, flowers, buds, bark, fruits, and seeds) and lichens were collected opportunistically over the study period from the home range of the study group. Samples were taken from several individuals of a given species to represent its spatial distribution. Samples were weighed fresh, dried to constant weights at 65–70°C in an electric oven (a potential issue because overheating may alter some components; a temperature less than 60°C has been recommended [Rothman et al., 2012]), and then packaged in airtight bags in the field. Water content was measured as (fresh weight–dry weight)/(fresh weight). The dried samples were taken to laboratories for the analysis of nutrients (crude protein, CP; crude fat, CFA; water soluble carbohydrate, WSC) and feeding deterrents (crude fiber, CF; condensed tannin, CT; total phenolic, TP). All samples were ground using a 1-mm mill and dried again to constant weights to remove atmospheric moisture before analysis. CP was determined using the standard macro-Kjeldahl method (CP = Nitrogen × 6.25) [No. 7.015 in AOAC, 1984]. CFA was determined via ether extraction using the Tecator Soxtec System HT 1034 Extraction Unit [Hanson et al., 2006]. WSC was measured with a standard of sucrose using the method of Dubois et al. [1956] and Rothman et al. [2006]. CF, containing cellulose, hemicellulose, and lignin, was measured by the standard method [No. 7.060 in AOAC, 1984]. Samples were extracted with 50% methanol to determine TP with Folin-Denis technique [Mowry et al., 1996]. Samples were extracted with 70% acetone to measure CT with butanol–HCL technique [Rothman et al., 2006]. The contents of CP, CFA, WSC, and CF were expressed as proportions of dry matter. For CT and TP, instead of actual concentrations, we reported the absorbance at five levels: I (<0.1), II (≥ 0.1, <0.5), III (≥ 0.5, <1.0), IV (≥ 1.0, <2.0), and V (≥ 2.0); assuming a higher level indicated more CT or TP present [Rothman et al., 2006, 2009].

The research protocols were reviewed and approved by the Animal Care Committee of the Department of Forestry of Hubei Province, China. The observations confirmed to the regulatory requirements of Shennongjia National Nature Reserve, China. This research adhered to the American Society of Primatologists principles for the ethical treatment of primates.

Data Analysis

We used Kruskal-Wallis tests to see whether there were differences in each component among plant parts/lichens, and whether there were differences in the ratio of CP to CF among mature/young leaves and lichens. If a test was significant, we conducted pairwise comparisons using Steel-Dwass tests. We then compared each component between food and non-food plant parts/lichens and between food plant parts and food lichens using Mann-Whitney U-tests. Similarly, the comparison of the ratio of CP to CF was made only for food and non-food mature/young leaves, and lichens. For CT and TP, the levels of absorbance were used in all statistical analyses. The variables with sample sizes of less than three were excluded in statistical analyses. Steel-Dwass tests were performed in R 2.14.2, and other tests were performed in SPSS 17.0. We reported results with a significance level of 0.05, as well as a marginal significance level of 0.10 because of small sample sizes.

RESULTS

Diet

Fruticose lichens were the most eaten food, accounting for 38.4% of the overall diet, while no foliose lichen was observed to be eaten (Tables I and II). In addition to fruticose lichens, the monkeys ate various parts from at least 15 plant species. Seeds (only of *Pinus armandii*) occupied 20.8% of the overall diet, young leaves 13.5%, fruits 9.5%, mature leaves (including ground herbs) 8.9%, and buds 5.8%. Flowers, bark, and insects accounted for very small proportions ($<2.0\%$ in sum) of the overall diet.

The diet showed clear seasonality (Table II). Flowers were mainly eaten from March to April, young leaves from April to July, mature leaves from May to September, fruits from June to October, seeds from September to March, and buds from December to April. Fruticose lichens were eaten through the year, ranging from 24.0% in October to 48.0% in April of the monthly diet.

Nutritional Chemistry

We analyzed the chemical components of 111 parts from 53 woody plant species and of 6 lichen species, among which 32 parts from 14 plant species and 3 lichen species were observed to be eaten during the study period (see Appendix I). The contents of CP, CFA, WSC, and CF were summarized by plant part and lichen (Fig. 1). For CT and TP contents, the numbers of plant/lichen species were counted by plant part/lichen and absorbance level (Table III).

Among Plant Parts and Lichens

Crude Protein

CP concentrations differed among plant parts and lichens ($\chi^2 = 34.56$, df = 5, $P < 0.001$). Flowers and buds contained more CP than mature leaves and young leaves, which further contained more CP than fruits and lichens, respectively (Table IV).

Crude Fat

CFA concentrations did not differ among plant parts and lichens ($\chi^2 = 8.34$, df = 5, $P = 0.14$).

Water Soluble Carbohydrate

WSC concentrations differed among plant parts and lichens ($\chi^2 = 8.34$, df = 2, $P < 0.05$). Lichens contained more WSC than mature leaves and young leaves, respectively, and mature leaves contained more WSC than young leaves (Table IV).

Crude Fiber

CF concentrations differed among plant parts and lichens ($\chi^2 = 17.62$, df = 5, $P < 0.05$). Lichens contained less CF than mature leaves, flowers, and fruits, respectively (Table IV).

TABLE I. Food Species and Their Proportions in the Overall Diet of *Rhinopithecus roxellana* in Shennongjia, China (August 2006 to July 2008)

Food species	Flowers	Young leaves	Mature leaves	Fruits	Seeds	Buds	Bark	Total
Actinidia chinensis		0.1						0.1
Aralia chinensis		1.6	0.3			0.2		2.1
Cerasus szechuanica	0.2	1.0		1.8		0.1		3.1
Cornus controversa				0.5				0.5
Crataegus hupehensis		1.5	0.8	0.1				2.4
Decaisnea fragesii		0.3	0.3				0.1	0.7
Euonymus alatus		1.6	0.5				0.1	2.2
Lindera obtusiloba	0.5	4.0	1.3	1.5		4.9		12.2
Litsea ichangensis	0.4	0.9		1.5		0.5		3.3
Malus hupehensis	0.1	0.3		0.1				0.5
Morus alba		1.2	0.2					1.4
P. armandii					20.8			20.8
Salix wallichiana	0.1	0.5				0.1		0.7
Schisandra glaucescens		0.2	0.6	0.4				1.2
Sorbus hupehensis		0.3		3.6				4.9
Fruticose lichens								38.4
Ground herbs			4.9					4.9
Insects								0.4
Unknown								1.4
Total	1.3	13.5	8.9	9.5	20.8	5.8	0.2	

Condensed Tannin

There were differences in the absorbance level in the assay of CT among plant parts and lichens ($\chi^2 = 16.44$, df $= 4$, $P < 0.05$). The absorbance level in lichens was lower than that in mature leaves and flowers, respectively (Table IV).

Total Phenolic

No difference in the absorbance level in the assay of TP was detected among plant parts and lichens ($\chi^2 = 7.01$, df $= 4$, $P = 0.14$).

Protein / Fiber Ratio

The ratio of CP/CF differed among mature and young leaves, and lichens ($\chi^2 = 5.85$, df $= 2$, $P = 0.05$). Lichens had a lower ratio of CP/CF than young leaves (Table IV).

Between Food and Non-Food Plant Parts/lichens

Food mature leaves contained more WSC and less CF than non-food mature leaves (Table V). Food lichens (i.e., fruticose) contained less CP than non-food lichens (i.e., foliose).

Between Food Plant Parts and Food Lichens

Food lichens contained less CP than any food plant part except food fruits, and less CF than any food plant part except food young leaves (Table V). Food lichens

TABLE II. Monthly Diet Composition of *Rhinopithecus roxellana* in Shennongjia, China (August 2006 to July 2008)

	Flowers	Young leaves	Mature leaves	Fruits	Seeds	Buds	Bark	Fruticose lichens	Insects	Unknown
Jan					26.7	29.1	1.2	43.0		
Mar	13.2		1.9		5.7	32.1		45.3		1.9
Apr	6.4	17.9	2.3	1.7	0.6	20.8		48.0		1.7
May	0.9	48.5	7.0	3.9		0.4		36.7	0.9	1.8
Jun		24.6	14.8	14.8				45.3		0.5
Jul		7.7	38.9	15.0				43.4		1.8
Aug		0.9	20.5	23.1				35.9	2.6	10.3
Sep			9.5	27.2	29.1			32.9	1.3	
Oct			4.0	11.8	69.3			24.0		0.7
Nov				2.0	51.4		0.7	36.1		
Dec					60.0	6.3		33.7		
Overall	1.3	13.5	8.9	9.5	20.8	5.8	0.2	38.4	0.4	1.4

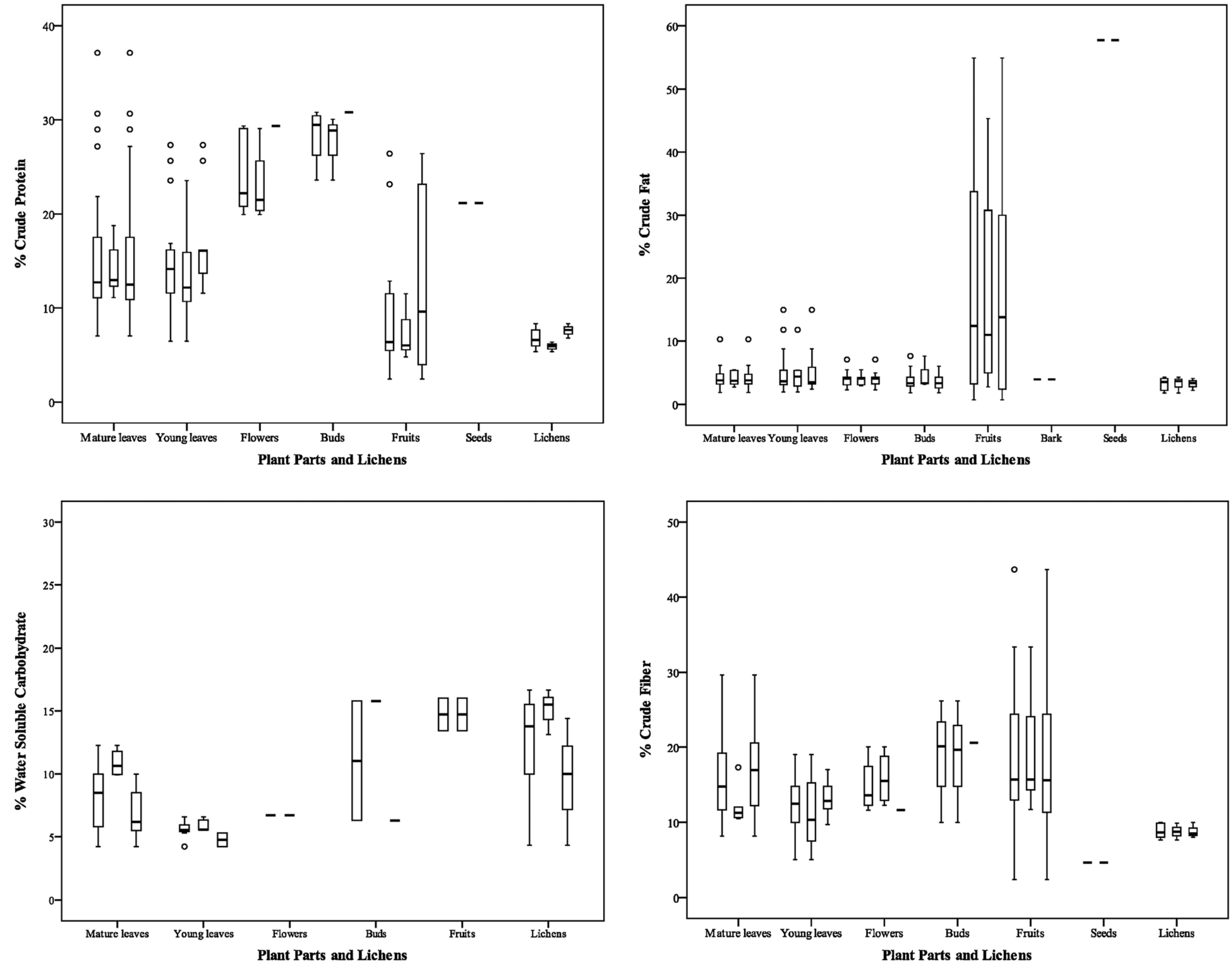

Fig. 1. Boxplots for the concentrations (% dry matter) of crude protein, crude fat, water soluble carbohydrate, and crude fiber measured in plant parts and lichens collected from the habitat of *Rhinopithecus roxellana* in Shennongjia, China (For each component in each item of plant part/lichen, the first box for combined food and non-food, the second for food, and the third for non-food).

TABLE III. The Numbers of Plant/Lichen Species at Different Absorbance Levels in the Assays (Dry Matter Based) of Condensed Tannin and Total Phenolic in the Habitat of *Rhinopithecus roxellana* in Shennongjia, China

		Condensed tannins					Total phenolics				
		I	II	III	IV	V	I	II	III	IV	V
Mature leaves	Food		1	2				1	1	1	
	Non-food		5	7	6	2	1	10	4	3	2
Young leaves	Food		2	2				2	2		
	Non-food		1							1	
Flowers	Food			2				1		1	
	Non-food		1	4	1	1		4	2		1
Buds	Food	1						1			
	Non-food		4	2	1		2	4		1	
Fruits	Food		1							1	
	Non-food				1				1		
Lichens	Food	1	2					3			
	Non-food	1	2					3			

Note: I: <0.1; II: ≥0.1, <0.5; III: ≥0.5, <1.0; IV: ≥1.0, <2.0; V: ≥2.0.

TABLE IV. Pairwise Comparisons for the Concentrations (% Dry Matter) of Chemical Components in Plant Parts and Lichens Collected From the Habitat of *Rhinopithecus roxellana* in Shennongjia, China (Steel-Dwass Tests)

	CP		WSC		CF		CT		CP/CF	
	Statistic	*P*-value	Statistic	*P*-value	Statistic	*P*-value	Statistic	*P*-value	Statistic	*P*-value
ML vs. YL	0.48	0.997	2.11	0.087	2.05	0.315	1.74	0.408	1.81	0.167
ML vs. FL	2.71	0.073			<0.01	>0.999	0.22	0.999		
ML vs. BD	2.72	0.072			1.11	0.879	1.94	0.296		
ML vs. FR	3.03	0.029			0.80	0.967				
YL vs. FL	2.62	0.091			1.21	0.830	1.53	0.540		
YL vs. BD	2.87	0.048			1.93	0.386	0.16	>0.999		
YL vs. FR	2.87	0.048			2.03	0.325				
FL vs. BD	1.47	0.684			0.98	0.924	1.58	0.508		
FL vs. FR	2.61	0.094			0.54	0.994				
BD vs. FR	2.83	0.053			0.34	0.999				
LI vs. ML	3.76	0.002	2.01	0.102	3.32	0.011	3.20	0.012	1.02	0.564
LI vs. YL	3.36	0.010	2.14	0.081	2.17	0.252	1.91	0.309	2.42	0.042
LI vs. FL	2.74	0.068			2.74	0.068	2.86	0.035		
LI vs. BD	2.56	0.101			2.35	0.176	1.58	0.508		
LI vs. FR	0.09	>0.999			2.89	0.044				

Note: The contents of CFA and TP were excluded because overall comparisons were not significant. See Appendix I for abbreviations.

contained more WSC, and had a lower ratio of CP to CF than food mature leaves and food young leaves, respectively. In addition, food lichens contained less CFA than food fruits, and had a lower absorbance level in the assay of CT than food mature leaves.

DISCUSSION

Although colobines are well known for their high intake of foliage and fermentative forestomach [Stanford, 1991; Struhasker & Leland, 1987], recent studies have showed that some colobine species have diverse diets with much seasonal variations [Dela, 2007; Sayers & Norconk, 2008]. In this study, the diet of *R. roxellana* in Shennongjia was diverse with strong seasonality, confirming previous findings for this species at our study site and in the Qinling Mountains [Guo et al., 2007; Li, 2001, 2006; Li et al., 2010]. We believed that the lack of data in February did not affect this seasonal pattern of diet.

TABLE V. Comparisons for the Concentrations (% Dry Matter) of Chemical Components Between Food and Non-Food Plant Parts/Lichens, and Between Food Plant Parts and Food Lichens in the Study of *Rhinopithecus roxellana* in Shennongjia, China (Mann-Whitney U-tests)

	F ML vs. NF ML		F YL vs. NF YL		F FL vs. NF FL		F BD vs. NF BD		F FR vs. NF FR		F LI vs. NF LI	
	U-stat	*P*-value	U-stat	*P*-value	U-stat	*P*-value	U-stat	*P*-value	U-stat	*P*-value	U-stat	*P*-value
CP	62.0	0.775	21.0	0.149					17.0	0.568	0.0	0.050
CFA	125.0	0.915	42.0	0.806	22.0	0.947	10.0	0.398	22.0	0.749	4.0	0.827
WSC	1.0	0.011									1.0	0.127
CF	36.0	0.102	25.0	0.290					19.0	0.775	4.0	0.827
CT	19.5	0.307									4.5	>0.999
TP	24.5	0.588									4.5	>0.999
CP/CF	45.5	0.263	35.0	0.923							2.0	0.275

	F LI vs. F ML		F LI vs. F YL		F LI vs. F FL		F LI vs. F BD		F LI vs. F FR	
	U-stat	*P*-value	U-stat	*P*-value	U-stat	*P*-value	U-stat	*P*-value	U-stat	*P*-value
CP	0.0	0.025	0.0	0.014	0.0	0.034	0.0	0.050	8.0	0.569
CFA	7.0	0.606	8.0	0.309	6.0	0.655	4.0	0.827	3.0	0.087
WSC	0.0	0.025	0.0	0.025						
CF	0.0	0.025	8.0	0.414	0.0	0.034	0.0	0.050	0.0	0.017
CT	1.0	0.099	2.0	0.115						
TP	4.0	0.121	3.0	0.180						
CP/CF	1.0	0.053	2.0	0.041						

Note: F, food; NF, non-food; see Appendix I for other abbreviations.

It is suggested that the diet of *R. roxellana* well reflected the seasonal availability of plant foods [Li, 2006]. Besides seasonal plant foods, *R. roxellana* ate a year-round available item, lichens, occupying 38.4% of the overall diet with a range of 24.0–48.0% in any given month. The Qinling population of *R. roxellana* was also reported to include a large proportion of lichens in the diet (29.0% varying from 1.6% in summer and 62.3% in winter) [Guo et al., 2007]. Lichens played a more important role in the diet of another China-endemic snub-nosed monkey species, *Rhinopithecus bieti*; dietary proportions of lichens varied across populations (Tacheng: 60% with a monthly range of 40–82%; Xiaochangdu: 74.8% with a monthly range of 30.7–98.2%; Wuyapiya: 85.9% with a monthly range of 64.3–97.8%) [Ding & Zhao, 2004; Grueter et al., 2009; Kirkpatrick, 1996; Xiang et al., 2007]. *Colobus angolensis*, a colobine living in the Nyungwe Forest, Rwanda, was observed to eat lichens, but lichens occupied only 5% of its overall diet [Fimbel et al., 2001]. Reindeers (*Rangifer tarandus*) may be the most well-known lichen-eating mammal, and lichens accounted for up to 26% of its diet in winter [Mathlesen et al., 2000]. Overall, however, lichens are an uncommon food source for nonhuman primates and other mammals.

Lichens were previously considered a low-quality or fallback food to supplement limited and seasonally available plant foods [Grueter et al., 2009; Li, 2006]. Indeed, compared to plant parts (except fruits), lichens in the Shennongjia forest could provide much less protein for *R. roxellana*. Food lichens contained even less protein than non-food lichens (means: 5.90% vs. 7.59% of dry matter), which were not eaten probably because their whole bodies attached to plant surface tightly and were difficult to be harvested. Protein concentrations in lichens were much lower than those (15–22% of dry matter) recommended by the National Research Council for feeding nonhuman primates [NRC, 2003]. Less protein in lichens relative to plant parts was also reported in a nutritional study of *R. bieti* at Wuyapiya [Kirkpatrick, 1996]. In reindeer, protein deficiency as a result of lichen eating in winter may lead to a temporary decrease in body weight because the animals need to break down muscles to compensate for the low-protein diet [Reimers & Ringberg, 1983]. For all populations of *R. roxellana* and *R. bieti*; however, lichens were one of main dietary components throughout (or almost) the year, suggesting that these monkeys relied on seasonal plant foods to meet their protein requirement.

Foliage is a major source of protein for nonhuman primates living in forests [Waterman, 1984], and many colobines are found to eat foliage to increase the consumption of protein [Fashing et al., 2007; Fimbel et al., 2001; Mowry et al., 1996; Yeager et al., 1997]. Foliage was eaten by *R. roxellana* in Shennongjia from April to September. Contrary to previous studies, mature leaves (and young leaves) *R. roxellana* ate had equivalent protein concentrations to those uneaten. Even if we lumped mature leaves and young leaves as foliage, there was also no difference in protein concentrations between food and non-food foliage (Mann-Whitney $U = 208.5$, $P = 0.564$). This result, however, was consistent with previous finding for the silver leaf monkey (*Trachypithecus auratus*) at Pangandaran, which did not select foliage higher in protein [Kool, 1992]. At our study site, protein concentrations measured in foliage (means: 15.51% of dry matter in mature leaves, 15.30% of dry matter in young leaves) appeared to meet the minimum protein requirement of the monkeys according to the recommendation of the National Research Council [NRC, 2003], though this may be a conservative estimate [Oftedal, 1991].

Flowers were eaten by *R. roxellana* in Shennongjia from March to April, and buds from December to April. The monkeys could obtain protein from these two parts, which had higher protein concentrations than foliage. Flowers consumed by lemurs [Yamashita, 2008] and orangutans [Hamilton, 1994] also contained high concentrations of protein, while buds were seldom considered a protein source in the diets of nonhuman primates in previous studies. In addition, seeds of *P. armandii* eaten from September to March contained higher protein concentrations (21.15% of dry matter) than foliage on average, although statistical tests could not be made due to the small sample size of seeds (Appendix I, Fig. 1). This was consistent with some studies showing that seeds contained high concentrations of protein, such as *Colobus polykomos* on Tiwai Island [Dasilva, 1994; Sourd & Gautier-Hion, 1986] and *T. auratus* at Pangandaran [Kool, 1992]. Thus, although lichens contained limited protein, *R. roxellana* in Shennongjia could likely obtain enough protein from seasonal plant foods. Oftedal [1991] claimed that protein deficiency was not a problem for most primates, according to his calculation on the protein requirement for the maintenance and reproduction of primate populations.

Fiber is often considered a negative index of leaf quality. Colobines can digest some fiber components, but not others (e.g., lignin) [Waterman & Kool, 1994]. Increasing concentrations of fiber can slow the rate of digestion and reduce the intake of protein [Milton, 1998]. Consistent with previous findings for *C. angolensis* [Fimbel et al., 2001] and *C. polykomos* [Mowry et al., 1996], mature leaves eaten by *R. roxellana* in Shennongjia contained less fiber than those uneaten. If we lumped mature leaves and young leaves as foliage, the difference in the concentrations of fiber between food and non-food foliage was more significant ($U = 132.0$, $P = 0.021$). Mature leaves usually contain more fiber than young leaves [Mowry et al., 1996], but this difference was not found in this study. Many studies have shown that colobines select foliage with higher protein to fiber ratios [Chapman et al., 2004; Fashing et al., 2007; Mowry et al., 1996; Yeager et al., 1997]. But we did not detect any difference in the protein to fiber ratio between food and non-food mature leaves (or young leaves). The protein to fiber ratio also did not differ between food and non-food foliage (lumped mature and young leaves) ($U = 178.0$, $P = 0.205$). Fiber was a better index than the protein to fiber ratio for the selection of foliage by *R. roxellana* in Shennongjia. Interestingly, both this study of *R. roxellana* and Kirkpatrick's [1996] study of *R. bieti* found that lichens contained less fiber compared to plant parts (except young leaves and buds for this study), which was probably one of nutritional aspects making lichens a good potential food source for these monkeys living in habitats with limited availability of plant foods.

Another nutritional aspect for lichens as a food source was that they were rich in WSC relative to mature and young leaves. In the nutritional study of *R. bieti*, lichens were also reported to contain more nonstructural carbohydrate (including WSC and starch) than foliage [Kirkpatrick, 1996]. Mature leaves with higher concentrations of WSC were selected by *R. roxellana* in Shennongjia. Foliage is not often considered a source of WSC. There are some studies, however, showing that mature leaves eaten by folivorous primates contained more WSC than those uneaten [*Gorilla gorilla*: Ganas et al., 2008]. Fruits are known to contain high concentrations of WSC [Conklin-Brittain et al., 1998], while few nutritional studies in colobines have included this assay because fruits are usually not as important as foliage in diets. Consistent with previous findings for some folivorous-frugivorous non-colobine primates [*Alouatta pigra*: Silver et al., 2000; *G. gorilla*: Remis et al., 2001; *Lemur catta*: Yamashita, 2008], fruits contained more WSC (mean: 14.71% of dry matter) than other plant parts, although statistical tests were not conducted due to small sample sizes (Appendix I, Fig. 1).

Fat is an important energy source for primates [NRC, 2003], whereas few nutritional studies in colobines have included this assay because the staple food (i.e., foliage) is usually low in fat. But fruits and seeds, two of main dietary components of *R. roxellana*, are known to be high in fat [Milton, 2008; Waterman & Kool, 1994]. In this study, mean fat concentrations measured in fruits (18.91% of dry matter) and seeds (57.72% of dry matter) were much higher than those in other plant parts and lichens ($<5.10\%$ of dry matter) (statistical insignificance for fruits was probably due to small sample sizes; no statistical analysis for seeds) (Appendix I, Fig. 1).

Consistent with some previous studies in colobines [Chapman & Chapman, 2002; Davies et al., 1988; Mowry et al., 1996], neither CT or TP content showed negative effects on the selection of mature leaves or lichens by *R. roxellana* in Shennongjia. Actually, if we interpreted an absorbance value of <0.10 to be the absence of CT or TP as in Rothman et al. [2006], the prevalence of both compounds was very high among plant parts and lichens (CT was absent only in buds of one plant species and two lichen species; TP was absent only in mature leaves of one plant species and buds of two plant species) (Table III). *R. roxellana* were tolerant to these compounds probably due to the inactivation or detoxification capability of the fermentative forestomach. Alternatively, there is increasing evidence that some plant secondary compounds may be helpful to the health of mammalian herbivores. Tannin, for example, can regulate iron metabolism by absorbing the excessive food iron leading to pathological iron storage diseases [Gaffney et al., 2004; Roy & Mukherjee, 1979]. Phenolic is suggested to be helpful to maintain the microbe population in the gut healthy [Sahoo & Soren, 2012].

The results of this study must be interpreted cautiously due to three major limitations. First, food samples were collected over the study period from the study site, not just when the monkeys were eating the food plants/lichens individuals and items. Previous studies have shown that there may be variations in the nutritional value among tree individuals and time periods [Chapman et al., 2003]. Secondly, CF contains cellulose, hemicellulose, and lignin, whereas the fiber content considered to be negatively correlated with food selection is the fraction of acid detergent fiber, only containing cellulose and lignin [Rothman et al., 2012; Van Soest et al., 1991]. Thirdly, except foliage, sample sizes were relatively small, which prevented us from conducting some statistical analyses and may have introduced bias in some others. Future studies using better techniques and more precise sample collecting methods are needed to obtain a better understanding of nutritional chemistry of foods eaten by *R. roxellana*.

ACKNOWLEDGMENTS

We thank the Administrative Bureau of Shennongjia National Nature Reserve, Hubei, China, for giving us permission to conduct the study. We appreciate professors Chaoxian Zhang and Dehua Wang who opened their laboratories (at the Institute of Plant Protection of the Chinese Academy of Agricultural Sciences and the Institute of Zoology of the Chinese Academy of Sciences, respectively) for us to conduct nutritional analyses. Their team members, Dr. Hongjuan Huang, Dr. Quansheng Liu, and Yan Liu, provided critical support. We also thank the field assistants for helping us collect behavioral data of the monkeys, and collect and process samples of plants and lichens in the field, including Yongfa Li, Yiguo Sun, Tianpeng Huang,

Feng Wu, Guangming Chen, Jinglong Yang, and Jingwen Yang.

REFERENCES

AOAC. 1984. Official methods of analysis. 11th edition. Washington, DC: Association of Official Analytical Chemists.

Baranga D. 1983. Changes in chemical composition of food parts in the diet of colobus monkeys. Ecology 64:668–673.

Chapman CA, Chapman LJ. 2002. Foraging challenges of red colobus monkeys: influence of nutrients and secondary compounds. Comp Biochem Physiol A 133:861–875.

Chapman CA, Chapman LJ, Rode KD, Hauck EM, McDowell LR. 2003. Variation in the nutritional value of primate foods: among trees, time periods, and areas. Int J Primatol 24:317–333.

Chapman CA, Chapman LJ, Naughton-Treves Lawes MJ, McDowell LR. 2004. Predicting folivorous primate abundance: validation of a nutritional model. Am J Primatol 62:55–69.

Chivers DJ. 1994. Functional morphology of the gastrointestinal tract. In: Davies AG, Oates JF, editors. Colobine monkeys: their ecology, behaviour and ecology. Cambridge: Cambridge University Press. p 205–228.

Conklin-Brittain NL, Wrangham RW, Hunt KD. 1998. Dietary response of chimpanzees and cercopithecines to seasonal variation in fruit abundance. II. Macronutrients. Int J Primatol 19:971–998.

Dasilva GL. 1994. Diet of *Colobus polykomos* on Tiwai Islands: selection of food in relation to its seasonal abundance and nutritional quality. Int J Primatol 15:655–680.

Davies AG, Bennett EL, Waterman PG. 1988. Food selection by two South-East Asian colobine monkeys (*Presbytis rubicunda* and *Presbytis melalophos*) in relation to plant chemistry. Biol J Linnean Soc 34:33–56.

Dela JDS. 2007. Seasonal food use strategies of *Semnopithecus vetulus nestor*, at Panadura and Piliyandala, Sri Lanka. Int J Primatol 28:607–626.

Ding W, Zhao QK. 2004. *Rhinopithecus bieti* at Tacheng, Yunnan: diet and daytime activities. Int J Primatol 25:583–598.

Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. 1956. Colorimetric method for determination of sugars and related substances. Anal Chem 28:350–356.

Fashing PJ, Dierenfeld ES, Mowry CB. 2007. Influence of plant and soil chemistry on food selection, ranging patterns and biomass of *Colobus guereza* in Kakamega Forest Kenya. Int J Primatol 28:673–703.

Fimbel C, Vedder A, Dierenfeld ES, Mulindahabi F. 2001. An ecological basis for large group size in *Colobus angolensis* in the Nyungwe Forest, Rwanda. Afr J Ecol 39:83–92.

Gaffney S, Williams V, Flynn P, et al. 2004. Tannin/polyphenol effects on iron solubilization *in vitro*. BIOS 75:43–52.

Ganas J, Ortmann S, Robbins MM. 2008. Food preference of wild mountain gorillas. Am J Primatol 70:927–938.

Gartlan JS, McKey DB, Waterman PG, Mbi CN, Struhasker TT. 1980. A comparative study of the phytochemistry of two African rain forests. Biochem Syst Ecol 8:401–422.

Grueter CC, Li DY, Ren BP, Wei FW, Xiang ZF, van Schaik CP. 2009. Fallback foods of temperate-living primates: a case study on snub-nosed monkeys. Am J Phys Anthropol 140: 700–715.

Guo ST, Li BG, Watanabe K. 2007. Diet and activity budget of *Rhinopithecus roxellana* in the Qinling Mountains, China. Primates 48:268–276.

Hagerman AE, Butler LG. 1991. Tannins and lignins. In: Rosenthal GA, Berenbaum MR, editors. Herbivores: their interaction with secondary plant metabolites. 2nd edition. New York: Academic Press. p 355–388.

Hamilton RA. 1994. A preliminary study of food selection by the orangutan in relation to plant quality. Primates 35:255–263.

Hanson AM, Hall MB, Porter LM, Lintzenich B. 2006. Composition and nutritional characteristics of fungi consumed by *Callimico goeldii* in Pando, Bolivia. Int J Primatol 27:323–346.

Kirkpatrick RC. 1996. Ecology and behavior of the Yunnan snub-nosed langur *Rhinopithecus bieti* (Colobinae) [PhD dissertation]. Davis (CA): University of California.

Kirkpatrick RC, Grueter CC. 2010. Snub-nosed monkey: multilevel societies across varied environment. Evol Anthropol 19:98–113.

Kool DM. 1992. Food selection by the silver leaf monkeys, *Trachypithecus auratus sondaicus*, in relation to plant chemistry. Oecologia 90:527–533.

Li YM. 2001. The seasonal diet of the Sichuan snub-nosed monkey (*Pygathrix roxellana*) in Shennongjia Nature Reserve, China. Folia Primatol 72:40–43.

Li YM. 2006. Seasonal variation of diet and food availability in a group of Sichuan snub-nosed monkeys in Shennongjia Nature Reserve, China. Am J Primatol 68:217–233.

Li YM. 2007. Terrestriality and tree stratum use in a group of Sichuan snub-nosed monkeys. Primates 48:197–207.

Li BG, Pan RL, Oxnard CE. 2002a. Extinction of snub-nosed monkeys in China during the past 400 years. Int J Primatol 23:1227–1244.

Li YM, Stanford CB, Yang YH. 2002b. Winter feeding tree choice in Sichuan snub- nosed monkeys (*Rhinopithecus roxellana*) in Shennongjia Nature Reserve, China. Int J Primatol 23:657–673.

Li YK, Jiang ZG, Li CW, Grueter CC. 2010. Effects of seasonal folivory and frugivory on ranging patterns in *Rhinopithecus roxellana*. Int J Primatol 31:609–626.

Mathlesen SD, Haga E, Kaino T, Tyler NJC. 2000. Diet composition, rumen papillation and maintenance of carcass mass in female Norwegian reindeer (*Rangifer tarandus tarandus*) in winter. J Zool 251:129–138.

McKey DB, Gartlan JS, Waterman PG, Choo GM. 1981. Food selection by black colobus monkeys (*Colobus satanas*) in relation to plant chemistry. Biol J Linnean Soc 16:115–146.

Milton K. 1984. The role of food-processing factors in primate food choice. In: Rodman PS, Cant JGH, editors. Adaptations for foraging in nonhuman primates. New York: Columbia University Press. p 249–279.

Milton K. 1998. Physiological ecology of howlers (*Alouatta*): energetic and digestive considerations and comparison with the Colobinae. Int J Primatol 19:513–547.

Milton K. 2008. Macronutrient patterns of 19 species of Panamanian fruits from Barro Colorado Island. Neotrop Primates 15:1–7.

Mowry CB, Decker BS, Shure DJ. 1996. The role of phytochemistry in dietary choices of Tana River red colobus monkeys (*Procolobus badius rufomitratus*). Int J Primatol 17:63–83.

Nakagawa N. 2003. Difference in food selection between patas monkeys (*Erythrocebus patas*) and tantalus monkeys (*Cercopithecus aethiops tantalus*) in Kala Maloue National Park, Cameroon, in relation to nutrient content. Primates 44:3–11.

NRC (National Research Council). 2003. Nutrient requirements of nonhuman primates. Washington, DC: The National Academies Press.

Oates JF. 1988. The diet of the olive colobus monkey, *Procolobus verus*, in Sierra Leone. Int J Primatol 9:457–458.

Oates JF, Swain T, Zantovska J. 1977. Secondary compounds and food selection by colobus monkeys. Biochem Syst Ecol 5:317–321.

Oftedal OT. 1991. The nutritional consequences of foraging in primates: the relationship of nutrient intake to nutrient requirements. Philosophical Trans R Soc Lond B 334:161–170.

Rautio P, Bergvall UA, Karonen M, Salminen JP. 2007. Bitter problems in ecological feeding experiments: commercial tannin preparations and common methods for tannin quantifications. Biochem Syst Ecol 35:257–262.

Reimers E, Ringberg T. 1983. Seasonal changes in body weights of Svalbard reindeer from birth to maturity. Acta Zool Fenn 175:69–71.

Remis MJ, Dierenfeld ES, Mowry CB, Carroll RW. 2001. Nutritional aspects of western lowland gorilla (*Gorilla gorilla gorilla*) diet during seasons of fruit scarcity at Bai Hokou, Central Africa Republic. Int J Primatol 22:807–836.

Ren RM, Kirkpatrick RC, Jablonski NG, Bleisch WV, Canh LX. 1998. Conservation status and prospects of the snub-nosed langurs (Colobinae: *Rh* inopithecus). In: Jablonski NG, editor. The natural history of the doucs and snub-nosed monkeys. Singapore: World Scientific Publishing. p 301–314.

Rothman JM, Dierenfeld ES, Molina DO, Shaw AV, Hintz HF, Pell AN. 2006. Nutritional chemistry of foods eaten by gorillas in Bwindi Impenetrable National Park, Uganda. Am J Primatol 68:675–691.

Rothman JM, Dusinberre K, Pell AN. 2009. Condensed tannins in the diets of primates: a matter of methods? Am J Primatol 71:70–76.

Rothman JM, Chapman CA, Van Soest PJ. 2012. Methods in primate nutritional ecology: a user's guide. Int J Primatol 33:542–566.

Roy SN, Mukherjee S. 1979. Influence of tannins on certain aspects of iron metabolism: part I—absorption and excretion in normal and anemic rats. Indian J Biochem Biophys 16:93–98.

Sahoo A, Soren NM. 2012. Phytochemicals and gut microbial populations in non-ruminants. In: Patra AK, editor. Dietary phytochemicals and microbes. Amsterdam: Springer. p 371–389.

Sayers K, Norconk MA. 2008. Himalayan *Semnopithecus entellus* at Langtang National Park, Nepal: diet, activity patterns, and resources. Int J Primatol 29:509–530.

Silver SC, Ostro LET, Yeager CP, Dierenfeld ES. 2000. Phytochemical and mineral components of foods consumed by black howler monkeys (*Alouatta pigra*) at two sites in Belize. Zoo Biol 19:95–109.

Sourd C, Gautier-Hion A. 1986. Fruit selection by a forest guenon. J Anim Ecol 55:235–244.

Stanford CB. 1991. The diet of the capped langur (*Presbytis pileata*) in a moist deciduous forest in Bangladesh. Int J Primatol 12:199–216.

Stanford CB, Nkurunungi JB. 2003. Behavioral ecology of sympatric chimpanzees and gorillas in Bwindi Impenetrable National Park Uganda: diet. Int J Primatol 24:901–918.

Struhasker TT, Leland L. 1987. Colobines: infanticide by adult males. In: Smuts BB, Cheney DL, Seyfarth RM, Wrangham RW, Struhasker TT, editors. Primate societies. Chicago: University of Chicago Press. p 83–97.

Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J Dairy Sci 74:3583–3597.

Wasserman WD, Chapman CA. 2003. Determinants of colobine monkey abundance: the importance of food energy, protein and fibre content. J Anim Ecol 72:650–659.

Waterman PG. 1984. Food acquisition and processing as a function of plant chemistry. In: Chivers DJ, Wood BA, Bilsborough A, editors. Food acquisition and processing in primates. New York: Plenum Press. p 177–211.

Waterman PG, Kool KM. 1994. Colobine food selection and plant chemistry. In: Davies AG, Oates JF, editors. Colobine monkeys: their ecology, behaviour and ecology. Cambridge: Cambridge University Press. p 251–284.

Xiang ZF, Huo S, Xiao W, Quan RC, Grueter CC. 2007. Diet and feeding behavior of *Rhinopithecus bieti* at Xianchangdu, Tibet: adaptations to a marginal environment. Am J Primatol 69:1–18.

Yamashita N. 2008. Chemical properties of the diets of two lemur species in southwestern Madagascar. Int J Primatol 29:339–364.

Yeager CP, Silver SC, Dierenfeld ES. 1997. Mineral and phytochemical influences on foliage selection by the proboscis monkey (*Nasalis larvatus*). Am J Primatol 41:117–128.

Appendix I. Nutritional composition of individual plant parts and lichens in the habitat of *Rhinopithecus roxellana* in Shennongjia, China.

Species	Part	H_2O	CP	CFA	CF	WSC	CT	TP
Abies fargesii	ML	62.73	9.63	10.28	23.18	9.29		
Acer oliverianum	ML	70.35	15.70	3.57	17.78	5.35	III	III
A. oliverianum	YL	67.49	13.70	3.27	16.79			
Actinidia chinensis	ML	60.00		5.38			III	IV
Aralia chinensis	ML[a]	66.71		5.48				
Betula albosinensis	ML	62.50	13.89	3.91	18.60		III	IV
B. albosinensis	YL	68.19	16.17	8.82	11.80			
Betula ermanii	ML	60.00		5.09				
Betula utilis	ML	69.66	11.75	2.65	17.07	6.35		
B. utilis	YL	72.83	16.09	4.91	10.22	4.22		
Carpinus fargesiana	ML	57.84	12.47	3.15	22.28			
Castanea seguinii	ML	58.14	12.48	6.16	19.13			
C. seguinii	FR	47.53	2.46	1.60	11.33			
Cerasus szechuanica	ML	56.07	7.01	1.88	8.27		II	II
C. szechuanica	YL[a]	53.18	6.45	1.97	7.80			
C. szechuanica	FL[a]	85.47	29.07	4.27	12.26			
C. szechuanica	BD[a]	74.38	28.87	7.68	10.00			
Cetralia delavayana[b]	LI		7.65	2.22	8.51	4.33	II	II
Cinnamomum glanduliferum	ML	73.63	27.17	4.08	9.60			
Cornus controversa	ML	67.85	11.93	4.10	12.23	7.72	IV	II
C. controversa	YL	68.10	14.14	3.30	9.70			
C. controversa	FR[a]	45.86	5.51	25.13	31.79	13.41		
Cornus hemsleyi	ML	64.95		2.85				
Cornus walteri	ML	63.39	10.34	3.80	9.95			
C. walteri	FR	59.95	6.36	13.81	43.67			
Crataegus hupehensis	ML[a]	59.21	12.32	3.21	10.48	9.92	III	III
C. hupehensis	YL[a]	74.53	23.54	2.91	10.64			
C. hupehensis	FL	75.00		2.88			III	III
C. hupehensis	FR[a]	64.16	4.81	2.76	33.35			
Decaisnea fargesii	ML[a]	72.44	18.77	5.38	10.64	12.25		
D. fargesii	YL[a]	75.00		11.79		6.34	II	II
Dendrobenthamia japonica	ML	73.00		3.60			IV	II
D. japonica	FL	79.00		2.29				
Elaeagnus pungens	ML	61.25		2.66			II	I
Euonymus alatus	ML[a]	62.44	11.10	2.74	12.03	11.30		
E. alatus	YL[a]	75.56	10.26	2.77	5.05	5.57	II	II
E. alatus	BK[a]	57.14		3.96	13.41			
Fagus engleriana	ML	55.56	10.24	4.38	25.62	5.62	IV	IV
F. engleriana	FL	53.33		3.26			III	III
F. engleriana	BD	72.16	30.82	2.99	20.60			
F. engleriana	FR	57.40	26.40	26.03	14.02			
Heterodermia spp.[b]	LI	12.01	6.79	3.40	10.01	9.99	II	II
Juglans cathayensis	ML	63.18		3.79				
Lindera obtusiloba	ML[a]	65.96	12.96	3.89	17.34	10.01	III	IV
L. obtusiloba	YL[a]	70.39	14.97	3.33	14.69	5.53		
L. obtusiloba	FL[a]	72.06	20.78	3.12	20.06	6.72	III	IV
L. obtusiloba	BD[a]	74.86	30.07	3.35	19.64	15.79		
L. obtusiloba	FR[a]	56.04	10.22	36.35	11.71	16.01		
Liriodendron chinense	ML	77.80	28.98	4.12	12.15			
Litsea ichangensis	ML	75.05	15.14	5.80	19.24		II	III
L. ichangensis	YL[a]	65.33	12.75	5.44	10.00	6.59		
L. ichangensis	FL[a]	81.54	19.95	5.51	13.59			
L. ichangensis	BD[a]	73.38	23.59	3.20	26.17		I	II
L. ichangensis	FR[a]	54.28	11.52	45.32	13.00		III	IV
Magnolia biondii	FL	89.71		7.12			II	II
M. biondii	BD	60.00		2.90			II	I
Malus hupehensis	ML	57.64	10.71	6.17	9.25			
M. hupehensis	YL[a]	63.09	11.59	4.42	7.22	5.55	III	III
M. hupehensis	FL[a]	80.00		4.11			III	II
M. hupehensis	BD	77.50		6.06			III	II
M. hupehensis	FR[a]	59.12	6.00	3.72	15.73			
Meliosma veitchiorum	ML	62.50		5.18			V	V

Appendix I. Continued

Species	Part	H_2O	CP	CFA	CF	WSC	CT	TP
Morus alba	ML[a]	71.32	16.17	3.61	11.28		II	II
Parmelia spp.[b]	LI		8.33	4.21	8.02	14.41	I	II
Platycarya strobilacea	ML	54.00		2.73				
Pinus armandii	ML	63.91	9.37	4.28	29.62			
P. armandii	YL	67.50		14.96			II	IV
P. armandii	SE[a]	29.27	21.15	57.72	4.63			
Populus simonii	ML	54.54	13.49	5.56	17.00			
P. simonii	YL	59.28	11.57	5.89	17.04			
Populus wilsonii	ML	79.63	37.11	3.07	13.36			
P. wilsonii	YL	87.62	27.32	3.24	14.81			
Prunus vaniotii	ML	71.84	20.65	3.15	13.64			
Pterocarya hupehensis	ML	55.00		3.32			III	III
Pterocarya insignis	ML	65.33		3.74				
Quercus glauca	ML	56.72	10.13	3.47	21.83		IV	II
Q. glauca	BD	47.87		3.73				
Q. glauca	FR	68.40	3.99	0.71	2.36			
Quercus spinosa	ML	50.00		2.64			IV	II
Quercus variabilis	ML	63.53	12.18	2.22	21.85	6.01	IV	II
Q. variabilis	YL	79.46	16.10	2.42	13.76	5.29		
Q. variabilis	BD	68.66		3.97			II	II
Q. variabilis	FR	35.08	23.14	54.90	17.26			
Ramalina americana[b]	LI[a]	11.53	5.37	1.80	9.91	16.65	II	II
Rhododendron spp.	FL	85.56		4.12			IV	V
Rhododendron spp.	BD	39.29		1.87		6.30		
Rosa henryi	ML	62.50		4.99			V	II
R. henryi	FL	85.00		3.61			V	II
R. henryi	BD	70.00		1.82			IV	II
R. henryi	FR	62.50		3.25			IV	II
Rhus potaninii	ML	72.15		3.50				
Rhus verniciflua	ML	69.83	18.78	3.52	13.18			
R. verniciflua	YL	76.79	25.64	3.67	12.88			
R. verniciflua	FR	53.43	12.86	33.71	24.40			
Salix wallichiana	ML	59.82	14.86	4.38	15.47		III	IV
S. wallichiana	YL[a]	68.37	16.87	4.79	19.02			
S. wallichiana	FL[a]	78.37	22.19	2.95	17.49			
Sapindus mukorossi	ML	79.50	30.66	3.43	8.15			
Schisandra glaucescens	FR[a]	76.79	5.65	10.98	16.32			
Schoepfia jasminodora	ML	72.96	21.83	4.17	14.12			
Sorbus hupehensis	ML	65.82	11.08	4.82	17.14	4.20		
S. hupehensis	YL[a]	68.21	11.12	5.38	15.86		III	III
S. hupehensis	FL	78.17	29.36	4.99	11.63			
S. hupehensis	FR[a]	65.18	7.29	6.26	15.65			
Stranvaesia davidiana	ML	61.54		3.64			II	II
Sulcaria sulcata[b]	LI[a]	10.42	6.37	3.69	8.77	13.11	II	II
Symplocos paniculata	ML	83.00		4.71			II	II
S. paniculata	FL	75.00		4.30			II	II
Tilia oliveri	ML	67.47	16.26	3.60	23.30		III	IV
T. oliveri	BD	80.00		2.60			III	V
Usnea aciculifera[b]	LI[a]	11.08	5.95	4.31	7.67	15.51	I	II
Viburnum utile	ML	68.00		6.21				
Vitis flexuosa	BD	76.00		4.31			II	II
Weigela japonica	ML	70.22	11.47	2.88	12.23	9.99	III	II
W. japonica	YL	73.80	11.81	3.03	12.51			
W. japonica	FL	80.00		4.12			III	II
W. japonica	BD	75.00		4.30			II	I

Note: ML, mature leaves; YL, young leaves; FL, flowers; BD, buds; FR, fruits; SE, seeds; BK, bark; LI, whole bodies of lichens. H_2O (water): % fresh weight; CP (crude protein): % dry matter; CFA (crude fat): % dry matter; CF (crude fiber): % dry matter; WSC (water soluble carbohydrate): % dry matter; CT (condensed tannin) and TP (total phenolic): level of absorbance (I: <0.1; II: ≥ 0.1, <0.5; III: ≥ 0.5, <1.0; IV: ≥ 1.0, <2.0; V: ≥ 2.0).

[a] Food parts.

[b] Lichen species.