Protein in Vegetative and Reproductive Tissues of Several Neotropical Species

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Crude protein content, percent water, productivity, and consumption by two species of monkeys were determined for vegetative and reproductive tissues of several native species of a Colombian cloud forest. Protein was highest in a young leaf sample of *Trema micrantha* with a crude protein content of 31.6%. Highest productivity was found in *Landerbergia macrocarpa* with a density of 18.8 trees/ha and having leaves, flowers, and fruit available over 80% of the time.

Tropical forests may represent a vast unexplored food and feed resources possibility. For example, Fittkau and Klinge (1973) found that as a standing crop leaf biomass alone amounted to 20 metric tons/ha in an Amazonian rain forest. However, current agricultural practices within tropical areas have primarily involved clearing the forested area and subsequent planting of cultivated crops, leading to destruction of adapted ecosystems. The food and feed value of most tropical forest species is unknown because systematic collection of plant samples for nutrient analysis is seldom undertaken in equatorial regions. This study evaluates the nutritional food and feed potential of vegetative and reproductive tissues from all native tree species and five native epiphytic species found within an equatorial Colombian cloud forest. Cloud forests occur at high altitudes (approximately 1800–2400 m) throughout the moist tropics of the world (Walter, 1971).

PROCEDURE

Sample Collection. All plant material was collected during the first 7 months of 1976 at Finca Merenberg, a privately owned natural reserve 2300 m above sea level in the Central Cordillera of the Andes in southwestern Colombia (2°12′N; 76°8′W). The Finca was founded in the early years of the twentieth century from essentially uninhabited forest, and the owners have conscientiously defended the biota from logging and colonization. Lack of time depth in the biological records of the region makes it impossible to test the idea, but the diversity of flora and fauna suggested the forested area represented a relatively intact ecological community. Further details on the sample area can be found in Gaulin (1977).

Techniques of sample collection involved tree climbing, the use of ropes, a flexible wire saw blade, and an extendable pruning pole (maximum length 8 m). Using one or a combination of these approaches, material was obtained from all 72 tree species plus five epiphytic species encountered in the test area. Species identification was made through collection of herbarium samples and subsequent comparison (with the aid of several staff scientists) to samples at the Herbario Nacional in Bogota; 12% could not be identified beyond the family level, 31% were identified to genus, and 57% were identified to genus and species.

Most species provided several different kinds of material (e.g., leaf, flower, fruit) and thus 225 different species-part types were collected. Each sample was composed of from 4 to 180 items of the same species-part type. Where individual items were very large, sampling error was reduced by making a composite sample from portions of a series of items. Replicate samples were collected over the course of study with the mean number of replicates at 3.88. The range of replicates was from 1 to 22. Collected material included leaves and fruit at two stages of maturity, plus flowers. In the case of very large leaves, leaf tissue was separated from the petiole for analytical purposes.

Analysis. To determine precent moisture, each freshly collected sample was weighed to the nearest 0.01 g on an Ohaus four-beam balance and subsequently placed in a Pyrex beaker. The beakers were then placed in a large aluminum container on top of a wood-burning stove until the samples were dried to a stable weight (usually requiring 36–48 h). Dried samples were reweighed and stored in separate plastic bags for return to the United States at the end of the collection period.

Protein content of each tissue was determined on a dry weight basis by means of a Nesserlization test (Lanni et al., 1950). This test was chosen because most of the tissue samples were quite small (0.5–5.0 g) and because the total number of samples to be analyzed was large. Each sample was ground through a 60-mesh screen and thoroughly mixed and a subsample was used for analysis. Absorbances were calibrated for nitrogen content by comparison to ammonium sulfate standard solutions. Percent protein was computed for each sample by multiplying nitrogen content by 6.25 (AOAC, 1975).

Potential Productivity. Estimations on potential productivity in the natural ecosystem were ascertained by examining species density and phenological patterns. To determine the abundance of individual tree species, each tree with a diameter at breast height (dbh) of 15 cm within a transect 20 m wide and 1036 m long was catalogued by species.

Since tropical plants frequently exhibit quite complex phenological patterns very unlike the temperature-related cycles of temperate zone plants, we monitored the patterns of leaf production, fruiting, and flowering on 150 individual trees (approximately two of each species) every 15 days over a 240-day period. During the monitoring, each individual tree was scored with respect to the presence or absence of new leaves, flowers, and developing fruit. The overall availability of vegetative and reproductive tissue was calculated as the decimal fraction of sample times that trees within the species sample displayed the particular leaf, flower, or fruit tissue. For example, a value of 1.00 for leaves of *Cecropia telealba* indicates that all censused individuals of this species were flushing new leaves during every census. The minimum value of 0.03 (e.g., fruits of *Hedyosmum*) means that a single individual of two sampled trees bore fruit during one census.

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0021-8561/79/1427-0791$01.00/0

Table I. Protein and Water Content Plus Relative Productivity and Edibility of Leaf Tissue in Native Species of a Tropical Cloud Forest

	young leaf[a]			mature leaf			productivity		
genus	no. of samples	moisture, %	protein, % dry wt	no. of samples	moisture, %	protein, % dry wt	leaf availability[b]	species density,[c] trees/ha	primate consumption[d]
Alchornea obovata	11	71.0 ± 1.2	5.7 ± 1.2	10	59.7 ± 1.1	5.3 ± 0.5	0.86	4.8	–
Astrocarcium no. 1				3	60.2 ± 0.7	12.2 ± 8.2	0.20	0.5	–
Billia colombiana	9	70.2 ± 1.2	4.8 ± 1.6	9	54.8 ± 1.5	3.6 ± 0.7	0.58	13.0	Y
Brunellia comocladifolia	4	69.1 ± 3.6	11.2 ± 4.4	9	54.5 ± 1.0	4.5 ± 0.4	0.70	5.8	Y
littlei	9	69.5 ± 0.6	7.1 ± 1.5	7	61.9 ± 0.9	4.9 ± 0.9	1.00	1.0	–
Calatola no. 1				2	60.9 ± 0.1	3.1 ± 1.9	0.13	0.5	–
Cecropia telealba	1	74.1	4.6	7	66.2 ± 1.0	4.0 ± 0.9	1.00	1.0	–
tessmannii				1	64.4	0.5	1.00	1.5	–
no. 1	2	79.3 ± 1.7	7.4 ± 0.8	7	66.9 ± 2.0	4.8 ± 0.5	1.00	9.7	Y + M
no. 2				1	59.3	6.2	1.00	1.0	–
Cestrum no. 1	2	72.9 ± 4.5	3.8 ± 0.7	5	64.9 ± 1.2	4.6 ± 0.7	0.57	0.5	–
Cinchona pubescens	2	76.0 ± 0	16.9 ± 1.0	4	65.2 ± 5.2	5.3 ± 1.6	0.67	2.9	–
Citharexylum no. 1				5	73.4 ± 1.3	9.8 ± 4.1	0.00	2.9	–
Clusiaceae no. 1	5	83.6 ± 0.5	8.9 ± 3.1	8	70.0 ± 0.9	5.8 ± 2.1	1.00	6.8	–
no. 2	5	81.7 ± 0.2	5.9 ± 2.2	8	72.8 ± 1.4	3.7 ± 0.5	0.50	3.9	Y
no. 3	6	84.2 ± 0.2	5.1 ± 1.3	6	72.8 ± 1.1	4.0 ± 1.1	1.00	0.5	–
no. 4	6	84.5 ± 0.3	8.5 ± 1.8	5	68.4 ± 0.2	3.4 ± 0.3	1.00	0.5	–
no. 5	4	81.6 ± 2.4	4.4 ± 0.6	5	73.1 ± 2.2	5.6 ± 2.7	1.00	0.5	Y
Cordia lanata	6	77.5 ± 1.2	16.1 ± 4.5	6	74.5 ± 1.0	6.8 ± 1.8	1.00	0.5	–
Croton no. 1	4	78.7 ± 0.8	10.4 ± 8.0	4	74.6 ± 0.9	4.3 ± 1.3	1.00	0.5	–
Dryopteris no. 1	1	77.8	4.8	7	67.8 ± 3.0	9.4 ± 3.5	0.60	1.9	–
Erythroxylon no. 1	4	71.6 ± 0.4	8.4 ± 3.2	6	52.0 ± 0.3	6.0 ± 1.4	0.56	0.5	–
Eupatorium no. 1	1	80.7	2.6	3	84.2 ± 1.9	6.0 ± 0.6	1.00	e	Y + M
Faramea flavicans	3	73.5 ± 1.6	7.0 ± 2.9	5	66.9 ± 1.3	6.5 ± 2.4	1.00	1.0	–
Ficus boyacensis	3	74.9 ± 0.9	7.3 ± 3.3	3	63.4 ± 0.2	4.9 ± 1.3	0.95	0.5	–
caucana	2	80.9 ± 0.3	3.9 ± 2.4	6	68.8 ± 0.6	5.2 ± 1.4	0.73	3.9	Y
cundinamarcensis	3	75.1 ± 1.7	3.8 ± 0.4	6	63.1 ± 2.0	4.4 ± 0.6	0.72	4.4	Y + M
dendrocida				2	61.8 ± 1.6	3.1 ± 7.0	0.50	0.5	–
garcia-barrigae	2	80.7 ± 2.9	5.5 ± 0.8	8	67.5 ± 0.8	1.6 ± 1.1	0.81	1.9	Y
gigantosyce	3	79.1 ± 1.2	1.4 ± 5.6	3	69.9 ± 1.5	4.0 ± 0.2	1.00	0.5	Y
insipida	13	74.6 ± 0.9	5.1 ± 0.4	22	63.2 ± 0.7	5.3 ± 0.9	1.00	11.1	Y
jaramilloi				1	74.0	1.9	0.44	0.5	–
sibudoya				1	75.3	6.2	0.87	0.5	–
no. 1	2	80.8 ± 1.0	4.8 ± 1.8	4	66.6 ± 4.6	7.3 ± 3.2	0.54	0.5	Y
no. 2	2	64.8 ± 6.4	3.2 ± 0.4	7	62.5 ± 1.3	4.2 ± 0.7	0.45	0.5	Y
no. 3	2	75.2 ± 1.0	4.7 ± 1.3	3	59.1 ± 3.2	3.5 ± 0.9	0.90	0.5	Y
Guarea no. 1	2	71.2 ± 0.9	17.9 ± 12.2	6	60.1 ± 1.2	10.1 ± 3.3	0.50	18.8	Y
Guettarda no. 1	2	69.1 ± 0.5	9.2 ± 2.8	3	66.5 ± 0.9	3.1 ± 1.1	1.00	1.0	–
Hedyosmum no. 1	6	82.6 ± 1.4	5.4 ± 1.8	6	72.2 ± 1.3	2.5 ± 0.4	1.00	5.8	–
Hieronyma colombiana	2	75.8 ± 0.6	17.0 ± 6.0	3	71.4 ± 1.8	5.5 ± 0.7	0.78	15.0	–
duquei	3	78.7 ± 0.1	10.2 ± 3.0	3	72.7 ± 0.7	3.8 ± 0.5	1.00	3.4	–
Landerbergia macrocarpa	10	74.9 ± 1.4	7.2 ± 1.3	12	68.2 ± 0.9	11.4 ± 2.7	0.81	18.8	M
Lauraceae no. 1	1	71.1	4.7	11	58.2 ± 1.1	4.6 ± 0.7	0.46	2.4	–
no. 2	3	79.0 ± 2.0	3.4 ± 1.1	6	55.9 ± 2.5	4.0 ± 0.9	0.61	2.4	Y
no. 3	2	71.7 ± 1.7	3.6 ± 0.6	3	53.6 ± 1.6	6.8 ± 5.1	0.80	0.5	–
no. 4	2	76.6 ± 4.7	19.3 ± 16.0	2	56.9 ± 2.0	4.1 ± 0.7	0.05	3.4	–
Loranthaceae no. 1	1	72.0	3.9	1	68.1	1.5	1.00	e	Y
Lozania mutisiana	2	79.4 ± 4.9	5.4 ± 1.3	2	68.0 ± 1.3	3.4 ± 0.3	0.95	7.7	–
Miconia theaezans	4	68.1 ± 1.9	4.5 ± 0.8	5	63.2 ± 3.3	3.3 ± 0.6	0.87	2.4	–
no. 1	8	68.5 ± 0.9	3.8 ± 0.6	8	67.6 ± 0.6	5.9 ± 1.2	0.91	1.9	–
no. 2	4	75.1 ± 3.1	3.0 ± 1.3	5	63.9 ± 2.9	5.7 ± 0.9	1.00	1.9	–
Morus no. 1	12	80.5 ± 0.6	10.2 ± 2.9	12	73.1 ± 1.3	12.7 ± 3.3	0.79	16.4	Y + M
Myrcia popayanensis	5	70.0 ± 3.3	2.6 ± 0.5	6	54.9 ± 1.5	2.7 ± 0.6	1.00	1.0	–
Nectandra no. 1	3	71.7 ± 4.0	10.5 ± 5.4	9	52.0 ± 1.4	5.6 ± 1.5	0.48	9.7	Y
Ocotea calophylla				2	67.2 ± 2.7	10.7 ± 7.3	0.56	3.4	–
Oreopanax no. 1	2	59.7 ± 0.3	2.4 ± 1.2	3	71.4 ± 7.4	5.2 ± 2.5	1.00	1.5	–
Palicourea cuatrecasasii	2	84.4 ± 1.0	7.6 ± 3.7	4	75.6 ± 1.4	8.0 ± 3.9	0.52	1.0	–
Phoebe no. 1	9	80.6 ± 0.3	8.8 ± 0	11	59.4 ± 0.7	7.2 ± 2.3	0.86	6.8	–
Prunus integrifolia	3	65.3 ± 0.6	4.5 ± 1.2	8	54.2 ± 0.9	5.2 ± 0.5	0.54	4.4	–
Psammisia falcata	7	72.8 ± 0.8	3.8 ± 0.9	9	54.7 ± 2.0	3.1 ± 0.5	1.00	e	Y
Quercus humboldtii	17	74.0 ± 1.0	4.5 ± 0.6	19	53.6 ± 1.4	4.6 ± 0.6	0.79	6.8	Y + M
Rapanea ferruginea	1	65.4	3.8	1	58.5	5.9	0.42	1.5	–
Rhamnus granulosus	1	70.1	7.5	1	62.7	1.8	0.03	0.5	–
Sapium cuatrecasasii	3	76.8 ± 0.5	20.6 ± 3.9	6	69.7 ± 0.3	3.6 ± 0.4	0.91	4.8	Y
putumayensis				4	70.8 ± 0.5	3.5 ± 0.4	0.14	0.5	–
Saurauia cuatrecana	5	80.4 ± 0.4	4.6 ± 0.8	5	66.2 ± 8.0	3.2 ± 0.5	0.87	7.3	–
Solanum no. 1	3	77.7 ± 1.5	13.8 ± 7.6	5	78.6 ± 1.1	1.0 ± 4.1	0.05	e	M
Souroubea no. 1	1	82.7	2.0	2	69.6 ± 1.9	3.2 ± 2.4	0.05	e	–
Trema micrantha	1	67.4	31.6	1	55.3	2.8	1.00	0.5	–
Turpinia paniculata				5	63.0 ± 0.8	5.5 ± 0.4	0.36	11.1	–

Table I. (Continued)

genus	young leaf[a] no. of samples	moisture, %	protein, % dry wt	mature leaf no. of samples	moisture %	protein % dry wt	productivity leaf availability[b]	species density,[c] trees/ha	primate consumption[d]
Urera no. 1	1	83.7	21.1	1	77.0	21.8	0.05	1.0	–
Viburnum lehmanii	8	71.0 ± 1.2	7.7 ± 2.0	9	61.5 ± 1.3	9.7 ± 3.5	0.71	1.9	–
triphyllum	8			1	60.3	4.1	0.75	1.0	–
Vismia nandurr	1	70.9	12.0	3	67.9 ± 6.5	4.3 ± 0.8	0.80	1.9	–
Weinmannia balbisiana	2	65.8 ± 0.3	5.6 ± 0.9	7	57.7 ± 0.5	3.8 ± 0.6	0.73	0.5	–
caquetana	4	64.5 ± 2.0	2.1 ± 0.5	7	59.8 ± 2.0	3.7 ± 0.8	0.82	4.4	–
sorbifolia	5	69.5 ± 1.6	3.3 ± 0.8	5	65.5 ± 0.7	1.9 ± 0.5	0.94	0.5	–

[a] Maturity of leaf tissue was determined on the basis of variance in size, color, and resistance to puncture among the leaves of any given species. "Young leaves" were systematically smaller, often lighter green (but sometimes more reddish), and easier to puncture than were "mature leaves." [b] Leaf availability represents the proportion of censused individuals producing new leaves during biweekly phenology surveys. [c] e indicates an epiphytic species for which density was not determined. [d] Primate consumption indicates whether young (Y), mature (M), or neither (–) kind of leaf tissue was eaten by resident nonhuman primates.

Table II. Protein and Water Content plus Relative Productivity and Edibility of Fruit Tissue in Native Species of a Tropical Cloud Forest

genus	unripe fruit[a] no. of samples	moisture, %	protein, % dry wt	ripe fruit no. of samples	moisture, %	protein, % dry wt	productivity fruit availability[b]	species density,[c] trees/ha	primate consumption[d]
Astrocarium no. 1	1	78.7	2.8	3	74.6 ± 3.5		0.80	0.5	–
Billia colombiana				2	79.5 ± 0.4	1.6 ± 1.1	0.15	13.0	–
Cecropia telealba	2	78.6 ± 1.8	3.9 ± 1.3	8	82.5 ± 0.8	8.4 ± 3.0	0.62	1.0	–
tessmannii				1	79.3	4.9	0.67	1.5	R
no. 1	5	80.9 ± 0.3	4.9 ± 0.4	10	78.5 ± 2.0	3.4 ± 0.4	0.94	6.8	R
Clusiaceae no. 1				3	87.7 ± 0.3	3.0 ± 0.6	0.72	9.7	–
Ficus boyacensis	1	69.6	0.6	3	76.2 ± 3.7	3.2 ± 1.0	0.33	0.5	R
cundinamarcensis	3	78.1 ± 0.9	3.3 ± 1.8	1	77.4	0.9	0.19	4.4	R
garcia-barrigae	2	76.6 ± 1.5	2.0 ± 0.2				0.19	1.9	–
insipida	8	81.7 ± 0.7	6.4 ± 2.5	6	86.0 ± 0.6	4.1 ± 0.9	0.14	11.1	U + R
no. 2	1	59.5	2.4	2	69.4 ± 3.6	3.7 ± 0.5	0.55	0.5	R
no. 3				1	69.4	3.5	0.10	0.5	U
Guarea no. 1	2	70.2 ± 0.2	11.3 ± 2.3				0.50	18.8	–
Hedyosmum no. 1				1	79.9	2.4	0.03	5.8	–
Landerbergia macrocarpa	2	81.5 ± 1.6	5.5 ± 1.8				0.91	18.8	–
Lauraceae no. 1				1	79.3	5.1	0.73	2.4	–
Miconia no. 1	1	72.2	7.7	3	68.6 ± 0.5	4.0 ± 0.7	0.27	1.9	–
Morus no. 1	2	78.2 ± 2.0	2.2 ± 0.3	2	80.2 ± 1.4	6.9 ± 2.2	0.15	16.4	R
Nectandra no. 1	1	76.0	2.6				0.20	9.7	–
Oreopanax no. 1	1	76.5	18.8				0.36	1.5	–
Phoebe no. 1				1	59.1	4.1	0.14	6.8	–
Prunus integrifolia	1	69.8	6.9	2	74.6 ± 4.8	3.4 ± 0.5	0.39	4.4	R
Psammisia falcata	1	71.9	1.1				1.00	e	R
Quercus humboldtii	3	57.7 ± 5.2	2.5 ± 0.1				0.33	6.8	–
Souroubea no. 1				4	71.3 ± 1.8	1.9 ± 0.3	0.10	e	R
Turpinia paniculata	2	71.1 ± 6.9	1.7 ± 0.3	3	70.1 ± 4.8	4.9 ± 1.2	0.64	11.1	–
Viburnum lehmanii	2	81.2 ± 13.9	1.5 ± 0.4	3	69.3 ± 5.8	2.4 ± 0.5	0.71	1.9	–

[a] Ripeness of fruits was determined on the basis of variance in size, color, and resistance to puncture among the fruit of any species. "Unripe fruit" were more difficult to puncture, often greener in color and smaller in size than "ripe fruit." "Ripe fruit" frequently exhibited some yellowish, reddish, or bluish tint. [b] Fruit availability represents the proportion of censused individuals that were bearing fruit during biweekly phenology surveys. [c] e indicates an epiphytic species for which density was not determined. [d] Primate consumption indicates whether unripe (U), ripe (R), or neither (–) kind of fruit tissue was eaten by resident nonhuman primates.

Potential Edibility. The human population was sparse in the study area and the prevailing modes of production involved the institution of artificial ecosystems. Native informants reported extremely meager use of native flora. Therefore, in this study we focused on the dietary habits of the nonhuman primate population in an attempt to assess the edibility of various kinds of plant material. Two nonhuman primate species occurred in the study area: *Alouatta seniculus*, the Red Howler Monkey, and *Cebus apella*, the Blackcapped Capuchin. The latter is insectivorous to a large extent but eats some fruits. *Alouatta* is wholly vegetarian in its food habits. A detailed daily observation of these two primates was conducted over the entire study period with identification of plant species and types of tissues they consumed.

RESULTS

The crude protein and moisture contents of vegetative and reproductive tissue of several tropical cloud forest species are presented in Tables I–III. On a dry weight basis, protein content of the vegetative tissue ranged from a high of 31.6% in a young leaf of *Trema micrantha* to a low of 0.5% in a mature leaf sample from *Cecropia tessmannii*. The percent moisture in tissue ranged from

Table III. Protein and Water Content Plus Relative Productivity and Edibility of Inflorescence Tissue in Native Species of a Tropical Cloud Forest

	flower[a]			inflorescence			productivity		
genus	no. of samples	moisture, %	protein, % dry wt	no. of samples	moisture, %	protein, % dry wt	flower availability[b]	species density,[c] trees/ha	primate consumption[d]
Landerbergia macrocarpa	2	88.9 ± 0.3	9.4 ± 5.6				0.82	18.8	F
Lauraceae no. 1				1	73.0	4.5	0.09	2.4	–
Miconia theaezans	1	71.1	3.6	1	70.9	2.7	0.27	2.4	–
no. 1	1	74.8	3.8				0.46	1.9	–
no. 2	1	73.3	4.5				0.06	1.9	–
Morus no. 1				4	83.0 ± 0.7	12.3 ± 6.3	0.18	16.4	I
Oreopanax no. 1	1			1	79.7	5.0	0.36	1.5	–
Psammisia falcata	2	77.2 ± 8.9	3.1 ± 2.5				0.46	e	–
Quercus humboldtii	2	76.6 ± 0.2	6.7 ± 3.5	1	76.5	6.8	0.24	6.2	I
Turpinia paniculata	1	81.3	4.2				0.27	11.1	–
Weinmannia balbisiana				1	71.7	4.7	0.64	0.5	–
caquetana	1	66.5	1.7	1	68.1	1.8	0.47	4.4	–

[a] In plants with large flowers, individual blossoms were analyzed. In plants with small flowers, the entire inflorescence was collected for analysis. [b] Flower availability represents the proportion of censused individuals that were flowering during biweekly phenology surveys. [c] e indicates an epiphytic species for which density was not determined. [d] Primate consumption indicates whether the flower (F), inflorescence (I), or neither (–) was eaten by resident nonhuman primates.

approximately 40 to 90%, varying with both tissue type and tissue maturity.

Productivity, based on species density and part availability, was highest in *Landerbergia macrocarpa* having a density of 18.8 trees/ha with leaves, flowers, and fruit available over 80% of the sampling times (Tables I–III). An unknown species of *Guarea* also had a density of 18.8 trees/ha with leaves and fruit available 50% of the sampling time (Tables I and II).

Of the 77 species inventoried in this study, 28 had portions of their tissue consumed by the Red Howler Monkey or the Blackcapped Capuchin (Tables I–III). There were no general indications of tissue preference as mature or immature specimens of fruit and leaves along with flowers were eaten from different species.

DISCUSSION

The ultimate value of any native ecosystem for agriculture depends upon the nutritional characteristics and availability of edible plants. Lack of inventories and nutritional analyses have prevented evaluation of tropical cloud forests as potential food and feed sources and thus little effort has been expended in preserving the adapted species of plants for agricultural use.

One of the greatest resource requirements in food production is protein (Pirie, 1975), and thus our initial analyses were for this food fraction. Of the plant tissues sampled, 10 have over 15% protein, the lower limit for a "protein source" designated by the International Biological Program (Pirie, 1975). Data from our analyses are consistent with previous reports where protein contents of tropical species have been examined. Hladik et al. (1971) in a sample of *Fiscus insipida* found 6.6% protein in immature fruit and an average of 5.3% protein in ripe fruit. Our analysis of *Fiscus insipida* indicated 6.4% protein in immature fruit and 4.1% protein in ripe fruit. Leaf samples of *Morus alba* and *Morus nigria* collected in India and West Pakistan (Malik, 1967; Sen, 1938) had 15 and 17% protein, respectively. Our analysis of mature leaves from an unidentified species of *Morus* indicated a protein content of 12.7%.

Actual use of plant species for food or feed purposes involves more than nutritional content. Such factors as productivity, edibility, and ease of harvest are also important criteria. A reasonable estimate of potential productivity can be related to the number of specific plants and the availability of the usable plant part. Our data reflected large differences in species density and leaf, fruit, or flower availability (Tables I–III). Problems of harvesting were not assessed in this study, but undoubtedly inefficiencies as well as the need to maintain healthy individuals for permitting repeated cropping would reduce realized harvests below the theoretical maximum production.

Consumption of plant parts by monkeys could indicate some species are edible by humans directly. Certainly these animals have evolved somewhat different digestive systems and enzymes than have humans (Fooden, 1964; Amerasinghe et al. 1971), and the generalization that humans can eat whatever monkeys can eat would be naive. This is particularly true with the *Alouatta* species, as these animals concentrate on plants of the family *Moraceae* (Gaulin, 1977) which often produce a copious and bitter latex. Nevertheless, monkeys in the sample area systematically chose foods of above average protein content (Gaulin, 1977).

Since protein content in this study is based on analysis of total nitrogen, the table values undoubtedly overestimate true protein content of tissue (Hansen, 1970). However, the tabular values should prove useful to individuals interested in relative protein content of tropical species and the protein-producing potential of native vegetation in tropical forests.

ACKNOWLEDGMENT

The authors thank Cynthia A. Gaulin for her assistance in collecting plant tissue, Gustavo Lozano C. and Roberto Jaramillo M., of the Herbario Nacional in Bogota, for their assistance in identifying plant specimens, the Büch family for their hospitality at Finca Merenberg and M. J. Starbuck for her assistance in protein analyses.

LITERATURE CITED

Amerasinghe, F. P., Van Cuylenberg, B. W. B., Hladik, C. M., *Ceylon J. Sci. Biol. Sci.* **9**, 75 (1971).
Association of Official Agricultural Chemists, "Official Methods of Analysis", 12th ed, Washington, DC, 1975.
Fittkau, E. J., Klinge, H., *Biotropica* **5**, 2 (1973).
Fooden, J., *Am. J. Phys. Anthropol.* **22**, 227 (1964).
Gaulin, S. J. C., Ph.D. Thesis, Harvard University, Cambridge, MA, 1977.
Hansen, E., in "The Biochemistry of Fruits and Their Products", Hulme, A. C., Ed., Vol. 1, 1970, p 147.
Hladik, C. M., Hladik, A., Bousset, J., Valdebouze, P., Veroben, G., Delort-Lawal, J., *Folia Primat.* **16**, 85 (1971).

Lanni, F., Dillon, M. C., Beard, J. W., *Proc. Soc. Exp. Biol. Med.* **74**, 147 (1950).
Malik, M. Y., Sheikh, A. A., Shah, W. H., *Pak. J. Sci.* **19**, 171 (1967).
Pirie, N. W., in "Food Protein Sources", International Biological Programme 4, Pirie, N. W., Ed., Cambridge University Press, 1975, p 16.
Sen, K. C., *Bull. Indian Coun. Agric. Res.* **No. 25** (1938).
Walter, H., in "Ecology of Tropical and Subtropical Vegetation", Walter, H., Ed., Van Nostrand Reinhold, 1971, p 177.

Received for review May 26, 1978. Accepted February 21, 1979. Financial support of this study was from NSF Grant No. BMS75-18154 and an L. S. B. Leakey Foundation grant to S.G.

Chemical Constituents of *Dolichos lablab* (Field Bean) Pod Exudate

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Analysis of the *Dolichos lablab* pod exudate by combined gas chromatographic–mass spectrometric method is described. The exudate is found to consist of homologous fatty acids and their methyl esters—42 in all—from C-11 through C-24, including the odd carbon chain compounds. Apart from *trans*-2-dodecenoic and *trans*-2-tetradecenoic acids, which constitute the major percentage of the oil, other homologous Δ^2-enoic acids and saturated acids and esters are also found.

Legume seeds form an important part of food, especially in poorer countries, and serve as a source of dietary protein (Evans et al., 1978; Mahadevappa and Raina, 1978). Seed pods of many legumes exude oily substances of an usually sweet odor. The exudates may be end products of a metabolic process or they may act as a protective coating for the pods. Because of their oderiferous character, they may possibly play some role in plant–insect relationships also. As a prelude to this study, we undertook to identify the chemical constituents of *Dolichos lablab* pod exudate, and the results are reported here.

Dolichos lablab, commonly referred to as field bean, is a legume some varieties of which secrete the so-called fragrant oil on the surface of their pods. In India it is an important multipurpose legume crop used as pulse, vegetable, and forage. Whereas its dried beans serve as pulse, its tender pod with beans or the green beans alone serve as vegetable. Because of its abundant foliage, the crop is employed as an excellent fodder. Besides India, it is also cultivated as a forage crop in the United States, Hungary, Nigeria, and many other countries. When used as a vegetable, the Indian consumers show preference for varieties with fragrant oil. Our preliminary observation has indicated that the exudate, even in low concentration, attracts the important insect pest of this crop, *Adisura atkinsoni*, whose life cycle appears to depend on the life cycle of the field bean plant (Govindan, 1974).

EXPERIMENTAL SECTION

The gas chromatographic–mass spectrometric (GC–MS) analyses were performed on a Finnigan 3200 E automated GC–MS instrument using a 1.52 m 3% OV-17 on Supelcoport 60/80 column, with temperature programmed at 12 °C/min from 50 to 300 °C. To establish the identities of the compounds in the exudate, GC–MS of the authentic samples were run under the same instrumental conditions.

Preparative GC was carried out on a Varian Aerograph Model 90-P using a 3.05 m 10% SE-30 on Chromosorb W column. Infrared spectra were obtained on a Beckman IR-33 infrared spectrophotometer, using liquid films between sodium chloride plates.

Isolation of the Exudate. The exudate was obtained by wiping the surfaces of mature green pods, while they were still on the plants, grown on GKVK Campus farm of the University of Agricultural Sciences, Bangalore, with small pieces (about 3 × 2 cm) of Whatman No. 1 filter paper. Each piece of filter paper with the exudate absorbed on it was quickly transferred to a bottle of petroleum ether (bp 50–60 °C). When the bottle was full, it was well shaken and the petroleum ether solution was decanted. Then the filter paper pieces were washed with methanol. The petroleum ether solution and methanol washings were combined and filtered. The solvents were removed under aspirator pressure at 40–50 °C, leaving a pleasant smelling oil, which was used as such for all subsequent work.

Separation of Acids from Esters A in the Exudate. About 2 g of the exudate was dissolved in 100 mL of ether and the resulting solution was extracted with saturated sodium bicarbonate solution (4 × 40 mL). The bicarbonate extracts were combined and carefully acidified with 3 M sulfuric acid. The regenerated free fatty acids were extracted with ether, dried over magnesium sulfate and the solvent was flash evaporated (aspirator pressure, 40–50 °C). The earlier neutral fraction was also dried ($MgSO_4$) and the solvent removed on a flash evaporator (aspirator pressure, 40–50 °C), leaving an oily residue referred to here as esters A. The weight ratio of esters A to free acids in the exudate is about 1:2.

Esterification of the Acids. The fatty acids were converted into their methyl esters (henceforth called esters B here) by the method of Clinton and Laskowski (1948) as described by Hickinbottom (1962). A solution of about 0.5 g of the acid mixture, 2 mL of methyl alcohol, and 5 drops of concentrated sulfuric acid in 15 mL of ethylene dichloride was refluxed overnight. After cooling, the reaction mixture was washed successively with water, sodium bicarbonate solution, and again water and then dried ($MgSO_4$). The solvent was rotoevaporated under aspirator pressure at room temperature to obtain esters B.

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0021-8561/79/1427-0795$01.00/0