Afr. J. Ecol. 1987, Volume 25, pages 279–293

Nutrients and toxins of plants in Amboseli, Kenya

S. A. ALTMANN*, D. G. POST† and D. F. KLEIN‡ *Department of Biology, University of Chicago, U.S.A. and Institute of Primate Research, National Museum of Kenya, †Department of Anthropology, Columbia University, and ‡Department of Anthropology, New York University, U.S.A.*

Summary

Nutrient and toxin analyses were carried out on wild foods that are eaten by the baboon (*Papio cynocephalus* (L.)) and black-faced vervet (*Cercopithecus aethiops* (L.)) and other animals in Amboseli National Park, Kenya. Data are provided on proximate composition (water, ash, fat, protein, fibre, other carbohydrates), fourteen minerals, four vitamins (folic acid, ascorbic acid, riboflavin, β-carotine) and a toxin (trypsin inhibitor). In total, 864 analyses were carried out on ninety-one foods from thirty-seven species of plants.

Résumé

On a réalisé des analyses des nutriments at toxines dans l'alimentation du babouin (*Papio cynocephalus* (L.)), du cercopithèque grivet (*Cercopithecus aethiops* (L.)) et d'autres animaux du Parc National d'Amboseli, Kenya. Les données fournies concernent la composition approximative en eau, carbone, graisse, protéine, fibres et autres carbohydrates. Quatorze minéraux, quatre vitamines (acide folique, acide ascorbique, riboflavine, carotène β) et un toxine (inhibitrice de la trypsin). Au total, 864 analyses furent réalisées sur nonante et un échantillons protant sur trente-sept espèces de plantes.

Introduction

As part of our researches on the behavioural ecology of primates (baboons and vervets) in the Amboseli region of southern Kenya, the nutritional compositions of many plant foods in the area are being analysed. Our results to date are summarized in this report. These data may be useful to others who are studying the foraging of animals in Amboseli or elsewhere.

Nutrients and toxins reported here include those obtained in a standard 'proximate analysis' (water, ash, lipids, proteins, fibres and non-fibre carbohydrates), several vitamins (folic acid, ascorbic acid, riboflavin, provitamin A), a toxin (trypsin inhibitor) and several mineral elements (P, K, Ca, Mg, Na, Al, Ba, Fe, Sr, B, Cu, Zn, Mn and Cr).

Materials and methods

All of the plant material was collected within the area formerly designated as the Maasai-Amboseli Game Reserve in southern Kenya, Africa. The habitat consists

*Correspondence: Prof. S. Altmann, 940 East 57th Street, Chicago, IL 60637, U.S.A.

Present addresses: †3225 33rd Place NW, Washington, DC 2008, U.S.A. and ‡Pratt Institute, Brooklyn, NY 11205, U.S.A.

primarily of savanna with scattered acacia trees. Permanent waterholes and swamps in the area have their own distinctive associated flora. The collection area of about 100 km^2 lies primarily within the boundaries of Amboseli National Park.

The collection area is bounded by Enkongo Narok Swamp on the east and north-east, by Nairabala Hill and the dry bed of Lake Amboseli on the west and north-west, and extends southward about 1 km south of Endoinyo Ositet Hill. The area is shown on the Kenya 1 : 50,000 map Series Y731, Sheet 181/1, Edition 2-SK (Survey of Kenya, 1963), in Squares BH and CH. Longitude 37°10'E and latitude 2°40'S run through the approximate centre of the area.

All of the samples were collected in 1973–1976 or 1980 during the phenophases in which they were being eaten by baboons or vervets, from within the home ranges of these animals. For each food, we attempted to collect at least 20 g each of representative samples of exactly what these primates eat, paying attention to plant part, size, colour, degree of ripeness, rejected components (e.g. rind, calyx, seeds, insect-infested material) and so forth. In some cases, material was analysed because the animals overtly avoided or discarded it, e.g. the seed coats of green seeds from umbrella trees (*Acacia tortilis*).

Further details on the role of these materials in the diets of baboons and vervets can be found in Altmann (1987), Klein (1978), Post (1978), Post *et al.* (1980). Many of these plant foods are eaten by other animals of the region, although for none of these other animals has foraging been investigated as intensively.

All samples with a number ending with /74 and all of the form M**/75 (where ** indicates two or three digits) were collected by D.P. All other samples whose references end with /75 and all of those ending /76 were collected by D.K. All others (designated 1A, 1B, 2A, 2B, etc.) were collected by S.A. except for 28B, collected by D.K. In many cases, one of the other co-authors or various other colleagues (see Acknowledgments) also helped.

The samples were preserved in one of three ways. For proximate analyses, most of S.A.'s and D.K.'s samples were frozen. This was done as soon after collecting as practical, usually within 1–2 h. These samples were collected in plastic-lined bags designed to hold freeze-dried foods (Foil Pak no. 6, Champion Packages Co., Columbus, GA). Particular care was taken with foods that were likely to desiccate rapidly after picking, e.g. the ovaries of *Trianthema ceratosepala*. The collecting bags were kept in the shade and were kept closed. The samples were collected, weighed, and frozen as quickly as possible.

After being sealed, the collecting bags were in turn sealed into clear polythene bags, to avoid changes in weight from surface condensation, then placed in a freezer or the freezing compartment of a refrigerator at Ol Tukai, in Amboseli. At about monthly intervals, these samples were packed with a bag of ice, wrapped in newspaper or other insulating material, and taken to Nairobi. There the samples were kept in a freezer until they were analysed. Other samples used for proximate analysis, including all of D.P.'s samples and the few samples used for mineral analysis, were air-dried, either in the sun (D.K.) or above an outdoor 'oven' (a heavy-gauge, steel ammunition box) that was kept warm by the coals of our campfire (D.P.).

For analysis of vitamins and trypsin inhibitor, samples were stabilized by placing them immediately after picking into 3–5% oxalic acid, in UV-proof jars. Very small items, such as the ovaries of *T. ceratosepala*, were placed directly into the solution. Larger items, such as the berries of *Azima tetracantha*, were first lanced, or cut into pieces. These wet-preserved samples were kept in a dark cabinet at our base camp at Ol Tukai until our next trip (usually monthly) to Nairobi, from which they were shipped by air freight to the Nutrition Division of the WARF Institute, in Madison, Wisconsin, where all of the vitamin analyses were carried out. Unfortunately, we did not know, at the time that we made our field collections, that Vitamin A and folicin are unstable in acid media (Altmann, 1979). Therefore, our values for these vitamins are probably underestimates. The preservation method that was used for each sample is indicated in the tabulated results below.

Quantitative analyses were carried out by three laboratories: the WARF Institute Inc., in Madison, Wisconsin, the National Agricultural Laboratories, Nairobi, and the Nutrition Laboratory, Department of Animal Production. University of Nairobi, Kabete. The methods of analysis, where indicated to us by the laboratories, are referenced in the Tables.

Except where data on water content were inadvertently missed, all analyses were converted to a fresh-matter basis, in order to compute the actual nutrient intakes of animals (Altmann, 1987).

At present, we have only limited tests of the consistency (replicability) of these chemical analyses and no tests of their accuracy (Altmann, unpubl). Although Table 1 lists several foods that were analysed more than once, the dates and places of collection for most of these materials were usually quite remote and the material was gathered by different people, so that one cannot rule out heterogeneity (sample-to-sample differences) as an explanation for any differences in composition. In one case, however, an attempt was made to check on consistency by analysing matched samples. Dry seeds of fever trees (*Acacia xanthophloea*) were divided into three piles. One pile (Sample 20B-2) was sent to WARF, the other two (21B, 22B), to the Nutrition Laboratory of the University of Nairobi. In each case, a proximate analysis was requested but the laboratories were not notified that these samples were in any way special. The difference between the largest and smallest of the three values for each nutrient are as follows: water 0%, minerals 0·2%, lipids 0·5%, proteins 1·0%, fibres 8·1%, soluble carbohydrates 7·6%. There is a large discrepancy for fibre, and therefore also for soluble carbohydrates, since the amount of the latter is determined 'by difference', i.e. by subtracting the sum of all other values from 100%. The discrepancy is primarily between laboratories: the two samples analysed in Kenya differ in fibre content by only 0·9%.

Results

The results of proximate analyses (water, ash, lipids, proteins, fibres and soluble carbohydrates) are given in Table 1 and those for several vitamins and trypsin inhibitor are given in Table 2. Results for mineral elements are given in Table 3.

In these Tables, each food is given a four-letter code. These codes are used to facilitate computerized data analysis of the data in these Tables (Altmann, 1987). The first two letters represent the taxon (species, where known). The third letter indicates the part of the plant: leaves, flowers, etc. The fourth letter represents the 'condition', e.g. degree of ripeness.

In Table 1, four assumed values are explained in the footnotes. One requires further comment. Our one laboratory report (721–75) for protein in dry *A. tortilis*

Table 1. Proximate compositions

Species Ref. no.	Date of collection (mo/day/yr)	Code	Plant part	Units in sample	g of fresh sample	g of unit	Water	Ash	Lipids	Protein	Fibre	Other carbo-hydrates	Preservation, laboratory§ and methods**
Abutilon mauritianum													
642/76	05/16/76	ABBU	Flower buds	200	15·98	0·080	84·3	1·3	0·5	3·5	3·2	7·2	F, UNNL†
Acacia tortilis													
13B	03/07/76	TOBS	Flowers	361	32·40	0·090	80·8	0·6	2·2	3·7	3·1	9·7	F, UNNL
M55/75	02/07/75	TOBS	Flowers	700	54·30	0·078	81·0	1·7	1·5	4·2	4·4	7·2	D, UNNL
12/76	01/28/76	TOBS	Flowers	478	30·30	0·063	78·9	1·2	2·2	4·4	3·7	9·7	F, UNNL
13/76	01/28/76	TOBU	Flower buds	485	24·70	0·051	80·5	1·1	1·9	4·8	3·5	8·2	F, UNNL
721/75	~09/25/75	TODR	Dry seeds	125	30·00	0·24	14·3	3·2	3·6	20·8	17·7	40·4(a)‡	N, UNNL
2B	08/02/74	TODU+YU	Green seeds+coats	260	17·55	0·068	69·9	1·2	0·6	7·3	4·6	16·3(b)	D, WARF–1
38B	07/20/76	TODU	Green seeds−coats	1429	59·78	0·042	65·8	1·8	0·4	3·3	4·2	24·4	F, UNNL
M331/75	07/13/75	TODU	Green seeds−coats	497	38·10	0·077	69·9	1·3	0·9	7·3	5·7	14·8	D, UNNL
653/76	07/22/76	TOGU	Sap		224·15		94·0	2·0	0·2	1·8	0·5	1·5	N, UNNL
717/75	10/03/75	TOLU	Young green leaves				69·9		1·3		3·6		F, UNNL
718/75	10/03/75	TOLU	Young green leaves	422	16·45	0·039	74·2	1·6	1·0				F, UNNL
719/75	10/03/75	TOLU	Young green leaves				69·9	1·9	1·3	5·2	3·8	18·0	F, UNNL
39B	07/20/76	TOYU	Coats of green seeds	1425	69·03	0·048	56·7	1·0	0·6	3·3	12·6	25·9	F, UNNL
40B	07/20/76	TOPU	Green pods−seeds	155	241·50	1·56	67·1	2·3	0·4	2·8	10·3	17·2	F, UNNL
M332/75	07/13/75	TOPU	Green pods−seeds	51	75·50	1·48	68·7	2·1	0·7	3·0	11·3	14·2	D, UNNL
M333/75	07/13/75	TOPU+DU	Green pods+seeds	158	352·90	2·23	72·4	1·9	0·8	4·0	8·6	12·3	D, UNNL
365/76	05/04/76	TOQU	Green thorns	375	21·18	0·056	78·5	0·6	0·9	6·0	3·6	10·5	F, UNNL
Acacia xanthophloea													
1892/74	10/24/74	FTBR	Detached flowers	1500	81·00	0·054	—	(7·0)	(4·9)	(11·3)	(15·0)	(61·8)	D, UNNL
5B	09/28/75	FTBS	Flowers	142	24·95	0·18	74·1	1·3	0·8	1·0	3·9	19·0	F, UNNL
720/75	~09/25/75	FTBS	Flowers	281	35·10	0·12	75·0	1·8	1·2	1·2	4·5	16·3	F, UNNL
20B–2	04/29/76	FTDR	Dry seeds		34·65		8·9	3·6	4·8	19·1	15·6	48·0	N, UNNL
21B	04/29/76	FTDR	Dry seeds	5131	24·95	0·005	8·9	3·7	4·3	18·1	22·8	42·3	N, UNNL
22B	04/29/76	FTDR	Dry seeds		24·60		8·9	3·8	4·3	18·9	23·7	40·4	N, UNNL
1899/74	10/24/74	FTDR	Dry seeds−coats		51·20		12·0	4·3	2·4	18·8	23·0	39·5	D, UNNL

50/76	02/20/76	FTDU	Green seeds − coats	551	19·95	0·036	75·3	2·0	2·6	10·7	2·7	6·7(c)	D, UNNL
1981.3	12/15/81	FTDU	Green seeds + coats	939	39·70	0·042	—	—	1·12	10·8	0·25	—	F, NAL
14B	03/07/76	FTGR	Brown/brown-black gum		136·50		18·0	4·3	2·1	1·4	18·4	55·8	N, UNNL
15B	03/07/76	FTGU	Clear/light amber gum		41·95		24·8	2·0	0·2	1·2	1·2	70·6	N, WARF–3
1894/74	10/24/74	FTGX	Gum		86·40		31·6	15·1	0·5	1·7	8·3	42·8	D, UNNL
2101/74	12/12/74	FTGX	Gum		130·90		11·2	3·1	1·6	0·6	1·1	82·4	D, UNNL
244/76	<04/13/76	FTLU	Young green leaves	338	33·70	0·10	72·2	1·9	0·7	5·9	3·8	15·6	D, UNNL
647/76	07/27/76	FTLU	Mature green leaflets	200	25·55	0·13	68·8	1·8	0·5	7·5	3·5	18·1	F, UNNL
32B	06/01/76	FTPR	Green pods + seeds	334	86·75	0·26	—	(5·4)	(1·7)	(9·7)	(39·4)	(43·8)	N, UNNL
1981.4	12/15/81	FTPU	Green pods − seeds	143	56·25	0·39	—	—	0·15	4·19	0·59	—	F, NAL
1981.1	12/15/81	FTPU + DU	Young green pods + seeds	186	62·90	0·34	—	—	0·90	6·81	0·85	—	F, NAL
2094/74	12/09/74	FTPU + DU	Green pods + seeds	500	144·00	0·29	77·3	2·0	0·9	4·1	10·3	5·4	D, UNNL
781/75	12/03/75	FTPU + DU	Green pods + seeds	97	24·15	0·25	75·3	1·6	1·4	3·5	6·1	12·1	F, UNNL
51/76	<04/13/76	FTQU	Green thorns	950	51·30	0·054	—	(2·7)	(9·1)	(20·9)	(16·9)	(50·4)	D, UNNL
M338/75	07/13/75	FTWC	Cambium		27·50		60·1	4·9	0·5	1·9	13·2	19·4	D, UNNL
Achyranthes aspera													
360/76	04/25/76	APLU	Young leaves	800	83·30	0·10	86·3	2·6	0·4	4·3	2·1	4·4	F, UNNL
Amaranthus graecizans													
7/76	12/20/75	AZWU + LU	Leaves + stems	450H	51·05	0·11	73·0	5·3	2·2	5·1	2·3	12·1	F, UNNL
363/76	04/25/76	AZWU + LU	Leaves + stems	1000H	53·75	0·054	89·6	2·8	0·2	2·6	1·4	3·3	F, UNNL
Azima tetracantha													
9B	06/12/76	ATFR	Ripe fruits	360	117·43	0·33	75·4	2·7	3·0	4·9	3·3	11·1	F, UNNL
777/75	11/03/75	ATFR	Ripe fruits	550	128·35	0·23	73·7	2·7	2·2	4·6	4·2	12·5	F, UNNL
1895/74	10/24/74	ATFS	Semi-ripe fruits	350	90·80	0·26	76·5	3·2	2·8	5·3	3·1	9·1	D, UNNL
34B	06/12/76	ATFU	Unripe fruits	335	76·28	0·23	72·7	3·6	3·7	6·9	4·3	8·8	F, UNNL
M325/75	07/12/75	ATFU	Unripe fruits	158	31·20	0·20	70·7	4·4	3·9	7·2	5·9	7·9	D, UNNL
Chlorophytum sp. *nr. bakeri*													
19B	04/29/76	CBLU	Green leaves	50	25·98	0·52	77·7	3·9	1·4	5·1	3·4	8·6	F?, UNNL
Commicarpus plumbagineus													
30B	05/29/76	SFFR	Ripe fruits	3988	32·23	0·008	57·4	4·3	9·6	13·0	4·9	10·8	F, UNNL
532/76	05/05/76	SFLU	Young green leaves	408	50·98	0·12	65·1	6·5	1·2	12·4	4·0	10·8	F, UNNL
Cordia gharaf													
M45/75	02/02/75	CFLU	Green leaves	40H	88·90	2·22	79·3	3·1	1·3	5·5	2·7	8·1	D, UNNL

Cont.

Table 1. (*Continued*)

Species Ref. no.	Date of collection (mo/day/yr)	Code	Plant part	Units in sample	g of fresh sample	g of unit	Water	Ash	Lipids	Protein	Fibre	Other carbo-hydrates	Preservation, laboratory§ and methods**
Cynodon dactylon													
M90/75	03/15/75	CDDU	Unopened seed heads	270	37·00	0·14	68·7	3·3	1·5	4·4	9·1	13·0	D, UNNL
8B	11/29/75	CDLU	Green tillers	325T	19·80	0·061	71·3	3·1	3·0	8·3	6·7	7·6	F, UNNL
8BS	12/09/75	CDLU	Green tillers	325T	22·80	0·070	66·6	3·1	2·5	6·5	8·0	13·3	F, UNNL
242/76	<04/13/76	CDDU+LU	Gr tillers+seed heads	674	35·80	0·053	—	(8·1)	(12·3)	(18·3)	(28·1)	(33·3)	D, UNNL
1893/74	10/24/74	CDLU	Green leaves	300H	80·90	0·27	72·1	4·6	1·2	4·0	8·9	9·2	D, UNNL
531/76	05/15/76	CDSU	Stolon node meristems	400	18·93	0·047	87·1	0·7	0·3	3·8	2·9	5·1	F, UNNL
643/76	07/08/76	CDTU	Pedicel meristems	900	9·27	0·010	87·1	0·7	0·5	1·7	4·1	6·0	F, UNNL
Cynodon plectostachyus													
M104/75	04/28/75	CPCU	Corms of green leaves	32	17·80	0·56	48·0	5·5	1·0	4·9	—	—	D, UNNL
1968/80	02/25/80	CPCR	Dry corms	288	27·75	0·10	31·8	3·1	1·2	9·2	9·8	45·0	F?, NAL
M46/75	02/02/75	CPLU	Green leaves	150H	47·80	0·32	71·0	5·2	2·3	5·9	5·0	10·6	D, UNNL
M103/75	04/28/75	CPLK	Leaves	70H	95·20	1·36	75·6	4·1	1·7	5·9	5·0	7·7	D, UNNL
Cyperus bulbosus													
23B	05/07/76	CUCU	Corms of green tillers	105	8·08	0·077		5·2	2·5	8·6	8·6		F, UNNL
Cyperus immensus													
M89/75	03/15/75	CILU	Green leaves	40H	87·10	2·18	85·2	1·3	2·1	0·8	2·2	8·4	D, UNNL
Cyperus laevigatus													
M326/75	07/12/75	CLWU	Stems	7H	82·10	11·73	77·9	2·6	0·7	1·3	8·4	9·1	D, UNNL
Cyperus obtusiflorus													
25B	05/07/76	COCU	Corms of green tillers	259	10·43	0·040	65·2	2·2	1·8	2·3	6·4	22·2	F, UNNL
M86/75	03/15/75	COCU	Corms of green tillers	370	25·80	0·070	27·7	6·6	4·9	5·2	12·5	43·1	D, UNNL
Dasysphaera prostrata													
M323/75	07/12/75	DPFX	Fruits	100	19·70	0·20	39·0	5·8	2·7	9·8			D, UNNL
Dicliptera albicaulis													
649/76	07/08/76	DIBS	Flowers	1100	14·65	0·013	72·9	1·7	0·4	3·7	7·4	13·9	F, UNNL
31B	05/29/76	DILU	Terminal growth		29·78		76·2	4·5	2·3	7·1	3·4	6·5	F, UNNL
M320/75	07/12/75	DILX	Green leaves	50H	42·90	0·86	66·2	6·6	4·4	7·2	6·5	9·1	D, UNNL
Erucastrum arabicum													
1966/80	01/11/80	ERPU+DU	Green pods+seeds	4613	130·20	0·028	63·7	6·1	4·4	10·2	5·9	9·7	F, NAL

Grewia villosa													
1967	02/19/80	GVFU	Green fruits	940	248·30	0·26	84·2	1·5	0·1	1·6	5·9	6·7	F, NAL
Justicia uncinulata													
319/75	07/12/75	JULU	Green leaves	100H	29·70	0·30	63·8	10·8	2·4	6·1	6·1	10·8	D, UNNL
Ludwigia stolonifera													
26B	05/15/76	LSWU	Stems	191·5 cm	27·18	1·60			2·3		27·7		F, UNNL
2099/74	12/11/74	LSWU	Leaves + stems	60H	37·50	0·63	82·4	1·6		4·3			D, UNNL
Lycium 'europaeum'													
364/6	12/09/75	TFBS	Flowers				80·3	1·7	1·0	5·5	4·4	7·2	F?, UNNL
29B	05/28/76	TFFR	Ripe fruits	932	45·88	0·049	70·8	1·7	6·5	8·4	4·5	8·2	F, UNNL
14/76	01/28/76	TFFR	Ripe fruits	1110	36·05	0·032	64·2	1·2	4·3	9·2	9·1	12·0	F, UNNL
644/76	07/22/76	TFLR	Mature leaves	400	20·43	0·051	82·3	3·9	0·4	5·0	2·0	6·4	F, UNNL
M53/75	02/07/75	TFLU	Green leaves	2200	93·30	0·042	83·8	4·7	1·1	4·7	2·6	3·1	D, UNNL
359/76	04/23/76	TFLU	Young green leaves	2945	112·95	0·038	90·1	1·9	0·6	3·9	1·2	2·3	F, UNNL
361/76	05/18/76	TFLU	Young green leaves	160	34·48	0·22	82·0	2·1	0·8	7·9	2·6	4·6	F, UNNL
Lyraeus mundtii													
M321/75	07/12/75	LMLU	Green leaves	40H	31·70	0·79	74·2	3·2	1·3	2·1			D, UNNL
Psilolemma jaegeri													
M329/75	07/12/75	PJLU	Leaves	20H	32·70	1·64	52·3	8·6	1·8	5·1	16·3	15·9	D, UNNL
Rhamphicarpa montana													
M48/75	02/02/75	RMBS	Flowers	70	27·90	0·40	80·2	3·0	2·0				D, UNNL
M50/75	02/02/75	RMLU	Green leaves	120H	42·60	0·36	80·3	4·0	1·5	5·1	3·1	5·9	D, UNNL
Salvadora persica													
M327/75	07/12/75	SPBS	Flowers	57H	48·40	0·85	71·8	6·0	1·4	6·7	4·8	9·3	D, UNNL
722/75	10/04/75	SPFR	Ripe fruits		17·90		84·3	1·2	0·9	0·7	3·5	9·5	N, UNNL
1898/74	10/24/74	SPFU + BS	Green fruit + flowers	40H	27·50	0·69	73·4	5·8	0·8	6·0	4·1	9·9	D, UNNL
1B	08/02/74	SPLU	Young green leaves	601H	20·00	0·033	72·1	6·1	0·5	8·1	2·3	10·8(d)	D, WARF–1
1897/74	10/24/74	SPLU	Young green leaves	700H	97·00	0·14	72·1	6·8	0·8	1·7	3·6	15·0	D, UNNL
Setaria verticillata													
27B	05/16/76	SVLU	Green tillers	159T	35·93	0·23	84·6	2·7	0·9	3·9	3·6	4·3	F, UNNL
M47/75	02/02/75	SVLU	Green tillers	40H	59·70	1·49	82·8	3·6	1·3		3·2		D, UNNL
M328/75	07/12/75	SVLU	Green tillers	20H	29·80	1·49	68·8	6·9	1·3	3·5	10·2	9·3	D, UNNL
366/76	04/24/76	SVLU	Young green tillers	500T	48·25	0·10	89·9	1·3	0·7	3·2	2·3	2·7	F, UNNL
Solanum dubium													
33B	06/05/76	SIFU	Unripe fruits	163	64·08	0·39	71·2	1·2	1·4	5·5	5·0	15·7(e)	F, UNNL

Cont.

Table 1. *(Continued)*

Species Ref. no.	Date of collection (mo/day/yr)	Code	Plant part	Units in sample	g of fresh sample	g of unit	Water	Ash	Lipids	Protein	Fibre	Other carbo-hydrates	Preservation, laboratory§ and methods**
Sphaeranthus suavolens													
2098/74	12/09/74	SLLU+WX	Green leaves+stems	60H	40·40	0·67	87·2	2·6		1·6			D, UNNL
Sporobolus 'africanus'††													
M54/75	02/07/75	SACR	Corms	425	21·20	0·050	44·1	7·6	2·7	6·5			D, UNNL
Sporobolus consimilis													
2097/74	12/09/74	SCLU	Green leaves		34·50		80·9	3·7		4·1			D, UNNL
M98/75	04/28/75	SCLU	Green leaves	14	31·70	2·26	65·0	3·1	0·9	2·7	14·6	13·7	D, UNNL
M97/75	04/28/75	SCTU	Lateral meristems	80	34·20	0·43	81·8	2·3	0·5	3·3			D, UNNL
243/76	<04/13/76	SCTU	Lateral meristems	200	30·15	0·15	76·3	3·5	1·2	5·9	4·7	8·5	D, UNNL
Sporobolus cordofanus													
3B	08/07/74	SMCR	Corms	223	7·80	0·035	11·7	16·3	0·8	11·9	18·2	41·1	N, WARF–1
M330/75	07/13/75	SMCR	Corms	78	21·20	0·27	39·8	5·2	1·7	8·7			D, UNNL
28B	05/05/76	SMDU	Unopened seed heads	500	22·98	0·046	76·4	1·5	0·9	4·9	6·7	9·7	F?, UNNL
M101/75	04/28/75	SMLU	Green leaves	190H	22·10	0·12	55·0	8·4	2·3	8·8	9·4	16·1	D, UNNL
M102/75	04/28/75	SMLU	Green leaves	240H	31·80	0·13	57·4	9·0	2·0	8·2	7·8	15·6	D, UNNL
Sporobolus kentrophyllus													
16B	04/09/76	SKCU	Corm cores	741	9·70	0·013	33·3	3·2	1·9	11·0	14·7	35·9	F, UNNL
M324/75	07/12/75	SKCU	Corms	45	21·00	0·47	25·2	4·9	1·1	9·5	18·2	41·1	D, UNNL
18B	04/08/76	SKLU	Green leaves	741T	2·45	0·003	71·3	4·1	1·6		7·0		F, UNNL
17B	04/08/76	SKPR	Dry corm sheaths	741	5·75	0·081	21·6	7·8	3·2	8·1	29·9	29·5	N, UNNL
Sporobolus spicatus													
M100/75	04/28/75	SSDR	Open seed heads	300	28·20	0·094	64·4	2·0	1·2	4·5	11·9	16·0	D, UNNL
M99/75	04/28/75	SSDU	Unopened seed heads	500	37·40	0·075	70·8	2·0	1·0	4·1	9·8	12·3	D, UNNL
2095/74	12/09/74	SSLU	Green leaves	700H	30·10	0·043	59·1	4·8	1·8	4·4	11·5	18·4	D, UNNL
Suaeda monoica													
648/76	07/25/76	SUBU	Terminal growth	125	39·98	0·32	80·6	0·9	0·3	7·5	1·6	9·1	F, UNNL
2096/74	12/09/74	SULU	Green leaves	90H	72·30	0·80	85·1	3·9		5·0	1·6		D, UNNL
M322/75	07/12/75	SULU	Green leaves	24H	79·40	3·31	81·7	5·8	0·8	2·2	1·5	8·0	D, UNNL

Trianthema ceratosepala													
7B	10/29/75	TCBU	Flowers	407	59·10	0·15	81·0	2·6	1·0	2·7	5·0	7·8	F, UNNL
1896/74	10/24/74	TCFU	Ovaries	608	9·90	0·016	53·4	3·7	3·1	8·2	18·5	13·1	D, UNNL
776/75	10/28/75	TCFU	Ovaries	934	30·35	0·032	72·0	2·8	2·3	4·7	10·6	7·5	F, UNNL
1900/74	10/24/74	TCPU	Pericarps	608	54·70	0·090	79·1	5·3	1·0	2·2	4·9	7·5	D, UNNL
Tribulus terrestris													
646/76	<08/01/76	TTFR	Dry fruits	1200	16·10	0·013	—	(7·3)	(13·6)	(17·2)	(45·7)	(16·2)	D, UNNL
24B	05/07/76	TTFU	Soft fruits	930	30·08	0·032	82·3	2·2	0·6	3·9	3·4	7·7	F, UNNL
M56/75	02/14/75	TTFU	Fruits	437	25·50	0·058	63·0	3·2			15·5		D, UNNL
M49/75	02/02/75	TTLU	Green leaves	800	26·20	0·033	75·0	3·8	2·3				D, UNNL
362/76	04/25/76	TTLU	Young leaves	1500	34·40	0·023	86·7	2·3	0·8	4·2	2·1	3·8	F, UNNL
Viscum hildebrandtii													
245/76	<04/13/76	VHFX	Fruits	80	7·65	0·096	8·8	7·9	11·1	3·9	12·0	56·3	F, UNNL
Withania somnifera													
35B	06/26/76	WSFR	Ripe fruits	321	25·93	0·081	65·3						F, UNNL
645/76	07/12/76	WSFR	Ripe fruits	180	14·15	0·079	61·1	0·9	2·8	7·3	12·9	15·1	F, UNNL
36B	06/26/76	WSFU	Unripe fruits	245	20·43	0·083	74·6	1·3	4·3	5·1	8·2	6·4	F, UNNL
2100/74	12/11/74	WSFU	Unripe fruits	260	17·50	0·067	80·9	1·3		3·8			D, UNNL

*All values are percentages by weight of fresh sample except figures in parentheses which are given on an anhydrous basis.

†(D) = dried; (F) = frozen; (H) = handfuls; (N) = no preservative; (T) = tillers.

‡(a) = Protein value assumed; (b) = Water content assumed from M331/75; (c) = Assumed water content from 781/75; (d) = Water content assumed from 1897/74; (e) = Fibre value assumed.

§*Laboratories:* NAL = National Agricultural Laboratories, Nairobi. UNNL = University of Nairobi Nutrition Laboratory, Department of Animal Production. WARF = WARF Institute, Inc., Madison, Wisconsin.

***Methods* UNNL: Water by air oven, ash by muffle furnace 600°C, fat by Soxhelt-diethyl ether extract, protein by macroKjeldahl, fibre by multiple extraction of nutrients, carbohydrates by difference.

WARF-1: Water by vacuum oven AOAC 122, 1970, 11th edition; ash by AOAC 123, 1970, 11th edition; fat by AOAC 128, 1970, 11th edition; protein by AOAC 16, 1970, 11th edition (%N × 6·25); fibre by AOAC 129, 1970, 11th edition; carbohydrates by difference; folic acid by AOAC 830, 1955, 8th edition; riboflavin by AOAC 789, 1970, 11th edition; ascorbic acid by *J. Biol. Chem.* **147,** 399, 1943.

WARF-2: Same as WARF-1 except riboflavin by AOAC 846, 1975, 43.139.

WARF-3: Water by AOAC 394, 1975, 12th edition, 22.013; ash by AOAC 222, 1975, 12th edition, 14·006; fat by AOAC 135, 1975, 12th edition, 7·047; protein by AOAC 15, 1975, 12th edition, 2·049 (%N × 6·25); fibre by AOAC 137, 1975, 12th edition, 7·054; carbohydrate by difference; folic acid by AOAC 770, 1965, 39·059; riboflavin by AOAC 846, 1975, 12th edition, 43·139.

WARF-4: same as WARF-3 except water by AOAC 282, 1975, 12th edition, 16·217; folic acid by AOAC 830, 1955, 38·48; anti-trypsin by *Cereal Chemistry* **51:** 376–382, 1974.

WARF-5: same as WARF-4 except folic acid by AOAC 770, 1965, 39·059; β-carotene by Ing. Eng. Chem., Anal. Ed., **13,** 600, 1941.

WARF-6: same as WARF-5 except folic acid by *Am. J. Clin. Nutr.* **21**(10): 1202, 1968; anti-tripsin by AOCS Ba 12–75, 3rd edition, Rev. 1976.

NAL: AOAC 1975, 12th ed.

††Almost surely *S. spicatus.*

Table 2. Vitamins, trypsin inhibitor

Species Ref. no.	Date of collection (mo/day/yr)	Code	Plant part*	Units in sample	g of fresh sample	(g/unit	Folic acid μg 100 g^{-1})	Ascorbic acid (mg 100^{-1})	Riboflavin (mg 100 g^{-1})	Trypsin inhibitor TIU (100 g^{-1})	β-carotene (mg 100^{-1})	Laboratory and methods‡
Acacia tortilis												
13A	03/07/76	TOBS	Flowers	200	20·00	0·10	35·4	178·3	0·5			WARF–3
2A	08/02/74	TODU	Green seeds + coats	236	15·60	0·066	<5·5	49·3	1·1			WARF–1
38A	07/20/76	TODU	Green seeds – coats	1120	39·85	0·036	2·1	<3·9	0·20	3284·4		WARF–7
39A	07/20/76	TOYU	Green seed coats	931	38·50	0·041	16·8	<4·8	1·7	5286·6		WARF–7
Acacia xanthophloea												
5A	09/28/75	FTBS	Flowers	150	20·90	0·14	48·3	110·8	1·3			WARF–2
20B–1	04/29/76	FTDR	Dry seeds		34·65		51·7	12·1	0·90	7·35		WARF–4
14A	06/25/76	FTGR	Brown/Brown-black gum		39·30		<5·1	13·4	0·08			WARF–5
15A	03/07/76	FTGU	Clear/light amber gum		56·55		14·5	<4·7	0·02			WARF–3
15AS	06/25/76	FTGU	Clear/light amber gum		49·35		<4·2	4·2	0·02			WARF–5
Azima tetracantha												
9A	02/09/75	ATFR	Ripe fruits	200	47·00	0·24	<14·7	49·0	0·14			WARF–2
9AS	06/29/76	ATFR	Ripe fruits	375	123·90	0·33	9·2	42·9	0·15			WARF–5
34A	06/12/76	ATFU	Unripe fruits	315	81·00	0·26	5·6	41·5	0·19			WARF–5
Chlorophytum sp. *nr bakeri*												
19A	04/29/76	CBLU	Green leaves	30	23·80	0·79	23·3	51·9	0·53			WARF–4
Commicarpus plumbagineus												
30A	05/29/76	SFFR	Ripe fruits	5054	30·00	0·006	33·2	12·0	0·72			WARF–5
Cynodon dactylon												
8A	11/29/75	CDLU	Green tillers	325T	19·80	0·061	<32·1	87·8	0·49			WARF–2
Ludwigia stolonifera												
26A	05/15/76	LSWU	Stems	168·5 cm	24·65	1·90	19·5	37·2	0·17			WARF–4
Lycium 'europaeum'												
10A	12/09/75	TFBS	Flowers	1013	12·30	0·012	85·0	35·7	1·1			WARF–2
29A	05/29/76	TFFR	Ripe fruits	1364	72·30	0·053	16·1	62·7	0·41		1·04†	WARF–5
11A	12/22/75	TFLU	Young green leaves	535	20·30	0·038	36·8	<7·5	0·50			WARF–4

Salvadora persica										
4A	09/28/75	SPFR	Ripe fruits	759	48·95	0·064	8·5	5·1	0·1	WARF–2
1A	08/02/74	SPLU	Young leaves	478	19·00	0·040	<4·2	127·5	0·58	WARF–1
Setaria verticillata										
27A	05/16/76	SVLU	Green tillers	152	31·85	0·21	49·8	56·6	0·20	WARF–4
Solanum dubium										
33A	06/05/76	SIFU	Unripe fruits	153	59·70	0·39	7·9	11·5	0·23	WARF–5
Sporobolus consimilis										
12A	03/06/76	SCTU	Lateral meristems	132	53·40	0·40	8·6	15·5	0·06	WARF–3
Sporobolus cordofanus										
3A	08/07/74	SMCR	Corms	121	8·05	0·067	<10·6	<35·3	0·24	WARF–1
Sporobolus kentrophyllus										
16A	04/08/76	SKCU	Corm cores	600	8·65	0·014	<25·1	<25·1	<0·25	WARF–4
Trianthema ceratosepala										
7A	10/29/75	TCBU	Floral buds	261	36·80	0·14	14·9	9·3	0·24	WARF–2
6A	10/29/75	TCFU	Fruits	591	20·20	0·034	14·1	14·1	0·87	WARF–2
Tribulus terrestris										
24A	05/07/76	TTFU	Soft fruits	1445	67·00	0·046	44·2	58·1	0·22	WARF–4
Withania somnifera										
35A	06/25/76	WSFR	Ripe fruits	512	49·05	0·10	8·9	61·8	0·43	WARF–5

*All samples preserved in oxalic acid except 20B–1 (no preservative).
†Equivalent to 1745 IU 100 g^{-1}.
‡See note (§) in Table 1.

Table 3. Elemental analysis, by emission spectroscopy (WARF Laboratories)

Species Ref. no.	Code	Plant part	%				Parts per million									
			P	K	Ca	Mg	Na	Al	Ba	Fe	Sr	B	Cu	Zn	Mn	Cr
Salvadora persica																
1B	SPLU	Young green leaves	0·12	0·84	1·45	0·26	0·03	59·6	12·4	48·4	206	28·9	2·5	4·8	26·2	4·1
Acacia tortilis																
2B	TODU+YU	Green seeds+coats	0·10	0·37	0·15	0·10	0·01	5·3	3·0	11·8	18·4	6·8	2·4	5·6	6·2	1·3
Sporobolus cordofanus																
3B	SMCR	Corms	0·40	1·38	1·27	0·69	0·90	4290	55·4	4050	192	37·0	10·7	18·1	216	14·2

seeds, namely 1·7%, is surely wrong, judging from the literature on leguminous seeds, including other *Acacia* species (Gwynne, 1969) and consequently so too is the reported very high carbohydrate level, which is calculated by difference. No other analysis of *A. tortilis* seeds has been found in the literature. We therefore used the mean (23·7% of dry weight) of the four values given by Gwynne (1969) for seeds of other acacias with indehiscent pods. This was converted to a fresh-matter 20·3% protein for seeds with a water content of 14·3%, and the value of carbohydrate was then adjusted accordingly. Even this value may be an underestimate, since protein in the pods with seeds of this species was 4·0% of fresh matter, equivalent to 14·6% of dry matter (17·8% of dry matter in Dougall, Drysdale & Glovers' 1964 report on material collected in nearby Tsavo National Park) and in Gwynne's 1969 report, the mean ratio of protein in seeds to protein in pods plus seeds for four analyses of indehiscent acacias was 2·0, which suggests 25·3% protein (fresh-weight basis) for the seeds of *A. tortilis*.

Taxonomic notes

We have relied on the East African Herbarium (now the Kenya Herbarium) for identification of plants in Amboseli, and a small herbarium collection is maintained in the Park. All plants used in this report were identified by the authors by comparison with these Herbarium-identified specimens.

The systematics of East African plants is still imperfectly known. The following taxonomic notes are based on our discussions and correspondence with the Herbarium staff, whose assistance and patience we are happy to acknowledge.

Some lilies recorded as *Ornithogalium donaldsonii* may have been *O. ecklonii*, which also occurs in Amboseli. Several grass species have recently been separated from *Cynodon dactylon* (Clayton, Phillips & Renvoize, 1979). Material gathered around a waterhole in the Amboseli study area during 1980 and typical of material formerly identified as *C. dactylon* was identified at the Kenya Herbarium as *C. nlemfuensis*. *Dasysphaera prostrata* is now a synonym of *Volkensinia prostrata* and *Solanum dubium* of *S. coagulans*. Plants that S.A. referred to as *Sericocomopsis hildebrandtii* are probably *Achyranthes aspera* L. var. *pubescens*. *Psilolemma jaegeri* (syn. *Odyssea jaegeri*) may have been confused with *Odyssea paucinervis*.

Sample descriptions

For the material included in each sample, we have prepared detailed descriptions that will be useful to anyone attempting to apply, replicate or compare our results. However, these descriptions are too bulky to publish. Copies of the full text are available from the authors or from the Primate Center Library, Wisconsin Regional Primate Research Center, Madison WI 53715 (tel. 608-263-3512). In addition, a copy has been deposited in the library of the Institute for Primate Research, National Museums of Kenya, Nairobi.

Discussion

This report gives the results of 864 biochemical analyses from ninety-one primate foods obtained from thirty-seven species of plants in Amboseli. Many of these foods are eaten by other animals, as well.

Several related studies have been carried out in Amboseli. Wrangham & Waterman (1981) analysed total phenols and tannins from many of the vervet monkeys' plant foods. Post (1978) mapped a large portion of this area into hundreds of plant zones, on the basis of a classification of twenty-three zone types. Altmann (1976) and Western (unpubl.) have been studying demographic changes in the acacia trees of Amboseli. The exudates of these trees have been analysed by Hausfater & Bearce (1976) and the effects of herbivores on them have recently been studied by Michael Milgroom. Klein (1978) has studied phenological changes in the Amboseli flora and effects of these changes on vervet monkey breeding seasons. We are currently monitoring key phenological changes on a routine basis. Long-term changes in the Amboseli habitat have been described by Western (1973) and by Western & van Praet (1973).

As a result of these studies, the Amboseli region is now one of the world's most intensively studied natural feeding areas for primates. Much work remains to be done, however. For a number of foods, proximate analyses have not yet been carried out and, to date, few analyses have been made of components within the proximate classes. So, for example, while complementarity between the amino acids of the grasses and legumes is suspected on the basis of related cultivars (Altmann, 1987), no analyses of amino acids have been carried out yet. (Such a study has recently been initiated by S. A. Altmann and Robert Heinrickson.) The only plant toxins that have been analysed to date are trypsin inhibitor, total phenols and tannins, and those only from a few Amboseli plants. Toxins of some of the local species, e.g. *Solanum incanum* (Watt & Breyer-Brandwijk, 1962) are known from research at other sites. Only a few analyses of micro-nutrients have been carried out (Tables 2 and 3) and at present we have only very limited data on phenological changes in nutrients and toxins.

Acknowledgments

Our research was supported by the following grants: MH 19617 from the U.S. Public Health Service to S.A.; grants from the National Science Foundation, the Society of Sigma Xi and the Boise Fund to D.P.; grants from the National Science Foundation, the National Institutes of Health and the Society of Sigma Xi to D.K. Several people worked with us in the field to collect the plant samples: Rachel and Michael Altmann, Glenn Hausfater, the Hans Kummer family, Jane Scott, Peter Stacey, Roxana Jansma, Vicki and Rob Foley. Much advice on field preservation of samples was provided by David Aulick of WARF Laboratories. The staff of the East African Herbarium (now the Kenya Herbarium) identified our numerous plant specimens, a service that was indispensible for this project. We are grateful to the Republic of Kenya for permission to do research in Amboseli and to the two successive wardens of Amboseli, Joseph Kioko and Bob Oguya, for their support and co-operation.

References

ALTMANN, S.A. (1976) *The Acacia Woodland of Amboseli National Park: Current Status and Future Developments.* Report to Director, Kenya National Parks.

ALTMANN, S.A. (1987) *Foraging for Survival: Yearling Baboons in Amboseli.* University of Chicago Press. Chicago.

ALTMANN, S.A. & ALTMANN, J. (1970) *Baboon Ecology: African Field Research.* University of Chicago Press, Chicago.

CLAYTON, W.D., PHILLIPS, S.M. & RENVOIZE, S.A. (1974) *Flora of Tropical East Africa, Gramineae (Part 2).* Crown Agents for Overseas Governments and Administrations, London.

DOUGALL, H.W., DRYSDALE, V.M. & GLOVER, P.E. (1964) The chemical composition of Kenya browse and pasture herbage. *E. Afr. Wildl. J.* **2,** 82–125.

GWYNNE, M.D. (1969) The nutritive values of *Acacia* pods in relation to *Acacia* seed distribution by ungulates. *E. Afr. Wildl. J.* **7,** 176–178.

HAUSFATER, G. & BEARCE, W.H. (1976) Acacia tree exudates: their composition and use as a food source by baboons. *E. Afr. Wildl. J.* **14,** 241–243.

KLEIN, D.F. (1978) *The Diet and Reproductive Cycle of a Population of Vervet Monkeys* (Cercopithecus aethiops). Ph.D. dissertation, New York University.

POST, D.G. (1978) *Feeding and Ranging Behavior of the Yellow Baboon* (Papio cynocephalus). Ph.D. dissertation, Yale University.

POST, D.G., HAUSFATER, G. & MCCUSKEY, S.A. (1980) Feeding behaviour of yellow baboons (*Papio cynocephalus*): relationship to age, gender and dominance rank. *Folia Primatol.* **34,** 170–195.

WATT, J.M. & BREYER-BRANDWIJK, M.G. (1962) *The Medicinal and Poisonous Plants of Southern and Eastern Africa.* Livingstone, London.

WESTERN, D. (1973) The changing face of Amboseli. *Africana* **5**(3), 23–29.

WESTERN, D. & VAN PRAET, C. (1973) Cyclical changes in the habitat and climate of an east African ecosystem. *Nature* (Lond.) **241,** 104–106.

WRANGHAM, R.W. & WATERMAN, P.G. (1981) Feeding behaviour of vervet monkeys on *Acacia tortilis* and *Acacia xanthophloea*: with special reference to reproductive strategies and tannin production. *J. Animal Ecol.* **50,** 715–731.

(Manuscript received 9 September 1984)