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ORIGINAL ARTICLE

Nutritional Composition of Some Wild Plant Foods and Honey Used by Hadza Foragers of Tanzania

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We report compositional data for several foods that comprise the annual diet among Hadza foragers near Lake Eyasi in northern Tanzania. Samples collected during daily gathering trips over three fieldwork seasons were prepared according to Hadza methods. All three types of honey show moisture and starch levels similar to United States' honeys but higher levels of protein, fat, and ash. Several samples had significant fat levels probably due to the inclusion of bee larvae. The macronutrient composition of six fruits is comparable to those of agricultural fruits, although they were somewhat higher in crude protein, carbohydrate, and energy and somewhat lower in fat. Baobab seed flour and fruit pulp are low in energy compared with most previously published results, partially because our study measured fiber directly, unlike the methods used in any other studies. Baobab seed is high in protein and fat as reported in other studies. Our field observations, in combination with our analytical data, suggest that baobab seed is an important source of energy and protein for these foragers.

Key Words: hunter-gatherers; Tanzania; East Africa; wild plant foods; baobab; honey; Hadza; food composition.

INTRODUCTION

Many wild plant and animal food resources are eaten across Africa in addition to the more commonly known agricultural foods and domesticated animals. We analyzed several of these foods that comprise a significant portion of the annual diet among the Hadza foragers who live in an area surrounding alkaline Lake Eyasi in northern Tanzania (Woodburn, 1968; Vincent, 1984; Hawkes *et al*., 1989). The region, which is semiarid with marked wet and dry seasons, encompasses open grassy plains, woodland/savanna, and wooded riverbeds. Due to inter- and intra-annual variability, there is no general consensus concerning the seasonal availability of specific foods but, in

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general, large animals, baobab (*Adansonia digitata*) fruit pulp and seeds, a few berry species, and a little honey are available during the dry season. Small animals, tubers, most fruits, baobab seeds and the majority of honey are available during the wet season (Woodburn, 1968; Vincent, 1984; Bunn *et al*., 1988; O'Connell and Hawkes, 1988; Hawkes *et al*., 1989).

Baobab (Prentice *et al*., 1993; Yazzie *et al*., 1994; Nordeide *et al*., 1996) is eaten opportunistically by several foraging and agricultural people across eastern and southern Africa. Yet, previous reports on baobab pulp and seeds from other regions (Busson, 1965; Wehmeyer, 1966; Nour *et al*., 1980; Addy and Eteshola, 1984; Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Salami and Okezie, 1994; Yazzie *et al*., 1994; Addy *et al*., 1995; Glew *et al*., 1997) include markedly inconsistent compositional data. The single study of Hadza foods (Vincent, 1984) reports on various species of tubers which also show inconsistent nutrient composition. Little is known about the macronutrients or energy provided by most of the fruits and of the honeys that are major non-meat foods for the Hadza during much of the year. Our aim was to provide such data.

A series of recent papers has begun to detail the nutritional contributions of wild foods in West Africa (Yazzie *et al*., 1994; Glew *et al*., 1997; Cook *et al*., 1998). The following is one of the first to provide such data for East Africa (see also Uiso and Johns, 1996). The significance of the results should apply to other groups in the region, since the area is marginal for agriculture, and commonly, there are periods of crop failure and animal die-offs in severe dry seasons. In a nearby, similarly marginal, agricultural region in north-central Tanzania, the Sandawe experienced at least 20 years of significant food shortage in a 100 year period, and their knowledge of indigenous foods has been credited for their survival (Newman, 1975).

METHODS

Field Collection

Plant and honey samples and processing information were collected during daily gathering trips in wet and dry seasons of 1993, 1994, and 1997. Samples obtained for analysis are representative of foods typically consumed by group members and reflect a significant number of foods eaten by the Hadza, with the exception of meat and tubers. Because food is not always abundant, the amount of sample available for collection was frequently limited. Our analyses were limited to the portion normally consumed as prepared by the Hadza.

Individual samples from 11 indigenous foods were obtained for analysis: honeys from three different types of bees, six fruit species, baobab fruit pulp, and a flour made from the baobab seeds dispersed throughout the fruit pulp. The edible portion of the 6–8 inches baobab fruit is surrounded by a hard, green shell covered by short hairs that feel similar to those covering agricultural peaches. Inside the shell is the pulp, a dry and chalky tissue that is usually consumed straight from the pod but is sometimes crushed and mixed with water. Baobab pulp was collected in the field by scraping the fruit flesh from the shell-like pod. The seeds were removed from the pulp by hand, crushed with a stone and winnowed on the surface of a dried animal hide to remove seed coats from the flour (see Fig. 1). The Hadza eat the flour dry or mixed with a little water. Our analyses were limited to seed flour produced in the Hadza manner. The Hadza also obtain undigested seeds from baboon dung piles beneath baobab trees (our unpublished data) which they wash, sun-dry and pound into flour as above.

FIGURE 1. A Hadza woman preparing baobab seed flour. The seeds are removed from the dry fruit-pulp, which is eaten separately. The flour is produced by crushing the seeds with a hammerstone followed by winnowing on the surface of a dried animal hide to remove seed coats. The Hadza eat the flour dry or mixed with a little water. Photograph by Shawn S. Murray, 1994.

Individual samples of six fruit species[3] were collected, including five berries [hlukayebe (*Grewia villosa* Willd.), kongolubi (*Grewia bicolor* Juss.), masakapi (*Cordia* cf *crenata* Del.), undushibi (*Cordia* cf *sinensis* K. Schum.), and kisinubi (*Cordia* cf *sinensis* K. Schum.)] and a drupe [pawe, *Sclerocarya birrea* or *Sclerocarya caffra*, also

[3] Herbarium plant samples were collected for identification purposes during the dry and early wet seasons of 1993/94 and the late wet season of 1995. Flowers, seeds, and leaves were taken as available, labelled, and air-dried in plant presses for return to the U.S. Samples were identified in Nairobi by Mr Frank Magogo, Herbarium Department, Kenya National Museums and in the United States by Shawn S. Murray under the direction of Dr Roy Gereau, Center for African Botany, Missouri Botanical Gardens.

known as marula; see Newman, 1975; Lee, 1979; Peters, 1988, 1993]. Two of the berries (kisinubi and undushibi) are distinguished with different names by the Hadza although they appear to be the same species (*Cordia* cf *sinensis*) based on leaf morphology (see footnote 3). The two were analyzed separately and are referred to below as different berries.

The berries tend to have little flesh with large seeds. The drupe, pawe, is apricot-like with soft flesh surrounding a hard nut which is valued for its nutmeat in eastern and southern Africa. The Hadza eat the pawe fruit flesh from the nut. When eating berries, they expectorate many seeds; the remainder passes through the Hadza digestive systems without alteration. Two of the berries, hlukayebe and kongolubi, are commonly eaten in a raisin-like state after they have dried on the bush, whereas the other berries and pawe are eaten when ripe and full of moisture. All fruits were collected in the state normally eaten by the Hadza. All fruits, with one exception, were air-dried in the shade to facilitate transport. Hlukayebe (*Grewia villosa*) was sun-dried and the dry, papery hull loosened from the berry by vigorous rubbing between the hands and winnowed by blowing, following the Hadza method. The six honey samples were not subjected to any in-field processing.

Laboratory Processing

Each honey sample was blended with distilled water (1:10, vol:vol) and lyophilized. Baobab fruit pulp and seed flour were ground using a mortar and pestle. Berry samples were stirred vigorously (35–39°C, $\sim$ 2.5 h) in distilled water to allow recovery of the edible portion for analysis. After 1 h of stirring, berry skins were punctured to facilitate berry disintegration and release of the berry flesh. One berry, kongolubi, had fibers that were tenaciously bound to the seeds. These were not forcefully detached from the seeds, as they probably were not typically removed in the mouth of the Hadza. Seeds were removed from the berry skin and flesh and the aqueous solutions containing berry skin and flesh were lyophilized and ground using a mortar and pestle. Berry seeds were not included in compositional analyses since swallowed seeds pass through the Hadza digestive system unbroken. Pawe flesh was separated from the pawe seed and only the flesh was analyzed as the Hadza eat the flesh from the seed.

Analytical Methods

The analytical procedures included determination of moisture, fat, protein, and ash. In addition, total dietary fiber and starch, where appropriate, were measured to distinguish the various carbohydrate fractions. The fraction containing mono- and disaccharides was calculated by difference. All analyses were conducted in duplicate using dry (i.e., lyophilized) sample.

Moisture contents of the honeys were determined by lyophilization to a constant weight (Marlett, 1992). The moisture contents of the baobab pulp and flour were determined by vacuum oven-drying (70°C, 5 h) (Marlett, 1992). Moisture content of the non-baobab fruits was calculated in the field with the seeds included as the difference between the collected sample weight (i.e., fresh weight or, in the cases of hlukayebe and kongolubi, raisin-like weight) and the sample weight after it had air-dried to a constant weight in shade or, in the case of hlukayebe, in sun. The drupe, pawe, was air-dried in the shade to a constant weight with the seed removed since the Hadza do not swallow the seed. Limited amounts of sample prevented measurement of residual moisture in the berries. Moisture was estimated to be $\sim$ 5% because the whole dried berries with skin intact did not take up moisture, as exposed flesh of fruit does.

Total fat was extracted using a modified AOAC method 14.019 (Conway and Adams, 1975). Briefly, fat was extracted from 1 g aliquots by heating in alcoholic HCl, followed by the addition of 95% ethanol. The sample was allowed to cool, ether and sodium sulphate were added, and the sample was shaken. Petroleum ether was added, and the sample was shaken again. The acidic ethanol layer was re-extracted twice more with a mixture of ether and petroleum ether. The combined, recovered supernatants were allowed to evaporate in a ventilated area, and any trace of moisture was eliminated by drying in a forced air oven (100°C, 1.5 h) prior to gravimetric determination.

Nitrogen was measured in small aliquots (25–100 mg) by a micro-Kjeldahl method (Buchi-Brinkman digestion unit model 430 and distillation unit model 320, Brinkman Instruments, Inc, Westbury, NY) (Monsma *et al.*, 1992). Crude protein was estimated as the nitrogen content multiplied by 6.25. To determine ash, 400 mg dry aliquots were ashed (450°C, 24 h), allowed to cool, wet with concentrated nitric acid, returned to the muffle furnace overnight ($\geq$ 16 h), and allowed to cool in a desiccator before weighing.

Total dietary fiber content was determined by an enzymatic-gravimetric procedure (AOAC method 985.29, Prosky *et al.*, 1992), using 1 g aliquots and reagents and enzymes from Sigma Chemical Co. (St. Louis, MO), as previously described (Vollendorf and Marlett, 1993). Fat was extracted from baobab seed flour prior to fiber analysis, as recommended. Starch was measured by an enzymatic-colorimetric method (AACC, 1976; method 76–11) on small samples (10–100 mg). Briefly, ethanol-extracted sample (to remove simple sugars) was autoclaved to gelatinize starch, incubated with enzyme to hydrolyze starch and the liberated glucose quantitated by glucose oxidase.

RESULTS

Fat Analysis

Among the three types of honeys analyzed, fat content is generally low (8% dry wt. or less), and two samples (N!ateko-2 and Kanoa-2) have extremely low levels ($<$2% dry wt.). Fat levels of the non-baobab fruits are also consistently low (2% dry wt. or less). Baobab pulp has the lowest ($<$1%) fat content by dry weight, whereas baobab seed has almost 30% fat by dry weight (see Table 1).

Protein Analysis

The three types of honeys, the six non-baobab fruits and the baobab pulp show consistently low crude protein levels. For the honeys and baobab pulp, the levels are $<$ 4% of dry weight and among the non-baobab fruits, the values range from a low of 3.6% (*Sclerocarya birrea*) to a high of 15.2% (*Cordia sinensis*) on a dry weight basis. In contrast, the baobab seed flour contained $\sim$ 36% protein in dry weight.

Carbohydrate Analysis

Several types of carbohydrates were measured, and the results vary across the different food types. In terms of starch, the honeys and baobab seed have only a trace. Starch was not measured in the non-baobab fruits because of limited sample but, based on compositions in other east African berries and drupes (Conklin-Brittain *et al.*, 1998), we assume that the ones eaten by the Hadza contain only a trace of starch. Only the baobab pulp contains measurable starch levels (11% dry wt.).

TABLE 1

Nutritional composition of foods consumed by Hadza foragers

Sample[1]	Moisture[2] %	Crude protein	Fat	Starch[3]	Simple sugars[4]	Dietary fiber[5]	Ash	Energy[6] (kJ (kcal) /100 g dry wt.)
		(g/100 g dry wt.)						
Honey								
Ba'alako-1	17.8	3.8	8.1	tr	87.7	—	0.4	1835 (439)
Ba'alako-2	12.4	2.7	6.2	tr	90.5	—	0.6	1793 (429)
N!ateko-1	23.5	3.2	5.1	tr	90.8	—	0.9	1764 (422)
N!ateko-2	—	3.1	1.3	tr	94.8	—	0.8	1685 (403)
Kanoa-1	21.6	3.1	6.2	tr	89.9	—	0.8	1789 (428)
Kanoa-2	—	1.7	1.5	tr	96.0	—	—[7]	1689 (404)
Baobab								
Ground seed	4.8	36.3	29.3	tr	11.2	14.1	9.1	1898 (454)
Pulp	4.7	2.5	0.7	11.0	35.6	45.1	5.1	849 (203)
Non-baobab fruit								
Kisinubi (*Cordia* cf *sinensis*)	73.0	12.6	1.8	—	68.8	11.6	5.2	1430 (342)
Undushibi (*Cordia* cf *sinensis*)	71.0	15.2	—[7]	—	61.4	13.6	7.8	1354 (324)
Masakapi (*Cordia* cf *crenata*)	69.0	12.7	1.9	—	62.5	17.8	5.1	1329 (318)
Hlukayebe (*Grewia villosa*)	24.0	7.1	—[7]	—	72.7	13.4	4.8	1409 (337)
Kongolubi (*Grewia bicolor*)	26.0	12.0	2.0	—	66.1	13.2	6.7	1379 (330)
Pawe (*Sclerocarya birrea*)	83.0	3.6	—[7]	—	49.9	37.7	6.8	970 (232)

Note: tr is < 0.5%; — is not determined.

[1] All samples were collected during the 1994 wet season, except Ba'alako-2, which was collected during the dry season of 1993, and Pawe which was collected during the dry season of 1997. The two samples of N!ateko were collected at different locations in the 1994 wet season.

[2] Non-baobab fruit moisture was measured in the field (see text) and is reported with seeds intact, except for Pawe where the nut-like seed was removed prior to weight determination.

[3] Based on carbohydrate analyses in other East African fruits (Conklin–Brittain *et al*., 1998), we assume that the berries contain only a trace of starch.

[4] The fraction containing monosaccharides and disaccharides was calculated by difference.

[5] Based on commercial honeys (Gojmerac, 1981), we assume that dietary fiber in the honeys is virtually absent.

[6] Energy was calculated using 16.7 kJ (4 kcal)/g for protein and carbohydrate and 37.6 kJ (9 kcal)/g for fat.

[7] Assumed level equivalent to that in similar samples.

In terms of dietary fiber, the honeys were not analyzed but based on commercial honeys (Gojmerac, 1981), we assume that dietary fiber is virtually absent. The five berries have relatively consistent fiber contents ranging from 12 to 18% dry wt., but the dry weight of pawe fruit has almost 40% fiber. Baobab seed has a level similar to the berries, and the pulp is similar to pawe fruit at 45% dietary fiber in dry weight.

In terms of mono- and disaccharides, the honeys contain the highest level (up to 96% dry wt.), followed by the berries (60–70% dry wt.) and the pawe fruit (50% dry wt.). This is followed by baobab pulp (36% dry wt.), and baobab seed has the lowest level (11% dry wt.).

Energy

In calculating the energy content of these foods, we used 38 kJ (9 kcal)/g for fat and 17 kJ (4 kcal)/g for protein and carbohydrate (all on a dry weight basis); dietary fiber was not included in the carbohydrate fraction for energy calculations. The honeys and the baobab seed provide roughly equivalent amounts of energy on a dry-weight basis [1670–1900 kJ (400–450 kcal)/100 g dry weight]. The berries are lower by about 420 kJ (100 kcal)/100 g dry weight at 1255–1420 kJ (300–340 kcal)/100 g dry weight. Pawe fruit and the baobab pulp are similar to one another at 835–960 kJ (200–230 kcal)/100 g dry weight and are lower than the berry fruits by about 420 kJ (100 kcal)/100 g dry weight.

Variation

Two of the three honeys show marked differences between the two individual samples analyzed. This probably reflects different amounts of included bee larvae and pollen, as discussed below.

DISCUSSION

The three types of honey all show consistently low crude protein, relatively high moisture, variable but relatively low fat, trace levels of starch, and low ash content. The percent of mono- and disaccharides in dry samples is $\sim 90\%$, and the energy level is > 1670 kJ (> 400 kcal) per 100 g of dry weight. The six samples of honey that we analyzed are similar to the average for 490 American honeys (White *et al.*, 1962) in levels of moisture and mono- and disaccharides, but the Hadza honeys show relatively higher levels of protein, fat, and ash. The Hadza do not remove the bee larvae from the combs as they are eaten, which probably accounts for these slightly higher levels compared with cleaned, United States' honeys. As expected, sugars were the major energy source in the honeys, providing 80–95% of the energy, although several samples had significant fat levels. Combs eaten by the Hadza, other than the ones we analyzed, may contain significantly more larvae; therefore, we suggest that they could provide an important fat source during parts of the year.

The non-baobab fruits consisted of 20–80% moisture, but the majority have $\sim$70%. The hlukayebe (*Grewia villosa*) and kongolubi (*Grewia bicolar*), which are eaten dry directly from the bush, have the lowest levels of moisture. In contrast, pawe (*Sclerocarya birrea*), which has the highest moisture level, and the berries with more moisture can provide a significant amount of water for the Hadza. The berries provide more energy than baobab pulp, although not at the level provided by baobab seeds or honey. When compared with agricultural American blackberries (*Rubus* sp.) and raspberries (*Rubus* sp.) (USDA, 1982), the Hadza fruits are somewhat lower in fat (around 2 g versus 2.8 g and 4.5 g/100 g dry wt., respectively) and somewhat higher in digestible carbohydrate (61–73 g versus 61 g and 54 g/100 g dry wt., respectively). Therefore, the Hadza fruits are higher in total energy [1329–1430 kJ (318–342 kcal)/100 g dry wt.] than are blackberries [1204 kJ (288 kcal)/100 g dry wt.) and raspberries [1179 kJ (282 kcal)/100 g dry wt.] (calculated from data in USDA, 1982). Thus, when available, these berries are good sources of energy for the Hadza. Hadza berries are also higher in protein (7–15 g/100 g dry wt.) than are blackberries (5 g/100 g dry wt.) and raspberries (7 g/100 g dry wt.), although the amino acid compositions are necessary to assess protein quality. We were unable to perform this analysis due to the small size of the available sample but assume that it is not of particularly high quality. When eaten fresh, the total protein of these fruits should be quite low.

Our data on baobab are, with some exceptions, similar to those previously published (see Table 2), although there is marked variation among the published values. Previous estimates for energy in seeds range from 1505 to 2341 kJ (360–560 kcal)/100 g of dry weight and our samples contained 1881 (450 kcal)/100 g of dry weight. The levels in pulp range from a low of 836 kJ (200 kcal)/100 g in our sample to a high of 1463 kJ (350 kcal)/100 g of dry weight (Saka and Msonthi, 1994). Some of the variability reported in baobab seeds and pulp is due to the use of different analytical methodologies and methods of reporting. In some cases, only cellulose (Busson, 1965) or crude fiber (Wehmeyer, 1966; Nour *et al.*, 1980; Saka and Msonthi, 1994; Salami and Okezie, 1994), rather than total dietary fiber, is reported. This underestimates the fiber content and increases the apparent amount of digestible carbohydrate because carbohydrate is calculated as the mass remaining after protein, fat, ash, and fiber are subtracted from 100 g of the dry sample. The result is an overestimate of the calculated energy content of a food. One strength of our study was that we measured dietary fiber directly. Because fiber, by definition, is not digested by the digestive enzymes from the human gastrointestinal tract, we did not include fiber in our energy calculations. This probably accounts for the relatively low energy levels (although high compared with other foods) we report for seed flour and fruit pulp. Beyond the obvious methodological differences, however, it is not known how much, if any, variation is due to the season in which the samples were collected, the portion of the seed used for analysis (e.g., flour only versus total seed), or the age of the plant.

Even though the energy levels we report are low compared with the majority of those published previously, it is clear that baobab seed flour is an important source of energy (see also Ralaimanarivo *et al.*, 1982) as well as protein for the Hadza. It is significantly higher in total protein than are local agricultural plants like sorghum (11.4% protein), millet (11.9% protein), and manioc (0.9% protein) (Glew *et al.*, 1997). Although local agricultural beans are high in protein (37.8% protein; Glew *et al.*, 1997), the Hadza do not trade for agricultural beans and eat none of the wild beans in their area. Compared with the WHO standard protein, baobab seed contains better amino acid quality than all of the agricultural plants, except beans, even though it has inadequate levels of histidine, methionine, and lysine (Glew *et al.*, 1997). The Hadza's removal of the seed coat apparently reduces the level of trypsin inhibitor in the flour (Addy and Eteshola, 1984) although other processing methods that reportedly enhance the availability of various nutrients in baobab foods (Obizoba and Amaechi, 1993; Obizoba and Anyika, 1994; Addy *et al.*, 1995) are not used by the Hadza. The pulp contains energy levels that are similar to those in non-baobab fruits, and because it is available for a much longer period throughout the year than is true for other fruits, the pulp could provide an important source of energy on an annual basis. In addition, the pulp contains significant levels of calcium (Prentice *et al.*, 1993) and vitamin C (Carr, 1955).

TABLE 2

Comparative data on the nutritional composition of Baobab pulp and seed

Sample	Moisture %	Crude protein	Fat	CHO	Fiber	Ash	Energy[1] (kJ (kcal) /100 g dry weight)
		(g/100 g dry weight)					
Pulp							
Busson (1965)	—[2]	2.5	0.8	81.3[3]	11.4[4]	4.0	1430 (342)
Wehmeyer (1966)	7	3.2	0.3	81.6[3]	9.4[5]	5.5	1430 (342)
Nour *et al*. (1980)	6.7	2.6	0.2	86.2[3]	5.7[5]	5.3	1492 (357)
Obizoba and Amaechi (1993)	19.9	19.1	5.1	73.4[3]	—[2]	2.4	1739 (416)
Saka and Msonthi (1994)[8]	13.2	3.1	4.3	79.4[3]	8.3[5]	5.0	1542 (369)
This study	4.7	2.5	0.7	46.6[6]	45.1[7]	5.1	849 (203)
Seed							
Busson (1965)	—[2]	41.6	31.5	16.0[3]	2.2[4]	8.7	2149 (514)
Obizoba and Amaechi (1993)[8]	8.1	32.7	34.1	30.0[3]	—[2]	5.0	2332 (558)
Salami and Okezie (1994)[8]	3.6	35.0	12.4	29.9	7.1[5]	15.7	1551 (371)
Addy and Eteshola (1984)[8]	4.0	28.4	29.7	24.1[3]	10.8[5]	6.9	1994 (477)
This study	4.8	36.3	29.3	11.2[6]	14.1[7]	9.1	1898 (454)

Note: [1] Energy was calculated using 16.7 kJ (4 kcal)/g for protein and carbohydrate and 37.6 kJ (9 kcal)/g for fat.
[2] Not determined.
[3] Carbohydrate determined by difference.
[4] Cellulose only.
[5] Crude fiber only.
[6] Sum of starch determined by enzymatic analysis and of mono- and disaccharides determined by difference (Table 1).
[7] Total dietary fiber.
[8] Dry weight totals do not add up to 100 g because each value is the average of multiple analyses.

Among the Hadza, men and women practice different food-collecting strategies, with men eating more meat and honey, and women eating more plant foods (Woodburn, 1968). Baobab seeds are a good source of protein and, due largely to their high fat content, their energy content is equivalent to that from honey. Although the seeds are inadequate in three essential amino acids, minimal amounts of meat would complete these requirements. In addition, the baobab seeds are a more dependable energy source than honey. Women consistently returned with dozens of baobab fruits or with significant quantities of seeds over the majority of months of the year either through direct fruit collection or through collection of seeds in baboon dung piles. Honey is available in quantity only for a few months each year, as is true for non-baobab fruits. Overall, this suggests that baobab is an important, probably preferred, plant food for the Hadza even though other plants are eaten in significant quantities. Maintaining areas with healthy baobab groves is important for the future of Hadza and of other people living in agriculturally marginal regions.

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