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The Amino Acid, Mineral and Fatty Acid Content of Three Species of Human Plant Foods in Cameroun

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ABSTRACT

Wild edible plants contribute significantly to the diets of populations in the hot, arid regions of the western Sahel, especially during periods of food scarcity. The following three human plant foods were collected in Cameroun and analyzed for their content of 23 minerals and trace elements, 30 fatty acids and the 18 amino acids common to proteins: the combined shoots and leaves of *Abrus precatorius* L, *Burnatia enneandra* nuts and *Cadaba farinosa* leaves and stems. Only the leaves of *C. farinosa* contained significant amounts of the two essential fatty acids: 4.11 g/ 100 g α-linolenic acid and 11.2 g/ 100 g dry weight linoleic acid. *B. enneandra* nuts and *C. farinosa* stems contained 16.7 and 8.32% protein, respectively. *A. precatorius* L. leaves and shoots and *C. farinosa* leaves contained 7.96 and 14.8% protein, respectively. Compared to a World Health Organization (WHO) standard protein, *A. precatorius* L. leaves and shoots had the highest essential amino acid scores and *C. farinosa* stems had the lowest scores. All of the plant proteins scored below the WHO protein standard for lysine. All three plants contained significant amounts of calcium, iron, potassium, sodium, magnesium, manganese and zinc. In conclusion, the amounts of protein and mineral elements in all three plant foods and the amounts of the essential omega-3 and omega-6 fatty acids in the leaves of *C. farinosa* could contribute significantly to the diets of indigenous populations in sub-Saharan Africa. These data should provide public health officials in the region with information that would be useful in advising local populations about the nutrient value of various spontaneous edible plants that grow in the region.

Keywords: *Abrus precatorius*, *Burnatia enneandra*, calcium, *Cadaba farinosa*, edible plants, fatty acid composition, α-linolenic acid, nutrient content
Abbreviations: **EFA**, essential fatty acids; **FA**, fatty acid; **FAME**, fatty acid methyl ester; **FFA**, free fatty acid; **FID**, flame ionization detector; **MUFA**, monounsaturated fatty acid; **PUFA**, polyunsaturated fatty acid; **SFA**, short-chain fatty acid; **TAG**, triacylglycerols; **WHO**, World Health Organization

INTRODUCTION

Though it is widely acknowledged that hundreds and perhaps even thousands of wild edible plants play a significant role in the economic and cultural life and diets of communities in sub-Saharan Africa, the literature contains little in the way of quantitative information about the nutrient composition of these plants that are especially important as 'famine foods' in times of severe food shortage.

Over the past dozen years or so, the authors have gathered more than 100 of these wild edible plants from the Republic of Niger, Nigeria and Burkina Faso and analyzed them for their content of nutrients relevant to human health, including essential amino acids and fatty acids, minerals and trace elements, and antioxidants (Yazzie *et al.* 1994; Glew *et al*. 1997; Cook *et al.* 1998; Sena *et al.* 1998; VanderJagt *et al.* 2000; Glew *et al.* 2004, 2005, 2006, 2009). The present study represents an extension of those studies to several different plant foods that grow spontaneously in Cameroun and are consumed by humans: leaves and shoots of *Abrus precatorius* L., *Burnatia enneandra* nuts, and leaves and stems of *Cadaba farinosa.*

Abrus precatorius is a member of the *Leguminosae* family. It is widely distributed across the tropics where it grows primarily along the shores of territorial waters. Local common names for *A. precatorius* include: coral-bead plant, love pea, red-bead vine, rosary pea, and wild licorice (Hedrick 1919). The Tupuri of northern Cameroun call it "danrai". Acting as a sweetener, the leaves and shoots, but not the toxic seeds of the plant (Olsnes 1978; Wu *et al.* 1992, 2001), are first sun-dried and then pounded with a cereal such as millet or maize to produce a porridge. The seeds are also used to treat diabetes, chronic nephritis, abrasions and leucoderma. Some African populations use the powdered seed as an oral contraceptive.

Burnatia enneandra (family *Alismataceae*) is a semi-aquatic herbaceous plant that grows in both water and soil in the Sudano-Sahelian regions of Africa. The nuts that become buried in the soil in the dry season germinate during the subsequent rainy season. The circular-ovoid nuts (diameter 5-6 mm), called "tingari" by the Tupuri of northern Cameroun, are covered by a protective fibrous outer layer. Other common names include: "anjakoore" (Peul or Fulani), "chrinpagni" (Kera), "doubar-ngaga" (Massa), "adjakodje", and "kikere" (Djidimbele 2002). Like *A. precatorius*, tingari is used as an additive to improve the taste and increase the density of cereal-based porridges, especially those consumed by children. Occasionally the nuts are eaten as a snack food either raw or after boiling or frying. The milky latex from freshly sliced nuts is used to treat wounds and to treat children for intestinal parasites.

Cadaba farinosa belongs to the family *Capparideae* and is a slender shrub with a strongly furrowed stem that grows in the African Sahel and Arabia (Hedrick 1919; Bar-

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tha 1970). It has a variety of common names: "tchen-tchen" by the Tupuri, "kalkacha" by the Orma in Kenya, "ndey-barga" by the inhabitants of Senegal, "legel" or "danyarafa" by Fulani in Nigeria, and "balamji" by the inhabitants of Niger. Both the leaves and green twigs of *C. farinosa*, after drying and pounding to a powder, are processed into gruel by boiling. Ground, dried leaves of *C. farinosa* are also added as a sweetener to cereal-based porridges called "kunun zaki" in Hausa (Gaffa *et al.* 2002; Terna *et al.* 2002; Ayo 2004). *C. farinosa* is appreciated by Fulani herdsmen of the western Sahel who prize its leaves for the nutritive value they provide for their cattle during the dry season, especially the minerals and trace elements (Le Houerou 1980; Dougall and Bogdan 1958).

We were interested in determining the fatty acid, amino acid, and mineral content of a flour made from *A. precatorius* leaves and shoots, a flour made from *B. enneandra* nuts, and ground leaf and stems of *C. farinosa*.

MATERIALS AND METHODS

Collection of plant specimens

The nuts of *B. enneandra* were purchased in the market in Yagoua, the North province of Cameroun and washed exhaustively with tap water. Following removal of the fibrous coating with the aid of a knife and after cracking the nuts, the kernels were diced into small pieces, sun-dried for three days and finally ground to a fine powder using a food blender with stainless steel blades (Waring blendor, Waring Products Division, New Hartford, CT, USA).

The fresh leaves and tender stems of *C. farinosa* and the leaves and shoots of *A. precatorius* were harvested in the bush in Yagoua, sun-dried for two days, and pulverized with the aid of a mortar and pestle and food-blender.

All plant specimens were shipped via air-mail to Albuquerque, New Mexico for analysis. Prior to analysis, samples were ground to a fine powder with the aid of a mortar and pestle and dried to constant weight under a vacuum and over anhydrous calcium chloride for four days at room temperature.

Lipid analysis

Total lipids from 1 g of sample were extracted using 20 mL of chloroform/methanol (1:1). The mixture was thoroughly mixed using a Virtis homogenizer (Gardiner, NY, USA) and then left standing at room temperature for 1 h before filtering. The residue was re-dissolved in a further 15 mL of chloroform: methanol (1:1), mixed and filtered. The filtrates were combined and the solvent was removed using a rotary evaporator. The lipid residue was dried under vacuum, weighed, and then dissolved in chloroform for storage at -70°C.

We elected to methylate the same total (i.e., crude) lipid extract using two different methylation procedures (acid and base) and compare the results (Kramer *et al.* 2001; Cruz-Hernández *et al.* 2004; Mossoba *et al.* 2009). This has scientific merit since it ensures that all lipid classes present in the crude lipid extract will become methylated and ultimately quantified. Very stable fatty acid-containing lipids can only be converted to their fatty acid methyl esters using an acid-catalyzed procedure, whereas *O*-acyl lipids can usually be readily methylated using a base-catalyzed procedure. We performed both methylation procedures and obtained very similar results, indicating that the fatty acid components of the lipids we extracted from all four plant samples were present as *O*-acyl lipids. Thus, the fatty acid values we report in this paper are the averages of two different methylation procedures, and represent reliable estimates of the mass percentage fatty acid composition and content (expressed as mass per g dry weight of specimen). A 1 mg aliquot of the total lipids was transferred into a 20 mL culture tube equipped with a Teflon-lined screw cap. After removing the chloroform and following the addition of 2 drops of benzene and 2 mL of a 5% solution of anhydrous HCl/methanol, the lipids were methylated for 1 h at 80°C. A similar procedure was conducted with another 1 mg of lipids but this time the methylation step was carried out using 1 mL 0.5 N $NaOCH_3$/methanol (Supelco Inc., Bellefonte, PA, USA) at 50°C for 15 min. An internal standard (methyl ester of 23:0) was added to each lipid aliquot prior to methylation. After completion of the methylation reactions, water was added (5% by volume) to each tube and the fatty acid methyl esters (FAMEs) were extracted separately with 4 mL hexane. The hexane solution was taken to dryness and the total methylated mixture was purified by thin layer chromatography (Silica Gel G plates, 20 cm × 20 cm, 250 μm thickness, Fisher Scientific, Ottawa, ON, Canada) using hexane/diethyl ether/ acetic acid (85:15:1) as developing solvent. The bands were visualized by UV after spraying the plates with 2'7'-dichlorofluorescein (0.001% solution in methanol). The band corresponding to FAMEs was scraped off the plate and the FAMEs were eluted from the silica gel using hexane. The hexane solution was adjusted to give a final fatty acid concentration of 1 to 2 μg/μL and transferred into an autosampler vial for analysis by gas chromatography.

The gas chromatograph (Hewlett-Packard, Model 5890, Series II, Palo Alto, CA, USA) was equipped with splitless injection port (flushed after 0.3 min), a flame ionization detector (FID), an autosampler (Hewlett-Packard, Model 7673), a 100 m CP-Sil 88 fused capillary column (Varian Inc., Mississauga, ON, Canada), and a Hewlett-Packard ChemStation software system (Version A.10). The injector and detector temperatures were both set at 250°C, H_2 served as carrier gas (1 mL/min), and the FID gases were H_2 (40 mL/min), N_2 (100 mL/min), and purified air (300 mL/min). The temperature program was as follows: initial temperature was 45°C held for 4 min, programmed at 13°C/min to 175°C and held for 27 min, then programmed at 4°C/min to 215°C and held for 35 min (Kramer *et al.* 2001; Cruz-Hernández *et al.* 2004). The FAME were identified by comparison with known FAME standards that included gas chromatography standard mixture #463 and #411 plus three separately purchased FAMEs (21:0, 23:0 and 26:0) from Nu-Check-Prep Inc., Elysian, MN, USA. The FID response was used to quantitate all the FAMEs.

Amino acid analysis

Each plant specimen was analyzed in triplicate. Five to nine mg of each specimen were weighed and placed in 2-mL ampoules, to which the internal standard (norleucine) and 0.45 ml of 6 N HCl were added. Norleucine was used as internal standard because this amino acid is not commonly found in proteins. The ampoules were evacuated, sealed and placed in an oven for 24 h at 110°C. After hydrolysis, 20 μl aliquots of the hydrolysates were dried, mixed with 10 μL of redry solution (ethanol: water: triethylamine, 2: 2: 1), dried again, and finally derivatized with 20 μL phenylisothiocyanate reagent (ethanol: water: triethylamine: phenylisothiocyanate, 7: 1: 1: 1) for 20 min at room temperature (Cohen and Strydom 1988; Hariharan *et al.* 1993). Excess reagent was removed with the aid of a vacuum at room temperature. Derivatized samples were dissolved in 0.1 mL of 0.14 M sodium acetate that had been adjusted to pH 6.4 with dilute acetic acid. A 20 μL aliquot was injected onto the column. Quantitation of amino acids was performed using a Waters C18 column (3.9 × 150 mm; Waters, Milford, MA, USA) with gradient conditions as described elsewhere (Glew *et al.* 2005). Derivatized amino acids were eluted from the column with increasing concentrations of acetonitrile. The eluate was monitored at 254 nm and the areas under the peaks were used to calculate the concentrations of the unknowns using a Pierce (Rockford, IL, USA) Standard H amino acid calibration mixture. A sample of egg white lysozyme, analysed in duplicate, served as the control protein.

Samples intended for the determination of cysteine were first oxidized with performic acid (80% formic acid and 30% hydrogen peroxide, 9: 1) for 18 h at room temperature (Hirs 1967). The oxidizing reagent was removed with the aid of an evaporative centrifuge and the samples were hydrolysed with 6 N HCl as described above.

Tryptophan was determined in a separate analysis. The weighed samples were placed in polypropylene tubes and following the addition of the internal standard (norleucine) they were hydrolysed in 4.67 M KOH containing 1% (w/v) thiodiglycol for 18 h at 110°C (Hugli and Moore 1972). After hydrolysis, the KOH was neutralized with 4.2 M perchloric acid, and the supernatant was adjusted to pH 3.0 with acetic acid. A 20 μL aliquot of the hydrolysed specimen was subjected to derivatization as described

Table 1 Fatty acid composition (mass percent) of plant foods from Cameroun[a].

Fatty acids[b]	*Abrus precatorius*	*Burnatia enneandra*	*Cadaba farinosa*	
			Stems	Leaves
14:0	0.79	0.35	0.66	0.39
15:0	0.47	0.73	0.32	0.11
16:0	30.2	27.7	26.8	18.8
16:1n-9	0.45	0.72	0.36	1.19
16:1n-7	0.43	0.26	0.15	0.28
17:0	0.81	1.09	0.75	0.30
17:1n-8	0.67	0.36	0.06	0.06
18:0	11.0	9.21	12.6	7.86
18:1 *trans*	3.01	3.17	2.83	0.92
18:1n-9	17.4	22.9	6.69	7.92
18:1n-7	1.33	0.46	0.77	0.48
18:1n-6	0.18	0.14	0.21	0.14
18:1n-5	0.13	0.08	0.12	0.06
19:0	0.32	0.20	0.31	0.17
18:2 *cis/trans*	2.15	1.11	0.55	0.51
18:2n-6	11.4	14.3	20.2	11.8
20:0	1.47	1.37	4.08	1.10
18:3n-6	0.03	0.04	0.01	0.04
20:1n-11	0.12	0.03	0.06	0.13
20:1n-9	0.16	0.30	0.30	0.09
18:3n-3	3.98	2.58	11.2	43.5
21:0	0.35	0.26	0.36	0.08
20:2n-6	0.05	0.05	0.13	0.04
22:0	5.69	2.75	3.47	0.93
22:1n-9	0.17	0.19	0.01	0.00
23:0	0.74	0.77	0.73	0.12
24:0	2.65	2.87	2.83	0.57
25:0	0.39	0.57	0.64	0.07
26:0	0.29	1.73	0.75	0.10
28:0	0.12	0.41	0.25	0.18
Sum SFAs	55.2	50.0	54.5	30.8
20:0 -28:0	11.7	10.7	13.1	3.15
cis MUFAs	21.1	25.6	8.83	10.4
Sum TFAs	5.24	4.32	3.49	1.81
n-6 PUFAs	11.5	14.4	20.4	11.9
n-3 PUFAs	4.11	2.64	11.3	43.8
n-6/n-3	2.79	5.43	1.81	0.27
% Lipid	2.63	6.85	2.57	9.45

[a] All values are the mean of two separate methylation procedures; see Materials and Methods section.
[b] MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; SFAs, saturated fatty acids; TFAs, trans fatty acids.

above. The solution of amino acid standards contained tryptophan. Quality control assurance for the tryptophan determination was obtained by demonstrating that the method yielded the correct number of tryptophan residues for egg white lysozyme. Tryptophan analysis was performed using a Waters C18 reversed-phase column (3.9 × 150 mm) (Waters, Milford, MA, USA) and the solvents and gradient conditions were as described by Hariharan and coworkers (Hariharan *et al.* 1993). Use of this elution protocol was necessary in order to adequately separate tryptophan from ornithine which results from the alkaline hydrolysis of arginine.

Mineral analysis

A single sample (50-500 mg) from each of the dried, powdered plant specimens was weighed, then wet-ashed by refluxing overnight with 15 mL of concentrated HNO_3 and 2.0 mL of 70% $HClO_4$ at 150°C. The samples were dried at 120°C and the residues were dissolved in 10 ml of 4.0 N HNO_3 in 1% $HClO_4$ solution. The mineral content of each sample solution was determined by inductively-coupled argon plasma atomic emission spectroscopy (ICP-AES, Jarrel-Ash, Perkin-Elmer, Palo Alto, CA, USA) as described elsewhere (Glew *et al.* 2005). The mineral contents of the samples were quantified against standard solutions of known concentrations which were analysed concurrently.

RESULTS

Fatty acid content and composition

Separation of the total lipid extracts by thin layer chromatography was used to assess the lipid class profile of each of the plant specimens. The total lipids present in the leaves and shoots of the legume (*A. precatorius*), herbaceous plant (*B. enneandra*) and shrub (*C. farinosa*) consisted mainly of wax esters, alcohols and sterols, but no triacylglycerols (TAGs). The lipid content was higher in the leaves (9.45%) than in the stem (2.57%) of the *C. farinosa* shrubs (stems plus leaves) (**Table 1**).

The percentage fatty acid (FA) composition of the three different species of plant foods differed considerably (**Table 1**). The leaves and shoots of the legume *A. precatorius*, *B. enneandra* nuts and the stems of *C. farinosa* contained high proportions of saturated fatty acids (SFAs), particularly 16:0 (26.8 to 30.2%), and a relative high content of long-chain SFAs greater than 20 carbon atoms that accounted for 11.7 to 13.1% of the total FA mixture. The two essential fatty acids (EFA), linoleic (18:2n-6) and α-linolenic acid (18:3n-3), were present in both the stems and leaves of *C. farinosa*. On the other hand, a considerably higher level of 18:3n-3 (43.5%) was found in the leaves than in the stems of *C. farinosa* (11.2%). The *trans* fatty acid (TFA) content was investigated in the plant lipids to assess product quality. In general, all three plant foods contained significant proportions (1.81-5.24%) of TFAs.

Table 2 shows the amount (in grams) of selected FA or FA groups present in 100 g of these three species of plants.

Table 2 Amounts (g/100 g × 10^{-1}) of selected fatty acids in plant foods from Cameroun.

Fatty acids	*Abrus precatorius*	*Burnatia enneandra*	*Cadaba farinosa*	
			Stems	Leaves
16:0	7.92	19.0	6.91	17.8
18:0	2.89	6.31	3.24	7.42
18:1n-9	4.56	15.7	1.72	7.49
18:1n-7	0.35	0.32	0.20	0.46
18:2n-6	2.99	9.77	5.21	11.2
20:0	0.39	0.94	1.05	1.04
20:1n-9	0.04	0.21	0.08	0.08
18:3n-3	1.05	1.77	2.88	41.1
22:0	1.49	1.88	0.89	0.88
23:0	0.19	0.53	0.19	0.11
24:0	0.70	1.96	0.73	0.54
25:0	0.10	0.39	0.16	0.07
26:0	0.08	1.19	0.19	0.09
28:0	0.03	0.28	0.06	0.17
Sum SFAs[b]	14.5	34.2	14.0	29.1
20:0-28:0	3.07	7.34	3.37	2.98
cis MUFAs	5.54	17.6	2.27	9.83
Sum TFAs	1.38	2.96	0.90	1.71
n-6 PUFAs	3.01	9.83	5.25	11.3
n-3 PUFAs	1.08	1.81	2.90	41.4
n-6/n-3	2.79	5.43	1.81	0.27
g/100 g[c]				
n-6 PUFAs	0.30	0.98	0.52	1.13
n-3 PUFAs	0.11	0.18	0.29	4.14
Men (% of requirement)[d]				
n-6 PUFAs	1.77	5.78	3.09	6.63
n-3 PUFAs	6.74	11.3	18.1	258
Women (% of requirement)[e]				
n-6 PUFAs	2.51	8.19	4.37	9.39
n-3 PUFAs	9.81	16.5	26.3	376

[a] All values were calculated based on the lipid content of each plant food.
[b] MUFAs, monounsaturated fatty acids;PUFAs, polyunsaturated fatty acids;SFAs, saturated fatty acids;TFAs, trans fatty acids.
[c] The n-6 and n-3 PUFA content expressed as g/100g of dried plant food.
[d] the adequate intake of 18:2n-6 and 18:3n-3 for men 19 to 50 years of age was estimated at 17 and 1.6 g/d, respectively (National Academy of Sciences 2002).
[e] The adequate intake of 18:2n-6 and 18:3n-3 for women 19 to 50 years of age was estimated at 12 and 1.1 g/d, respectively (National Academy of Sciences 2002).

Table 3 Amino acid composition (mg/g dry weight) of plant foods from Cameroun.

Amino acid	*Abrus precatorius*	*Burnatia enneandra*	*Cadaba farinosa*	
			Stems	Leaves
Alanine	4.32 ± 1.09	5.58 ± 0.25	3.62 ± 0.27	8.20 ± 0.09
Arginine	4.08 ± 1.13	12.7 ± 0.40	4.96 ± 0.53	9.32 ± 0.24
Aspartic	10.2 ± 3.20	27.3 ± 0.60	20.0 ± 1.49	25.2 ± 0.20
Cysteine	2.17 ± 0.12	3.55 ± 0.24	1.26 ± 0.00	2.27 ± 0.23
Glutamic	12.4 ± 3.45	35.1 ± 1.62	9.86 ± 0.86	20.5 ± 0.12
Glycine	3.03 ± 0.80	8.15 ± 0.33	2.38 ± 0.29	5.45 ± 0.13
Histidine	2.16 ± 0.53	3.26 ± 0.06	2.13 ± 0.19	3.73 ± 0.12
Isoleucine	2.97 ± 0.80	4.46 ± 0.19	2.52 ± 0.25	5.28 ± 0.07
Leucine	5.65 ± 1.53	8.66 ± 0.38	4.56 ± 0.45	10.8 ± 0.12
Lysine	3.89 ± 1.05	7.56 ± 0.12	3.79 ± 0.36	7.83 ± 0.58
Methionine	0.61 ± 0.13	2.16 ± 0.11	0.67 ± 0.13	1.16 ± 0.03
Phenylalanine	3.67 ± 1.03	6.65 ± 0.23	2.82 ± 0.28	6.50 ± 0.21
Proline	5.34 ± 1.28	5.83 ± 0.22	7.03 ± 0.49	8.14 ± 0.08
Serine	5.75 ± 1.45	9.93 ± 0.46	4.93 ± 0.32	8.11 ± 0.13
Threonine	4.71 ± 1.26	6.91 ± 0.29	2.94 ± 0.22	6.60 ± 0.05
Tyrosine	2.21 ± 0.48	5.56 ± 0.22	1.92 ± 0.17	4.65 ± 0.21
Tryptophan	1.21 ± 0.10	3.74 ± 0.26	1.21 ± 0.08	3.18 ± 0.09
Valine	4.27 ± 1.17	7.92 ± 0.29	3.57 ± 0.24	7.18 ± 0.37
Total	79.6	167	83.2	148

The value of 100 g was arbitrarily chosen to represent a reasonable portion that one might consume. Based on the recommendations for adequate intake of the essential fatty acids (EFAs) in the US for men and women ages 19 to 50 (Food and Nutrition Board 2002), the percent of adequate intake of the two EFAs provided in 100 g of each of these four plant foods was calculated (**Table 2**). Even though the percentage of total SFAs was 50% or higher in *A. precatorius* leaves and shoots, *B. enneandra* nuts and the stems of *C. farinosa*, these FAs accounted for less than 3.5 g per 100 g of dry matter. Half or more of the total SFAs in all of the plant foods was accounted for by palmitic acid (16:0). The amount of oleic acid (18:1n-9) in the plant foods was relatively low (<1.6 g/100 g of dry matter). The amounts of total TFAs these plant foods could contribute to a diet is minimal (<0.4 g/100 g), and would be even less if consumed fresh.

The amounts of essential fatty acids (EFAs) in these plant foods and the levels needed to meet the daily human requirements were of interest to us. In general, while *A. precatorius* leaves and shoots would not be a very good source of EFAs, they do represent a somewhat better source of 18:3n-3 for adults (about 9% of the recommended requirement) when compared to 18:2n-6 that would meet only about 2% of the daily need for 18:2n-6 (see footnote, **Table 2**). *B. enneandra* nuts represent a slightly better source of EFAs, providing about 7 and 13% of the daily requirements for adults for 18:2n-6 and 18:3n-3, respectively. On the other hand, the leaves of *C. farinosa* stems and leaves appear to be an excellent source of 18:3n-3, with 100 g dry matter providing about three times the daily requirement, while the content of 18:2n-6 in leaves was limited (providing only about 7% of the daily requirement).

By comparison, 100 g of the stems of *C. farinosa* contained sufficient 18:3n-3 to satisfy about 20% of the daily requirement, but only enough 18:2n-6 to provide approximately 3% of the daily requirement for this particular essential fatty acid. The 18:2n-6/18:3n-3 ratio was lowest in leaf lipids of *C. farinosa* (0.27) and considerably higher in the stems of the same plant (1.8). On the other hand, the n-6/n-3 ratio of the two EFAs in the other plant foods ranged from 2.79 to 5.43.

Protein content and amino acid composition

B. enneandra seeds and *C. farinosa twigs* contained 16.7 and 14.8% protein, respectively (**Table 3**). *A. precatorius* leaves and stems and the twigs of *C. farinosa* contained 7.96 and 8.32% protein, respectively.

In addition to wanting to know their protein content, we were interested in comparing the nutritional quality of the various plant proteins. We therefore compared the percentages of essential amino acids in the various plant specimens to the percentages of these same amino acids in a World Health Organization protein standard (World Health Organization 1985) (**Table 4**); a score of 100 or more for a particular amino acid means the plant protein meets or exceeds the percentage of that amino acid in the WHO standard protein. In the present study the lysine score was below the WHO standard for all of the plant proteins, ranging from 78-91%. *A. precatorius* had the highest overall amino acid score; except for lysine, the scores for all other essential amino acids in *A. precatorius* ranged from 108-174%. The tryptophan percentage for all of the plants analyzed in the current study exceeded that of the WHO standard.

Minerals and trace elements

Of the plant foods we analyzed herein, the leaves of *C. farinosa* contained the highest amount of calcium (12.2 mg/g dry weight) (**Table 5**). *A. precatorius* leaves and shoots, *B. enneandra* nuts and *C. farinosa* stems and leaves also contained reasonable amounts of this bone-building mineral. The potassium content of all of the plant foods was substantial, with *A. precatorius* leaves having the most calcium (15 mg/g dry weight). The sodium content of most of the plant foods was relatively low, with the exception of *B. enneandra* seeds (0.619 mg/g dry weight). All of the plant food specimens contained nutritionally significant amounts of copper, iron, phosphorus, manganese, magnesium, zinc, chromium, and molybdenum. Of those elements and trace minerals not required by humans, it is noteworthy that several of the plant foods contained large quantities of aluminium and strontium. Selenium, an essential element for humans, was not detected in any of the plants analyzed.

DISCUSSION

The plant foods we analyzed in this study had a low to moderate lipid content (<10%), but the lipid fraction of one of them (the leaves of *C. farinosa*) contained a high percen-

Table 4 Comparison of the essential amino acid content of plant foods from Cameroun with that of the World Health Organization ideal pattern (% of total amino acids).

Amino acid	WHO ideal pattern	*Arbus precatorius*		*Bernatia enneandra*		*Cadaba farinosa*			
		(% of total)	(% of ideal)	(% of total)	(% of ideal)	Stems		Leaves	
	(% of total)					(% of total)	(% of ideal)	(% of total)	(% of ideal)
Isoleucine	2.8	3.73	133	2.67	95	3.03	108	3.57	127
Leucine	6.6	7.10	108	5.19	79	5.48	83	7.30	111
Lysine	5.8	4.89	84	4.53	78	4.56	79	5.29	91
Methionine + cysteine	2.5	3.49	140	3.42	137	2.32	93	2.32	93
Phenylalanine + tyrosine	6.3	7.39	117	7.31	116	5.70	90	7.53	120
Threonine	3.4	5.92	174	4.14	122	3.53	104	4.46	131
Tryptophan	1.1	1.52	138	2.24	204	1.45	132	2.15	195
Valine	3.5	5.36	153	4.74	136	4.29	123	4.85	135

Table 5 Trace mineral content of plant foods from Cameroun (µg/g dry weight).

Mineral	*Arbus precatorius*	*Bernatia enneandra*	*Cadaba farinosa*	
			Stems	Leaves
Al	82.8	428	99	662
Ba	63.3	70.6	10.1	12.4
Ca	6,820	3,240	7,550	12,200
Cd	0.202	0.118	0.539	0.743
Cr	1.86	2.05	2.58	3.35
Cu	6.00	5.46	10.3	14.6
Fe	74.5	144	84.0	335
Li	0.079	0.227	0.102	0.308
Mg	2,110	2,100	818	1,410
Mn	28.8	94.0	43.4	129
Mo	0.391	0.278	0.310	0.206
Na	107	619	232	223
Ni	0.782	0.993	11.86	4.12
P	775	3,920	1,170	1,730
Pb	nd	0.316	nd	0.426
Se	nd	nd	nd	nd
Sr	34.2	21.8	38.6	43.4
Ti	1.09	0.547	1.60	6.71
V	nd	0.526	nd	0.641
Y	nd	0.174	0.499	0.750
K	15,000	9870	11,200	13,200

nd, not detected

tage of α-linolenic acid (**Table 1**). *A. precatorius* seeds and shoots and the stems of *C. farinosa* had a very low lipid content (about 2.6%) and high proportion (50-55%) of SFAs. The linoleic acid/α-linolenic acid ratios for oils of *A. precatorius* leaves and shoots and the stems of *C. farinosa* were 2.8 and 1.5, respectively. *B. enneandra* seeds exhibited similar fatty acid characteristics to those of *A. precatorius* and the stems of *C. farinosa*, but had a higher lipid content (6.85%). The leaves of *C. farinosa* contained the most lipid (9.5%) and were a rich source of α-linolenic acid (43.5%, 41.1 mg/g dry weight). In terms of fatty acid content and percent composition, *C. farinosa* leaves appear to represent a healthful food supplement for humans in that they contained significant amounts of the two essential fatty acids, namely linoleic acid and α-linolenic acid. The amounts of saturated fatty acids in selected plant foods may be high but this can be compensated for by the consumption of other foods. The leaves of *C. farinosa* with their high α-linolenic acid content could have anti-inflammatory effects in those who consume them. A high omega-6/omega-3 ratio is common in most Western diets and is associated with an increased risk of certain diseases, including cardiovascular disease, breast cancer, and inflammatory and autoimmune diseases (Simopoulos 2002; Gebaur *et al*. 2004).

B. enneandra seeds and *C. farinosa* leaves contain relatively large amounts of protein (approximately 15%) and, with the exception of lysine, their amino acid compositions compare favourably to the WHO standard (**Table 4**). *A. precatorius* leaves and stems contained a moderate amount of protein (7.96%) and scored well above the WHO standard in seven of eight essential amino acid categories. Overall, in terms of protein content and quality, stems of *C. farinosa* appear to be the least useful as a protein source for humans.

All of food the plants foods in this study contained nutritionally useful amounts of many minerals and trace elements, particularly potassium, copper, iron, phosphorus, manganese, magnesium, zinc, chromium, and molybdenum, and they all contained reasonable amounts of calcium. However, the undetectable levels of selenium and higher amounts of strontium and aluminium in these plant sources may be a concern.

The quantitative and qualitative nutritional information provided in this report should be regarded as provisional since the full value of the minerals, fatty acids and proteins contained in the various plant foods we have analyzed will necessarily be determined by the bioavailability of these nutrients, which in turn will depend upon the efficiency of their digestion and absorption. For example, although a plant food may contain significant amounts of calcium, the presence of chelating agents (e.g., phytates, oxalates) can markedly decrease the bioavailability of that calcium. The rapidly increasing number of published reports of the content of nutrients in wild edible plants of sub-Saharan Africa underscores the need for studies aimed at determining the bioavailability of the specific nutrients they contain, calcium being an excellent case in point. In addition, future studies need to address the question of the content of potentially toxic alkaloids, terpenes, saponins, steroids and glycosides in these plant foods and their possible pathophysiologic effects on humans. Nevertheless, the data in the present report will provide public health officials in sub-Saharan Africa with nutritional information that should be helpful in advising local populations about the particular nutrient value of various spontaneous plants that grow in the region.

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