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Original Article

The nutrient content of three edible plants of the Republic of Niger

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Abstract

People in Niger and elsewhere in the western Sahel consume wild and cultivated edible plants to satisfy their nutritional requirements. In many parts of the Republic of Niger farmers in rural areas produce insufficient yields of millet, the staple grain of the region. During periods of grain shortage people in rural Niger increase their reliance on wild plant foods to supplement their diets. Having a database of the nutrient content of wild and cultivated edible plants available in the region would be of value to educators and public health officials positioned to provide dietary advice to the food-stressed populations. Herein we report the fatty acid, amino acid and mineral and trace element content of three leafy plant foods collected in July 2002 in the villages of Droum and Zongon Mallam in the Republic of Niger: cecego (*Sesbania pachycarpa*), godilo/gudai (*Crataeva religiosa*), and cabbage leaf (*Brassica oleracea* var. *capitata*). All three plants contained large amounts of protein (18.6–36.2%) whose proportions of essential amino acids compared favorably with the WHO standard. Godilo/gudai and cabbage leaf contained large amounts of calcium (23.5–27.4 mg/g dry weight). All three plants contained potentially useful amounts of copper, zinc, iron, and a number of other essential minerals and trace elements, but no detectable selenium. However, the levels of the essential fatty acids, linoleic acid and α-linolenic acid, were low compared to other edible plant foods that are widely available in Niger. The data in this report underscore the potential value and utility of wild edible plants relative to the nutrition of people who live in rural Niger and elsewhere in the Sahel.

Keywords: Fatty acids; Minerals; Protein; Niger; Nutrients; Wild plant foods

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1. Introduction

According to the most recent United Nation Development Program quality of life index (United Nations Development Program-Human Development Report, 2002), the Republic of Niger is ranked 172 out of 173 countries considered. Quality of life indicators reflect the challenge of living in the Sahel, particularly for those residing in rural areas. In many areas farmers are unable to produce enough millet, the staple grain eaten in the region, to last until the next harvest which usually takes place in October. This grain deficit often begins in March at a time when grain prices in the market are high. During these periods people in rural Niger increase their reliance on wild plant foods to supplement their diets. Research has indicated that many of the wild plant foods consumed in the Sahel have nutritional benefits (Humphry et al., 1993; Yazzie et al., 1994; Kim et al., 1997; Glew et al., 1997; Freiberger et al., 1998; Sena et al., 1998; Cook et al., 2000).

The villages of Droum and Zongon Malam are representative of life in rural Niger where farmers cannot produce sufficient millet (even in good years) to last until the following harvest. A wide range of plant foods are eaten in Zongon Malam and Droum. The plant foods eaten generally take two forms (leaf and seed/fruit) and are used in one of three ways: (1) they are added to sauces that are eaten at the evening meal; (2) they are dried and eaten alone (like nuts); or, (3) they are cooked and eaten in combination with a mixture of dried peanut extract, red pepper, salt and other spices in the form of a ‘‘leaf bundle’’. Most of these plant foods are only available for fresh specimen collection during the rainy season (June–September). However, they can be dried and stored for later consumption or sale in the market. These plant foods play an important role in local diets and are often eaten throughout the year. However, during times of grain scarcity or non-availability, such plant foods take on added importance. In this paper we analyze the fatty acid, amino acid, and mineral and trace element content of three plants that were not included in previous studies, namely cecego (a.k.a., tchetcheko) and godilo/gudai that grow wild and cabbage which is cultivated. These three plant foods are part of a larger group of wild plant foods that play a key role in local diets. The nutrient data presented in this report illustrate the benefits to human health for those who consume these plants. The data add to our knowledge of the role that non-cultivated, indigenous plant foods play in this part of the Sahel.

2. Materials and methods

2.1. Collection of plant specimens

Samples of the plants analyzed in this paper were collected in the villages of Zongon Malam and Droum during July 2002. Cecego (*Sesbania pachycarpa*) was collected from three sources within walking distance of the village of Zongon Malam and sun-dried. Cecego is also called ‘‘tchetcheko’’ by the local population. In Droum, samples of godilo/gudai leaves (*Crataeva religiosa*) were collected from four trees that were growing within 2 km of the village and immediately sun-dried. Cabbage leaves (*Brassica oleracae* var. *capitata*) that were provided to us in Droum in sun-dried form were from the previous year’s gardening season (November–February). The sample contained plants collected from three vendors in the Droum market.

2.2. Amino acid analysis

Plant specimens were ground to a fine powder with the aid of a stainless-steel mill and dried under vacuum at room temperature until a constant weight was reached. Each sample was analyzed in duplicate. Five to nine milligrams 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 it is an amino acid not commonly found in proteins. The ampoules were evacuated, sealed and placed in an oven for 24 h at 110°C.

The water content of the sun-dried specimens before they were subjected to vacuum desiccation was 8–20%. Thus, the content of the various nutrients in the three kinds of plant foods reported herein on a dry weight basis provides a close approximation of the quantities of these nutrients that would be consumed by persons ingesting the sun-dried leaves as they would be purchased in the marketplace in Niger.

After hydrolysis, 20 μL aliquots of the hydrolysates were dried, mixed with 10 μL of redried 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). 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) with gradient conditions as described elsewhere (Bidlingmeyer et al., 1984). 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 Standard H amino acid calibration mixture (Rockford, IL). Norleucine was the internal standard used in all amino acid determinations. A sample of egg white lysozyme, analyzed 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 hydrolyzed with 6 N HCl as described above.

The tryptophan content was determined in a separate analysis. The weighed samples were placed in polypropylene tubes and after the addition of the internal standard (norleucine) they were hydrolyzed 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 hydrolyzed specimen was subjected to derivatization as described above. The solution of amino acid standard standards was supplemented with 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) and the solvents and gradient conditions were as described by 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.

2.3. Mineral analysis

Two replicate aliquots (50–500 mg) from each of the dried, powdered plant specimens were 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_3-1% $HClO_4$ solution. The mineral content of each sample solution was determined by inductively coupled argon plasma atomic emission spectroscopy (ICP-AES, Jarrel-Ash as described elsewhere (Humphry et al., 1993; Yazzie et al., 1994)). The mineral contents of the samples were quantified against standard solutions of known concentrations which were analyzed concurrently. For quality control purposes, a standard reference specimen (orchard leaves) was analyzed at the same time the three plant foods were analyzed.

2.4. Fatty acid analysis

Triplicate samples of each of the dried specimens were extracted with chloroform:methanol (2:1, v/v) and the solid, non-lipid material was removed by filtration. The total extracted lipid material was recovered after solvent removal in a stream of nitrogen. The samples were then redissolved in anhydrous chloroform/methanol (19:1, v/v) and clarified by centrifugation at $10{,}000 \times g$ for 10 min. Transmethylation was performed using 14% (w/v) boron trifluoride (BF_3) in methanol (Morrison and Smith, 1964). Fifty nanograms of heptadecanoic acid (internal standard) and a 1 mL aliquot of each sample were transferred to a 15 mL Teflon-lined screw-cap tube. After removal of solvent by nitrogen gassing, the sample was mixed with 0.5 mL of BF_3 reagent (14% w/v), placed in a warm bath at 100°C for 30 min and cooled. After the addition of saline solution, the transmethylated fatty acids were extracted into hexane. A calibration mixture of fatty acid standards was processed in parallel.

Aliquots of the hexane phase were analyzed by gas chromatography. Fatty acids were separated and quantified using a Hewlett-Packard gas chromatograph (5890 Series II) equipped with a flame-ionization detector. One or two microliter aliquots of the hexane phase were injected in split-mode onto a fused-silica capillary column (Omegawax; 30 m $\times$ 0.32 mm ID, Supleco, Bellefonte, PA). The injector temperature was set at 200°C, detector at 230°C, oven at 120°C initially, then 120–205°C at 4°C per min, 205°C for 18 min. The carrier gas was helium and the flow rate was approximately 50 cm/s. Electronic pressure control in the constant flow mode was used. The internal standard (heptadecanoic acid, C17:0) and calibration standards (NuCheck, Elysian, MN) were used for quantitation of fatty acids in the lipid extracts. The fatty acids reported represent the average of three determinations.

The amino acid, fatty acid, and mineral and trace element contents are reported as mean values.

3. Results

3.1. Comments on the plants and collection sites

Zongon Malam is typical of villages in the Tanout region in several respects. First, farmers face the challenge of farming in a minimal rainfall zone. Second, people also struggle to find water for drinking, cooking and bathing. Women must travel to local water sources, commonly traveling up to 10 km each way, in order to obtain water for the village. Third, in addition to farming, villagers also keep livestock, primarily goats and sheep which are taken daily to graze in the local grazing zones. Older members of the community noted that during their lifetimes, rainfall in the region had diminished considerably. In fact, some areas are now rocky wastelands because winds have blown away the topsoil.

People employ several strategies to address the water and food deficit situation. One strategy involves seasonal migration in which young men leave the village following the harvest season in October. From Zongon Malam young men travel to points south to villages in the Mirria and Matameye districts of Niger as well as to destinations in Nigeria. In these villages the young men perform a range of commercial activities including selling water as well as gardening and other forms of manual labor. This serves two functions; first it reduces the demand on village grain supplies at home and second, it allows men to earn and send money back to family members in Zongon Malam. In order to obtain millet when granaries are empty, residents will sell livestock to raise the money needed. It is also common for people to rely on wild food plants during times of grain shortage, particularly dilo whose nutrient content we reported on in 1997 (Kim et al., 1997). These plants are either collected locally or bought in the market. In times of extreme distress people will resort to excavating termite mounds to recapture grains of millet stored by the termites.

The village of Droum, located to the south of Zongon Malam, is relatively large in comparison, having a population of approximately 5000 residents. Droum is situated near dry river beds with a relatively high water table, thereby permitting off-season gardening of fruits and vegetables. While the quality of the farmland and pastureland is not perceived as having changed considerably in recent history, population increases have added pressure on the land to produce enough food for local residents. Like most villages in this region the millet harvested in the months of September and October usually does not carry them through the year. In most years the granaries are empty by March, leaving at least 5 months until the next harvest. Like their neighbors to the north in Zongon Malam, young men in Droum also seasonally migrate, often to the large urban centers of Nigeria such as Kano, Ibadan and Lagos.

3.2. Protein content

The protein content of the three plant foods was estimated by summing the weights of their composite amino acids (Table 1). Cecego contained the most protein (36.2%), followed by godilo/gudai at 24.5% and cabbage at 18.6%. In order to assess the nutrient quality of the protein component of these plants, we compared their content of the essential amino acids to a World Health Organization (WHO, 1985) standard protein. More specifically, this was accomplished by calculating the percentage of each of the various essential amino acids or essential amino acid pairs (e.g., phenylalanine plus tyrosine) and then expressing that value as a percentage of the proportion of the same amino acids(s) in the WHO standard. As the data in Table 2 show, cecego had the highest protein content of the three plants we analyzed and scored well vis-à-vis the WHO standard: its essential amino acid pattern exceeded the standard in all eight amino acid categories. For example, in terms of relative proportions, cecego contained 1.34 times as much leucine and 2.43 times as much tryptophan as the WHO standard. The quality of godilo/gudai was also

Table 1
Amino acid content of the three edible plants of Niger (mg/g dry weight)

Amino acid	(mg/g) Cabbage ($n = 2$)		Cecego ($n = 2$)		Godilo/gudai ($n = 2$)	
	Mean (S.D.)	Mean (% of total)	Mean (S.D.)	Mean (% of total)	Mean (S.D.)	Mean (% of total)
Cys	1.62 (0.24)	0.90	5.48 (1.54)	1.51	2.94 (0.19)	1.20
Asp	14.1 (4.03)	7.55	36.5 (3.66)	10.1	14.9 (2.39)	6.07
Glu	24.3 (4.06)	13.0	44.0 (3.37)	12.2	28.8 (1.61)	11.76
Ser	7.47 (0.24)	4.01	16.5 (0.97)	4.56	14.1 (1.33)	5.76
Gly	7.61 (0.25)	4.08	17.5 (0.36)	4.83	12.3 (1.10)	5.03
His	5.95 (0.38)	3.19	9.1 (0.30)	2.51	6.98 (0.85)	2.85
Arg	16.9 (1.03)	9.05	27.9 (1.21)	7.71	22.3 (2.71)	9.09
Thr	7.48 (0.42)	4.01	18.7 (0.61)	5.15	12.4 (0.87)	5.05
Ala	8.93 (0.19)	4.79	20.3 (0.60)	5.61	13.9 (1.30)	5.66
Pro	32.9 (1.62)	17.7	17.6 (0.31)	4.87	21.6 (1.41)	8.81
Tyr	4.68 (0.13)	2.50	14.9 (0.82)	4.11	9.53 (1.79)	3.89
Val	10.4 (0.52)	5.59	21.6 (0.38)	5.96	14.6 (1.19)	5.97
Met	2.57 (0.19)	1.38	7.41 (1.17)	2.04	3.47 (0.13)	1.42
Ile	7.36 (0.34)	3.95	18.8 (0.30)	5.18	11.4 (1.35)	4.65
Leu	11.3 (0.41)	6.08	32.1 (0.93)	8.86	19.8 (1.45)	8.10
Phe	9.71 (0.26)	5.21	21.7 (0.10)	6.00	15.0 (1.04)	6.13
Trp	3.53 (0.25)	1.89	9.68 (0.95)	2.67	6.68 (1.62)	2.73
Lys	9.61 (0.23)	5.15	22.5 (0.22)	6.20	14.3 (0.59)	5.83
Total		186		362		245

satisfactory in that the percentages of all of the essential amino acids (or amino acid pairs) in its protein fraction equalled or exceeded those of the WHO standard. Finally, cabbage, whose protein content was the lowest of the three plant foods we studied, had lysine, leucine, and methionine-plus-cysteine percentages that were below those of the WHO standard. These results indicate that in terms of total amino acid content and proportions of the essential amino acids, cecego appears to be superior to godilo/gudai and cabbage.

3.3. Fatty acid content

We were interested not only in the total fatty acid content but also in the amounts of the two fatty acids which are essential for humans and that were contained in the total (crude) lipid extract of each of the three plants: namely, linoleic acid (18:2n-6) and α-linolenic acid (18:3n-3). As shown in Table 3, cecego contained the greatest quantity of total fatty acid (1.11 mg/g dry weight), followed by godilo/gudai (0.776 mg/g dry weight) and cabbage (0.485 mg/g dry weight). As for linoleic acid, the best sources appear to be cecego (126 μg/g dry weight) and godilo/gudai (115 μg/g dry weight), followed closely by cabbage (72 μg/g dry weight). The same was true for α-linolenic acid where cecego and godilo/gudai contained about the same amounts of this n-3 fatty acid (225 and 233 μg/g dry weight, respectively) and cabbage contained slightly less (178 μg/g dry weight). Thus, cecego appears to contain the greatest amounts of both of the essential fatty acids.

Table 2
Essential amino acid content of cabbage, cecego and godilo/gudai compared to the WHO "ideal protein[a]"

Amino acid	Cabbage		Cecego		Godilo/gudai		WHO ideal protein
	% of total[b] amino acids	% of total/ % in "ideal protein"	% of total[c]	% of total/ % in "ideal protein"	% of total[d]	% of total/ % in "ideal protein"	% of total amino acids
Isoleucine	4.0	141	5.2	185	4.7	166	2.8
Leucine	6.1	92	8.9	134	8.1	123	6.6
Lysine	5.2	89	6.2	177	5.8	101	5.8
Methionine + Cysteine	2.3	91	3.6	142	2.6	105	2.5
Phenylalanine + Tyrosine	7.7	122	10.1	160	10.0	159	6.3
Threonine	4.0	118	5.2	151	5.1	149	3.4
Tryptophan	1.9	172	2.7	243	2.7	248	1.1
Valine	5.6	160	6.0	170	6.0	171	3.5

[a] WHO (1985).
[b] Total protein, 186 mg/g dry weight.
[c] Total protein, 362 mg/g dry weight.
[d] Total protein, 245 mg/g dry weight.

3.4. Minerals and trace elements

Table 4 is a summary of the results of our mineral and trace element analyses, where all of the data are reported on a dry weight basis. All three of the food plants contained relatively large quantities of calcium (> 15,000 μg/g), iron (165–260 μg/g), manganese (45.5–69.2 μg/g), and useful amounts of many other nutritionally essential elements, including: chromium, copper, phosphorus, and zinc. The nutritionally significant element selenium was not detected in any of the plants. Molybdenum was absent from cecego. In addition, appreciable levels of a number of toxic metals were found in these edible plants; these included aluminium (118–220 μg/g), arsenic (0.11–0.39 μg/g), cobalt (0.37–0.48 μg/g), and yttrium (0.24–3.56 μg/g). Overall, of the three plant foods, cecego contained the largest quantities of most of the nutritionally essential minerals and trace elements.

4. Discussion

In order to place in local context the nutrient data we derived from our analyses of three widely used plant foods that are the focus of this report, we elected to compare these data with similar data we obtained for several dozen other wild edible plants of the Western Sahel that we have analyzed in recent years and which, like godilo/gudai, cecego and cabbage, are consumed widely and frequently by the inhabitants of the semi-arid regions of West Africa (Humphry et al., 1993; Freiberger et al., 1998; Sena et al., 1998). With respect to protein, all three of these plants contained 2 to 3-times more total protein than baobab leaf and most of the other leaf-based plant

Table 3
Total lipid and fatty acid content of three edible plants of Niger

Fatty acid	(μg/g dry weight)		
	Cecego ($n = 3$)	Godilo/gudai ($n = 3$)	Cabbage ($n = 3$)
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
10:0	ND	ND	0.43 (0.00)
12:0	2.43 (0.43)	0.53 (0.00)	2.15 (0.30)
14:0	5.77 (0.31)	6.33 (0.52)	3.89 (0.09)
14:1	4.10 (0.23)	13.4 (0.86)	2.53 (0.07)
15:0	1.09 (0.00)	0.87 (0.28)	3.24 (0.48)
16:0	375 (24.2)	243 (11.0)	121 (2.75)
16:1	5.98 (0.13)	11.5 (1.58)	4.49 (0.75)
18:0	67.4 (3.97)	60.7 (4.04)	21.5 (0.22)
18:1n-9	254 (19.1)	49.2 (2.06)	38.5 (1.17)
18:1n-7	7.85 (0.21)	4.34 (0.29)	4.19 (0.23)
18:2n-6	126 (10.9)	115 (7.36)	72.0 (1.68)
18:3n-3	225 (13.8)	233 (17.0)	178 (5.62)
20:0	8.78 (0.78)	13.2 (0.54)	7.02 (0.08)
20:1n-9	1.74 (0.01)	0.44 (0.08)	0.59 (0.37)
20:2n-6	1.23 (0.11)	0.54 (0.15)	7.92 (0.36)
20:3n-6	0.74 (0.00)	ND	ND
20:4n-6	0.19 (0.00)	ND	ND
20:3n-3	1.22 (0.11)	ND	3.60 (0.60)
20:5n-3	1.60 (0.78)	ND	ND
22:0	6.12 (0.17)	8.59 (0.33)	6.13 (0.40)
22:1n-9	1.28 (0.06)	2.51 (0.52)	2.33 (0.46)
24:0	13.3 (1.60)	11.0 (0.93)	4.01 (0.82)
22:6n-3	1.74 (0.6)	1.93 (0.00)	0.75 (0.11)
Total lipid (μg/g dry wt)	1112	776	485

ND, not detected (<0.005 mg/g dry weight).

foods of Niger that we analyzed previously (Humphry et al., 1993; Yazzie et al., 1994; Kim et al., 1997; Glew et al., 1997; Freiberger et al., 1998; Sena et al., 1998; Cook et al., 2000). Furthermore, as assessed in terms of essential amino acid pattern (Table 2), the protein quality of cecego and godilo exceeded that of the WHO standard (WHO, 1985). Thus, in terms of both quantity and quality, our overall conclusion is that all three of the leafy plant foods we have reported herein represent potentially useful and important protein sources for the people of Niger.

The amounts of the two fatty acids that are essential for humans, namely linoleic acid and α-linolenic acid, that we found in cassia, cecego and nigerienne cabbage were very low compared to baobab and most of the wild edible plants of the western Sahel that we analyzed previously (Yazzie et al., 1994; Kim et al., 1997; Glew et al., 1997; Freiberger et al., 1998; Sena et al., 1998; Cook et al., 2000). For example, the amount of linoleic acid in any one of the three plant foods we analyzed in the present study was only about 10% the amount of linoleic acid provided by baobab leaf (Yazzie et al., 1994). As for the α-linolenic acid, the comparison is even worse; whereas

Table 4
Mineral content of cecego, godilo/gudai, and cabbage

Mineral	(μg/g dry weight)		
	Cecego ($n = 2$)	Godilo/gudai ($n = 2$)	Cabbage ($n = 2$)
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
Aluminum, Al	220 (17.0)	118 (14.8)	211 (23.3)
Arsenic, As	0.11 (0.16)	0.39 (0.11)	0.12 (0.17)
Barium, Ba	43.3 (0.14)	82.6 (1.77)	103 (4.38)
Beryllium, Be	0.03 (0.005)	0.03 (0.004)	0.06 (0.01)
Calcium, Ca	15,000 (300)	23,500 (700)	27,400 (200)
Cadmium, Cd	0.02 (0.03)	0.14 (0.006)	0.13 (0.01)
Cobalt, Co	0.45 (0.01)	0.37 (0.001)	0.48 (0.08)
Chromium, Cr	2.25 (0.03)	2.05 (0.12)	2.18 (0.01)
Copper, Cu	9.90 (0.08)	5.94 (0.45)	2.27 (0.18)
Iron, Fe	260 (12.7)	165 (12.0)	198 (26.9)
Potassium, K	13,600 (0.00)	13,700 (141)	18,450 (919)
Lanthanum, La	0.41 (0.01)	0.49 (0.001)	0.67 (0.15)
Lithium, Li	0.12 (0.01)	0.20 (0.002)	0.93 (0.01)
Magnesium, Mg	852 (0.71)	4215 (7)	4215 (275)
Manganese, Mn	45.50 (0.85)	61.85 (0.07)	69.15 (3.23)
Molybdenum, Mo	ND	2.53 (0.06)	3.89 (0.26)
Sodium, Na	285 (108)	47.4 (7)	4020 (57)
Nickel, Ni	2.43 (0.01)	1.73 (0.00)	0.78 (0.06)
Phosphorus, P	3460 (14)	2205 (7)	2490 (156)
Lead, Pb	0.23 (0.004)	0.31 (0.04)	0.16 (0.04)
Antimony, Sb	ND	1.19 (1.68)	ND
Selenium, Se	ND	ND	ND
Strontium, Sr	63.3 (0.00)	121 (2.12)	132 (7.78)
Titanium, Ti	2.02 (0.04)	1.26 (0.09)	1.9 (0.44)
Thallium, Tl	ND	3.31 (0.18)	1.05 (0.04)
Vanadium, V	0.34 (0.02)	0.31 (0.007)	0.45 (0.08)
Yttrium, Y	0.24 (0.01)	3.56 (0.02)	0.30 (0.02)
Zinc, Zn	40.2 (1.77)	15.6 (0.28)	32.8 (1.13)
Zirconium, Zr	0.24 (0.06)	0.67 (0.64)	0.26 (0.04)

ND, not detected. The following elements were not detected: Ag, Te (silver, tellurium).

baobab leaf contains about 4100 μg/g dry weight α-linolenic acid (Sena et al., 1998), cassia, cecego, and nigerienne cabbage each contained only about 200 μg/g dry weight of α-linolenic acid. Thus, it appears while godilo/gudai, cecego and nigerienne cabbage appear to be excellent sources of good quality protein, they are not likely to satisfy to any appreciable extent the essential fatty acid requirement of humans.

With regard to minerals and trace elements, godilo/gudai, cecego and cabbage contained potentially useful quantities of many essential minerals and trace elements including chromium, magnesium, manganese, sodium and phosphorus. However, noteworthy were the very large amounts of calcium contained in the three plant foods, especially godilo/gudai and cabbage, which contained 23,500 and 27,400 μg calcium per g dry weight, respectively. Of all the edible plants of Niger whose nutrient composition we analyzed previously, only *Ximenia Americana*, which is called ''tsada'' in Hausa, *Amaranthus viridus* (''alayyaho'', Hausa), and the leaves of the baobab tree (*Adansonia digitata*; ''kuka'', Hausa) contained comparable quantities of calcium. The availability of calcium-rich edible plants in Niger and other regions of the western Sahel is significant when one considers the high incidence of calcium-deficiency rickets among the local populations, particularly those in the rural areas (Thacher et al., 1999; VanderJagt et al., 2001). Of course, the human bioavailability of the calcium in these calcium-rich plants is not known and could be compromised by the co-presence of natural products such as oxalates and phytates that can chelate calcium, thereby rendering this critical divalent cation unavailable for absorption in the intestine.

Given the relatively high prevalence of iron deficiency anemia among all age groups in the rural populations of Niger, we were interested in knowing the iron content of the three plants we report herein. Although godilo/gudai, cecego and cabbage do all contain modest amounts of iron (165–260 μg/g dry weight), these quantities are only one-tenth to one-half of those reported for baobab leaf (Yazzie et al., 1994; Sena et al., 1998), *Cerathotheca sesamoides* (Sena et al., 1998) (called ''yodo'' in Zarma), and *Amaranthus viridus* leaves (Sena et al., 1998). Nevertheless, cecego, godilo and cabbage could still contribute significant amounts of iron to the diet.

The amounts of zinc contained in cecego and cabbage were substantial (40.2 and 32.8 μg/g dry weight, respectively) and compared favorably with the zinc levels we previously documented in many other edible plants that grow in Niger (Yazzie et al., 1994; Sena et al., 1998). Zinc is nutritionally critical for several reasons, among them its role in the immune system (Bhaskaram, 2002; Dardenne, 2002), the secretion of insulin (Chausmer, 1998), the release of vitamin A from liver stores (Hwang et al., 2002), and key enzymes such as superoxide dismutase (Boron et al., 1988).

Godilo/gudai and cecego contained relatively high amounts of copper (5.94 and 9.90 μg/g dry weight, respectively) which is an essential component of many enzymes that catalyze oxidation–reduction reactions and processes, including certain components of the mitochondrial electron transport (Nittis et al., 2001; Takahashi et al., 2002) and lysyl oxidase which is involved in collagen biosynthesis (O'Dell, 1981; Pereira et al., 2002).

Unfortunately, none of the three plant foods contained measurable levels of selenium that is required by glutathione peroxidase, an enzyme which protects tissues against oxidative damage. In contrast, cecego, godilo/gudai and cabbage did contain detectable quantities of several metals that are detrimental to human health; these included aluminium, arsenic, lead, and yttrium. The levels of these toxic metals in the three plants were relatively low, such that in light of the quantities of these food items that would normally be consumed in Niger, they would not pose a health problem to the local population. We previously reported on the presence of high levels of yttrium in another wild edible plant of Niger, namely dilo (Kim et al., 1997).

Although the literature contains few reports of the nutrient content of cecego and godilo/gudai, others have published the results of their analyses of the fatty acid, protein, and mineral content of *B. oleracea*. With regard to fatty acid composition, though the proportions of palmitic acid, oleic acid, linoleic acid and α-linolenic acid relative to one another resemble closely the relative proportions of these four fatty acids reported by Lu and co-workers (2001) in Japan, the content of erucic acid (22:1n-9) in the cabbage leaves from Niger that we analyzed was much lower than that reported by these Japanese investigators. This difference in the erucic acid content of the cabbage leaves we and they analyzed could be due to genetic factors resulting from cross-breeding (Lu et al., 2001).

With regard to minerals and trace elements, the cabbage leaves from Niger had levels of copper, manganese, lead, arsenic, cadmium, chromium and zinc that were comparable to those reported by Lachas et al. (2000); however, the amount of molybdenum we found in *B. oleracea* was 10–20 times higher than they reported. Likewise, the calcium content of *B. oleracea* we report herein (27.4 mg/g dry weight) is also 10–20 times higher than the calcium value reported recently by Barta and Tibbitts (2000) (1.0–2.1 mg/g dry weight). These same investigators reported the magnesium content of cabbage leaves to be 3.5 mg/g dry weight, which agrees with the value we determined for magnesium in the present study (4.2 mg/g dry weight).

The protein content we found for *B. oleracea* (25%) compares to corresponding values in the 30–40% range reported in the literature (Food and Agricultural Organization, 1968), assuming in the latter case that the "raw leaves" contained 70% water.

In assessing the nutritional value of these edible plants, it is important to know how well the various nutrients it contains are absorbed through the intestine. Therefore, there is a need for studies of the digestibility and overall bioavailability of the nutrients contained in godilo/gudai, cecego and cabbage. In addition, if these plant foods were to contain significant levels of protease (e.g., trypsin) inhibitors (VanderJagt et al., 2000), the utilization of the proteins in these plants and the amino acids they contain could be impaired. Similarly, other anti-nutrients such as chelating agents (e.g., phytic acid) could make divalent cations (e.g., magnesium, manganese, calcium) non-absorbable. It would be useful to know the content of other anti-nutrients such as nitrate, lectins and saponins in these three plant foods from Niger.

Nutrient composition studies of wild plant foods like the one reported herein provide valuable data on the potential nutritional benefits to the human diet. Published reports have documented (Humphry et al., 1993) that many of these uncultivated plant foods are consumed as part of the evening meal that also includes grain staples such as millet and sorghum. Alternatively, some of these plants, including cecego, godilo/gudai and cabbage, are consumed in the form of a "leaf bundle" in which case they are eaten in combination with solid peanut extract and other seasonings. As has been pointed out in previous reports by us (Freiberger et al., 1998, Cook et al., 2000) and others (Humphry et al., 1993), the value of the kind of nutrient data we and others have generated on wild edible plants of the western Sahel ultimately depends on the use local public health officials and community leaders make of this information, particularly whether they promulgate recommendations regarding their incorporation into the diets of their citizens.

The information contained in this report should stimulate the local public health authorities in Niger to consider the question of recommending that cecego, godilo/gudai and cabbage be consumed by adults and children alike in Niger, including pregnant women and others with higher than normal nutritional requirements. The ability to provide scientifically informed advice about the use of wild edible plants with high nutritional value increases the likelihood that this information will be used by governmental and non-governmental organizations involved in health and nutrition programmatic planning in the Sahel.

Finally, the present study highlights the importance of understanding the cultural context and uses of wild plant foods. It may be that not all wild plant foods are consumed by all the members of a community. Consumption patterns, for example, can vary by gender or age, or even physiologic state (e.g., pregnancy). Nutrient information would be critical to the success of efforts to promote the wider use of indigenous plant foods as part of a broader program aimed at educating local populations with regard to the nutritional benefits of the many wild plant foods that exist in their environment.

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