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Original Article

Nutritional analysis of the edible pit of *Sclerocarya birrea* in the Republic of Niger (*daniya*, Hausa)☆

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Abstract

Wild plant foods in the Sahel region of West Africa play an important role in the diets of local residents. During periods of grain shortage, people in rural Niger increase their reliance on wild plant foods to supplement their diets. We report the partial nutrient content of the pit of the seed *Sclerocarya birrea*, a snack food eaten by children in rural Niger. The pit contained relatively large amounts of copper (24.8 μg/g dry wt), magnesium (4210 μg/g dry wt), and zinc (62.4 μg/g dry wt). The protein content of the pit was high (36.4% of dry wt); however, the protein fraction contained relatively low proportions of leucine, phenylalanine, lysine, and threonine. Fatty acids accounted for 47 mg/g dry wt of the pit, two-thirds of which was due to oleic acid. The essential fatty acid linoleic acid was present (24.5 mg/g dry wt), but the other essential fatty acid, α-linolenic acid, was absent. Such data are useful for health and nutrition program planning by governmental and non-governmental organizations in Niger. The consumption of *daniya* pits by just children highlights the need to better understand the cultural context of how wild plant foods are used in a particular local context.

Keywords: *Sclerocarya birrea*; *Daniya*; Niger; Famine food; Amino acids; Fatty acids; Minerals; Nutrients

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1. Introduction

In the Sahel region of West Africa wild plant foods are widely consumed to supplement cultivated cereals such as millet and sorghum. In some regions of the Sahel, farmers' crop yields are often insufficient to last until the following harvest season. In many villages in the Republic of Niger, for example, granaries often become exhausted months before the next planting season begins (usually in late June or early July). This results in a "hungry season" during which people are forced by circumstances to purchase grain in local markets at an elevated price. Consequently, during times when staple cereals are scarce or costly, the inhabitants of rural Niger are compelled to increase their reliance on wild edible plants for food. Research on the nutritional assets of wild plant foods in the Sahel indicates that many of them have considerable nutritional attributes for humans (Humphry et al., 1993; Kim et al., 1997; Glew et al., 1997; Freiberger et al., 1998; Sena et al., 1998; VanderJagt et al., 2000; Cook et al., 1998, 2000).

The nutrient information reported in this study should enhance efforts to promote the wider use of wild plant foods like the pit of *Sclerocarya birrea* 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. Obviously, such an effort requires the support of government agriculture and health authorities. In order to maximize the likelihood that the data from this study will be used in this manner, we discussed the research project with and received the support of numerous government authorities in Niger. Per Nigerian governmental regulations, we received research clearance from the proper governmental authorities. Before beginning the fieldwork we met and discussed this study with the Permanent Secretary for Early Warning and Crisis Management as well as agricultural engineers and economists from the Cabinet of the Prime Minister. In addition, we consulted extensively with a former National Secretary of State for Agriculture. A report of the findings of the study will be sent to these authorities for them to review and make decisions with regard to how the data may be used in public health planning.

The samples of *S. birrea* analysed in this study were collected in the village of Droum located in south-central Niger about 50 km south of Zinder, the second largest city in Niger with a population of 120,000. The approximately 5000 Hausa-speaking residents of Droum rely heavily on the farming of millet and off-season farming of fruits and vegetables to make their living. 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. In some villages in this region, the millet harvested in the months of September and October does not last through the year. During interviews with farmers in Droum, we learned they are often unable to produce enough millet (even in good years) to last until the following harvest. According to these farmers it is not uncommon for millet stocks to be depleted by January or February. In most years, the granaries are empty by March, leaving at least 5 months until the next harvest.

Previous studies have documented the nutritional content of the wide range of types of plant foods that are eaten in Droum, Niger (Humphry et al., 1993; Kim et al., 1997; Freiberger et al., 1998; Sena et al., 1998; VanderJagt et al., 2000; Cook et al., 1998, 2000). The plant foods eaten generally are in the form of leaves, fruits and seeds 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 (e.g., 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.

We were interested in the nutritional content of the waxy pit of the fruit *S. birrea*, known locally in the Hausa language as *daniya*. In the eastern, Zarma-speaking region of Niger, where the fruit and pits are also consumed, it is known as *lulay*. The tree is found throughout Africa where both the fruit and contents of the pit are consumed. Previous studies have reported on the nutritional content of the flesh of the *daniya* fruit and content of the pit for other regions of Africa (Engelter and Wehmeyer, 1970; Shone, 1979; Burger et al., 1987; Erromosele and Eromosele, 1993; Smith and McGill, 1986; Sena et al., 1998); however, analysis of the nutrient content of the *daniya* pit from the Droum area has yet to be reported. In certain regions of Niger, including the village of Droum, *daniya* pits are generally eaten by children as a snack food. The small *daniya* fruits that fall from the tree are eaten by goats and sheep who remove the flesh of the small round fruit and then "clean" the pit as it passes through their system. The durable pits are collected and then opened by children using rocks as hammer and anvil. Because in the study area the contents of the pit are only eaten by children, this study highlights the need to understand the cultural context in which wild plant foods are consumed. It appears that since the seeds have passed through goats, they are not consumed by adults because they are perceived to be unclean. The present study reports the results of our analysis of the quantities of fatty acid, amino acid, and minerals and trace elements contained in *daniya* pits.

2. Materials and methods

2.1. Collection of daniya

Seed specimens for this study were collected in July 2002 in three different areas where *S. birrea* trees were abundant and which were located 1–2 km from the outskirts of the village of Droum. Approximately 50 seeds were collected at each site. The edible portion of the 150 seeds from each of the three sites was pooled separately prior to performing the various analyses. All pits that were collected were in a dried state at the time of collection and stored in plastic bags for two weeks until which time they were carried to New Mexico for analysis. Once the seeds were cracked open with the aid of a hammer, the waxy, white contents were removed with a spatula and ground to a fine powder using a stainless steel mill. The powder was dried to constant weight under a vacuum at room temperature. Each of the three sets of samples from different trees were analysed in duplicate or triplicate for their content of fatty acids, amino acids, and minerals and trace elements.

2.2. Interviews

Group interviews were held with residents of Droum to learn about the use of various wild plant foods in the village. A two and one-half hour interview, conducted in Hausa, was held with eight women known for having expertise on wild plant use for food as well as medicine. A group of 15 men were interviewed for three hours to gather information on the farming methods and yields of staple crops, such as millet, as well as income generating off-season gardening of fruits and vegetables.

2.3. Amino acid analysis

Plant specimens were analysed in duplicate. 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 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. After hydrolysis, a 20 μL aliquot of the hydrolysate was withdrawn, dried, hydrated, redried and subjected to derivatization.

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.

Amino acids were quantified using the Pico-Tag system (Waters Inc., Milford, MA). After hydrolysis, aliquots 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 at room temperature with the aid of a vacuum pump. 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.

Amino acid analysis was performed using a Waters C18 column (3.9 × 150 mm) with gradient conditions as described elsewhere (Bidlingmeyer et al., 1984). The column was eluted with increasing concentrations of acetonitrile to separate the individual amino acids. The retention times of the various amino acids were determined using an amino acid calibration mixture. Quantitation of individual amino acids was achieved by monitoring the absorption of the column eluate at 254 nm and comparing the areas under the individual peaks with those of the corresponding amino acid standards. A sample of egg white lysozyme, analysed in duplicate, served as the control protein.

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) 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 above. Quantification of individual amino acids was performed using a Pierce Standard H amino acid calibration mixture (Rockford, IL) that was supplemented with tryptophan. Norleucine was the internal standard used in all amino acid determinations. 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, Sundar, and Vannoord (1993). Use of this elution protocol was necessary in order to adequately

Table 1
The mineral content of *daniya* pit

Mineral (symbol)	Mean ± S.D. (μg/g dry wt) ($n = 3$)[a]
Aluminum (Al)	1.97 ± 0.72
Antimony (Sb)	0.38 ± 0.03
Arsenic (As)	0.37 ± 0.03
Barium (Ba)	17.4 ± 0.19
Beryllium (Be)	0.005 ± 0.001
Cadmium (Cd)	0.01 ± 0.005
Calcium (Ca)	1540 ± 47.3
Chromium (Cr)	3.98 ± 0.35
Cobalt (Co)	0.35 ± 0.004
Copper (Cu)	24.8 ± 0.11
Iron (Fe)	27.7 ± 1.16
Lithium (Li)	0.03 ± 0.001
Magnesium (Mg)	4210 ± 64.3
Manganese (Mn)	6.27 ± 0.04
Molybdenum (Mo)	0.18 ± 0.01
Nickel (Ni)	3.20 ± 0.05
Phosphorus (P)	10400 ± 153
Potassium (K)	3640 ± 58.6
Selenium (Se)	0.36 ± 0.09
Sodium (Na)	42.7 ± 1.39
Strontium (Sr)	9.88 ± 0.13
Zinc (Zn)	62.4 ± 0.31

[a] Refers to the number of specimens analysed; each specimen was the result of pooling the edible portions of 25 pits. The following elements were not detected: lanthanum, lead, silver, tellurium, thallium, titanium, vanadium, yttrium.

separate tryptophan from ornithine which results from the alkaline hydrolysis of arginine. The data are reported in Table 1 as the mean ± SEM of three determinations.

2.4. Mineral analysis

Three replicate aliquots (50–500 mg) from each of the three dried 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 (Kim et al., 1997; Yazzie et al., 1994). The mineral contents of the samples were quantified against standard solutions of known concentrations which were analysed concurrently. Results are reported in Table 1 and represent the average of three determinations.

2.5. Fatty acid analysis

The dried specimens were extracted with chloroform:methanol (2:1, vol/vol) as described elsewhere (Chamberlain et al., 1993) 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*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 (15%, w/v), placed in a warm bath at 100°C for 30 min and cooled. After the addition of a 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 analysed 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 × 0.32 mm i.d., 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/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.

3. Results

3.1. Comments regarding the pit

Fig. 1 is a photograph of the intact pit of *S. birrea* fruit and a cross-section of the pit made along its long axis. The average weight of the seeds we analysed was 1.52 g and the dimensions were, on average, 1.4 × 1.9 cm. The edible portion of the pit weighed 0.16 g when dried to constant weight in a vacuum at 22°C. Thus, to obtain 10 g of the edible material would require cracking open and extracting the core of approximately 60 seeds.

3.2. Minerals and trace elements

Table 1 is a summary of the results of the analysis of the mineral and trace element content of *daniya* seed. While providing significant quantities of many elements that are essential to man, the seed contains relatively large amounts of several minerals that are important to human nutrition; these include copper, magnesium, and zinc. Relative to the 13 non-cultivated plant foods of Niger that we reported in 2000 (Cook et al., 2000) and whose copper content ranged from 3.39 to 15.4 μg/mg dry weight, *daniya* seed contained 24.8 μg of copper per gram dry weight. The magnesium content of *daniya* (4210 μg/g dry weight) compares favorably to that of two other seeds that grow wild in Niger, namely *Hibiscus esculentus* (5455 μg/g dry weight) and *Parkia biglobosa* (3193 μg/g dry weight). Likewise, the zinc content of *daniya* (62.4 μg/g dry weight) is within the range of values defined by *P. biglobosa* seed (40.1 μg/g dry weight) and *H. esculentus* seed (87.4 μg/g dry weight) (Cook et al., 2000).

Fig. 1. Bottom row: representative examples of intact *S. birrea* pits. Top row: cross-section of *S. birrea* pit with edible portion (left) and after removal of the edible portion (right).

Compared to other wild edible seeds, flowers, beans and fruit of Niger that were analysed previously (Humphry et al., 1993; Kim et al., 1997; Freiberger et al., 1998; Sena et al., 1998; VanderJagt et al., 2000; Cook et al., 1998, 2000), the iron content of *daniya* (27.7 μg/g dry weight) is very low, as is that of manganese (6.27 μg/g dry weight), sodium (42.7 μg/g dry weight) and potassium (3640 μg/g dry weight). Finally, *daniya* contains useful quantities of cobalt, chromium, selenium, and phosphorus.

3.3. Protein and amino acids

The amino acid and total protein content of *daniya* seed is summarized in Table 2. The protein content of the edible portion of *daniya* seed was surprisingly high (36.4% of dry weight), particularly in light of the fact that it is regarded as a lipid-rich seed (Table 4). However, when compared with the WHO protein standard, the seeds were found to contain low proportions of several of the essential amino acids, including leucine, lysine, the phenylalanine/tyrosine pair, and threonine (Table 3). Thus, the pits of *daniya* seed appear to represent a potentially rich source of some, but not all, of the amino acids that are essential for humans. Noteworthy in the amino acid profile of the protein fraction of *daniya* seed was the presence of unusually high amounts of the basic amino arginine (14.4% of total).

3.4. Lipid and fatty acids

The fatty acid composition and content of the pit of *daniya* seed are summarized in Table 4. The total fatty acid content of the seed was high (47.0% of dry weight). The major fatty acid was

Table 2
The amino acid composition of *daniya* pits

Amino acid (abbreviation)	Mean ± s.d. (mg/g dry wt)	Percent of total
Alanine (Ala)	9.03 ± 0.35	2.48
Arginine (Arg)	52.3 ± 1.97	14.4
Aspartic acid (Asp)	46.2 ± 2.45	12.7
Cysteine (Cys)	8.92 ± 0.41	2.45
Glutamic acid (Glu)	108.7 ± 7.91	29.9
Glycine (Gly)	12.9 ± 0.36	3.55
Histidine (His)	9.23 ± 0.42	2.54
Isoleucine (Ile)	12.0 ± 0.13	3.30
Leucine (Leu)	17.4 ± 0.29	4.78
Lysine (Lys)	7.29 ± 0.41	2.04
Methionine (Met)	5.89 ± 0.21	1.62
Phenylalanine (Phe)	13.2 ± 0.35	3.62
Proline (Pro)	10.0 ± 0.50	2.75
Serine (Ser)	14.9 ± 0.60	4.09
Threonine (Thr)	8.69 ± 0.26	2.39
Tryptophan (Trp)	5.39 ± 0.16	1.48
Tyrosine (Tyr)	7.43 ± 0.71	2.04
Valine (Val)	14.3 ± 0.04	3.93
Total protein (mg/g)	363.7	

$n = 3$.

Table 3
The essential amino acid composition of *daniya* pit compared to the WHO "ideal protein[a]"

Amino acid	*Daniya* pit		WHO ideal protein
	% of total amino acids[b]	% amino acid/ideal × 100	(%)
Isoleucine	3.3	118	2.8
Leucine	4.8	73	6.6
Lysine	2.0	35	5.8
Methionine + Cysteine	4.1	163	2.5
Phenylalanine + Tyrosine	5.7	90	6.3
Threonine	2.4	70	3.4
Tryptophan	1.5	136	1.1
Valine	3.9	112	3.5

$n = 3$.
[a] WHO, 1985.
[b] Total protein, 363.7 mg/g dry weight.

monoenoic oleic acid (18:1n-9) and it accounted for 63% of the fatty acid total. Since most edible plants contain both of the two fatty acids that are essential in humans, namely linoleic acid (18:2n-6) and α-linolenic acid (18:3n-3), it was surprising to find that *daniya* seed did not contain detectable amounts of α-linolenic acid. Furthermore, the linoleic acid level of *daniya* seed was

Table 4
The total lipid and fatty acid content of *daniya* pit

Fatty acid	*Daniya* pit mean ± S.D. (mg/g dry wt)
10:0	ND
12:0	ND
14:0	0.5 ± 0.1
14:1	ND
15:0	ND
16:0	73.5 ± 4.6
16:1	1.1 ± 0.1
18:0	52.2 ± 3.5
18:1n-9	297.1 ± 21.1
18:1n-7	4.1 ± 0.3
18:2n-6	24.5 ± 2.3
18:3n-3	ND
20:0	5.9 ± 0.5
20:1n-9	2.5 ± 0.2
20:2n-6	ND
20:3n-6	ND
20:4n-6	ND
20:3n-3	ND
20:5n-3	ND
22:0	1.8 ± 0.3
22:1n-9	3.1 ± 0.7
22:6n-3	ND
24:0	3.9 ± 0.5
Total fatty acids (mg/g dry weight)	470.1 ± 32.0

$n = 3$.
ND, not detected (<0.005 mg/g dry weight).

relatively low (24.5 μg/g dry weight). Also noteworthy in the fatty acid profile (Table 4) was the absence of any n-6 series fatty acids containing more carbon atoms or carbon–carbon double bonds than linoleic acid. This observation indicates that the desaturase and elongase pathway that increases the chain length and degree of unsaturation of fatty acids of the n-6 family in most eukaryotes is not expressed in *daniya* seed. Overall, the fatty acid composition of *daniya* seed is relatively simple.

4. Discussion

The nutrient analyses of *daniya* seed we report herein provide a basis for regarding this plant as a useful food supplement not only for the children of Droum who consume them, but for the larger population as well. Nearly half of the dry weight of the seed's white, waxy core is comprised of fatty acids, contained presumably in triglycerides. This storage lipid thereby represents a concentrated source of energy for the local population, which is often hard-pressed for calories, especially during times when staple cereals (e.g., millet, rice, maize) are in short supply. A child consuming 10 g of the edible portion from 60 pits would be ingesting approximately 5 g of fatty acid which translates into 45 kcal of energy or about 2–3% of their daily total energy requirement.

Apart from providing energy, the lipid fraction of *daniya* seed contains modest but useful amounts of the essential fatty acid, linoleic acid. Linoleic acid itself is an important component of membrane phospholipids; it is also a precursor to another critical fatty acid one finds in virtually all tissue membranes of humans, namely arachidonic acid. Arachidonic acid is important for another reason; it is metabolized to various prostaglandins which regulate many normal processes, including blood pressure and gastric acid secretion (Lauritzen et al., 2001; Gravito and De Witt, 1999). Prostaglandins also play a critical role in inflammation and anaphylaxis.

Another noteworthy aspect of the fatty acid composition of the lipid component of *daniya* is its high content of oleic acid (63%, Table 2). Edible triglycerides, such as those in olive oil and which are rich in oleic acid, have cardioprotective effects, as opposed to dietary fats that are rich in saturated fatty acids and which are associated with increased risk of macrovascular diseases (e.g., stroke, heart attack).

Daniya seed, in addition to its high fatty acid content, is also an excellent source of protein. Its protein content is (36.4%, Table 3) is one of the highest we have found in the more than 75 edible plant foods of the western Sahel that we have analysed (Sena et al., 1998; Cook et al., 1998, 2000). The edible portion of 60 daniya seeds would provide a child with 3–4 g of protein and satisfy about 20% of their recommended daily allowance of protein. Unfortunately, the pattern of essential amino acids in the protein fraction of *daniya* pits falls far short of the WHO standard when it comes to several essential amino acids (Table 4). At 14.4%, the arginine content of the protein fraction of *daniya* pit stands as one of the highest levels of arginine in any plant protein that has been reported in the literature.

Arginine plays vital roles in nutrition and metabolism. It is classified as an essential amino acid in infants and young children and as a conditionally essential amino acid in adults at times of trauma or disease. Arginine is metabolized to nitric oxide, creatine, ornithine, proline, polyamines, and protein (Wu and Meininger, 2000). Arginine-rich proteins have been described in plants. The percentage of arginine in *hanza/dilo*, the seed of the *Boscia senegalensis* plant that grows wild in Niger, is also very high (13.7%) (Kim et al., 1997). It has been suggested that these arginine-rich proteins in desert plants have unusual water-binding properties which inform the seeds that contain them as to when environmental conditions, the water content of the soil in particular, are sufficient and suitable to support germination (Kim et al., 1997; Goldraij et al., 1998). Apart from interest in the nutritional aspects of *daniya* seed, the unusual proteins contained in its pit are deserving of further investigation. Studies of the structural features of these arginine-rich proteins might provide important information about the mechanisms plants of the hot, arid Sahel use to cope with the harsh and uncertain conditions that prevail in that part of the world.

Although the *daniya* seed is unremarkable in terms of the quantities of many essential minerals and trace elements it contains (e.g., calcium, iron, manganese, selenium), the copper, magnesium and zinc levels are relatively high compared with other edible wild plants of the western Sahel (Sena et al., 1998; Cook et al., 1998, 2000). Zinc is nutritionally important for many reasons, among them being its role in the immune system (Dardenne, 2002; Bhaskaram, 2002), the secretion of insulin (Chausmer, 1998), the release of vitamin A from the liver (Hwang et al., 2002) and critical enzymes such as superoxide dismutase (Boron et al., 1988; Hwang et al., 2002).

Copper is important because it participates in numerous enzyme-catalysed oxidation–reduction reactions and processes, including mitochondrial electron transport (Lin et al., 2002; Takahashi et al., 2002; Nittis et al., 2001), and lysyl oxidase which is involved in collagen biosynthesis (Pereira et al., 2002; O'Dell, 1981). Magnesium is required by many enzymes, especially the sugar and protein kinase families of enzymes that catalyse ATP-dependent phosphorylation reactions.

Certainly, it is rare for any single plant, cultivated or otherwise, to provide humans with adequate levels and proper proportions of all nutrients. While the contents of *daniya* pits are consumed only by children in Droum as a snack food, it provides a useful source of many different essential nutrients to their diet. The use of *daniya* as a snack food is important because children in the western Sahel often become full from eating millet or other grains and would therefore benefit from non-cereal supplements like *daniya* that contain relatively large amounts of critical nutrients (e.g., essential amino acids, zinc).

In assessing the nutritional value of *daniya*, one must consider how well the nutrients it contains are absorbed through the intestine. Therefore, there is a need for studies of the digestibility and overall bioavailability of the various nutrients in *daniya*. Finally, if *daniya* were to contain significant levels of protease (e.g., trypsin) inhibitors, the utilization of the proteins in *daniya* and the amino acids they contain could be impaired.

Nutritional studies of wild plant foods provide valuable data on the potential nutritional benefits to the human diet. As previous studies have established (Humphry et al., 1993), 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 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 have generated on the *daniya* pit ultimately depends on the use local public health officials and community leaders make of this information, particularly whether they promulgate recommendations regarding its incorporation into the diets of its citizens.

The information contained in this report should stimulate the local public health authorities in Niger to consider the question of recommending that *daniya* be eaten by members of the population other than just children. For example, the nutrients in *daniya* could be beneficial to 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. As our study illustrates, not all edible 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). Interviews we conducted with local residents of Droum revealed that *daniya* pits are commonly consumed by children but not adults. Cultural norms which explain why adults do not regularly consume the contents of the pits would need to be addressed. Thus, in addition to ''cleaning'' of the pit that takes place as it passes through the goat, what other means might be employed to ''clean'' the pit make this an acceptable source or nutrition to adults. Thus, nutrient information reported in this study is critical to the success of efforts to promote the wider use of wild plant foods like *daniya* seed 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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