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Research article

Influence of soaking on biochemical components of tiger nut (*Cyperus esculentus*) tubers cultivated in Cameroon

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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. Tiger nut tubers (*Cyperus esculentus*) which are used by local populations as nibble food were collected in the Northern of Cameroon are treated by soaking in different solutions and analyzed for their biochemical components. The tubers were soaked four different ways for consumption: non-treated (i.e., raw tubers), soaking in vitamin C, soaking in $Ca(OH)_2$ and soaking in *kanwa* solutions (1 g/L) at 40°C. In general, the nutrient content of tiger nut tubers was dependent on soaking solution. After the analysis, we noted that tiger nut tubers contained significant amounts of fatty acid (26% of dry weight) which were contained mostly in triacylglycerols (triacylglycerides) and consisted of palmitic acid (16:0; 40.4 mg/g dry weight), oleic acid (18:1n-9; 167 mg/g), linoleic acid (18:2n-6; 30.7 mg/g), and α-linolenic acid (18:3n-3; 0.7 mg/g). This plant contained 7.54% protein and it scored well the WHO protein standard. *C. esculentus* contained nutritionally useful amounts of many minerals and trace elements, including, copper, iron, manganese, zinc, chromium, selenium and molybdenum, and, it is a very good source of potassium, phosphorus and magnesium. Soaking in alkaline solutions ($Ca(OH)_2$ and *kanwa*) leads to significant loss of soluble proteins (7.54 to 4.85%), ascorbic acid (250 to 61.58% mg/100g DM) and vitamin E (120 to 94.05 mg/100g DM), in return, vitamin C solution preserves biochemical components of tiger nut tubers.

These data should provide public health officials in sub-Saharan Africa with information that would be useful in advising local populations about influence of treatment on the nutrient value of various spontaneous edible plants that grow in the region.

Keywords: nutrients, Cameroon, *Cyperus esculentus*, fatty acids, amino acids, minerals, soaking.

Running title: Influence of soaking on biochemical Composition of tiger nut tubers cultivated in Cameroon

List of abbreviations: EFAs, Essential Fatty Acids; FA, Fatty Acid; FAME, Fatty Acid Methyl Ester; FFAs, Free Fatty Acids; FID, Flame Ionization Detector; MUFAs, Monounsaturated Fatty Acids; PUFAs, Polyunsaturated Fatty Acids; RT, Raw Tuber; SFAs, Short-chain Fatty Acids; TAGs, 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. Tiger nut tubers belong to the foodstuffs having a high nutritional potential but which remain under-exploited (Ukwuru *et al.*, 2011 and Bamishaiye *et al.*,

2010). This nutritional value of the tubers is appreciable and it varies from an area to another. Many authors evaluated the chemical composition of this foodstuff in various regions; it comes out from this work that the chemical characteristics of the tubers are influenced by the zones of culture (Eteshola, and Orasedu, 1996 and Pascual, Maroto, San Bautista, Alagarda and Lopez-Galarza, 2003).

In Cameroon, tiger nut tubers are cultivated in the Soudano-sahelian zone, more precisely in the soudanian sector of altitude although it is found on sale on all the local markets. With more than 17000 T of production, the Far North region of Cameroon seems to be the principal area of culture in the country. The tubers are usually consumed like food of nibbling, in spite of its abundance in the area, its valorization is very weak, which justifies its low price on the market (less than 0,5 $.kg-1). Moreover, the plant has attracted very little scientific and technological attention apart work from Kapseu, Mbofung & Kayem (1997). The development produced again starting from the tubers can raise the interest granted to this plant. For this purpose, several opportunities are offered by the plant like: source of food fibers, production of milky drink (horchata de chufa), and use of its oil in the culinary field or the preparation of salads, production of caramel to be used like food additive. The major use of the tiger nut tubers comes from Spain where the tubers are used for the production of commercial milk called “horchata” (Pascual, Maroto, Lopez-Galarza, Sanbautista & Alagarda, 2000). These forms of use can imply, according to the case, a treatment of saoking (in acid or alkaline solutions). These treatments are suitable for induce modifications of the nutritional value of the tuber.

Although the literature does contain reports of the nutrient content of tubers of *C. esculentus* (Bosch, Alegria and Fare, 2005; Djomdi and Ndjouenkeu, 2007; Ejoh, Djomdi and Ndjouenkeu, 2006; Glew *et al*., 2005; Glew *et al*., 2006, in press), we were interested in determining how different methods used to treat the tubers for consumption in northern Cameroon might influence their biochemical composition. We therefore compared the content of these nutrients in raw tubers and tubers that had been either soaked in vitamin C solution or under alkaline conditions (pH 9.8-10.1) using a locally-prepared natural rock salt called ‘kanwa’ comprised of sodium carbonate and sodium bicarbonate (Makanynola and Beetlestone, 1975) and $Ca(0H)_2$ solutions.

Materials and Methods

Collection of samples

Tiger nut tubers were purchased in the local market in the town of Guily in Far-North Region of Cameroon, washed with distilled water and sun-dried for four days. One portion was set aside and designated ‘untreated raw tubers’. A second portion was soaked in vitamin C solution (1 g/L) at 40°C for maximums turgescent while a third and fourth portion was soaked for maximums turgescent in kanwa and $Ca(OH)_2$ 1 g/L at 40°C respectively and designated ‘alkali-soaked- tubers’. Soaking experiments, carried out according to Turhan *et al.* (2002). All plant samples were shipped via air-mail to Albuquerque, New Mexico for analysis. Prior to analysis, samples were ground once again with the aid of a mortar and pestle and dried to constant weight after maintaining them under a vacuum over anhydrous calcium chloride for four days at room temperature.

Analysis

Dry matter and ash were determined by UICPA (1979) methods; starch by Mestres et Mestres (2011) procedure; fiber, ascorbic acid, reducing sugar, caloric value were determined by AOAC (1984) procedures; vitamin E was determined by Chase et Long (1998) method.

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) 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^{o}C. Analyze was conducted as describe by Kramer, Cruz-Hernandez and Zhou (2001) and Cruz-Hernandez *et al*. (2004). The FAME were identified by comparison with known FAME standards that included gas chromatography standard mixture plus three separately purchased FAMEs (21:0, 23:0 and 26:0) from Nu Check Prep. The FID response was used to quantify all the FAMEs.

Amino acid analysis

Each plant sample was analyzed in triplicate. Five to nine mg of each samples 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^{o}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) with gradient conditions as described elsewhere (Glew *et al.,* 2005). The tryptophan content was determined in a separate analysis (Hugli and Moore, 1972) and the solvents and gradient conditions were as described by Hariharan and coworkers (Hariharan, Sundar and Van Noord, 1993).

Mineral analysis

A single sample (50-500 mg) from each of the dried, powdered sample 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^{o}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) 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

Biochemical composition of tiger nut tubers

Results of the different levels of biochemical components are found in table 1. No significant changes in starch and total sugars content were observed for the different treatments ($P< 0.05$). The analysis of variance indicates the existence of a significant difference ($p < 0.05$) between soaking solutions on proteins, ascorbic acid and vitamin E content. Alkaline solutions lead to loss of these components by their solubilisation in soaking solutions. Medoua (2005) observed the same effect on yams soaked in kanwa solution; and Yudkin (1988) specified that soaking in alkaline solutions of foodstuff cause loss of ¾ of vitamins. In fact, ascorbic acid and vitamin E are unsteady in these solutions as a consequence of oxidation and the dissolution of those vitamins in soaking solutions (Boudier et Luquet, 1981). On the other hand, vitamin C solution has stabilizing effect on vitamin E but increases ascorbic acid in tiger nut tubers soaked in this solution (Table 1).

Table 1: Biochemical composition of tiger nut tubers soaked in alkaline solutions (1 g/L) ($Ca(OH)_2$ et Kanwa) and acid solution (Vitamin C, 1 g/L) at 40°C.

	Soaking solution (1 g/L)			
Characteristics (mg/100 DM)	**Vitamin C**	**$Ca(0H)_2$**	**Kanwa**	**RT[1] (Control)**
Water content	57.342 ± 0.23^{b}	57.385 ± 0.54^{b}	57.297 ± 0.35^{b}	7.385 ± 0.141^{a}
Proteins	7.428 ± 0.42^{b}	5.62 ± 0.49^{a}	4.85 ± 2.12^{a}	7.54 ± 0.33^{b}
Lipids	26.25 ± 0.53^{b}	26.47 ± 0.18^{b}	27.74 ± 1.02^{c}	25.08 ± 0.32^{a}
Starch	25.13 ± 2.10^{a}	24.90 ± 0.15^{a}	24.59 ± 3.93^{a}	25.28 ± 4.03^{a}
Fibers	11.03 ± 0.94^{a}	12.53 ± 0.53^{a}	12.79 ± 0.54^{a}	14.14 ± 0.38^{a}
Ash	1.84 ± 0.07^{a}	3.73 ± 0.14^{b}	$4.60 \pm 1.35b$	2.60 ± 0.05^{a}
Total sugar	47.52 ± 0.84^{a}	48.54 ± 0.94^{ab}	48.84 ± 0.83^{ab}	49.78 ± 0.74^{bc}
Reducing sugar	23.74 ± 0.74^{a}	25.56 ± 1.52^{b}	26.05 ± 0.85^{b}	26.12 ± 0.24^{b}
Ascorbic acid (mg/100g)	328 ± 4.37^{d}	80.47 ± 1.39^{b}	61.58 ± 3.52^{a}	250 ± 0.62^{c}
Vitamin E (mg/100g)	118.79 ± 3.26^{c}	101 ± 1.23^{b}	94.05 ± 2.15^{a}	120 ± 0.56^{c}
Caloric value (kcal)	450 (1881 kJ)^{c}	446 (1864 kJ)^{b}	451 (1885 kJ)^{c}	442 (1847 kJ)^{a}

Values on the same row with the same superscript are not significantly different at $P<0.05$

[1]RT, Raw Tuber

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 tiger nut tubers preparation. The total lipid content in the four different preparations of *C. esculentus* tubers varies from 25.08 (RT) to 27.74% of total dry matter (Tubers soaked in kanwa solution) (Table 2) was considerably higher than in the other varieties and location (24.2% of total dry matter, Temple, Ojebe and Kapu (1989). There were no significant differences in the FA composition of the different preparations of *C.*

esculentus. The lipids of the tuber consisted mainly of oleic acid (18:1n-9) (64%) and much lower levels of total SFAs (22%) compared to legumes. They had 18:2n-6 levels (11%) that were similar to what was seen with the other plant specimens, but only trace amounts of 18:3n-3 (0.2%) were present (Table 2). The *trans* fatty acid (TFA) content was investigated in the plant lipids to assess product quality. Soaking in the alkaline conditions of the samples may have contributed to the increased levels of TFAs. Possibly the higher oil content and the TAG structure may have provided greater protection of the PUFAs in the tuber lipids of *C. esculentus* against isomerization. Table 2 shows the amount of selected FA or FA groups present in 100 g of plant foods. 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 (National Academy of Sciences, 2002), the percent of adequate intake of the two EFAs provided in 100 g was calculated (Table 2).

Table 2: Fatty acid composition of *Cyperus esculentus* from Cameroon soaked in alkaline and acid solutions (1 g/L) at 40°C

Fatty acids[1] (%)		**Vitamin C**	**$Ca(OH)_2$**	**Kanwa**	**RT[2]**
Myristic	14:0	0.12±0.00[a]	0.12±0.00[a]	0.12±0.00[a]	0.11±0.01[a]
Palmitic	16:0	15.40±0.23[a]	15.44±0.05[a]	15.80±0.22[a]	14.50±0.31[b]
Palmitoleic	16:1n-9	0.03±0.00[a]	0.03±0.02[a]	0.03±0.04[a]	0.03±0.00[a]
Stearic	18:0	4.59±0.41[b]	5.03±0.08[a]	5.19±0.11[a]	4.51±0.21[b]
Oleic	18:1n-9	65.47±0.19[a]	62.69±0.41[c]	62.33±0.45[c]	64.84±0.42[b]
Linoleic	18:2n-6	12.69±0.83[a]	10.87±0.11[c]	10.64±0.31[c]	11.38±0.11[b]
Arachidic	20:0	0.84±0.04[a]	0.76±0.07[b]	0.73±0.03[b]	0.75±0.02[b]
Gadoleic	20:1n-9	0.25±0.07[a]	0.24±0.01[a]	0.23±0.01[a]	0.23±0.03[a]
Linolenic	18:3n-3	0.25±0.03[a]	0.17±0.00[c]	0.18±0.02[c]	0.20±0.02[b]
Béhenic	22:0	0.24±0.09[a]	0.20±0.01[b]	0.19±0.00[b]	0.19±0.01[b]
Lignocetric	24:0	0.28±0.01[a]	0.25±0.03[a]	0.23±0.01[a]	0.24±0.02[a]
Cerotic	26:0	0.08±0.00[a]	0.09±0.00[a]	0.08±0.00[a]	0.08±0.00[a]
Sum SFAs		20.75±0.87[b]	22.07±0.12[a]	22.54±0.21[a]	20.58±0.23[b]
20:0 -26:0		1.53±0.05[a]	1.37±0.03[b]	1.31±0.03[b]	1.35±0.03[b]
cis MUFAs		65.18±0.19[b]	6 3.48±0.44[c]	63.15±0.09[c]	66.61±0.83[a]
Sum TFAs		1.02±0.04[d]	1.25±0.08[b]	1.35±0.02[a]	1.07±0.05[c]
n-6 PUFAs		11.69±0.64[a]	10.88±0.55[c]	10.64±0.07[d]	11.39±0.34[b]
n-3 PUFAs		0.25±0.04[a]	0.17±0.02[c]	0.16±0.01[c]	0.20±0.00[b]
n-6/n-3		46.68±0.84[d]	54.78±0.17[c]	60.74±0.44[a]	57.44±0.64[b]
Total lipids		**26.25±0.93[b]**	**26.47±0.19[b]**	**27.74±0.32[a]**	**25.08±0.27[c]**

Values on the same row with the same superscript are not significantly different at P<0.05

All values are mean of two separate methylation procedures; see Material and Methods section.

Values on the same row with the same superscript are not significantly different at P<0.05

[1] MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; SFAs, saturated fatty acids; TFAs, trans fatty acid.

[2]RT, Raw Tuber

Table 3: Amounts of selected fatty acid (mg/g dry wt) in *Cyperus esculentus* from Cameroon[a] treated in different ways by soaking in alkaline and acid solutions (1 g/L, at 40°C)

Fatty acid (mg/g)[b]	**RT[1]**	**Vitamin C**	**$Ca(0H)_2$**	**Kanwa**
16:0	36.37	40.44	40.88	43.84
18:0	11.31	12.04	13.31	14.40
18:1n-9	175.70	166.63	168.59	163.63
18:1n-7	2.74	2.73	2.92	3.08
18:2n-6	29.52	30.69	28.78	28.55
20:0	1.88	2.19	2.00	2.03
20:1n-9	0.57	0.65	0.63	0.64
18:3n-3	0.53	0.66	0.50	0.49
22:0	0.49	0.62	0.52	0.51
23:0	0.05	0.06	0.06	0.05
24:0	0.61	0.73	0.65	0.64
25:0	0.07	0.09	0.09	0.09
26:0	0.21	0.22	0.23	0.22
28:0	0.05	0.05	0.05	0.04
Sum SFAs	51.61	57.10	58.43	62.53
20:0 -28:0	3.39	4.01	3.63	3.62
cis MUFAs	167.09	171.12	173.33	180.74
Sum TFAs	2.69	2.68	3.31	3.75
n-6 PUFAs	29.53	30.69	28.79	28.56
n-3 PUFAs	0.50	0.66	0.53	0.49
n-6/n-3	57.44	46.68	54.78	60.74
g/100g[c]				
n-6 PUFAs	2.95	3.07	2.88	2.86
n-3 PUFAs	0.05	0.07	0.05	0.05
Men (% of requirement)[d]				
n-6 PUFAs	17.37	18.05	16.94	16.80
n-3 PUFAs	3.11	4.11	3.29	3.04
Women (% of requirement)[e]				
n-6 PUFAs	24.61	25.58	23.99	23.80
n-3 PUFAs	4.52	5.98	4.78	4.42

[a] *All values were calculated based on the lipid content of each sample.*
[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 per 100 g 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 g/d 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 g/d and 1.1 g/d, respectively (National Academy of Sciences, 2002*)

[1]*RT, Raw Tuber*

The total lipid fraction of tiger nut tubers contained a relatively low percentage of all SFAs, it provided nearly double the amount of total SFAs (about 6 g/100 g). The availability of EFAs in these plant foods and the levels needed to meet the daily human requirements was of primary interest in this study. The tubers of tiger nut analyzed in the present study are the good source mainly in their content of 18:2n-6 which represented about 17% and 25% of the daily requirements for men and women, respectively, but very low levels of 18:3n-3 (about 4% of daily requirement for an adult).

Processing of the tiger nut tubers had no effect of the total content of EFAs or the ratio of the two EFAs.

Protein content and amino acid composition

The four samples of *C. esculentus* tubers from Cameroon (including the raw tuber) contained 4.29%-4.82% protein (average, 4.6%) from tubers soaking in alkaline solutions, which was lower than the protein content of untreated tubers of tiger nut (7.58%). In addition to wanting to know their protein content, we were interested in comparing the nutritional quality of the various sample proteins. We therefore compared the percentages of essential amino acids in the different treatments to the percentages of these same amino acids in a World Health Organization protein standard (WHO, 1985) and determine the chemical index (Table 4 and 5); a score of 100 or more for a particular amino acid means the sample protein meets or exceeds the WHO standard protein. In the present study the leucine and lysine score were below the WHO standard for all treatment of the sample proteins, ranging from 73-86 and 79-91% respectively. The tryptophan percentage for all of the different treatment of plants analyzed in the present study exceeded that of the WHO standard. The amino acid scores for the different preparations of *C. esculentus* were not similar, indicating that the different treatment methods (e.g., alkali-soaking) had significant effect on the amino acid composition of the proteins they contained. Alkali treatment reduces significantly chemical index from 107 to 92.

Table 4: Aminoacids composition (mg/g dry weight) of *Cyperus esculentus* from Cameroon treated in different ways by soaking in alkaline and acid solution (1 g/L, at 40°C)

	Aminoacids	Vitamin C	$Ca(OH)_2$	Kanwa	RT*
Essential aminiacids (mg/g)	His	0.94±0.16^{a}	0.82±0.14^{b}	0.78±0.09^{b}	0.98±0.07^{a}
	Ile	1.44±0.22^{a}	1.15±0.09^{b}	1.21±0.05^{b}	1.32±0.07^{a}
	Leu	2.73±0.48^{a}	2.14±0.14^{b}	2.22±0.04^{b}	2.41±0.13^{b}
	Lys	2.48±0.43^{a}	2.26±0.13^{a}	2.09±0.06^{b}	2.37±0.14^{a}
	Met	0.57±0.18^{b}	0.55±0.09^{b}	0.58±0.04^{b}	0.71±0.01^{a}
	Phe	1.63±0.28^{a}	1.23±0.11^{b}	1.30±0.05^{b}	1.45±0.06^{a}
	Thr	1.99±0.21^{a}	1.40±0.23^{b}	1.49±0.18^{b}	1.44±0.17^{b}
	Tyr	1.12±0.20^{a}	0.79±0.21^{b}	0.89±0.05^{b}	1.04±0.07^{a}
	Trp	0.85±0.02^{b}	0.86±0.03^{b}	0.71±0.06^{b}	0.92±0.04^{a}
	Val	2.10±0.25^{a}	1.72±0.19^{b}	1.80±0.08^{b}	1.90±0.12^{a}
Banal aminoacids (mg/g)	Ala	2.34±0.31^{a}	1.93±0.15^{c}	2.22±0.09^{bc}	2.30±0.14^{a}
	Arg	4.74±0.41^{d}	6.51±0.51^{b}	5.05±0.30^{c}	6.89±0.61^{a}
	Asp	4.11±0.85^{a}	4.47±0.22^{a}	3.76±0.17^{b}	4.27±0.56^{a}
	Cys	0.63±0.04^{a}	0.65±0.02^{a}	0.56±0.02^{b}	0.75±0.12^{a}
	Glu	6.09±1.02^{bc}	6.69±0.45^{b}	5.86±0.36^{d}	7.37±0.73^{a}
	Gly	1.67±0.31^{a}	1.44±0.10^{b}	1.32±0.08^{b}	1.54±0.06^{a}
	Pro	1.73±0.34^{a}	1.38±0.16^{b}	1.44±0.10^{b}	1.78±0.06^{a}
	Ser	2.04±0.43^{a}	1.51±0.11^{b}	1.63±0.11^{b}	1.88±0.11^{a}
	Tyr	1.12±0.20^{a}	0.79±0.21^{b}	0.89±0.05^{b}	1.04±0.07^{a}
	Total (mg/g)	**78.20±0.73^{a}**	**44.53±0.52^{b}**	**42.92±0.49^{b}**	**75.4±0.68^{a}**

Values on the same row with the same superscript are not significantly different at P<0.05

*RT, Raw Tuber

Minerals and trace elements

The sodium content of the plant foods was relatively low, and not surprisingly high, for the alkali-treated tubers of *C. esculentus* (1.41 g per g dry weight). All of the four sample contained nutritionally significant amounts of copper, iron, phosphorus, manganese, magnesium, zinc, chromium, selenium and molybdenum. Of those elements and trace minerals not required by humans, it is noteworthy that several of the sample contained large quantities of aluminium and strontium. Alkali treatment seemed to be associated with an increase in the content

of several minerals (e.g., calcium, molybdenum, phosphorus, zinc, sodium but a decrease in the content of others (e.g., copper, iron, manganese) in tiger nut tubers.

Table 5: Comparison of the essential aminoacids content of plant foods from Cameroon with that of the World Health Organization ideal pattern (% of total amino acids)

Essential aminoacids	**WHO[1] Standard**	**Vitamin C**		**$Ca(OH)_2$**		**Kanwa**		**RT[2]**	
			%		%		%		%
Ile	2.8	2.82	101	2.58	92	2.69	96	2.85	102
Leu	6.6	4.97	75	4.81	73	5.17	78	5.21	79
Lys	5.8	5.01	86	5.08	88	4.87	84	5.12	88
Met-Cys	2.5	2.82	113	2.70	108	2.66	106	3.15	126
Phe-Tyr	6.3	4.93	78	4.54	72	5.10	81	5.38	85
Thr	3.4	3.47	102	3.15	93	3.11	91	3.38	99
Trp	1.1	1.93	176	1.77	166	1.66	160	1.76	150
Val	3.5	3.92	117	3.80	109	4.20	120	4.10	112
Chemical Index	**100**		**111**		**100**		**92**		**107**

[1]WHO, World Health Organization

[2]RT, Raw Tuber

Table 6: Trace mineral content of *Cyperus esculentus* from Cameroon soaked in alkaline and acid solutions (1 g/L) at 40°C

Mineral (mg/100 g DM)	**RT[1]**	**Vitamin C**	**$Ca(0H)_2$**	**Kanwa**
Al	9.410	10.300	2.400	2.200
Ba	0.352	0.344	0.290	0.360
Ca	33	31.500	53.400	36.700
Cd	0.010	0.010	0.008	0.008
Co	0.014	0.013	nd	Nd[2]
Cr	0.261	0.224	0.181	0.202
Cu	0.442	0.434	0.312	0.252
Fe	15.90	18	9.860	8.210
K	504	476	454	403
Li	0.007	0.008	0.012	0.009
Mg	115	101	104	107
Mn	0.741	0.682	0.622	0.620
Mo	0.032	0.032	0.018	0.025
Na	30.80	33.100	12.100	141
Ni	0,113	0.091	0.048	0.048
P	240	238	232	239
Pb	Ns[3]	nd	ns	ns
Se	0.062	0.067	0.086	0.064
Sr	0.485	0.465	0.503	0.481
Zn	2.890	2.600	1.640	2.920

[1]RT, Raw Tuber

[2]nd, not detected;

[3]ns, below detection limit

DISCUSSION

The *C. esculentus* tubers, regardless of how they were prepared for consumption, had a relatively high oil content (about 26%) that was even greater than that of tiger nuts (about 15%) collected in the border region between the Republic of Niger and Nigeria (Ejoh *et al.,* 2006; Glew *et al.,* 2006). However, the fatty acid composition of the *C. esculentus* tubers in the present study was about identical to that from Niger (Glew *et al.,* 2006): the main fatty acids were oleic acid (18:1n-9)(63-65%) and linoleic acid (18:2n-9)(10-12%), with much lower levels of α-linolenic acid (18:3n-3)(0.2-0.3%).

Although the level of total SFAs in *C. esculentus* tubers was relatively high (20-23%) compared to most oil seeds (7-15%), the relatively high palmitic acid (16:0) to stearic acid (18:0) ratio is typical of plant oils. Therefore, the oil from *C. esculentus* does not appear to provide a balanced fatty acid profile even though it does

contain relatively high amounts of one of the essential fatty acids, namely linoleic acid. All four preparations of *C. esculentus* contained such low amounts of α-linolenic acid that they should be considered deficient in this essential fatty acid, particularly in light of the high linoleic acid content. The high linoleic acid/α-linolenic acid ratio (approximately 55) we found for *C. esculentus* is similar to that reported for a number of vegetable oils such as sunflower, corn and safflower oils. A more nutritionally desirable ratio would be in the range of 5/1 to 15/1 (Smit, *et al.,* 2003; Food and Nutrition Board, 2002). However, this ratio is only one component that should be considered when evaluating the EFA status of a diet; other factors include the amount and type of all the PUFAs in the diet and an individual's total energy intake (Gebauer *et al.,* 2005).

The lipid quality of the oil-rich *C. esculentus* tubers was excellent as judged by the low *trans* fatty acid content (<1%). The *trans* fatty acid isomer pattern was random, ranging from 6trans to 8trans-18:1 to 12trans-18:1, indicating that the deterioration was probably oxidative and thermal in nature. The *trans* fatty acid (TFA) content was investigated in the plant lipids to assess product quality. Soaking in the alkali conditions of the samples may have contributed to the increased levels of TFAs. Possibly the higher oil content and the TAG structure may have provided greater protection of the PUFAs in the tuber lipids of *C. esculentus* against isomerization.

The tubers of *C. esculentus* from Cameroon in the present study contained about one-third less protein than tiger nut tubers from Niger (Glew *et al.,* 2006). This difference could be due to differences in the strains of *C. esculentus* that grow in Cameroon and Niger, or to differences in soil and climate. The amino acid composition of *C. esculentus* tubers reported herein also differs significantly from that of the raw tiger nuts from Niger (Glew *et al.,* 2006). Whereas the percentages of essential amino acids in tiger nuts from Niger met or exceeded the WHO standard in every amino acid category, the amino acid patterns of soaking in alkaline solutions of tiger nut tubers from Cameroon was inferior to the WHO standards for two of the eight essential amino acid or amino acid pairs (leucine, lysine, phenylalanine plus tyrosine, and threonine). An implication of these apparent differences in the protein content and amino acid composition of tiger nut tubers from Cameroon versus tiger nut tuberss gathered in Niger is that, at least from the perspective of protein quantity and quality, the later appear to be a superior protein source. Noteworthy is the fact that the essential amino acid scores for the raw tiger nut tubers and acid solution soaked tubers (Table 4) were somewhat better than the corresponding scores for the other preparations of tiger nut. These observations are in accord with those of Khalil and Monsour (1995) but contradict those of Ziena (1989) who conducted similar studies with faba beans. *C. esculentus* contained nutritionally useful amounts of many minerals and trace elements, including, copper, iron, manganese, zinc, chromium, selenium and molybdenum, and, it is a very good source of potassium, phosphorus and magnesium.

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 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. 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 plants foods that grow in the region.

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