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An Indigenous Plant Food Used by Lactating Mothers in West Africa: The Nutrient Composition of the Leaves of *Kigelia Africana* in Ghana

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Although the leaves of Kigelia africana *are used to make a palm-nut soup which is consumed mainly by lactating women in many parts of sub-Saharan Africa, little is known about the nutrient qualities of this underutilized and underappreciated plant food. Leaves of* Kigelia africana, *called "sausage tree" in English and "nufuten" in the Twi language of Ghana, were collected in Kumasi and analyzed for their content of nutritionally important fatty acids, amino acids, minerals, and trace elements. The dried leaves contained 1.62% fatty acids, of which α-linolenic acid and linolenic acid accounted for 44% and 20%, respectively, of the total. Protein accounted for 12.6% of the dry weight and, except for lysine, its overall essential amino acid profile compared favorably to a World Health Organization protein standard for school children.* Kigelia *leaf contained considerable amounts of many essential elements, including calcium (7,620μg/g), iron (161μg/g), magnesium (2,310μg/g), manganese (14.6μg/g), zinc (39.9μg/g), and chromium (0.83μg/g); selenium, however, was not detected. These data indicate that* Kigelia africana *leaf compares favorably with many other commonly-consumed green leafy vegetables such as spinach and provides a rational basis for promoting the conservation and propagation of the plant and encouraging its wider use in the diets of populations in sub-Saharan Africa.*

KEYWORDS Kigelia africana, *nutrients, leaves, minerals, fatty acids, protein, amino acids, Ghana*

INTRODUCTION

Whenever arable land anywhere in the world is a constraint in satisfying the dietary needs of the local population, economic, agricultural, and nutritional considerations become imperatives to be weighed when individual farmers and governments are deciding which crops to plant. This is especially true in developing countries when the prices of commodities on the global market prohibit the importation of cereal staples, fruits and vegetables, and other food products. In such circumstances, food security and independence place great pressure on farmers to make wise, informed decisions regarding which crops they will grow on finite areas of farmland. Knowledge of the comparative nutrient value of the various crop options is therefore critical if individuals or governments are to optimize use of the farmland available to them.

Leafy vegetables such as spinach and cabbage have long been appreciated as useful sources of protein, essential minerals and trace elements, and water-soluble vitamins, folate in particular. A recent survey (Amisah et al.

2002) of the extent to which a wide range of leafy vegetables are consumed by various populations in Ghana revealed that the food value of several dozen of these indigenous plant foods is currently underappreciated. We therefore embarked on a long-term study of indigenous leafy vegetables that are grown widely in Ghana and elsewhere in sub-Saharan Africa with the main aim being to determine their content of critical nutrients such as fatty acids, protein, and minerals. In this study we analyze these nutrients in the leaves of *Kigelia africana* (Lam.) Benth, the sole member of the *Bignoniacea* family.

Kigelia africana, known as "sausage tree" in English and *nufuten* in the Twi language, grows in many parts of Africa. It is found throughout Africa ranging from Senegal in the west to Tanzania in the east and South Africa to the south. The semi-deciduous tree which grows wild can reach heights of 25 m bearing long, sausage-shaped fruits. The name *nufuten*, or "hanging breast" translated from the Twi language, is derived from the long narrow fruits which hang from the tree. In Africa, the bark, roots, flowers, and leaves of *Kigelia africana* are used to treat a variety of illnesses, including: iron-deficiency anemia, sickle-cell anemia, epilepsy, protein-calorie malnutrition (e.g., kwashiorkor), and ailments of the liver, digestive, cardiovascular, and respiratory systems (Irvine 1961; Burkill 1985, 2000; Grace and Davis 2002). Extracts of *Kigelia* africana have been shown to be hepatoprotective against toxins (e.g., acetaminophen) (Olaleye and Rocha 2008). In addition, the leaves are sometimes boiled in water to make a concoction that is consumed orally to improve growth and general well-being (Dalziel 1937). *Kigelia africana* thus provides a potential nutritious food source during periods of food scarcity. Animals as well, particularly cattle, forage the leaves.

Once common in Ghana, *Kigelia africana* is now an endangered species because of human impact on vegetation in the region. Records from the herbarium in the Botany Department at the University of Accra contain information on the plant in Ghana during the early twentieth century. In 1926 Howes collected specimens from the eastern part of Ghana and noted the large trees with dark green foliage, dense flowers, and purplish fruits (Herbarium reference number 1088). Irvine recorded in 1931 that the fruits of the tree were sold as medicine at the Accra market in south eastern Ghana, some up to 3 ft long (Herbarium reference number 1525). Also, Morton collected specimens of *Kigelia africana* around Axim in western Ghana in 1934 and noted the fruit of the tree grew to over a foot long and looked like a large sausage (Herbarium reference number 2238). He also noted that local residents use the bark of the tree to treat gonorrhea.

Kigelia africana continues to be used as food and medicine in Ghana by traditional birth attendants and herbalists. In rural areas birth attendants prescribe consumption of the leaves of the tree to lactating mothers with the belief that the plant facilitates lactation and ameliorates anemia. Typically, consumption of the plant as food is limited to lactating mothers who consume young leaves of the tree in sauce that accompanies the staple foods of the area such as yams and maize.

The tree, which grows wild, is accessible to individuals who enter the forest to collect the leaves. Herbalists continue to use the bark of the tree to treat various sexually transmitted diseases. Given the significant decrease in the presence of the tree in Ghana due to exploitation of plant resources, the tree is now considered an endangered species. Because of the multiple potential benefits of *Kigelia africana* to human well-being, it is particularly timely to scientifically investigate these benefits. Finally, because the tree is fast disappearing from Ghanaian forests, local knowledge about its various uses may also begin to erode. Clearing of forests for the creation of agricultural land argues for the need to focus attention on conservation, including replanting efforts, of *Kigelia africana*.

Thus, there are four reasons why we chose to study *Kigelia africana*: first, there is a dearth of information in the literature regarding the nutrient composition of the leaves of the plant; second, there is concern in Ghana that the plant itself may be endangered; third, *Kigelia africana* leaves are an underappreciated and underutilized food source; and fourth, the young leaves of *Kigelia africana* are used in making palm-nut soup which is given to lactating mothers. This food is believed to restore the "richness of the blood" after child birth, and is also believed to enhance the quality and volume of the milk of lactating mothers. The nutritional information we present in this article should provide an objective basis for encouraging the wider use of the leaves of *Kigelia africana* in the diets of populations in sub-Saharan Africa and for taking measures to ensure the plant's availability.

MATERIALS AND METHODS

Collection and Processing of Plant Specimens

The leaves of three *Kigelia africana* trees in Kumasi, located in central Ghana, were collected, rinsed thoroughly with tap water to remove extraneous contamination, sun-dried and then ground to a fine powder with the aid of a stainless-steel mill. Immediately prior to analyzing the milled leaves for their content of fatty acids, amino acids, minerals, and trace elements, they were dried for 7 days in a vacuum desiccator. All three sets of analyses were performed in triplicate and results are reported as the mean, plus or minus one standard deviation.

Lipid Extraction and Fatty Acid Analysis

Prior to lipid extraction, powdered specimens of leafy vegetables were vacuum dried using an Eyela centrifugal evaporator CVE-1000 (Tokyo, Japan) for 12 h. Total lipids from samples were extracted according to a modification of the method previously described by Folch and coworkers (Folch, Lees, and Stanley 1957). Briefly, approximately 1 g of sample was extracted with 20 mL of chloroform/methanol (2:1, v/v) at 4°C for 18 h. The extracted lipids in the chloroform phase were separated from the aqueous phase by shaking and partitioning with 4 mL of 0.9% (w/v) NaCl, collected and evaporated under a stream of nitrogen gas. The lipids were then dissolved with 5 mL of chloroform.

To prepare fatty acid methyl esters, 0.1 mL of sample was added and evaporated under a stream of nitrogen gas, and then treated with 14% (w/v) BF_3 - methanol for 20 min at 95°C (Morrison and Smith 1964). The fatty acid methyl esters were extracted into hexane, analyzed and quantified using an Agilent 6890 gas chromatograph equipped with a flame-ionization detector and a fused-silica capillary column (Omegawax; 30 m × 0.32 mm, i.d., film thickness 0.25 μm, Supelco, Bellefonte, PA, USA). Helium was used as the carrier gas. The injector was set at 205°C and the detector was at 240°C. The temperature of the oven was initially 120°C, and then raised to 205°C at 4°C/min and held for 20 min. The fatty acid peaks were identified by comparing their retention times to those of a standard mixture of fatty acid methyl esters (RL-461, Nu-Chek-Prep, Inc., Elysian, MN, and USA). Quantification was carried out using the technique of internal standardization with triheptadecanoin (Sigma, St. Louis, MO, USA). The coefficient of variation ranged from 1.5 to 5% for the fatty acids. Alkanes (e.g., hentriacontane, tritriacontane) were not detected by the gas chromatography procedure used in the present study.

Mineral Analysis

Samples (0.2 g) of the dried, powdered leaves were weighed into 125 mL Phillips beakers and digested with 15 mL concentrated nitric acid and 1 mL perchloric acid. The samples were covered with watch glasses, allowed to stand for 1 h at room temperature, and then placed on a hot plate. The temperature was increased at a rate of 50°C/15 min to 150°C where they were refluxed for 24 h. The watch-glass covers were removed and the samples were brought to near dryness at the 150°C. The samples were cooled to room temperature and brought to 10 mL with 4% (v/v) nitric acid/1% (v/v) perchloric acid. Samples were analyzed for their metal content by ICP-OES as described elsewhere (Fernandez et al. 2003).

Amino Acid Analysis

Twenty milligrams of dried, milled *Kigelia africana* leaf were hydrolyzed in 6 N HCl containing 0.1% phenol at 110°C for 24 h under vacuum, and the resultant amino acids were separated and quantified using a Hitachi 8800

Chromotographic System using a Transgenomic column, Pickering buffers, and a customized gradient profile optimized for amino acid resolution. For determination of methionine and cysteine, samples were oxidized with performic acid (Hirs 1967) prior to acid hydrolysis. The reproducibility of the method ranged from 0.6–11% for the amino acids reported. Tryptophan was not determined.

RESULTS

Fatty Acid Analysis

The fatty acid composition of the total lipid extract of *Kigelia africana* leaves was relatively simple in that 3 fatty acids accounted for about 85% of the fatty acids (Table 1): the omega-3 essential fatty acid α-linolenic acid (18:3n-3), the omega-6 essential fatty acid linoleic acid (18:2n-6), and the saturated fatty acid palmitic acid (16:0) accounted for 44.0, 20.0, and 20.1%, respectively, of the total fatty acids in a total lipid extract of *Kigelia africana* leaves.

As shown in Table 1, the total fatty acid content of *Kigelia africana* leaves was relatively low at 1.62% of the weight of the dried, milled leaves; however, this value is in keeping with the fatty acid content reported for other leafy vegetables such as spinach and lettuce (Ndlovu and Afolayan 2008). Ten grams of dried *Kigelia* leaves would contribute 0.71 g of α-linolenic acid and 0.32 g of linoleic acid to the diet.

A noteworthy aspect of the fatty acid profile of *Kigelia africana* leaf is the favorable linoleic acid/α-linolenic acid ratio of about 0.5; this ratio is

TABLE 1 Fatty Acid Composition (Mass %) and Content (mg/g Dry Weight) of *Kigelia africana* Leaves

Fatty acid	Mass %	Content ± (mg per g dry weight)
14:0	2.55 (0.40)*	0.41(0.06)*
14.1	ND	–
15.0	ND	–
16:0	20.1(0.2)	3.25(0.30)
16:1n-7	0.39(0.04)	0.06(0.01)
18:0	3.86(0.09)	0.61(0.04)
18:1n-9	8.16(0.05)	1.32(0.12)
18:1n-7	0.21(0.19)	0.03(0.03)
18:2n-6	20.0(0.1)	3.23(0.03)
18:3n-3	44.0(0.4)	7.12(0.62)
20:0	1.10(0.02)	0.18(0.02)
20:1	0.47(0.03)	0.08(0.01)
20:2n-6	ND	–
22:0	ND	–
22.1	0.18(0.32)	0.03(0.05)
24:0	ND	ND
Total	100	16.2

*The number in parentheses indicates one standard deviation.

TABLE 2 Mineral Content of *Kigelia africana* Leaves

Mineral	Content (μg per g dry weight)
Al	241(14.5)*
Ba	3.48(0.14)
Ca	7,620(71)
Co	0.047(0.006)
Cr	0.827(0.045)
Cu	7.65(0.24)
Fe	161(9)
K	16,500(300)
Mg	2,310(6)
Mn	14.6(0.4)
Mo	0.245(0.002)
Na	343(6)
P	4,740(170)
Pb	ND
Se	ND
Sr	23.8(0.9)
Ti	1.06(0.14)
V	ND
Y	ND
Zn	39.9(3.7)

ND, not detected (<0.10 μg/g dry weight).
*The number in parentheses indicates one standard deviation.

commonly less than 1.0 for most leafy vegetables. It has been suggested that a healthful linoleic acid/α-linolenic acid ratio for foods is less than 1.0 (Simopoulos, Leaf, and Salem 1999; Harris et al. 2009).

Mineral Analysis

Of the 23 metals that were analyzed in *Kigelia africana* leaf, measureable levels were found for 16 of them (Table 2). With regard to minerals required by humans in relatively large amounts, on a per gram dry-weight basis, *Kigelia africana* leaf contained 7,620 μg calcium, 161 μg iron, 16,500 μg potassium, 2,310 μg magnesium, 343 μg sodium, and 4,740 μg phosphorus, and for the trace minerals 0.827 μg chromium, 7.65 μg copper, 14.6 μg manganese, 0.245 μg molybdenum, and 39.9 μg zinc. Noteworthy was the fact that selenium, which is essential for humans, was not present at a detectable level in *Kigelia africana* leaf. Toxic metals such as lead, cobalt, and yttrium were not detected.

Amino Acid Content

Based on amino acid analysis, protein accounted for 12.6% of the dry weight of the *Kigelia africana* leaves (Table 3), a value which is about one-half the

TABLE 3 Amino Acid Composition (mg/gram Dry Weight) of *Kigelia africana* Leaves

Amino acid	Mean
Cysteine	1.85 (0.17)*
Aspartic acid	15.5 (1.3)
Threonine	6.34 (0.54)
Serine	6.29 (0.53)
Glutamic acid	16.2 (1.2)
Proline	7.79 (0.01)
Glycine	8.17 (0.71)
Alanine	8.99 (0.82)
Valine	9.18 (0.79)
Methionine	0.57 (0.07)
Isoleucine	7.25 (0.65)
Leucine	12.7 (1.13)
Tyrosine	3.08 (0.18)
Phenylalanine	8.25 (0.71)
Histidine	3.30 (0.28)
Lysine	3.70 (0.23)
Arginine	7.24 (0.66)
Total	126 (11)

*The number in parentheses indicates one standard deviation.

TABLE 4 Comparison of the Amino Acid Composition of *Kigelia africana* Leaves to the WHO Ideal Protein[1]

Amino acid	WHO Ideal* (% of amino acid total)	*Kigelia africana* (% of amino acid total)	*Kigelia africana* WHO Ideal × 100
Isoleucine	2.8	5.8	208
Leucine	4.4	10.1	230
Lysine	4.4	2.9	66
Methonine plus cysteine	2.2	1.9	86
Phenylalanine plus tyrosine	2.2	8.2	372
Threonine	2.8	5.0	179
Valine	2.5	7.3	293

[1]Food and Agricultural Organization and World Health Organization. 1991. Protein Quality Evaluation; Report of a Joint FAO/WHO Expert Consultation, Food and Agricultural Organization of the United Nations: Rome, Italy, pp 26–28.

protein content of spinach and lettuce (Ndlovu and Aofloyan 2008). As shown in Table 4, when compared with the World Health Organization protein standard set for children (FAO/WHO 1991), the *Kigelia africana* leaf protein scored above the standard for leucine (230), isoleucine (208), phenylalanine plus tyrosine (372), threonine (179), and valine (293), but below the WHO protein standard for school children (10–12 years) for lysine (66) and the sulfur amino acid pair, methionine plus cysteine (86).

DISCUSSION

Leafy vegetables have long been known to be indispensable ingredients in table sauces that accompany cereal staples in Africa and most other parts of the world. The new knowledge in the present report should increase both the awareness and appreciation of the value of indigenous leafy vegetables as vital components of daily diets. In particular, we document the fact that *Kigelia africana* leaves can provide significant amounts of essential amino acids and fatty acids, and many critical minerals and trace elements to the diets of the inhabitants of sub-Saharan Africa.

The main goal of this study was to assess the potential of *Kigelia africana* leaves to provide critical nutrients to the diets of populations in sub-Saharan Africa. To this end, we compared the fatty acid, amino acid, and mineral compositions of *Kigalia africana* leaves obtained in Ghana to corresponding literature values of 2 other leafy vegetables, namely baobab leaf and spinach, both of which are widely respected for their overall nutritional value. With regard to protein content, *Kigelia africana* leaves compare favorably with baobab leaves and spinach. For example, on a dry weight basis, the protein content of *Kigelia* leaf was 12.6% compared to spinach (Ndlovu and Afolayan 2008) where protein accounts for 18.7% of dry weight and baobab where 10.6% of the dry mass of the leaves is protein (Yazzie et al. 1994). However, relative to the WHO standard for children 10–12 years of age (FAO/WHO 1991), the protein of *Kigelia* leaf was deficient in the essential amino acid lysine and the 2 sulfur amino acids methionine plus cysteine (Table 4).

Despite these shortcomings, *Kigelia africana* leaf could still be a useful source of protein in environments where other plant protein sources such as soybean are available to supplement the essential amino acid lysine that is lacking in *Kigalia africana* leaves. With regard to fatty acids, they account for only 1.62% of the dry weight of *Kigelia* leaves. In contrast, about 6% of the dry mass of spinach is contributed by fatty acids (Nguyen et al. 2004). Thus, the fatty acid content of *Kigelia* leaf is unlikely to contribute significantly to satisfying the caloric needs of an individual. However, 44% of the total fatty acids in *Kigelia* are accounted for by the healthful omega-3 fatty acid α-linolenic acid. Moreover, the ratio of linoleic acid to α-linolenic acid was a favorable 0.5. The linoleic acid/α-linolenic acid ratio for spinach is also 0.5 (Nguyen et al. 2004). Omega-3 fatty acids have anti-inflammatory effects that reduce the risk of cardiovascular disease and type 2 diabetes (Simopoulos et al. 1999; Harris et al. 2009). The recommended daily intake of α-linolenic acid is 2.2–3.3 g per day (Simopoulos et al.1999). Thus, 100 g dry-weight worth of *Kigelia africana* leaves would satisfy about one-fourth the daily requirement for α-linolenic acid. The typical intake of *Kigelia africana* leaves by an adult corresponds to about 25 g of dried leaves.

Kigelia africana leaves appear to provide useful amounts of several minerals. For example, the calcium content of *Kigelia africana* leaf was 7,620 μg per g dry weight, which is between that of baobab leaf (Sena et al. 1998) and spinach (1,320–2,120 μg per g dry weight) (Yadev and Sehgal 1995). Calcium is required for the growth and maintenance of bone and is a cofactor for many enzymes. Like baobab leaf which is a good source of magnesium (Yazzie et al. 1994), *Kigelia africana* leaf is also a good source of magnesium (2,310 μg per g dry weight) which plays key roles in energy metabolism, hormone synthesis, and nerve function. *Kigelia africana* leaves also contain moderate amounts of the essential minerals phosphorus, potassium, zinc, molybdenum, manganese, chromium, and copper (Table 3). The iron content of *Kigelia africana* leaf compares favorably with that of spinach (Ndlovu and Afolayan 2008) and baobab leaf (Yazzie et al. 1994). Dietary iron is important in sub-Saharan Africa where the incidence of iron-deficiency anemia is high (Agyei-Frempong et al. 2001). In contrast, unlike baobab and spinach leaves which contain nutritionally-significant amounts of selenium which has anti-inflammatory and antioxidant properties, the *Kigelia africana* leaves we analyzed herein did not contain detectable selenium. However, this shortcoming could be addressed by including selenium-containing plant foods such as the leaves of the baobab tree, *Hibiscus sabdarifa, Corchorus tridens, Leptadenia hastata, Moringa oleifera and Amaranthus viridus (*Yazzie et al. 1994; Freiberger et al. 1998).

This study highlights the importance of studying indigenous plant foods in Africa and other world regions because of the significant role they play in the diets of local populations. Related to this issue is the need for additional research by social scientists to further our understanding of indigenous knowledge systems regarding foods in Africa. A multi-disciplinary approach in studying the role of indigenous plant foods allows for a more complete understanding of the roles these plant foods play in the communities where they are consumed. Such information would be critical to any efforts made by governmental and non-governmental agencies to promote and advocate consumption of particular plants with the goal of improving human health.

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