JOURNAL OF MEDICINAL FOOD
J Med Food 14 (11) 2011, 1289–1297

DOI: 10.1089/jmf.2010.0327

REVIEW

Gnetum africanum: A Wild Food Plant from the African Forest with Many Nutritional and Medicinal Properties

Fadi Ali,[1] Mafu Akier Assanta,[2] and Carole Robert[1]

[1]*PharmAfrican, Lévis, Québec, Canada.*
[2]*Food Research and Development Centre, Agriculture and Agri-Food Canada, Saint-Hyacinthe, Québec, Canada.*

ABSTRACT *Gnetum africanum* is a forest liana that grows abundantly in Central Africa, South America, and tropical and subtropical Asia. Its leaves are eaten as a vegetable, either raw or finely chopped and cooked; they are also widely used as an ingredient in soups and stews and are much in demand for their nutritional and therapeutic properties. In the latter application, various fractions of *G. africanum* are used medicinally to treat many different illnesses. Many studies have also shown that the chemical composition of the leaves of this plant gives it significant nutritional properties, and its high fiber, protein, and calorie content support these claims. Several molecular compounds related to the families of stilbenes, glycosylflavones, and flavonostilbenes have been isolated and identified in the leaf extract of this plant. These molecules give the plant its interesting properties and biological activities.

KEY WORDS: • ***African forest*** • **Gnetum africanum** • ***nutritional value*** • ***therapeutic properties*** • ***vegetable*** • ***wild food plant***

INTRODUCTION

GNETUM AFRICANUM WELW. is a shade-loving climbing gymnosperm liana that grows in dense equatorial forests and preforest fallow. The common names of this species in the three local languages of the Democratic Republic of the Congo are *mfumbwa* (in Kikongo), *longongia* (in Lingala), and *banvale* (in Azande). The seeds of this plant are eaten cooked, and its edible leaves are sold in markets. The leaves of *G. africanum* are green vegetables with a high nutritional value.

Gnetum is the sole genus in the family Gnetaceae and comprises about 30 species, most of them lianas distributed in the tropical regions of Asia, South America,[1] and Central Africa.[2] The plants are dioecious: the males produce catkins of stamens, and the female produce catkins of ovules barely protected by an envelope.[3]

In Africa, two different species of *Gnetum* are found: *G. africanum* and *Gnetum bucholzianum*. They are distributed in the tropical rainforests from Nigeria through Cameroon, the Central African Republic, and Gabon and the Democratic Republic of the Congo to Angola.[4] These two species are so similar that it is hard to distinguish them except by the shape of their leaves and the characteristics of the male reproductive organs.[5]

Manuscript received 1 December 2010. Revision accepted 15 May 2011.

Address correspondence to: Dr. Mafu Akier Assanta, Food Research and Development Centre, Agriculture and Agri-Food Canada, 3600 Casavant Boulevard West, Saint-Hyacinthe, QC, Canada J2S 8E3, E-mail: akierassanta.mafu@agr.gc.ca

To ensure and enhance the continued survival of *G. africanum*, studies have been undertaken on its selection, genetic improvement vegetative propagation, and management *ex situ*.[6] The goal of these studies is to ensure not only that *Gnetum* remains available in the future but also that the new varieties to be cultivated will be genetically superior. Reports have been published on the production of genetic material from 85 different sources for future selection and genetic improvement with a view toward large-scale production of plant material with a broad genetic base.

IMPORTANCE AND BENEFITS OF *GNETUM*

G. africanum and *G. bucholzianum* are of great importance to many forest communities and have many different vernacular and commercial names. For example, in the Central African Republic, Gabon, Congo, the Democratic Republic of the Congo, and Angola, both species are called *KoKo* locally.[7] In the Democratic Republic of the Congo, *G. africanum* is called *mfumbwa* or *fumbwa* in the Kikongo language, and in Angola the leaves are also called *m'fumbua* or *fumbua*. In the English-speaking part of Cameroon the local name is *eru*, whereas in the French-speaking part it is *okok*. Lastly, in Nigeria, the Igbo tribe calls the leaves of this plant *ukase*, and the Efiki/Ibibio tribe calls them *afang*. In the past, *G. africanum* was known as ''wild spinach'' in English.

G. africanum grows abundantly in many different habitats: fallows, abandoned farmland, secondary forest, and dense forest. In complex rainforests, *Gnetum* vines tolerate a very wide variety of supports, such as large and small trees,

dead trees, young shrubs, and other climbing plants, such as rattans, as well as other plant hosts. *Gnetum* grows luxuriantly and produces large amounts of leaf biomass.

In the wild, *Gnetum* grows and forms underground roots or tubers in which the plant stores its food reserves. These tubers can survive for many years, even when the vegetation and *Gnetum* vines above have been cleared and the soil surface has been laid bare. Authors report that certain local tribes in eastern Cameroon and in the Democratic Republic of the Congo eat these tubers as wild yams, especially during the dry season.[7] When the vines are cut, the buds on these tubers are often damaged, and it can take some time before the new buds produce new vines. In some cases, overly aggressive harvesting of the vines injures the tubers and roots, which thus become more vulnerable to fungi and rot. The effects of intensive harvesting clearly interfere with regrowth and renewal of the stock of *Gnetum* leaves.

Also, when *Gnetum* vines are being harvested, the trees on which they grow are often cut down, causing serious damage. Thus, harvesting *Gnetum* in the wild is not a sustainable method. Moreover, many of the forests where *Gnetum* grows are suffering substantial degradation from uncontrolled, illegal harvesting of timber, as well as from farming, road construction, and other kinds of economic development activity.[8]

G. africanum leaves are an important commercial food commodity in Africa, where gathering *Gnetum* leaves for sale at local and regional markets is a daily activity. Because the two species of *Gnetum* are evergreens, their leaves can be harvested throughout the year, which has considerably increased the volume exported in recent years.

Cameroon exports *Gnetum* to Nigeria, Gabon, and Congo through the two ports of Idenau and Kribi. After being exported, *Gnetum* leaves are transported to the large border cities and sold in the markets. In order to meet the high demand, harvesting of *Gnetum* has extended into the most remote regions. Each year, an estimated 600 tons of this product, valued at 1.8 billion CFA francs on the local market ($US 3,000,000), pass through only the port of Idenau.[9] Besong *et al.*[10] have estimated the total annual income from this trade between Idenau and Nigeria at CFA francs 1,060,800,000–1,560,000,000 ($US 1,500,000–2,200,000). According to Food and Agrcultural Organization statistics from 2002, a total of 44.427 tons of *G. africanum* (*eru*), valued at CFA francs 591,017,000, were sold in 1997, and 50% of the volume exported from Africa comes from Cameroon.[11] This large volume of trade provides many young people in Cameroon and neighboring countries with well-paid jobs. For example, monthly sales for one of the merchants who works full-time in the *Gnetum* trade in Idenau reaches CFA francs 450,000 (roughly $US 750).[6]

CHEMICAL COMPOSITION

The average chemical composition of *G. africanum* is shown in Table 1. This composition varies depending on the variety of *Gnetum* analyzed. The plant is rich in fiber (28–37%) and protein (13–18%). Its mineral content is 2–9%. However, its fat content depends on the variety. It is on the order of 2–10% for the Asutan, Oron, Ikom, and Welw. varieties and 0.5% for Koko (Table 1).

The carbohydrate content of the plant is high for the first four varieties listed (38–44% dry matter [DM]). However, the Koko variety has a low percentage of carbohydrates (5% DM on average). The stem appears to contain more minerals and proteins than the leaves, but the leaves contain more fiber than the stems.[15] Also, the amount of vitamin C in the leaves of *G. africanum* has been estimated at 113 mg/100 g.[14]

CHEMICAL CHARACTERIZATION OF *G. AFRICANUM*

The criteria for evaluating the nutritional value of plants refer to their protein composition in amino acids and lipid composition in fatty acids. The vitamin, antioxidant, and mineral contents for which most tropical plants are known as a good source are also taken into account.

Proteins

G. africanum is an abundant source of protein, especially for its content in essential amino acids (isoleucine, leucine,

Table 1. Chemical Composition of Different Varieties of *G. africanum*

Variety	*Source*	*Humidity (%) (wet weight)*	*Chemical composition of* G. africanum *(% of dry matter)*					*Reference*
			Ash	*Fiber*	*Fat*	*Protein*	*Carbohydrate*	
Asutan	Leaves	13.0	3.0	28.6	6.7	17.9	43.8	Isong *et al.*[12]
Oron	Leaves	14.0	2.0	34.2	9.6	15.5	38.7	Isong *et al.*[12]
Ikom	Leaves	12.0	3.0	37.8	2.4	12.8	44.0	Isong *et al.*[12]
Welw.	Leaves and stem	73.2	6.74	33.0	7.53	15.2	37.5	Eyo *et al.*[13]
	Leaves	73	—	25.5		15.2	37.4	Mensah *et al.*[14]
Koko	Leaves	—	4.6	87.8	0.3	7.2	0.2	Popovich *et al.*[15a]
	Liana	—	8.7	59.3	0.6	21.5	10.1	Popovich *et al.*[15a]
	Average	—	6.65	73.6	0.45	14.4	5.2	Popovich *et al.*[15a]
Afang	Seeds	31.6	1.2	0.8	3.1	17.5	87.6	Ekop[16]

[a]Total dietetic fiber.

lysine, methionine, phenylalanine, threonine, tryptophan, and valine) and nonessential amino acids (aspartic acid, serine, glutamic acid, proline, glycine, alanine, cysteine, tyrosine, histidine, and arginine). The amino acid composition of *G. africanum* is presented in Table 2.

As shown in Table 2, *G. africanum* contains most of the amino acids at varying levels. It contains high levels of glutamic acid, leucine, and aspartic acid and low levels of cysteine, ammonium, and histidine; tryptophan is not detectable in the plant's protein profile. The percentage of non-nitrogenous amino acids present in *G. africanum* is 41.5%, which is greater than that of other forest plants.[13] It is noteworthy that the level of non-nitrogenous proteins in *G. africanum* is high. These proteins are essential for the synthesis of nonessential amino acids in the human body. It should also be noted that the amino acid content of *G. africanum* is comparable to that recommended by the Food and Agriculture Organization.

Oils and fats

The oils of the leaves of African forest plants are known for their antioxidant and antimicrobial effects. Yellow oil can be extracted from powdered dry leaves of *G. africanum* with a yield of 3.6%.[17] The extraction make by treating the powder with *n*-hexane solvent, then performing a Soxhlet extraction, letting the solvent evaporate, washing the oil with warm water, and then removing the water.[18] The physiochemical properties of this oil are shown in Table 3.

The oil content, acid value, and peroxide value are low, but the saponification value, iodine value, unsaponifiable material, β-carotene, β-sitosterol, and phospholipids are high. The high levels of carotenoids and sterols, which are known for their antioxidant properties, explain the relative stability of the oil extracted from this plant, as well as their long storage and activity time.[17] These components also protect the oil from rancidification by oxidation and decomposition by microorganisms. The oil's high phospholipid content explains its gelatinous form, which gives it emulsifying properties. Hence one possible application of this oil in the pharmaceutical industry would consist in extracting the lecithin from this plant to be used as a binder in making tablets.

Phytochemical tests have shown that the leaves of *G. africanum* also contain tannins, saponin, flavonoids, alkaloids, and glycosides. Saponin is known for its ability to reduce serum lipids and can therefore help to fight atherogenesis. However, flavonoids inhibit oxidation, so they are beneficial against peroxidation reactions associated with biological systems. The consumption of *G. africanum* together with seafood contributes further to reducing hypolipidemia activity and applying a therapy against cardiovascular disease.[17] Mensah *et al.*[14] have also detected alkaloids, inulins, and tannins in the leaves of this plant, but these authors did not detect any saponin in the leaves of *G. africanum* Welw.

The physiochemical properties of the oil are also related to its chemical composition in fatty acids. The proportions of these acids in the oil of the leaves of *G. africanum* are shown in Table 4. The oil of this plant is thus richer in unsaturated fatty acids, with a percentage of 57.8%, than in

Table 2. Amino Acid Composition of the Protein of *G. africanum*

Amino acid	*Content (mg/g of dry matter)*	*Content (mg/16 g of nitrogen)*	*FAO (mg/16 g of nitrogen) recommendation*
Cysteine	1.23	0.8	—
Aspartic acid	8.65	5.7	—
Methionine	3.63	2.4	2.3
Threonine	3.63	3.7	2.9
Serine	4.47	2.9	—
Glutamic acid	10.24	6.8	—
Proline	5.97	3.9	—
Glycine	6.66	4.4	—
Alanine	7.50	4.9	—
Valine	5.94	3.9	4.3
Isoleucine	4.74	3.1	4.3
Leucine	10.48	6.9	4.9
Tyrosine	4.87	3.2	2.9
Phenylalanine	5.70	3.8	—
Histidine	2.78	1.8	—
Lysine	5.70	3.8	4.3
Ammoniac	2.45	—	—
Arginine	7.47	4.9	—
Tryptophan	—	—	—

Source: Eyo *et al.*[13]
FAO, Food and Agriculture Organization.

Table 3. Physicochemical Properties of the Oil of *G. africanum*

Indication	*Value*
Free fatty acid (oleic)	0.12 mg of KOH/g
Acid value	0.4 mg of KOH/g
Iodine value	122.6 (Wijs method)
Peroxide value	0.1 MEq/L
Saponification value	130 mg of KOH/gram
Unsaponifiable matter	1.4% g/g
β-Carotene	0.4 mg/100 mL
β-Sitosterol	0.35 mg/100 mL
Stigmasterol (anticholesterol)	0.28 mg/100 mL

Source: Njoku *et al.*[17]

Table 4. Fatty Acid Composition of the Oil of *G. africanum*

Fatty acid	*Formula*	*Percentage (% wt/wt)*
Myristic acid	$C_{14:0}$	—
Palmitic acid	$C_{16:0}$	15.75
Palmitoleic acid	$C_{16:1}$	2.69
Stearic acid	$C_{18:0}$	5.34
Oleic acid	$C_{18:1}$	9.85
Linoleic acid (ω6)	$C_{18:2}$	8.70
Linolenic acid (ω3)	$C_{18:3}$	33.84
Arachidic acid	$C_{20:0}$	5.17
Arachidoleic acid	$C_{20:1}$	2.73
Behenic acid	$C_{22:0}$	1.66

Source: Njoku *et al.*[17]

Table 5. Mineral Content for the Various Varieties of *G. africanum*

Variety	Source	Mineral content							Reference
		Ca	*Mg*	*Fe*	*Zn*	*P*	*Na*	*K*	
Asutan	Leaves	130[a]	89[a]	76.1[a]	1.3[a]				Isong *et al.*[12]
Oron	Leaves	165[a]	39[a]	78.3[a]	1.0[a]				Isong *et al.*[12]
Ikom	Leaves	249[a]	39[a]	121[a]	0.8[a]				Isong *et al.*[12]
Welw.	Leaves	4.1[c]	0.3[c]	0.01[c]			1.5[c]	0.08[c]	Mensah *et al.*[14]
Afang	Leaves					300[b]			Udosen and Ukpanah[20]
	Soup	3,930[d]	840[d]	130[d]	14[d]	580[d]			Akpanabiatu et al.[21]
	Seeds	7.0[e]	5.5[e]	1.5[e]	1.1[e]	0.03[e]	15.6[e]	38.7[e]	Ekop[16]

[a]In parts per million.
[b]In mg/100 g of dry matter.
[c]In mg/100 g of dry matter.
[d]In mg/100 g of dry matter.
[e]In %.

saturated ones. Among these unsaturated fatty acids, those with C_{18} are found at higher levels, especially $C_{18:3}$. Consequently, the oil of this plant may be used as a supplement in the diets of persons suffering from hyperlipidemia.[19]

Minerals

G. africanum leaves are rich in minerals. The levels of some of these minerals are shown in Table 5. These levels vary with the variety of *G. africanum*. The Ikom variety is richer in calcium and iron, whereas Asutan is richer in magnesium and zinc. The significance of these minerals for the nutritional value of *G. africanum* leaves and of *Gnetum*-based dishes is discussed below in the section on the nutritional importance of the plant.

MEDICINAL AND PHARMACEUTICAL IMPORTANCE

In Nigeria, the leaves of *G. africanum* are used to treat enlarged spleens and sore throats, and also as a cathartic.[18,22] In Oubangui, Democratic Republic of the Congo, Edet *et al.*[18] stated that this plant is used as a remedy for nausea and regarded as an antidote for certain types of poisons. In the Republic of the Congo (Brazzaville), *Gnetum* leaves are used as a dressing for warts, hemorrhoids, and boils. *Gnetum* cuttings are used to brew herbal teas to soothe labor pains.[10] The plant is also used as a medicinal plant in Mozambique.[2] Because of its high fiber content, it is often recommended to ease constipation and to control blood sugar levels in diabetics.[23]

Table 6. Volatile Compounds Identified in the Essential Oil of *G. africanum*

Peak number	Compound	Value (%)
1	β-Caryophyllene	18.1
2	(*E*)-Phytol	16.5
3	β-Selinene	15.0
4	(*E*)β-Ionone	12.2
5	6,10,14-Trimethyl-2-pentadecanone	9.7
6	(*E*)α-Ionone	8.8
7	Dendrolasin	7.3
8	Dicyclopentadiene	3.6
9	δ-Cadinen	3.2
10	Cyperen	2.6
11	α-Humulene	2.6
12	α-Selinene	2.1
13	α-Copaene	1.9

Source: Edet *et al.*[18]

In recent years, studies have been conducted to identify the molecules and active compounds in *G. africanum*. Some of these studies have identified the chemical composition of the essential oil obtained from *G. africanum* leaves. This oil was extracted from fresh plants by the hydrodistillation process over a period of 4 hours, with a yield of 0.45% (vol/wt). The volatile compounds identified in this oil by gas chromatography/mass spectrometry are shown in Table 6. The main compounds in this volatile oil are β-caryophyllene, (*E*)-phytol, β-selinene, and (*E*)β-ionone. These account for $>61.8\%$ of the volatile compounds in this essential oil. According to Edet *et al.*,[18] other compounds detected in trace amounts in the essential oil of *G. africanum* include α-pinene, camphene, *trans*-β-damascenone, valencene, α-zingiberene, γ-cadinene, 7-*epi*-α-selinene, and methyl palmitate. In some studies, the essential oil of *G. africanum* has displayed certain types of biological activity. Edet *et al.*[18] observed that the essential oil of *G. africanum* had a moderately inhibiting effect on the growth of *Escherichia coli* (minimal inhibitory concentration, 39 μg/mL). The presence of phytol in this oil of *G. africanum* enhances the plant's nutritional value because the phytol can be converted into vitamins E and K_1. The essential oil of *G. africanum* can also be used in other applications, such as the manufacturing of perfume. Caryophyllene, one of the compounds identified in the essential oil of *Gnetum*, can be used in the synthesis of substances such as perfume and other fragrances.

Many phenolic compounds, such as trimeric stilbenes, flavonostilbenes, and flavones have been isolated and identified in various varieties of *G. africanum*.[18] What kinds

TABLE 7. LIST OF THE ACTIVE COMPOUNDS AND MOLECULES ISOLATED FROM *G. AFRICANUM*

Name of isolated compound	*Formula*	*Concentration (mg/kg)*	*Source*	*Chemical group*	*Reference*
Isoswertisin	8-C-Glucosyl-7-*O*-metylapigenin	ND	Leaves	Glycosylflavones	Ouabonzi *et al.*[24]
Vicenin 2	6,8-Di-C-xylosyl-8-C-glucosylapigenin	ND			
Vicenin 3	6-C-Glucosyl-8-C-xylosylapigenin	ND			
Compound **1**	2-*O*-Xylosylisoswertisin	ND			
Compound **2**	2-*O*-Glucosylisoswertisin	ND			
Compound **3**	2-*O*-Rhamnosylisoswertisin	ND			
Compound **4**	Apigenin 7-neohesperidoside	ND			
Gnemonoside H	$C_{46}H_{52}O_{21}$ (gnetin C 4a,4b,11a-*O*-*β*-triglucopyranoside)	4	Stem	Stilbene glucosides	Iliya *et al.*[19]
Gnemonoside I	$C_{40}H_{42}O_{17}$ (gnetin D 4a,4b-*O*-*β*-diglucopyranoside)	ND			
Gnemonoside J	$C_{40}H_{42}O_{17}$ (gnetuhainin A 4a,4b-*O*-*β*-diglucopyranoside)	6			
Compound 1	Resveratrol 3,4′-*O*-*β*-diglucopyranoside	ND			
Compound 2	Pinceatanol 4′-*O*-*β*-glucopyranoside	ND			
Compound 3	Pinceatanol 3,4′-*O*-*β*-diglucopyranoside	ND			
Compound 4	Gnemonosides A	ND			
Compound 5	Gnemonosides B	ND			
Compound 6	Resveratroloside	ND			
Compound 7	Gnetin E	ND			
Compound 8	Gnetofolin E	ND			
Compound 9	Gnetofolin K	ND			
Bisisorhaphontigenin B	$C_{30}H_{26}O_8$	26.9	Stem	Stilbene dimers	Iliya *et al.*[25]
Gneafricanin A	$C_{29}H_{24}O_8$	16.9			
Gneafricanin B	$C_{29}H_{24}O_8$	13.8			
Isorhaphontigenin		28.5		Stilbenoids	
Resveratrol	3,5,4'-Trihydroxystilbene	24.6			
Gentol	$C_{14}H_{12}O_4$	9.2			
Gentofolin E		40.8			
Gentin C		15.4			
Gentin D		13.1			
Gentin E		26.9			
Longusol A	$C_{28}H_{22}O_7$	31.5			
Gneafricanin C	$C_{28}H_{22}O_8$	20	Stem	Stilbene dimers	Iliya *et al.*[26]
Gneafricanin D	$C_{28}H_{22}O_6$	6.2			
Gneafricanin E	$C_{28}H_{22}O_7$	8.5			
Gneafricanin F	$C_{30}H_{26}O_8$	1.5			
Gnetin F		ND		Stilbenoids	
Scirpussin A		ND			
Gnetin D		ND			
Gnetuhainin A		ND			
Gnetoflavanol A	$C_{30}H_{26}O_9$	23.1	Stem	Flavonostilbenes	Iliya *et al.*[27]
Gnetoflavanol B	$C_{29}H_{24}O_8$	6.2			
Gnetoflavanol C	$C_{29}H_{24}O_9$	11.5			
Gnetoflavanol D	$C_{29}H_{24}O_9$	3.8			

ND, not detectable.

of compounds are isolated depends on what part of the plant is analyzed. Working with extract from *G. africanum* leaves, Ouabonzi *et al.*[24] identified certain glycosylflavones. Working with the polar fraction of extract from *G. africanum* stems, Iliya *et al.*[19,25–27] isolated stilbene glucosides, flavonostilbenes, and dimeric stilbenes. A summary of those compounds identified is shown in Table 7.

Ouabonzi *et al.*[24] believed that flavone-*O*-glycosides are the major and distinctive flavonoids present in *G. africanum*. Iliya *et al.*[25] isolated from the stems of *G. africanum* two stilbenes dimers, termed gneafricanins A and B, and bisisorhapontignenin with eight previously known stilbenoids. Iliya *et al.*[26] isolated also from the stems of *G. africanum* four new stilbenes dimers, termed gneafricanin C, D, E, and F, with four known stilbenes. Iliya *et al.*[19] also isolated from the polar fractions of acetone extract of the stem lianas of *G. africanum* three new stilbenes, termed gnemonoside I, J, and H, with nine known stilbenoids.

The large numbers of molecules that have already been identified show that *G. africanum* is rich in molecules and active ingredients. Most of the molecules shown in Table 7 are recognized for their anti-inflammatory, antioxidant, and anticarcinogenic activity and their health benefits. An analysis of the antioxidizing power of certain of these

Table 8. Antioxidant Activities of Stilbenoid Compounds Isolated from *G. africanum*

Name of stilbene	*Lipid peroxide inhibition IC_{50} (μM)*	*Scavenging activity of superoxide IC_{50} (μM)*
Gneafricanin C (1)	13	10
Gneafricanin D (2)	50	33
Gneafricanin E (3)	32	30
Gnetin F	29	26
Longusol A	15	16
Bisisorhaphontigenin	45	29
Gneafricanin A	34	20
Gnetoflavanol A (1)	32	34
Vitamin E	1,000	2,100

Source: Iliya *et al.*[26,27]
IC_{50}, 50% inhibitory concentration.

molecules is presented in Table 8. As shown in Table 8, the stilbenes in *G. africanum* display considerable antioxidant activity. Compounds **1**, **2**, and **3** display lipid peroxide inhibition activities of 13, 50, and 32 μM and scavenging activity for superoxide of 10, 33, and 30 μM. Vitamin E has less antioxidant capacity than these compounds. As mentioned earlier, this shows the importance of the presence of phytol in the essential oil of *G. africanum*.

Nutritional Importance

The chemical composition of the leaves of *G. africanum*, which are used by the people of many countries, gives this plant many potential nutritional properties.[22] When it cooked and mixed with various other ingredients (meat, dried or salted fish, etc.), these leaves constitute an important source of proteins, amino acids, and minerals.[4,24,28,29] These leaves have such a high protein content, ranging from 7 to 18 g per 100 g (DM), that they might be usable for preparing food protein concentrates. In general, the calorie content of most vegetables is low (on the order of 30–50 kcal/100 g), but as Table 9 shows, the caloric values found for *G. africanum* leaves are far higher, ranging from 248 to 307 kcal/100 g.[12] The mineral content of *G. africanum* leaves is also reported to be fairly high. Consequently, soups prepared from this plant are rich in minerals, proteins, oils, and other fats. Akpanabiatu *et al.*[21] reported that

Table 9. Nutritional Values of Leaves of *G. africanum*

Variety of G. africanum	*Source*	*Calorie value (kcal/100 g)*	*Reference*
Asutan	Leaves	307.1	Isong *et al.*[12]
Oron	Leaves	303.2	Isong *et al.*[12]
Ikom	Leaves	248.8	Isong *et al.*[12]
Afang	Seeds	448.3	Ekop[16]

compared with soups made from other plants, soup made from *G. africanum* is the richest in calcium (3,920 mg/100 g of DM) but the poorest in iron (130 mg/100 g of DM). The levels of Mg, Cu, and P are also among the highest, but that of Zn is close to the lowest. However, the levels of Ca, Mg, Fe, and P in *Gnetum* are sufficient to provide adults with their recommended daily intake of these minerals.

An analysis of the chemical composition of *G. africanum* seeds shows that they have low amounts of essential minerals compared with other vegetable seeds. Also, the level of antinutritional components in *Gnetum* seeds is higher. For this reason, *Gnetum* seeds must be pretreated through cooking and processing operations before being eaten.[16]

Fiber

The fiber content of *G. africanum* is high, averaging about 33.4 g/100 g of DM. The composition, length, and width of the fibers depend on the age of the leaves (Table 10). The length and width of the fibers in leaves more than 12 months old decrease as the leaves mature. The length of the fibers is positively correlated with the crude fiber content, whereas the width of the fibers is negatively correlated with age, protein content, and the digestibility of these proteins. Older leaves have a high content of crude long fibers. Leaves that are only 2–3 months old have the fibers that are the shortest and hence are the most readily digestible and should therefore be selectively recommended for consumption.[12]

Older leaves have a greater laxative effect than younger leaves because of their higher levels of long, less digestible fibers. A diet of *G. africanum* fiber thus seems to promote gastric transit and water retention and have a stool-softening effect. For this reason, older leaves could be a good addition to the diets of patients with hypertension and atherosclerosis because these leaves would aid in lowering plasma cholesterol levels by reducing the bile acid.[12]

Table 10. Parameters of Evolution of the Chemical Characteristics and the Nutrition of the Leaves of *G. africanum* According to Their Age and to the Variety

Variety of G. africanum	*Age (months)*	*Raw fiber (%)*	*Protein (%)*	*Digestibility* in vivo *(%)*	*Length of fibers (mm)*	*Width of fiber (mm)*
Oron	2–3	17	18	60	1.2	0.00112
	6–12	29	25	48	1.4	0.0115
	36–48	49	12	36	1.3	0.0110
Austan	2–3	14	16	67	1.0	0.0109
	6–12	24	22	53	1.3	0.0117
	36–48	42	14	44	1.2	0.0109

Source: Isong *et al.*[12]

Weight-reducing effect of G. africanum

The presence of fiber is very important in a healthy diet. Based on the results of epidemiological studies showing that consuming more than 25 g of fiber/day reduces the risks of several different pathologies, the recommended daily intake is 30 g. Fiber plays an important role in digestion, facilitates intestinal transit, and prevents constipation. Fiber also facilitates weight loss by providing a greater feeling of satiety, and it removes food from the walls of the intestines. Fiber protects the arteries by inhibiting fatty deposits and thus preventing heart disease.[30]

The high fiber content of *G. africanum* leaves gives them a weight-reducing effect, despite their high protein content. *In vivo* studies have shown that mice fed a *G. africanum*–based diet absorbed only 57–70% of the nitrogen that they ingested, compared with mice fed a reference diet.[12,28] This resulted in a weight loss on the order of 9 g per 10-day interval among the mice fed the *G. africanum* diet. This weight loss (Table 11) is similar to that obtained with the mice that were fed a protein-free diet (11.8 g per 10-day interval). Fokou and Domngang[28] explain this slower growth in the mice by the fact that the amino acids are used for energy production because of the reduced nitrogen intake. These authors observed that urine nitrogen levels were 69% lower in the mice fed *G. africanum* than in the reference mice. Also, fecal nitrogen was 168% higher in the mice fed *G. africanum* than in the reference mice. The authors therefore concluded that in the cell, there was no minimal utilization of the amino acids in the *G. africanum* diet, but it was rather the digestibility of this diet that was lower, with a digestibility coefficient only 72–74% that of the reference diet (Table 11). All of the biological parameters for nutritional value, protein efficiency ratio, net protein efficiency ratio, and biological value were lower in the *G. africanum* diet than in the reference diet (Table 11). These results are consistent with those obtained in the variation in weight. Likewise, Fokou and Domngang[28] estimated that the cellulose content of *G. africanum* leaves is high. The authors concluded that the weight-reducing effect of the *G. africanum* diet is due mainly to its high content of fiber, saponin, and other components that reduce the amount of nutrients absorbed in the gastrointestinal tract.

Isong *et al.*[12] also observed weight loss in mice that were fed *G. africanum*–based diets (Table 11). These authors demonstrated that *G. africanum* leaves could be used to produce a protein extract with a protein content of 61% (DM). These same authors reported that *in vivo*, the digestibility coefficient, protein efficiency ratio, and net protein efficiency ratio for whole leaves are lower than those for this protein extract (Table 11). This indicates that the preparation of protein extract improves the nutritional value or protein intake from *G. africanum* leaves. This is due to the reduction in fiber content and the enriched protein content of the leaf extract.

In general, protein plants pose three problems: a low concentration of protein (1–2 g/100 g), low digestibility, and a low biological value.[31] *G. africanum* solves these problems when various products can be made from its leaves in accordance with market and consumer needs, conferring, from this standpoint, undeniable advantages on this plant.

Toxicity and antinutrients

The antinutritional components existing in *G. africanum* occur at levels below the toxicity threshold. The toxicity level for hydrocyanic acid is 35 mg/10 g (DM);[32] the analyses show that the level of this acid in the leaves of this plant is only 0–5.4 mg/100 g (Table 12). Regarding oxalate, to be toxic, it must be present in concentrations on the order of 2–5 g/100 g (DM),[33] whereas in *G. africanum* concentrations of 16–68 mg/100 g DM have been detected (Table 12). It should be stressed that the raw leaves are not toxic for human beings.[20]

Table 11. Nutritional Parameters of Growth of Mice Fed by Diets with Leaves of *G. africanum*

Reference, diet	*Ingested*[a]	*Weight gain/loss*[b]	*Coefficient of protein efficiency*	*Coefficient of protein total efficiency*	*Coefficient of digestive use*
Fokou and Domngang[28]					
Casein (reference)	204.4	+2.65	2.08	3.43	91
G. africanum[c]	117.8	–1.47	–1.99	0.34	66
Protein-free	16.9	–1.72	—	—	—
G. africanum (% reference)[d]	57	—	—	9.9	72
Isong *et al.*[12]					
Casein (reference)	82	+8.4	2.1	2.3	98.1
G. africanum–based diet[e]	57.5	–4.3	–1.7	1.1	72.5
Extract of protein of leaves	80	–6.4	3.9	2	89.6
Protein-free	60.3	–6.3	—	—	—
G. africanum–based diet (% reference)[d]	70	—	—	48	74

[a]Amount of nitrogen ingested in milligrams per mouse per day in data from Fokou and Domngang[28] and quantity in grams in data from Isong *et al.*[12]

[b]In grams per mouse per day in data from Fokou and Domngang[28] and total in grams in data from Isong *et al.*[12]

[c]Whole leaves of *G. africanum* were steam cooked for 1 hour, dried, and finely ground.

[d]% reference is the ratio of the value obtained with *G. africanum* or with whole leaf diet to the value obtained with the casein diet (reference diet).

[e]Raw, powdered whole leaves of *G. africanum* were used in compounding the diet with cornstarch, sucrose, salt, vitamin, and palm oil.

Table 12. Content of Some Antinutritional and Toxic Substances Found in Some Varieties of *G. africanum*

		Content (mg/100 g of dry matter)						
		Oxalate						
Variety of G. africanum	Source	Total	Soluble	Tannins (mg/g of catechin)	Glucosinate	Hydrocyanic acid	Phytic acid	Reference
Asutan	Leaves	18.3	15	8.1	1.1	—	—	Isong *et al.*[12]
Oron	Leaves	16.1	12.7	4.0	1.3	—	—	Isong *et al.*[12]
Ikom	Leaves	21.7	17.3	2.4	1.1	—	—	Isong *et al.*[12]
Afang	Leaves	67.8	—	—	—	5.4	250	Udosen and Ukpanah[20]
	Soup	5.0	—	—	—	0.32	745	Akpanabiatu *et al.*[21]
	Seeds	209	—	100.7	—	540	238.3	Ekop[16]

As for tannins, the concentration detected is 2.4–8.1 mg of catechin/g. These molecules are known for their astringent effect, and they complicate the bioavailability of the proteins. The effect of the tannins on the digestibility of the proteins can be reduced by cooking the *G. africanum* leaves (Table 13). The digestibility of the proteins is improved after the leaves have been cooked (>275% for the Oron variety of *G. africanum*, 185% for Ikom, and 180% for Austan). Consequently, the biological value of the cooked leaves is greater than that of the raw leaves.

Glucosinate inhibits the absorption of iodine, calcium, and iron at a low concentration for the three varieties of *G. africanum* (Table 12). Recently, these antinutrients have been identified as an anticarcinogenic chemoprotective diet.[34] Phytic acid, which is present in *G. africanum* leaves, accounts for 83% of all the detectable phosphorus in the plant. This acid also reduces the bioavailability of minerals such as calcium, iron, zinc, and phosphorus, as well as reacting with these minerals to form complexes that are insoluble and that are not readily hydrolyzed by the enzymes in the intestine.[20]

The nutritional values of dishes prepared with *G. africanum* are not compromised by the presence of these antinutrients. It is known that most of these antinutrients are eliminated and destroyed during processing and cooking.[16,20] *Gnetum*-based soups contain low levels of antinutrients such as hydrocyanic acid and oxalate on the order of 0.32 mg/100 g (DM) and 5 mg/100 g (DM), respectively, for the soup made with *G. africanum,* fish, vegetables, and oil. The low level of oxalate makes its effect of minimizing calcium absorption negligible, which does not affect its bioavailability. Consequently, the hydrocyanic acid and oxalate in *G. africanum* soup do not pose a nutritional problem.[21] Regarding phytic acid, its high level corresponds to a low ratio of phytates to zinc. The bioavailability of the zinc is therefore not notably affected by the presence of phytates.[21] Consequently, the bioavailability of the mineral-rich *G. africanum* soup is not influenced by the presence of the antinutrients.

Table 13. Digestibility of Proteins of *G. africanum In Vivo*

	Digestibility (% nitrogen total)	
Variety	Raw leaves	Cooked leaves
Asutan	39.4	71.1
Oron	27.4	75.5
Ikom	36.3	67.2

Source: Isong *et al.*[12]

CONCLUSIONS

This review has shown that *G. africanum*, a leaf vegetable that is rich in various elements, can be used as a food or a nutritional supplement. Thus, by virtue of its physiochemical composition, this plant offers tremendous health benefits. Hence *G. africanum* has important functional or nutraceutical properties. Also, because of its various kinds of biological activity, *Gnetum* is regarded as a medicinal plant with anticancerogenic and anti-inflammatory properties due to its natural content of active ingredients such as stilbenes and glycosylflavones. We can therefore conclude that *Gnetum* has sufficient genuine potential for the agrifood industry to explore the possibility of developing food or pharmaceutical ingredients from it. But, in order to do so, more in-depth knowledge of this plant must be developed, so that greater advantage can be taken of its many beneficial properties.

AUTHOR DISCLOSURE STATEMENT

F.A. and C.R. are employees of PharmAfrican. M.A.A. declares no competing interests.

REFERENCES

1. Mialoundama F, Paulet P: Regulation of vascular differentiation in leaf primordial during the rhythmic growth of *Gnetum africanum. Can J Botany* 1986;64:208–213.
2. Watt JMA, Breyer-Brandwijk MG: *The Medicinal and Poisonous Plants of Southern and Eastern Africa*. E & S Livingstone, Edinburgh, 1962.
3. Letouzey R: *Manual of Forest Botany: Tropical Africa. Vol. 1. General Botany*. CTFT, Norgent Surmarne, France, 1986.
4. Mialoundama F: Nutritional and socio-economic value of *Gnetum* leaves in Central African forest. In: *Tropical Forests, People and*

Food: Biocultural Interactions and Applications to Development (Hladik A, Linares OF, Hladik CM, Pagezy H, UNESCO, eds.). Parthenon Publishing Group, Carnforth, United Kingdom, 1993, pp. 177–182.
5. Lowe J: *Gnetum* in West Africa. *Nigerian Field* 1984;49:99–104.
6. Shiembo PN: Pour une gestion durable des Okok (*Gnetum africanum* et *Gnetum bucholzianum*): des produits forestiers non ligneux surexploites dans les forets d'afrique centrale. In: *Recherches Actuelles et Perspectives pour la Conservation et le Développement*. Department of Forestry, Food and Agriculture Organization, Rome, 1999, pp. 65–70.
7. Bahuchet S: The Akwa pygmies: hunting and gathering in the Lobaye Forest. In: *Food and Nutrition in the African Rain Forest*. Food Anthropology Unit 263, UNESCO, New York, 1990.
8. Mialoundama F, Lauzac M, Paulet P: The periodic induction of dormancy during the rhythmic growth of *Gnetum africanum. Physiol Plantarum* 1984;61:309–313.
9. Bokwe A, Ngatoum D: *Effectuée Autour du Mont Cameroun (Province du Sud-Ouest) relatif au Recensement de Certaines Espèces des Produits Forestières Secondaires en Voie de Disparition. Rapport de la Mission*. MINEF, Yaounde, Cameroon, 1994.
10. Besong M, Samalang P, Abia C: Commercialisation as an incentive and threat for *Gnetum* spp (eru) in Cameroon. Proceedings of *A Workshop on Incentive Measures for Sustainable Use and Conservation of Agro-Biodiversity*. Lusaka, Zambia, September 11–14, 2001, pp. 69–72.
11. Saidou A: *Rapport des Activités de la Semaine de la Journée Internationale de la Biodiversité, du, 17–22 Mai, République du Cameroun*, Peace-Work-Fatherland, Ministry of the Environment and Forestry, *Technical Adviser No.1*, Yaounde, Cameroon, 2004.
12. Isong EU, Adewusi SAR, Nkanga EU, Umoh EE, Offiong EE: Nutritional and phytogeriatological studies of three varietes of *Gnetum africanum. Food Chem* 1999;64:489–493.
13. Eyo ES, Mohme N, Abel HJ: Chemical composition and amino acid contents of *Gnetum africanum*, *Heinsia crinita* and *Piper guineense. Nigerian J Nutr Sci* 1983;4:57–62.
14. Mensah JK, Okoli RI, Ohaju-Obodo JO, Eifediyi K: Phytochemical nutritional and medical properties of some leafy vegetables consumed by Edo people of Nigeria. *Afr J Biotechnol* 2008;7:2304–2309.
15. Popovich D, Jenkins DJA, Kendall CWC, Dierenfeld ES, Carroll RW, Tariq N, Vidgen E: The Western Lowland gorilla diet has implications for the health of humans and other hominoids. *J Nutr* 1997;127:2000–2005.
16. Ekop AS: Determination of chemical composition of *Gnetum africanum* (AFANG) seeds. *Pak J Nutr* 2007;6:40–43.
17. Njoku OU, Eneh FU, Nwanguma BC: Investigation of test lipids of *Gnetum africanum. J Pharm Res Dev* 1997;2:8–10.
18. Edet UU, Ehiabhi OS, Ogunwande IA, Walker TM, Schmidt JM, Setzer WN, Ogunbinu AO, Ekundayo O: Analyses of the volatile constituents and antimicrobial activities of *Gongronema latifolium* (Benth and *Gnetum africanum* L). *J Essent Oil Bearing Plants* 2005;8:324–329.
19. Iliya I, Tanaka T, Iinuma M, Furusawa M, Ali Z, Nakaya K, Murata J, Darnaedi D: Five stilbene glucosides from *Gnetum gnemonoides* and *Gnetum africanum. Helv Chim Acta* 2002; 85:2394–2402.
20. Udosen EO, Ukpanah UM: The toxicants and phosphorus content of some Nigerian vegetables. *Plants Foods Hum Nutr* 1993; 44:285–289.
21. Akpanabiatau MI, Bassey NB, Udosen EO, Eyong EU: Evalution of some minerals and toxicants in some Nigerian soup meals. *J Food Comp Anal* 1998;11:292–297.
22. Burkill HM: *The Useful Plants of West Tropical Africa. Volume 2: Families E–I*. Royal Botanic Gardens, Kew, United Kingdom, 1994.
23. Tandu-umba: Promotion de la biodisponibilité du fer alimentaire au sein de la population obstétricale de Kinshasa [Promoting iron bioavailability among pregnant women in Kinshasa, Zaire]. *Med Nutr* 1995;31:19–22.
24. Ouabonzi A, Bouillant ML, Hapin J: C-Glycosyflvones from *Gnetum buchholzianum* and *Gnetum africanum. Phytochemistry* 1983;22:2632–2633.
25. Iliya I, Tanaka T, Iinuma M, Ali Z, Furusawa M, Nakaya K: Dimeric stilbenes from stem lianas of *Gnetum africanum. Heterocycles* 2002;57:1057–1062.
26. Iliya I, Tanaka T, Iinuma M, Ali Z, Furusawa M, Nakaya K, Matsuura N, Ubukata M: Four dimeric stilbenes in stem lianas of *Gnetum africanum. Heterocycles* 2002;57:1507–1512.
27. Iliya I, Tanaka T, Ali Z, Iinuma M, Furusawa M, Nakaya K, Shirataki Y, Murata J, Darnaedi D, Matsuura N, Ubukata M: Six flavonostilbenes from *Gnetum africanum* and *Gnetum gnemon. Heterocycles* 2003;60:159–166.
28. Fokou E, Domngang F: In vivo assessment of the nutritive value of proteins in situ in the leaves of *Solanum nigrum*, *Xanthosoma* spp, and *Gnetum africanum. Indian J Nutr Diet* 1989; 26:366–373.
29. Busson F: *Plantes Alimentaires de l'Ouest Africain: Etude Botanique, Biologique et Chimique*. Ministère de la Cooperation, Leconte, Marseille, 1965, p. 568.
30. Linden G, Laurient C: *Biochimie Alimentaire*. Masson, Paris, 1987.
31. Devlin TM, ed.: *Textbook of Biochemistry*. John Wiley and Sons, Chichester, United Kingdom, 1982, pp. 1180–1181.
32. Oke OL: Role of hydrocyanic acid in nutrition. *World Rev Nutr Diet* 1969;11:170–198.
33. Murno A, Bassir O: Oxalate in Nigerian vegetables. *W Afr J Biol Appl Chem* 1969;12:14–17.
34. Bresnick E, Birt DF, Wolterman K, Wheeler M, Martin RS: Reduction in mammary tumorigenesis in the rat by cabbage residue. *Carcinogenesis* 1990;11:1159–1163.