Food Reviews International
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lfri20

Sclerocarya birrea (Marula), An African Tree of Nutritional and Medicinal Uses: A Review

Abdalbasit Adam Mariod [a] & Siddig Ibrahim Abdelwahab [b]
[a] Department of Food Science and Technology, College of Agricultural Studies, Sudan University of Science and Technology, Khartoum North, Sudan
[b] Department of Pharmacy, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia

Available online: 21 Feb 2012

To cite this article: Abdalbasit Adam Mariod & Siddig Ibrahim Abdelwahab (2012): Sclerocarya birrea (Marula), An African Tree of Nutritional and Medicinal Uses: A Review, Food Reviews International, 28:4, 375-388

To link to this article: http://dx.doi.org/10.1080/87559129.2012.660716

Food Reviews International, 28:375–388, 2012

ISSN: 8755-9129 print / 1525-6103 online
DOI: 10.1080/87559129.2012.660716

Taylor & Francis
Taylor & Francis Group

Sclerocarya birrea (Marula), An African Tree of Nutritional and Medicinal Uses: A Review

ABDALBASIT ADAM MARIOD[1] AND SIDDIG IBRAHIM ABDELWAHAB[2]

[1]Department of Food Science and Technology, College of Agricultural Studies, Sudan University of Science and Technology, Khartoum North, Sudan
[2]Department of Pharmacy, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia

Sclerocarya birrea *(Anacardiaceae) is a popular African wild tree distributed in many African countries where the leaves, stem bark, root, and fruits are used in food and traditional medicine; the fruit is rich in ascorbic acid. The fruit juice contains sesquiterpene hydrocarbon, which are terpenes found in plants that are reported to have bacteriostatic properties. The fruit contains a hard brown seed. The seed encloses a soft white kernel rich in oil and protein. The oil contains oleic, palmitic, myristic, and stearic acids; the kernel protein contains amino acids, with a predominance of glutamic acid and arginine. The extracts from different parts showed high total phenolic compounds and radical-scavenging capacities and antioxidant activities.* Sclerocarya birrea *is widely studied with regard to its antidiabetic, anti-inflammatory, analgesic, antiparasitic, antimicrobial, and antihypertenisve activities.*

Keywords Antidiabetic, Anti-inflammatory, Antimicrobial, Antioxidant, Phenolic compounds, Protein, Oil, *Sclerocarya birrea*

Introduction

Sclerocarya birrea (Anacardiaceae), English name Marula, is a savannah tree, belonging to the family Anacardiaceae, with a plum-like pale yellow fruit of 3–4 cm in diameter with a juicy mucilaginous flesh. *Sclerocarya birrea* is deciduous and mainly dioecious, although there have been reports of monoecious trees. It is a medium-sized tree reaching heights of between 7 and 17 m, with gray fissured bark, stout branchlets, and pale foliage.(1) The rough stem bark is flaky, with a mottled appearance due to contrasting gray and pale-brown patches. The leaves are divided into 10 or more pairs of leaflets, each about 60 mm long, dark-green above, and with sharp point. The flowers are borne in small, oblong clusters. Male and female flowers occur separately, usually, but not always, on separate trees. The flowers are small, with red sepals and yellow petals.(2) The fruit is pale yellow when ripe, approximately 15–25g in weight, about 30 mm in diameter, and borne in profusion in late African summer to mid-winter.(3) The outer skin of the fruit has a rather pungent, apple-like odor, and its flavor has been described as resembling some other fruits, e.g., mango. The tree grows in a wide variety of soils but prefers well-drained soil. It exists

Address correspondence to Abdalbasit Adam Mariod, Department of Food Science and Technology, College of Agricultural Studies, Sudan University for Science and Technology, PO Box 71, Khartoum North, Sudan. E-mail: basitmariod@yahoo.com

at altitudes varying from sea level to 1800 m and in areas of an annual rainfall range of 200–1500 mm.[4]

The fruit of the *Sclerocarya birrea* tree has multiple uses.[5] The fruits are eaten fresh or fermented to make a beer. The kernels are eaten or used to extract oil. The leaves are consumed by livestock and also have medicinal uses, as does the bark.[6] Mizrahi and Nerd[7] mentioned that an effort has been made to domesticate the *Sclerocarya* tree in South Africa and Israel to establish orchards that will supply both fresh fruit and fruit for the canning and beverage industry. From these efforts, 4-year-old trees have mean heights of between 3 and 6 m, circumferences of 40–58 cm, and 25% of the planted trees produce an average of 27 kg of fruit per year, whereas 12-year-old trees produce 500 kg of fruit per year.[7]

Biochemical Composition and Proximate Analysis

The proximate analysis of *Sclerocarya birrea* fruit revealed that it is rich in ascorbic acid and the fruit juice contains sesquiterpene hydrocarbons (including caryophyllene, α-humulene, and copaene). Sesquiterpene is a member of the terpene group; it comprises three units of isoprene. Its molecular formula is $C_{15}H_{24}$. The fruit kernels contain high amount of oil and protein. The oil-rich seeds contain oleic, myristic, and stearic fatty acids and different types of amino acids, with a predominance of glutamic acid and arginine. The bark yields 3.5–20.5% tannin, 10.7% tanning matter, and traces of alkaloids.[8] Tannins and flavonoids are present in leaves but no alkaloids, steroids, or triterpenoids have been detected.[9]

In general, *Sclerocarya birrea* seed had adequate quantities of phosphorus, calcium, magnesium, potassium, iron, and copper. The contents of sodium, manganese, and zinc were below recommended levels required by ruminants for growth and productivity.[10] Glew et al.[11] reported high protein content (36.4%) of the edible portion of *Sclerocarya birrea* seed. However, when compared with the World Health Organization (WHO) protein standard, the seeds were found to contain low proportions of several of the essential amino acids, including leucine, lysine, the phenylalanine/tyrosine pair, and threonine (Table 1).

Table 1
The essential amino acid composition of *Sclerocarya birrea* kernel compared to the WHO "ideal protein"[11]

	Sclerocarya birrea kernel		
Amino acid	% of total amino acids[b]	% amino acid/ ideal × 100	WHO ideal protein %[a]
Isoleucine	3.3	118	2.8
Leucine	4.8	73	6.6
Lysine	2.0	35	5.8
Methionine + cysteine	4.1	163	2.5
Phenylalanine + tyrosine	5.7	90	6.3
Threonine	2.4	70	3.4
Tryptophan	1.5	136	1.1
Valine	3.9	112	3.5

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

The fruit is rich in ascorbic acid and juice extracts yield 33 sesquiterpene hydrocarbons.[12] The fruit contains two to three edible kernels, which contain 53.0%, 28.0%, and 8.0% of oil, protein, and carbohydrates, respectively. The gum is rich in tannin (0.4%). Tannins and flavonoids are present in leaves but no alkaloids, steroids, or triterpenoids have been detected.[9] Salama[13] worked on Sudanese *Sclerocarya*, and reported a fatty acid composition of the oil markedly different from that of Ogbobe[14] who studied Nigerian *Sclerocarya* seed oil and reported 50.7% stearic acid, 22.6% palmitic acid, 8.4% arachidonic acid, with an iodine value of 102 and 3.1% unsaponifiable matter. The fruit pulp contains citric and malic acids, ascorbic acid, and sugar. The gum from the tree is rich in tannin, and is sometimes used in making an ink substitute.[8]

Sclerocarya birrea Tree: A Promising Source of Food and Energy

Sclerocarya birrea *Proteins*

In South Africa, the kernels are obtained from the seeds by cracking the nuts against a stone slab, and then removing the kernels individually with a sharp needle-like tool. The kernel from Nigerian *Sclerocarya birrea* was found to contain 36.7% crude protein,[14] whereas Sudanese *Sclerocarya birrea* contained only 28.0% of protein, with lysine as the limiting amino acid. The protein contains a good level of sulfur-containing amino acids (methionine and cysteine), when compared to that of four different food materials (Table 2). The in vitro protein digestibility of *Sclerocarya birrea* was almost similar to that of soy bean protein concentrate and less than that of lupine, where 79% of the *Sclerocarya birrea* seed protein was found digestible by pancreatic enzyme, which was similar to 79% of soybean concentrate and less than 83.2% of lupine.[15] With a chemical score of 33.0%, based on the essential amino acids pattern requirements for children, the limiting amino acid in *Sclerocarya* protein is lysine.[15] Glew et al.[11] reported a protein content of 36.4% of dry weight; however, the protein fraction contained relatively low proportions of leucine, phenylalanine, lysine, and threonine. Because of the widespread occurrence, potentially high fruit production, and use of *Sclerocarya birrea*, products have been produced from seed kernels by adding them to Halva confectionary (a confectionary made of sesame paste and mixed sugars) and biscuits. In the case of Halva confectionary, 10% unroasted, blanched, and roasted kernels were added, whereas in biscuits *Sclerocarya* seed oil instead of hydrogenated oils was used. The results showed a statistically significant difference ($P \leq 0.05$) in texture, flavor, and overall preference between the Halva developed products. Biscuits processed by using the seed oil instead of hydrogenated oils were found to be significantly ($P \leq 0.05$) less acceptable using sensory scores (1–9) than the conventional biscuits.[15] *Sclerocarya birrea* oil was used in blending, cosmetics, and biodeisel production with for its high stability.

Sclerocarya birrea *Kernel Oil*

The *Scleocarya birrea* nut comprises an average 90% shell and 10% kernel, making kernel and oil yields relatively low per fruit. However, the oil content of kernels from *Sclerocarya birrea* amount to 53%,[15,16] which is high compared to conventional oil seeds. Salama[13] found more oil in the kernels (63.3%), whereas seeds investigated by Ogbobe[14] contained lower amounts (11.0%). Two to three kernels are found inside one seed and covered with very thick woody hulls.

Table 2
Amino acid composition of *Sclerocarya birrea* protein compared to levels in four different foods (mg/g nitrogen)

Amino acid	*Sclerocarya birrea*[15]	Broad bean[75]	Lentil[75]	Wheat flour[75]	Soy flour[75]
Ile	250	250	270	210	280
Leu	356	440	480	410	490
Lys	118	400	450	150	400
Met	100	40	50	100	80
Cys	137	50	60	160	100
Phe	250	270	330	280	310
Tyr	168	200	200	190	200
Thr	131	210	250	170	240
Trp	ND*	60	60	70	80
Val	306	280	310	280	300
Arg	612	560	540	130	450
His	268	150	170	230	160
Ala	181	260	270	310	270
Asp	487	700	720	1710	730
Glu	1418	940	1040	250	1170
Gly	275	260	260	660	260
Pro	206	250	270	330	340
Ser	243	280	330	5930	320
TAA**	5512	5600	6060	1960	6180
TEAA***	2129	2510	2740	33	2630
EAA****	38.4	44.8	45.2	4.3	2.9
% (Met + Cys)	4.3	1.6	1.8		

Note. Ile = isoleucine; Leu = leucine; Lys = lysine; Met = methionine; Cys = cysteine; Phe = phenylalanine; Tyr = tyrosine; Thr = threonine; Trp = trptophan; Val = valine; Arg = arginine; His = histidine; Ala = alanine; Asp = aspartic acid; Glu = glutamic acid; Gly = glycine; Pro = prolamine; Ser = serine.

*ND = not determined; **TAA = total amino acid; ***TEAA = total essential amino acid; ****EAA = % essential amino acid.

Marula oil contains a large proportion of monounsaturated fatty acids and natural antioxidants. It can be classified as a high–oleic acid (70–78%) with relatively low tocopherol content. The exceptional stability has, therefore, been suggested to be due to its fatty acid composition.[11] However, recent studies have mentioned that some of the minor components in the oil may also be contributing to this important antioxidant property.[17] Marula oil contains a similar fatty acid composition to olive oil; however, it is 10 times more stable to oxidation.

The oil contains 67.2% oleic acid, 5.9% linoleic acid, 14.1% palmitic acid, and traces of linolenic acid.[18] Glew et al.[11] reported that the fatty acids of *Sclerocarya birea* oil accounted for 47 mg/g dry weight of the seed, two-thirds of which was oleic acid. The essential fatty acid linoleic acid was present (24.5 mg/g dry weight), but the other essential fatty acid, α-linolenic acid, was absent. These results were in contradiction with the fatty acids reported by Ogbobe[14] who reported stearic, palmitic and archidonic acids as predominant, representing 50.7%, 22.5%, and 8.4%, respectively (Table 3).

Table 3
Fatty acid composition (%) of *Sclerocarya birrea* kernel oil as reported in the literature

Fatty acid	Mariod[18]	Salama[13]	Ogbobe[14]	Glew et al.[11]
14:0	0.33	0.20	2.12	0.10
16:0	14.16	17.10	22.56	15.63
16:1 n-7	0.15	**	**	0.23
18:0	8.84	10.90	50.76	11.10
18:1 n-9	67.25	67.00	04.13	63.19
18:1 n-11	0.84	**	**	0.87
18:2 n-6	5.93	4.30	**	5.21
18:3 n-3	0.12	**	**	**
20:0	0.91	0.90	8.46	1.25
20:1 n-9	0.36	0.70	0.14	0.53
22:0	0.22	**	**	0.38
24:0	0.31	**	4.13	0.82

Note. All determinations were carried out in triplicate and mean value ± standard deviation (SD) reported.

Sclerocarya birrea oil content and fatty acid composition is affected by harvesting time, a quantitative increase in the oil content was observed to reach 63.0% at the end of the last harvesting date (the last date of harvesting is last day of June). The percentage of total fatty acids had altered and palmitic acid content was found to be 16.8% at the first date of harvesting (first March) and dropping for the rest of the dates to reach 14.6% by the end of the harvesting process. In the same manner, stearic acid was found to be 15.2% at the first date and this dropped dramatically to reach 8.8% by the end of the harvesting, whereas oleic and linoleic acids increased from 58.9% and 4.3% to 67.3% and 5.9%, respectively.[19]

The major fraction in *Sclerocarya birrea* seed oil was triacyglycerol, representing 76.5% of the total lipid, followed by phospholipids 12.5% and diacyglyecrol 5.6%.[18] Unlike other nut oils, marula oil is a poor source of tocopherols. The tocopherol content of *Sclerocarya birrea* oil amounted to 13.7 mg/100 g oil, with γ-tocopherol predominant, amounting to 13.0 mg/100 g oil, followed by α-tocopherol at 0.4 mg/100 g oil, and δ-tocopherol at 0.3 mg/100 g oil.[20] During harvesting time of *Sclerocarya birrea*, the α- and γ-tocopherols decreased rapidly, whereas the δ-tocopherol and δ-tocotrienol were 4.8 and 4.9 mg/100 g, respectively, at the beginning and had disappeared completely by the last harvesting date.[19]

The sterol fraction in oils is analyzed for the identification of a fat or oil to distinguish between oils of similar fatty acid composition, for the detection of the addition of non-declared cheap oils to more expensive or to distinguish between different qualities of the same.[21,22] The total content of sterols in *Sclerocarya birrea* oil was 287 mg/100 g oil, with β-sitosterol as the main compound, with about 60% of the total sterols and a high amount of Δ5-avenasterol, which was found at 16% of the total sterols; Δ5-avenasterol is known to act as an antioxidant and as an antipolymerization agent in frying oils.[20] *Sclerocarya birrea* oil is believed to preserve meat depending on its high stability.[23] When compared with other oils, *Sclerocarya birrea* kernel oil could serve as a source of edible stable oil, and of fatty acids of technical grade, such as conjugated linoleic acid, which represents 0.5% of total fatty acids and serves as an antioxidant, anticarcinogenic, and antiatherogenic.[20]

Oils containing fatty acids of low molecular weight are slightly less viscous than oils of an equivalent degree of unsaturation containing only high-molecular-weight acids.[24] The viscosity of *Sclerocarya birrea* was measured by the viscotester between 25 and 125 °C. In general, the viscosity of the oil decreased slightly with increase in unsaturation and it decreased with increase of temperature and *Sclerocarya birrea* oil was found to be less viscous (37.6 mPas) compared with sesame (57.0 mPas), groundnut (65.7 mPas) and sunflower (62.1 mPas) oils.[18]

Oxidative stability is an important parameter for evaluating the quality of oils and fats, as it gives a good estimation of their susceptibility to oxidative deterioration, the main cause of their alteration.[25] The oxidative stability of *Sclerocarya birrea* oil, as measured by the Rancimat test at 120 °C, was 43 hours. This high oxidative stability may be due to a high percentage of monosaturated fatty acids in addition to other minor bioactive components such as sterols and phenolics.[20] Mariod et al.[26] investigated the oxidative stability of marula oil and compared it with sesame, peanut, sunflower, and cottonseed oils, which are conventional edible oils consumed in Sudan. They reported significantly ($P \leq 0.05$) higher stability of marula oil over conventional oils.

The behavior of crude *Sclerocarya birrea* kernel oil during deep-frying of par-fried potatoes was studied with regard to chemical, physical, and sensory parameters, such as content of free fatty acids, tocopherols, polar compounds, oligomer triglycerides, volatile compounds, oxidative stability, and totox value [2·(peroxide value) + anisidine value]. Potatoes fried in *Sclerocarya birrea* oil were found of good sensoric properties after 24 hours of deep-frying at 175 °C.[27] *Sclerocarya birrea* oil, given its high stability, was used in blending with sunflower oil to increase its stability as measured by Rancimat and peroxide value. The blending resulted in a remarkable improvement of the oxidative stability by 147%. The results revealed a good correlation between the content of oleic acid and the oxidative stability of oils.[28] Another method to compare the oxidative stability of oils is the storage under accelerated conditions at 70 °C and measurement of the peroxide value at certain times. When *Sclerocarya birrea*was was stored at 30 ± 2 °C in the dark for 24 months, the fatty acid composition in the oil remained almost unaltered with no significant change in its oxidative stability.[29]

Phenolic compounds from *Sclerocarya birrea* oil seed cake extracted by overnight and ultrasound extraction resulted in a higher amount of total phenolic compounds. The addition of the extracts obtained from sunflower oil showed an inhibition of oxidation and a remarkable antioxidative activity, reducing oil deterioration.[30] Crude oils obtained by oilseed processing have to be refined before consumption in order to remove undesirable accompanying substances, such as free fatty acids, phosphoacylglycerols, sterols, pigments, glucosides, waxes, and hydrocarbons.[31] In laboratory experiments, crude oil from *Sclerocarya birrea* was processed by refining. Changes in composition and also the stability against oxidation were determined. Phosphatides, peroxides, tocopherols, sterols, as well as the oxidative stability were reduced during processing, whereas free fatty acids were nearly totally removed (Table 4).[32] The total amounts of volatiles as well as the amounts of hexanal were decreased during the different processing steps as well.

Antioxidant activity and stability of oils may be related to their fatty acid, tocopherols, and phenolic compounds. The antioxidant activity of 3,4-dihydroxyphenylethanoland and phenyl acids (caffeic acid, *p*-coumaric acid, ferulic acid, syringic acid, and vanillic acid) that are found in virgin olive oil has been studied, and their high antioxidant activity has been demonstrated.[33]

Table 4
Effects of processing steps on composition, stability, sterols, and tocopherols (mg/100 g) of *Sclerocarya birrea* oil[32]

	Composition*				
	Phosphorus (ppm)**	PV(meq/kg)•	FFA (%)•	Sterols(mg/100 g)	IP (hours)•
Crude oil	29.2[a]	0.8[a]	2.1[a]	386.6[a]	43.0[a]
Degummed	21.4[b]	0.6[b]	2.1[a]	346.8[b]	35.4[b]
Neutralized	4.9[c]	1.0[c]	0.2[b]	301.0[c]	7.3[c]
Bleached	4.8[c]	1.0[c]	1.5[c]	158.3[d]	5.2[d]
Deodorized	4.8[c]	0.1[d]	0.1[d]	142.6[e]	8.5[e]

	Phytoterols*						
	Cholesterol	Campesterol	Stigmasterol	β-Sitosterol	Δ5-Avenasterol	Δ7-Stigmasterol	Total**
Crude oil	2.6[a]	104[a]	20.9[a]	221.1[a]	17.1[a]	20.9[a]	386.6[a]
Degummed	2.3[b]	95.8[b]	17.7[b]	205.9[b]	15.3[b]	9.7[b]	346.8[b]
Neutralized	2.0[c]	77.9[c]	13.4[c]	187.0[c]	13.3[c]	6.7[c]	301.0[c]
Bleached	1.2[d]	40.5[d]	6.2[d]	99.4[d]	6.9[d]	4.1[d]	158.3[d]
Deodorized	1.0[d]	35.2[e]	4.3[e]	95.5[e]	4.0[e]	2.6[e]	142.6[e]

	Tocopherols*			
	α-T	γ-T	δ-T	Total**
Crude oil	0.4	13.5	0.32	13.7[a]
Degummed	0.0	13.4	0.28	13.6[b]
Neutralized	0.0	13.1	0.28	13.4[c]
Bleached	0.0	9.9	0.27	10.2[d]
Deodorized	0.0	8.2	0.22	8.4[e]

*The values shown are the average of three replicates. **Means followed by different letters within a column are significantly ($P < 0.05$) different. •PV = peroxide value; FFA = free fatty acids; IP = induction period.

Pharmacology of *Sclerocarya birrea*

In view of its wide range of medicinal uses, *Sclerocarya birrea* has undergone extensive biological studies (antioxidant activity, antidiabetic properties, antagonistic effect, antiplasmodial and antimalarial activities, etc.) and many studies have been performed on the basis of its chemical constituents and traditional uses. Important biological findings are summarized in Table 5.

Antioxidant Activity

Research has pointed out that an effective method to reduce oxidative stress is antioxidant supplementation. When added to foods, antioxidants minimize rancidity, retard the formation of toxic oxidation products, maintain nutritional quality, and increase shelf life.[34] The methanolic extracts from *Sclerocarya birrea* leaves, roots, barks, and kernel oil cake were examined for radical-scavenging capacities and antioxidant activities. The extracts showed high total phenolic compounds and they were markedly effective in inhibiting the oxidation of linoleic acid and subsequent bleaching of β-carotene in comparison with the control (Fig. 1). Based on these findings, the seedcake extract is the most effective, followed by root, leaves, and bark extracts. Similarly, the antioxidant activity determined by the DPPH (1,1-diphenyl-β-picrylhydrazyl) method revealed that the seedcake extract had the highest antioxidant activity.[29] *Sclerocarya birrea* juice was found to be a potent antioxidant; its effects were attributed to high contents of flavonoids and polyphenolic compounds.[35] These phenolic compounds, besides having high antioxidant and free radical-scavenging activities, appear to regulate signaling pathways involved in cellular survival, growth, and differentiation.[36] Thus, diets with a high content of such phenolic-rich antioxidants emerge as a promising approach to help strengthen the physiological antioxidant defense system and to improve chronic diseases. The marula fruit juice, with its high antioxidative capacity, is a potential candidate for this approach.

Antidiabetic Activity

Sclerocarya birrea is most widely studied with regard to its antidiabetic effect and the plant has shown hypoglycemic activity.[37–40] The stem-bark ethanol extract was found to be used as complementary remedy in diabetes.[41] *Sclerocarya birrea* was evaluated for the treatment of type II diabetes[2] using in vitro models. Complications are frequently encountered in diabetes and these are associated with irreversible functional and structural changes in various organs, particularly the kidneys, eyes, nerves, heart, and blood vessels.[35] The extract caused significant reduction in blood pressure in anesthetized and conscious normal and diabetic rats.[41]

Anti-inflammatory and Analgesic Properties

Sclerocarya birrea is used in folk medicine for the treatment of inflammatory disorders.[42–44] Ojewole[43] evaluated the anti-inflammatory effect of stem-bark aqueous and methanolic extracts of *Sclerocarya birrea*. Both the aqueous and methanolic extracts (500 mg/kg per os [p.o.]) reduced rat paw edema induced by subplantar injections of fresh egg albumin, due to the inhibition of histamine and prostaglandin pathways and to its antioxidant activity, as indicated by the glutathione and malondialdehyde levels in rats.

Table 5
Some investigated biological activities of *Sclerocarya birrea*

Biological activities	Plant part and extracting solvent	References
Antidiabetic properties	Stem-bark aqueous extract, methylene chloride/methanol extract, and cold dichloromethane: methanol (1:1) and water extract	36, 37, 38, 39, 2
Antagonistic effect on caffeine-induced calcium	Crude decoction, aqueous, ethanolic, and chloroformic extracts	41
Antiplasmodial and antimalarial activities	Stem-bark aqueous and methanol extracts aqueous leaf, stem bark, and fruit extracts	42, 43
Antioxidant activity	Leaves methanol extract, 50% aqueous methanol of the peel and pulp of the fruits	44, 45, 30, 29, 46, 45
	Extracts from kernel oil cake, methanolic extracts from leaves, roots, barks, and kernel oil cake	
	Methanolic and acetone extracts of fruit	
	Aqueous methanolic extracts of fruits	
Antibacterial activity	Bark and leaves	47
Antifungal activity	Methanolic extract of leaves and roots	48
Anti-inflammatory properties	Stem-bark aqueous and methanol extracts, stem-bark aqueous extract	49, 50, 51
Antidiarrheic activity of	Lyophilized decoction of bark extract, procyanidin (pure compound)	52, 53
Modulation of glomerular filtration rate (GFR)	Stem-bark ethanolic extract	54
Modulation of mean arterial blood pressure (MAP)	Stem-bark ethanolic extract	54
Molluscacidal activity	Methanolic and water extract	55
Analgesic activity	Stem-bark aqueous extract	51
Antihypertensive	Stem-bark aqueous extract	56
Pesticidal properties		57
Anticonvulsant	Stem-bark aqueous extract	58
Antispasmodic	Lyophilized decoction of leaves extract	59
Hepatoprotective	Aqueous stem-bark extract	60
Trypanocidal effect	Methanolic extract of leaves	61
Antiamebic activity	Ethanol and water extracts of plants	62

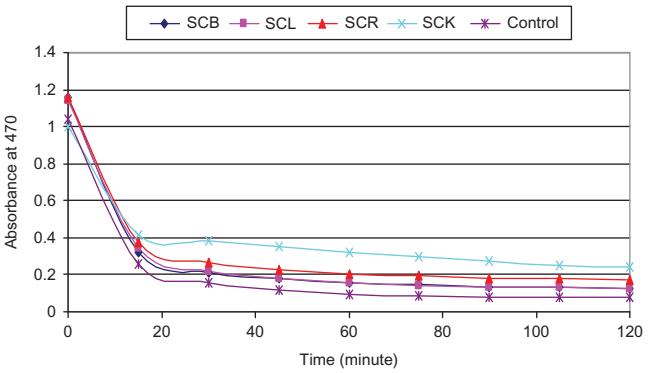

Figure 1. Effect of different *Sclerocarya birrea* methanolic extracts on oxidation of β-carotene/linoleic acid at 50 °C.[29] SCB = *Sclerocarya birrea* bark; SCL = *Sclerocarya birrea* leaves; SCR = *Sclerocarya birrea* root; SCK = *Sclerocarya birrea* seedcake. The extracts were prepared by dissolving 2 mg of β-carotene in 10 mL chloroform and 40 mg of purified linoleic acid and 200 mg of Tween 40, in 100 mL of aerated distilled water. Aliquots (5 mL) of the prepared emulsion were transferred to a series of tubes containing 2 mg of each extract or 0.2 mg of butylated hydroxyanisole (BHA). (color figure available online.)

Antiparasitic and Antimicrobial Activities

Several studies have shown the usability of medicinal plants in the treatment of trypanosomiasis, which causes economical and epidemiological hazards.[45–47] The methanolic extract of *Sclerocarya birrea* leaves and stem bark showed complete mortality of *Trypanosoma brucei brucei* in vitro.[47] Although complete mortality of the organism was observed, these studies did not provide a mechanism by which this extract exhibit its effect nor was the active pure compound reported.[47,48] Ethanol and water extracts of marula, which is used by South African traditionally to treat dysentery, also showed antiamebic activity when tested using the microtiter plate and *Entamoeba histolytica*.[49] *Sclerocarya birrea* was tested for in vitro antiplasmodial and in vivo antimalarial activities against *Plasmodium falciparum* and *Plasmodium berghei*, respectively. *P. falciparum* was more sensitive to the plant extracts than *P. berghei*. *Sclerocarya birrea* methanol extract is more active than aqueous one.[50]

Gastrointestinal and Antihypertenisve Activities

Sclerocarya birrea is one of plant species used widely in traditional medicine in Africa against many diseases and affections, such as hypertension, dysentery, stomachache or gastroenteritis.[51] Studies have been carried out on the effect of this plant on smooth and skeletal muscles.[51–54] The lyophilized decoction of this plant demonstrated antidiarrheic activity in experimental models of diarrhea induced by magnesium sulfate and sodium picosulfate.[53] On the other hand, the antispasmodic effect of *Sclerocarya birrea* extract was studied on isolated rat duodenum where the extract has exhibited an inhibitory effect on the dose-response curves induced by acetylcholine (Ach) on rat duodenum and reduced the maximal response of Ach in a concentration-dependent manner.[52] On the other hand, (−)-epicatechin-3-galloyl ester, which was isolated from the bark of *Sclerocarya birrea*, has shown secretagogue activity.[55]

Ethnonutritional and Ethnomedicinal Uses

Dried seeds and nuts are widely consumed by local populations in Africa, especially those who inhabit rural areas.[56] In some African countries, the stem bark, roots, and leaves of *Sclerocarya birrea* are used for an array of human ailments, including malaria and fevers, diarrhea and dysentery, stomach ailments, headaches, sore eyes, toothache, backache and body pains, infertility, schistosomiasis, constipation, abdominal cramps and some other unspecified gastrointestinal problems, toothaches and swollen or infected gums, cough, hypertension, arthritis, proctitis, epilepsy, diabetes mellitus, sores, boils, carbuncles, abscesses and certain other bacterial infections, etc.[8,43,57,58] In East Africa, roots are an ingredient in an alcoholic medicine taken to treat an internal ailment known as kati, whereas the bark is used for stomach disorders.[59]

Conclusions

Sclerocarya birrea has been part of a supplemental diet in many African countries. Consumption of its leaves, fruits, and kernels is becoming increasingly popular. Many products have been developed from different parts of *Sclerocarya birrea* for either nutritional or medicinal uses. Crude fixed seed oil is a valuable source of essential fatty acids, tocopherols, phytosterols, and phospholipids. The high levels of those bioactive lipids are of importance in nutritional applications. On the contrary, different parts from *Sclerocarya birrea* have significant effects on multiple biological systems. The pharmacological activities are attributed to the presence of different active components.

References

1. Coates, P.K. *Trees of Southern Africa*; C. Struik Publishers: Cape Town, 1977.
2. Van de Venter, M.; Roux, S.; Bungu, L. C.; Louw, J.; Crouch, N.; R.; Grace, O.M.; Maharaj, V.; Pillay, P.; Sewnarian, P.; Bhagwandin, N.; Folb, P.Antidiabetic screening and scoring of 11 plants traditionally used in South Africa. J. Ethnopharmacol. **2008**, *119*, 81–86.
3. Shackleton, B.J.; Emanuel, P.L. Productivity and abundance of *Sclerocarya birrea* subsp. *caffra* in and around rural settlements and protected areas of the Bushbuckridge Lowveld, South Africa. Forests Trees Livelihoods **2003**, *13*, 217–232.
4. Wynberg, R.; Cribbins, J.; Leakey, R.; Lombard, C.; Mander, M.; Shackleton. S.E.; Sullivan, C.A. A summary of knowledge on *Sclerocarya birrea* subsp. caffra with emphasis on its importance as a non-timber forest product in South and southern Africa. Part 1: Taxonomy, ecology, traditional uses and role in rural livelihoods. S. Afr. Forestry J. **2002**, *196*, 67–78.
5. FAO. *Traditional Food Plants*; Food and Nutrition, paper no. 42; United Nations: Rome, Italy, 1988.
6. Shackleton, C. Growth and fruit production of *Sclerocarya birrea* in the South African lowveld. Agroforestry Syst. **2002**, *55*, 175–180.
7. Mizrahi, Y.; Nerd, A. New crops as a possible solution to the troubled Israeli export market. In *Progress in New Crops*; Janick, J., Simon, J.E., Eds.; ASHS Press: Alexandria, VA, 1996, pp 56–64.
8. Watt, J.M.; Breyer-Brandwijk, M.G. *The Medicinal and Poisonous Plants of Southern and Eastern Africa*; E.S. Livingstone: Edinburgh, 1962.
9. Gueye, S. Contribution a l'étude pharmacodynamique d'une plante antidiabétique (*Sclerocarya birrea*). Thèse, faculté mixte de médecine et de pharmacie du Sénégal, Sénégal, 1973.
10. Aganga, A.A.; Mosase, K.W. Tannin content, nutritive value and dry matter digestibility of *Lonchocarpus capassa, Zizyphus mucronata, Sclerocarya birrea, Kirkia acuminata* and *Rhus lancea* seeds. J. Ethnopharmacol. **2001**, *76*, 305–308.

11. Glew, R.S.; Vander Jagt, D.J.; Huang, Y.S.; Chuang, L.T.; Bosse, R.; Glew, R.H. Nutritional analysis of the edible pit of *Sclerocarya birrea* in the Republic of Niger (daniya, Hausa). J. Food Comp. Analy. **2004**, *17*, 99–111.
12. Pretorius, V.; Rohwer, E.; Rapp, A.; Holtzhausen, L.C.; Mandery, H. Volatile flavour components of marula *Sclerocarya birrea* subsp. *caffra* juice. Z. Lebensmittel Untersuch. Forsch. **1985**, *181*, 458–461.
13. Salama, R.B. The seed oil of *Sclerocarya birrea*. Sudan J. Food Sci. Technol. **1973**, *5*, 4–6.
14. Ogbobe, O. Physico-chemical composition and characterization of the seed and seed oil of *Sclerocarya birrea*. Plant Foods Human Nutri. **1992**, *42*, 201–206.
15. Mariod, A.A.; Ali, A.O.; Elhussein, S.A.; Hussien, I.H. Quality of Proteins And Products Based on *Sclerocarya birrea* (Marula) Seed. Sudan J. Sci. Technol. **2005**, *6*, 184–192.
16. Mizrahi, Y.; Nerd, A.; New crops as a possible solution for the trouble Israeli export market. In *Progress in New Crops*; Janick, J., Ed.; Ashs Press: Alexandria, 1996, pp 37–45.
17. Wynberg, R.P.; Laird, S.A.; Shackleton, S.; Mander, M.; Shackleton, C.; Du Plessis P.; den Adel, S.; Leakey, R.R.; Botelle, A.; Lombard, C. Marula policy brief. Marula commercialization for sustainable and equitable livelihoods. Forests Trees Livelihoods **2003**, *13*, 203–215.
18. Mariod, A.A. Investigations on the oxidative stability of some unconventional Sudanese oils, traditionally used in human nutrition. PhD thesis, Münster University, Münster, Germany, 2005.
19. Mariod, A.; Matthäus, B.; Idris, ; Y.M.A.; Abdelwahab, S.I. Fatty acids, tocopherols, phenolics and the antimicrobial effect of *Sclerocarya birrea* kernels with different harvesting dates. J. Am. Oil Chem. Soc. **2010**, *87*, 377–384.
20. Mariod, A.; Matthaus, B.; Eichner, K. Fatty acid, tocopherol and sterol composition as well as oxidative stability of three unusual Sudanese oils. J. Food Lipids **2004**, *11*, 179–189.
21. Holser, R.A.; Bost, G.; Van Boven, M. Phytosterol composition of hybrid *Hibiscus* seed oils. J. Agric. Food Chem. **2004**, *52*, 2546–2548.
22. Fischer, C.; Holl, W. Free sterols, sterylesters, and lipid phosphorus in Needles of Scots pine (*Pinus sylvestris*). Lipids **1991**, *26*, 934–939.
23. Palmer, E.A. *Field Guide to the Trees of Southern Africa*; Vol. 2; Williams, J., ED.; Struik: Cape Town, South Africa, 1977.
24. Hidalgo, F.J.; Zamora, R. Fat: Physical properties. In *Handbook of Food Science, Technology, and Engineering*; Vol. 1; Hui, Y.H., Ed.; Marcel Dekker: New York, 2005.
25. Mateos, R.; Trujillo, M.; Pérez-Camino, M.C.; Moreda, W.; Cert, A. Relationships between oxidative stability, triacylglycerol composition, and antioxidant content in olive oil matrices. J. Agric. Food Chem. **2005**, *53*, 5766–5771.
26. Mariod, A.; Matthäus, B.; Eichner, K.; Hussein, I.H. Study of fatty acids, tocopherol, sterols, phenolic compounds and oxidative stability of three unconventional oils in comparison with four conventional ones. Arab J. Food Nutr. **2009**, *23*, 50–55.
27. Mariod, A.; Matthäus, B.; Eichner, K.; Hussein, I.H. Frying quality and oxidative stability of two unconventional oils. J. Am. Oil Chem. Soc. **2006**, *83*, 529–538.
28. Mariod, A.; Matthäus, B.; Eichner, K.; Hussein, I.H. Improving the oxidative stability of sunflower oil by blending with *Sclerocarya birrea* and *Aspongopus viduatus* oils. J. Food Lipids **2005**, *12*, 150–158.
29. Mariod, A.; Matthäus, B.; Hussein, I.H. Antioxidant properties of methanolic extracts from different parts of *Sclerocarya birrea*. Int. J. Food Sci. Technol. **2008**, 43, 921–926.
30. Mariod, A.; Matthäus, B.; Eichner, K.; Hussein, I.H. Antioxidant activity of extracts from *Sclerocarya birrea* kernel oil cake. Grasas Y. Aceites **2006**, *57*, 361–366.
31. Pokorný, J. Trans unsaturated fatty acids in fats and oils. Eur. J. Lipid Sci. Technol. **2000**, 102, 630–631.
32. Mariod, A.; Matthäus, B.; Eichner, K.; Hussein, I.H. Effects of processing steps on the quality and stability of three unconventional Sudanese oils. Eur. J. Lipid Sci. Technol. **2006**, *108*, 298–308.
33. Baldioli, M.; Servili, M.; Perretti. G.; Montedoro, G.F. Antioxidant activity of tocopherols and phenolic compounds of virgin olive oil. J. Am. Oil Chem. Soc. **1996**, *73*, 1589–1593.

34. Jadhav, S.J.; Nimbalkar, S.S.; Kulkarni, A.D.; Madhavi, D.L. Lipid oxidation in biological and food systems. In *Food Antioxidants*; Madhavi, D.L., Deshpande, S.S.; Salunkhe, D.K., Eds.; Dekker: New York, 1996, pp 5–63.
35. Borochov-Neori, H.; Judeinstein, S.; Greenberg, A.; Fuhrman, B.; Attias, J.; Volkova, N.; Hayek, T.; Aviram, M. Phenolic antioxidants and antiatherogenic effects of marula (*Sclerocarrya birrea* subsp. *caffra*) fruit juice in healthy humans. J. Agri. Food Chem. **2008**, *56*, 9884–9891.
36. Rice-Evans, C. Flavonoid antioxidants. Curr. Med. Chem. **2001**, *8*, 797–807.
37. Braca, A.; Politi, M.; Sanogo, R.; Sanou, H.; Morelli, I.; Pizza, C.; De Tommasi, N. Chemical composition and antioxidant activity of phenolic compounds from wild and cultivated *Sclerocarya birrea* (Anacardiaceae) leaves. J. Agric. Food Chem. **2003**, *51*, 6689–6695.
38. Dieye, A.M.; Sarr, A.; Diop, S.N.; Ndiaye, M.; Sy, G.Y.; Diarra, M.; Gaffary, I.R.; Sy, A.N; Faye, B. Medicinal plants and the treatment of diabetes in Senegal: Survey with patients. Fundam. Clin. Pharmacol. **2008**, *22*, 211–216.
39. Dimo, T.; Rakotonirina, S.V.; Tan, P.V.; Azay, J.; Dongo, E.; Kamtchouing, P.; Cros, G. Effect of *Sclerocarya birrea* (Anacardiaceae) stem bark methylene chloride/methanol extract on streptozotocin-diabetic rats. J. Ethnopharmacol. **2007**, *110*, 434–438.
40. Gondwe, M.; Kamadyaapa, D.R.; Tufts, M.; Chuturgoon, A.A.; Musabayane, C.T.; *Sclerocarya birrea* [(A. Rich.) Hochst.] [Anacardiaceae] stem-bark ethanolic extract (*Sclerocarya birrea*) modulates blood glucose, glomerular filtration rate (GFR) and mean arterial blood pressure (MAP) of STZ-induced diabetic rats. Phytomedicine **2008**, *15*, 699–709.
41. Musabayane, C.T.; Gondwe, M.; Kamadyaapa, D.R.; Moodley, K.; Ojewole, J.A.O. The effects of *Sclerocarya birrea* [(A. Rich.) Hochst.] [Anacardiaceae] stem-bark aqueous extract on blood glucose, kidney and cardiovascular function in rats. Endocrine Abstracts **2006**, *2*, SP36.
42. Fotio, A.L.; Dimo, T.; Nguelefack, T.B.; Dzeufiet, P.D.; Ngo, Lemba, E.; Temdie, R.J.; Ngueguim, F.; Olleros, M.L.; Vesin, D.; Dongo, E.; Kamtchouing, P.; Garcia, I. Acute and chronic anti-inflammatory properties of the stem bark aqueous and methanol extracts of *Sclerocarya birrea* (Anacardiaceae). Inflammopharmacology **2009**, *17*, 229–237.
43. Ojewole, J.A. Evaluation of the anti-inflammatory properties of *Sclerocarya birrea* (A. Rich.) Hochst. (Family: Anacardiaceae) stem-bark extracts in rats. J. Ethnopharmacol. **2003**, *85*, 217–220.
44. Ojewole, J.A. Evaluation of the analgesic, anti-inflammatory and anti-diabetic properties of *Sclerocarya birrea* (A. Rich.) Hochst. stem-bark aqueous extract in mice and rats. Phytother. Res. **2004**, 18, 601–608.
45. Grover, J.K.; Yadav, S.P. Pharmacological actions and potential uses of *Momordica charantia*: A review. J. Ethnopharmacol. **2004**, *93*, 123–132.
46. Feierman, E.K. Alternative medical services in rural Tanzania: A physician's view. Soc. Sci. Med. B Med. Anthropol. **1981**, *15*, 399–404.
47. Mikail, H.G. In vitro trypanocidal effect of methanolic extract of *Sclerocarya birrea, Commiphora kerstingii* and *Khaya senegalensis*. Afr. J. Biotech. **2009**, *8*, 2047–2049.
48. Jensen, R.E.; Simpson, L.; Englund, P.T. What happens when *Trypanosoma brucei* leaves. Afr. Trends Parasitol. **2008**, *24*, 428–431.
49. Fennell, C.W.; Lindsey, K.L.; McGaw, L.J.; Sparg, S.G.; Stafford, G.I.; Elgorashi, E.E.; Grace, O.M.; van Staden, J. Assessing African medicinal plants for efficacy and safety: Pharmacological screening and toxicology. J. Ethnopharmacol. **2004**, *94*, 205–217.
50. Gathirwa, J.W.; Rukunga, G.M.; Njagi, E.N.; Omar, S.A.; Mwitari, P.G.; Guantai, A.N.; Tolo, F.M.; Kimani, C.W.; Muthaura, C.N.; Kirira, P.G.; Ndunda, T.N.; Amalemba, G.; Mungai, G.M.; Ndiege, I.O. The in vitro anti-plasmodial and in vivo anti-malarial efficacy of combinations of some medicinal plants used traditionally for treatment of malaria by the Meru community in Kenya. J. Ethnopharmacol. **2008**, *115*, 223–231.
51. Belemtougri, R.G.; Constantin, B.; Cognard, C.; Raymond, G.; Sawadogo, L. Effects of *Sclerocarya birrea* (A. rich) Hochst (Anacardiaceae) leaf extracts on calcium signalling in cultured rat skeletal muscle cells. J. Ethnopharmacol. **2001**, 76, 247–252.

52. Belemtougri, R.G.; Traore, A.; Ouedraogo, Y.; Sanou, S.D.; Sawadogo, L. Toxicological effects of *Sclerocarya birrea* (A. Rich) Hochst (Anacardiaceae) and *Psidium guajava* L. (Myrtaceae) leaf extracts on mice and their pharmacological effects on rat duodenum. Int. J. Pharmacol. **2007**, *3*, 68–73.
53. Galvez, J.; Zarzuelo, A.; Crespo, M.E.; Utrilla, M.P.; Jimenez, J.; Spiessens, C.; Dewitte, P. Antidiarrheic activity of Sclerocarya-birrea bark extract and its active tannin constituent in rats. Phytother. Res. **1991**, *5*, 276–278.
54. Garba, S.H.; Ahmadu, S.; Ia, J. The effect of aqueous stem bark extract of *Sclerocarya birrea* (Hoechst) on alcohol carbon tetrachloride induced liver damage in rats. Pakistan J. Biol. Sci. **2006**, *9*, 2283–2287.
55. Bodley, A.L.; Wani, M.C.; Wall, M.E.; Shapiro, T.A. Antitrypanosomal activity of camptothecin analogs structure-activity correlations. Biochem. Pharmacol. **1995**, *50*, 937–942.
56. Galvez, Peralta, J.; Zarzuelo, A.; Busson, R.; Cobbaert, C.; de Witte, P. (−)-Epicatechin-3-galloyl ester: A secretagogue compound from the bark of *Sclerocarya birrea*. Planta Med. **1992**, *58*, 174–175.
57. Ojewole, J.A. Hypoglycemic effect of Sclerocarya birrea [(A. Rich.) Hochst.] [Anacardiaceae] stem-bark aqueous extract in rats. Phytomedicine **2003**, *10*, 675–681.
58. Glew, R.H.; Glew, R.S.; Chuang, L.T.; Huang, Y.S.; Millson, M.; Constans, D.; Vanderjagt, D.J. Amino acid, mineral and fatty acid content of pumpkin seeds (*Cucurbita* spp) and *Cyperus esculentus* nuts in the Republic of Niger. Plant Foods Hum. Nutr. **2006**, *61*, 51–56.
59. Van Wyk, J.A.; Malan, F.S.; Randles, J.L. How long before resistance makes it impossible to control some field strains of *Haemonchus contortus* in South Africa with any of the modern anthelmintics? Vet. Parasitol. **1997**, *70*, 111–122.