Physicochemical Properties of Some Underexploited and Nonconventional Oilseeds

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Six nonconventional oilseeds, *Bauhinia monandra*, *Bauhinia refescens*, *Caesalpinia pulcherrima*, *Cyperus esculentus*, *Hildergadia bateri*, and *Garcenia kola*, were analyzed for their proximate composition, minerals, fatty acids, iodine values, acid values, saponification values, viscosities, refractive indexes, and specific gravity values. Their moisture content ranged from 3.8 to 9.8%. The crude protein values varied between 0.2% in *G. kola* and 26.6% in *C. pulcherrima*. The crude oil content ranged from 0.2% in *G. kola* to 30.8% in *C. rufescense*. The oilseeds were generally high in potassium (265 ± 2.1 to 1050 ± 4.2%) and sodium (100 ± 1.4 to 260 ± 1.4%). The fatty acid composition ranged from C_{14} to C_{18}, including unsaturated $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$. The unsaturated fatty acids were predominant. Iodine values varied between 82.4 ± 3.04 in *H. bateri* and 123.0 ± 3.55 in *C. pulcherrima*. The saponification values ranged from 165.8 ± 0.05 in *H. bateri* to 246.8 ± 0.47 in *C. pulcherrima*. Acid values varied between 2.3 ± 0.01 and 6.5 ± 0.02 in the oilseeds. The viscosity values were low and, at 30 °C, values ranged from 13.18 ± 0.03 cSt in *B. monandra* to 27.54 ± 0.04 cSt in *B. rufescens*. The refractive indices and specific gravity values show little variation in the samples.

Keywords: *Oilseeds; physicochemical properties; nonconventional*

INTRODUCTION

It goes without saying that the production and use of vegetable oils are older than recorded history. For centuries, man had used them in a variety of ways besides as foods. The continued increase in world population and the ever-increasing demand both for oils and oilmeals has resulted in increases in the prices of oils. This increase in price necessitates the need to investigate new sources of oils, especially among the nonconventional and unexploited oilseeds.

Currently, despite the relatively high oil and seedmeal production in the United States, the USDA (U.S. Department of Agriculture) continues to investigate nonconventional seeds. The example set forth by the USDA is worth emulating by the developing countries that are more in need of alternate oil sources. According to Balogun and Fetuga (1986), lack of information on the composition and utilization of the many and varied oilseeds indigenous to the tropics is more of problem than is a real shortage of oils. There exist already abundant data on the proximate composition, mineral content, and other characteristics of the more conventional oilseeds, but not on the nonconventional oilseed types (Oyenuga, 1968). According to Afolabi et al. (1985) and Kamel et al. (1985), two areas that have often been neglected in augmenting available raw materials, especially oilseeds, are the use of underutilized and underexploited local substitutes and the lack of production on an industrial scale.

The research and development program of the USDA over the past 40 years on new, nonconventional oilseeds that could compete with and supplement the conventional ones has yielded some positive results. Some of the potential crops could be produced now, whereas others require additional input (Princen, 1979). Also, the Northern Regional Center in the United States has a screening program for oilseeds from all over the world to identify domestic sources for imported oils now filling industrial needs. Some of the promising seeds include Carola, Jojoba, and the Cuphea and Limnanthes species (Princen, 1979).

In this study, six underutilized, nonconventional oilseeds—*Bauhinia monandra* (Panumo aabo), *Bauhinia refescens* (Panumo abafe), *Caesalpinia pulcherrima* (Pride of Barbados, eko omonde), *Cyperus esculentus* (Tigernut, Ofio), *Hidergadia bateri* (Rope tree, igi okun), and *Garcinia kola* orogbo)—are investigated for their physicochemical properties. The results are used to determine the suitability of these oilseeds as substitutes for the more conventional oil types like soybean, olive, corn, coconut, peanut, cotton seed, palm, sunflower, and rapeseed oils. These conventional types are more expensive and thus not affordable for many poor people of developing countries of the world.

MATERIALS AND METHODS

Materials. All the seeds, except *Cyperus esculentus* and *Garcina kola*, were obtained from parks and gardens of Obafemi Awolowo University, Ile-Ife, Nigeria. *C. esculentus* and *G. kola* were purchased locally at the Oshodi market in Lagos, Nigeria. Shelling of the seeds, with the exception of *C. esculentus* and *G. kola* was done manually. The seeds were cracked, dehulled, and ground in a Hammer hill. The final products were stored in labeled polythene bags in a refrigerator until needed for analysis.

Methods. The proximate composition (i.e., moisture, crude protein, crude oil, and crude carbohydrate contents), minerals, fatty acid composition, iodine values, saponification, and acid values were determined by methods described by the Association of Official Analytical Chemists (AOAC, 1975, 1980, 1984). The oils were obtained from the ground seeds by solvent extraction with a soxhlet extractor. The mineral contents and values of iodine, saponification, acid, and viscosity were

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Table 1. Proximate Composition of Oilseeds

oilseed	moisture content, %	ash content, %	protein content, %	oil content, %	carbohydrate content, %
B. monandra	4.0	8.6	26.2	24.0	24.0
C. pulcherrima	3.8	10.0	26.6	14.7	35.5
B. rufescens	4.6	6.2	21.7	30.8	23.8
C. esculentus	9.8	10.0	5.0	22.5	33.8
H. bateri	4.8	4.2	25.0	27.5	27.5
G. kola	7.6	5.7	0.2	0.2	–

determined in triplicate by analyzing three samples each of different oilseeds. Viscosity measurements [in centistokes (cSt)] were performed with the Oswald kinematic viscometer equipped with an attached water bath and a thermostat. The viscosities were determined at 30, 40, 50, 60, and 70 °C. Refractive indices of the oils (at room temperature) were determined with an Abbe refractometer, and the specific gravity measurements were also done at room temperature with the specific gravity bottle.

RESULTS AND DISCUSSION

The results of the proximate composition of the oilseeds are presented in Table 1. The moisture contents of the seeds ranged from 3.8% in *C. pulcherrima* to 9.8% in *C. esculentus*. The moisture values for *G. kola* (7.6%) are comparable to values found in seeds such as Carica papaya (Marfo et al., 1986) and cashew nut (Fetuga et al., 1973). The ash contents of the seeds followed a similar trend (Table 1). The crude protein values ranged between 0.2% in *G. kola* and 26.6% in *C. pulcherrima*. Members of the leguminaceae family had fairly high values (21.7, 26.2, and 26.6% in *B. rufescens*, *B. monandra*, and *C. pulcherrima*, respectively). Oil contents of the seeds varied between 14.7% in *C. pulcherrima* and 30.9% in *B. rufescens*. The highest carbohydrate value was given by *C. pulcherrima*.

The mineral composition of the species investigated are shown in Table 2. The results indicate significantly high concentrations of potassium [265 ± 2.1 (SD)–1050 ± 4.2 (SD) $\mu g\ g^{-1}$] and sodium [100 ± 1.4 (SD) – 260 ± 1.4 (SD) $\mu g\ g^{-1}$]. Calcium level was highest in *C. pulcherrima* [171 ± 4.2 (SD) $\mu g\ g^{-1}$]. There was close similarity in the zinc contents of the seeds, varying from 145 ± 2.8 (SD) $\mu g\ g^{-1}$ in *B. monandra* to 176 ± 2.8 (SD) $\mu g\ g^{-1}$ in *B. rufescens*. The copper levels are generally low in all samples.

The fatty acid composition of the oils are presented in Table 3. The carbon chain length found in the samples ranged from C_{14} to C_{18}, including unsaturated fatty acids (i.e., $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$). Lauric acid was completely absent in all the oils. Palmitic acid contents ranged from 13.4% in *C. esculentus* to 22.5% in *B. rufescens*. Stearic acid varied from as low as 3.0% in *C. esculentus* to 12.8% in *B. rufescens*. Apart from *C. esculentus*, which has much higher values (64.2%), all the other oils gave close range values of oleic acid (10.0% – 25.0%). All the oils except *C. esculentus* (19.8%) are good sources of linoleic acid, with values ranging from 30.0% in *H. bateri* to 60.0% in *C. pulcherrima*. Only *H. bateri* contained a detectable level of linolenic acid (17.8%). Generally, the percentage unsaturation in the species are high and varied between 64.8% in *B. rufescens* and 83.8% in *C. esculentus*.

The values of the viscosity measurements are shown in Table 4. Values at 30 °C ranged from 13.18 ± 0.03 cSt for *B. monandra* to 27.54 ± 0.04 cSt for *B. rufescens* at the same temperatures. Values determined at higher temperatures (i.e., at 40, 50, 60, and 70 °C) are shown in Table 4. For instance, the vlaues at 70 °C varied between 6.31 ± 0.04 cSt in *B. monandra* and 10.31 ± 0.01 cSt in *B. rufescens*. For each determination at different temperatures, *B. monandra* gave the lowest viscosities and *B. refescens* gave the highest values.

Iodine values varied between 82.4 ± 3.04 in *H. bateri* and 123.0 ± 3.55 in *C. pulcherrima*. The saponification values were between 165.8 ± 0.05 in *H. bateri* and 246.8 ± 0.47 in *C. pulcherrima*. The *C. pulcherrima* gave the highest values of both the iodine and saponification values (Table 5). The acid values ranged from 2.3 ± 0.01 in *C. esculentus* and *H. bateri* to 6.5 ± 0.02 in *C. pulcherrima* (Table 5). The values of the refractive indices obtained for the oils from the seeds are close (1.460–1.466). The same is true for the specific gravity values, which ranged from 0.910 in *C. esculentus* to 0.920 in *B. refuscens* (Table 5).

On the basis of the results of this study, the seeds are fairly good sources of proteins and carbohydrates. The protein values are comparable to those reported for some conventional oilseeds (*Bailey's Industrial Oil and Fat Products*, 1964), like peanut (30.3%), castor seed (18.9%), sunflower (19.5%), and safflower seed (29.3%). The values are also comparable to those reported for water lemon seed (35.7%; Oyenugua and Fetuga, 1975) and for cashew nut (21.2%; Fetuga et al., 1973). The values are comparable to those reported by Oyenunga (1968) for some underexploited leguminous wild species and the decorticated peanuts. The protein value for *B. monandra* obtained in this study is comparable to that reported for the same oilseed by Balogun and Fetuga (1986). Analysis of variance (ANOVA) was conducted to determine the amount of variation within and between a population of the samples studied and another population of common conventional oilseed (with data obtained from Bailey, 1964); this analysis revealed that there are no significant differences between the means of the protein content of the two populations ($\alpha = 0.05$).

The ash analyses showed that the oilseeds studied are good sources of minerals. The calcium levels are comparable with those reported for lemon seed, which is a conventional oilseed (Kamel et al., 1985). Their crude oil contents are equally high for all of the seeds except for *G. kola*, which has a small value of 0.2%. Thus, these nonconventional oilseeds have good potential as alternative sources of protein, carbohydrate, oils, and minerals for both human and livestock feeds and could serve as substitutes for some of the conventional oil types. It should be borne in mind, however, that the potential supply of any foodstuffs as a source of the major elements depends on the availability rather than the total content of the minerals. Certain plant constituents, like phytates, could significantly reduce the overall availability of the minerals found in them. This concern still needs to be investigated in the oilseeds.

The results of the fatty acids composition compare favorably with those reported for some conventional oilseeds by Canvin (1985) and by Kamal and Dawson (1985). The values of the polyunsaturated fatty acids reported in this study are better than those reported by Canvin (1965) for the conventional oil types like coconut oil ($C_{18:1}$, 7%; $C_{18:2}$, 2%) and cottonseed oil ($C_{18:1}$, 24%; $C_{18:2}$, 40%), and they compare very favorably with those reported for soybean ($C_{18:1}$, 25%; $C_{18:2}$, 51%; $C_{18:3}$, 9%), olive ($C_{18:1}$, 64%; $C_{18:2}$, 16%; $C_{18:3}$, 2%), corn ($C_{18:1}$, 29%; $C_{18:2}$, 56%; $C_{18:3}$, 1%), peanut ($C_{18:1}$, 61%; $C_{18:2}$, 22%), palm ($C_{18:1}$, 38%; $C_{18:2}$, 9%), and sunflower

Table 2. Mineral Composition of Oilseeds[a]

oilseed	Na	K	Ca	Mg	Zn	Cu
B. monandra	120 ± 2.8	330 ± 3.5	99 ± 1.4	46 ± 1.4	145 ± 2.8	Tr
C. pulcherrima	260 ± 1.4	710 ± 4.2	171 ± 4.2	51 ± 1.4	163 ± 5.0	31 ± 1.4
B. rufescens	255 ± 5.7	680 ± 5.0	98 ± 3.6	49 ± 2.8	176 ± 2.8	16 ± 0.1
C. esculentus	100 ± 1.4	265 ± 2.1	Tr[b]	43 ± 1.4	158 ± 2.8	Tr
H. bateri	165 ± 2.8	790 ± 2.8	73 ± 1.4	50 ± 0.7	156 ± 1.4	22 ± 2.1
G. kola	195 ± 4.2	1050 ± 4.2	86.6 ± 4.2	50 ± 0.7	166 ± 0.7	16 ± 2.1

[a] Expressed as mean ± SD in μg/g. [b] Tr, trace.

Table 3. Percentage Fatty Acid Composition of Oilseeds

oilseed	palmitic acid, C_{16}	stearic acid, C_{20}	oleic acid, $C_{18:1}$	linoleic acid, $C_{18:2}$	linolenic acid, $C_{18:3}$	total unsaturation, %
B. monandra	18.9	9.0	16.5	55.0	ND[a]	71.9
B. rufescens	22.5	12.8	17.5	47.5	ND	64.8
C. esculentus	13.2	3.0	64.2	19.8	ND	83.8
C. pulcherrima	20.8	5.6	10.0	60.0	ND	72.6
H. bateri	21.2	5.0	25.0	30.0	17.8	73.3

[a] ND, not detectable.

Table 4. Viscosity Measurement[a]

	temperature, °C				
oils	30	40	50	60	70
B. monandra	13.18 ± 0.03	10.90 ± 0.04	8.92 ± 04	7.46 ± 0.04	6.31 ± 0.04
C. pulcherrima	19.50 ± 0.3	15.42 ± 0.03	12.19 ± 0.05	10.00 ± 0.03	8.13 ± 0.04
B. rufescens	27.54 ± 0.04	20.77 ± 0.01	16.46 ± 0.01	12.36 ± 0.03	10.31 ± 0.01
C. esculentus	15.6 ± 0.2	1.59 ± 0.01	10.05	8.24 ± 0.01	6.87 ± 0.01
H. bateri	21.88 ± 0.03	16.90 ± 0.01	13.15 ± 0.01	10.74 ± 0.02	8.76 ± 0.02

[a] Values are expressed as means ± standard deviation in cSt.

Table 5. Other Characteristics of the Oilseeds[a]

characteristic	*B. refescens*	*B. monandra*	*C. pulcherrima*	*C. esculentus*	*H. barteri*
iodine value	92.7 ± 4.20	108.3 ± 3.81	123. ± 3.55	84.5 ± 6.12	82.4 ± 3.04
saponification value	194.4 ± 0.81	187.5 ± 0.52	246.8 ± 0.47	168.5 ± 0.09	165.8 ± 0.05
acid value	3.5 ± 0.02	6.4 ± 0.03	6.5 ± 0.02	2.3 ± 0.01	2.3 ± 0.01
refractive index	1.463	1.463	1.466	1.455	1.460
specific gravity	0.920	0.914	0.915	0.910	0.917

[a] Values are means ± SD.

($C_{18:1}$, 17%; $C_{18:2}$, 72%). *G. kola* has very low crude oil contents (0.2%); therefore, its fatty acid composition is negligible.

B. monandra, *B. refescens*, *C. esculentus*, and *C. pulcherrima* can be classified in the oleic-linoleic acid group. Many of the more important conventional oilseeds, such as peanut, sesame, olive, corn, cottonseed, and sunflower seeds, belong to this group because of their high oleic and linoleic acid content and are good as edible oils. Linoleic acid, undoubtedly one of the most important polyunsaturated fatty acids in human food because of its prevention of distinct heart vascular diseases (Boelhouwer, 1983), is present in high amounts in *B. monandra* (55%), *B. refescens* (47.5%), and *C. pulcherrima* (60%). Oleic acid, on the other hand, contains predominantly *C. esculentus* (64.2%). These nonconventional oils, therefore, have good potential as substitutes for the conventional oilseeds. In particular, *C. esculentus* has been shown to be a potential supplement to or substitute for imported olive oil in terms of its fatty acid composition and other physicochemical properties. Most members of the group studied here would be able to produce good edible oils with partial hydrogenation. The presence of the high amount of oleic and linoleic acids in all the oilseeds (except in *G. kola*) and the significant amount of linolenic acid in *H. bateri* coupled with the high iodine values would afford high drying properties to these oilseeds, which could have good application in the coating industry. Thus, they could supplement or substitute the conventional oil types used in this industry, like linseed, soybean, and hempseed oils. The relatively high levels of saturated fatty acid (i.e., palmitic and stearic acids) in *B. infescens* (C_{16}, 22.5%; C_{20}, 12.8%), *C. pulcherrima* (C_{16}, 20.8%), and *H. bateri* (C_{16}, 21.2%) could be applied to yield soap of the desired degree of firmness, harness, and stability, an asset that could be utilized in the soap industry where the nonconventional oilseeds could substitute oils such as coconut and palm.

An important trend in the new investigations on oilseeds is their use as fuels to supplement or substitute the fast depleting fossil resources (Pryde and Carlson, 1985). Among the advantages of vegetable oils as fuels are their potability, heat content, ready availability, and the fact that they are renewable resources (Pryde, 1983). Much of the current work is being performed in countries that have little or no internal petroleum resources (e.g. South Africa, Brazil, and Australia; Bartholomew, 1981). Among the conventional oils tested, the order of ranking from best to poorest was soybean, sunflower, peanut, and then cottonseed.

Based on the specification reported by Ryan et al. (1984), the properties of the nonconventional oils studied this work, especially their low viscosity values (except *G. kola* and *H. bateri*) afford them potential as materials for use as diesel fuels. This is subject to further investigation though. The viscosities for these oilseeds were considerably lower than those reported by Kamman and Phillips (1985) for some common and tested oils at 30 °C, such as soybean (31cSt), cottonseed (36 cSt), and sunflower (43 cSt). This lower viscosity is an advantage for the nonconventional oils. The tendency of petroleum and natural gas to be in shorter supply (Boelhouwer, 1983) and the much more stable position of the renewable fatty oils in this respect will favor the significance of the renewable fatty oils as indispensable resources in the forthcoming decades. This significance will surely motivate strong efforts in research and development for the applicability of renewable fatty acids.

Many of the nonconventional oilseeds studied (e.g., *B. monandra*, *B. rufescens*, and *C. pulcherrima*) are widely distributed ornamental plants that grow along roads, in parks, and gardens. *C. esculents*, which is originally cultivated in northern Nigeria, is also common in Ghana where it is made into a sweetmeal and, among some tribes in Togo, is used chiefly uncooked as a side dish. *H. bareti* is also a widely distributed plant, common on the West African coastal regions from Ivory Coast to Nigeria. The seeds of *G. kola* are found along the West African coast. All of the oilseeds studied seem to have potential for commercial cultivation, which could make them useful for the many purposes discussed.

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