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Oil content and fatty acid composition of some underutilized legumes from Nigeria

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Abstract

Three underutilized legumes from Nigeria, *Brachystegia eurycoma*, *Tamarindus indica* and *Mucuna flagellipes*, have been subjected to standard analytical techniques in order to evaluate proximate composition, physicochemical properties and contents of nutritional valuable elements and fatty acids of the seeds and oils. The proximate analysis indicated that the oil content was 5.87 ± 0.30, 7.20 ± 0.45 and 3.77 ± 0.21 g/100 g for *B. eurycoma*, *T. indica* and *M. flagellipes*, respectively. The seeds are rich in protein and carbohydrate, the protein content ranging from 11.82 ± 0.25 g/100 g–24.94 ± 0.18 g/100 g dry matter. These compare favourably with high protein animal sources like oyster, beef, pork and marine fishes. The iodine value of two of the oils place them in the non-drying group of oils, while the composition of all the oils compare well with those of rape seed, sesame, sunflower and groundnut seed oils. This suggests their use as edible oils.

Analyses of the oils for fatty acids indicate that the oils contain linoleic acid which is one of the three essential fatty acids. The dominant fatty acids however are linoleic, palmitic, oleic and stearic acids with oleic acid having the highest percentage 24.13–31.50%. Eight nutritional valuable minerals were determined in the seed flours. The seeds are rich in potassium 52.1 mg/100 g–131 mg/100 g. They also contain significant concentration of iron 4.55 mg/100 g–8.20 mg/100 g.

Keywords: Oil content; Fatty acid; Mineral elements; Legumes

1. Introduction

The problems of industrial waste are becoming harder to solve, and much effort will be needed to develop the nutritional and industrial potential of by-products, waste and under-utilized agricultural products. Only a small portion of plant material is utilized directly for human consumption. To be economically viable, both oil and meal from fruit seeds must be utilized (Kamel & Kakuda, 1992). The remainder of plant material may be converted into nutrients for either food or feed, or into fertilizer, thus an important contribution to food resources or industrial products could be made (Kamel, Deman, & Blackman, 1982).

Brachystegia eurycoma and *Tamarindus indica* belong to the same family of Caesalpiniodeae while *Mucuna flagellipes* belong to the Papilionoideae family. They are all legumes from the Leguninosae family. *B. eurycoma* is a fine tree that occurs in the forest from south of Nigeria to Cameroon. It can be recognized by its large size, irregular bole, huge twisted spreading branches and by the rough fibrous bark which peels off in untidy patches and often exudes a brownish buttery gum (Keay, 1989). It is used by the Igbos in Nigeria as an antihelmintic (Iwu, 1986). The bark yields a yellowish or reddish greasy gum which hardens to a guatta – like mass

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(Aubreville, 1970). The root has been examined for a possible lethal action on the fresh water snail, *Bulius glotutus*, one of the vectors in schitosomas and found to be without effect (Adewunmi & Sofowora, 1980).

Tamarindus inidica, commonly known as Tsamiya in Nigeria, is a large leguminous tree that grows wild in the tropics, it thrives well in the North of Nigeria where the fruit is popular. *T. indica* is a rich source of sugars and an excellent source of vitamin B (Burkill, 1995). The pulp is used widely for food and beverages and the seeds are sometimes used as soup thickener.

Mucuna flagellipes, a Papilionoideae, is a glabrous lofty climber with creamy, white or yellowish flowers which turn black on drying. The leaves of *M. flagellipes* are used to blacken cloth and pottery (Burkill, 1995). Phyto-chemical examination of the plant has shown the presence of an emulsifying and suspending agent of pharmaceutical application in preparing suspensions of sulphadimine and zinc oxide (Iwu, 1984).

Information on the chemical composition of *B. eurycoma* seeds and oil content is very scanty while previous workers (Ishola & Agbaji, 1990) in the Northern part of the country have given incomplete data on the chemical composition of the seed and oil content of *T. indica*. There is no reported data on the oil content and fatty acid composition of *M. flagellipes*. This paper therefore reports on the oil content and fatty acid composition of the seeds of *B. eurycoma*, *T. indica* and *M. flagellipes* obtained from the Southern part of Nigeria in order to assess what they can render in terms of industrial development.

2. Materials and methods

2.1. Materials

Seeds of *Brachystegia eurycoma* (BE), *Tamarindus indica* (TI) and *Mucuna flagellipes* (MF) were purchased from Ojoo and Sabo markets in Ibadan, Oyo State. They were then taken to the Herbarium Unit (HIU), Botany Department of University of Ibadan where they were identified.

2.2. Physical characterization

The physical characterization of *B. eurycoma*, *T. indica* and *M. flagellipes* seeds were carried out following the method of Femenia, Rosells, Mullet, and Canellas (1995). The weight of 50 seeds was taken after which the length and width of each seed was noted.

2.3. Sample preparation

The seeds were shelled by cracking with a small iron rod and manually peeled to remove the kernels. The kernels were then ground in a Hammer mill and the final products were wrapped in polyethylene bag and stored in an air-tight sample bottle in a refrigerator (4 °C).

2.4. Proximate analysis

The recommended methods of the Association of Official Analytical Chemists (AOAC, 1990) were adopted to determine the levels of moisture, ash, crude protein and crude fat. Moisture content was determined by heating 2.0 g of each sample to a constant weight in a crucible placed in an oven maintained at 105 °C for 3.5 h. Ash was determined by the incineration of 1.0 g of each sample placed in muffle furnace maintained at 550 °C for 5 h. Crude protein (% total nitrogen × 6.25) was determined by the Kjeldahl method using 1.0 g samples. Crude fat was obtained by exhaustively extracting 100.0 g of each sample in a Soxhlet apparatus using petroleum ether (boiling point range 40–60 °C) as the extractant (Oderinde & Ajayi, 1998). Total carbohydrate was obtained by difference [100 − (protein + crude fat + ash + crude fibre moisture)] (Ajayi & Oderinde, 2002; AI-Khalifa, 1996).

2.5. Physicochemical analysis

Seed oils were extracted using the continuous Soxhlet extraction technique with petroleum ether (40–60 °C) for 8 h. The oils were then subjected to physical and chemical characterization. Colour and state of the oils at room temperature were noted by visual inspection. The refractive index of the oils was determined using the Abbe refractometer as outlined by Pearson (1976), while the specific gravity which was measured at room temperature was estimated by the use of a specific gravity bottle. The saponification, acid and peroxide values were determined by the method described by the Association of Official Analytical Chemists (1984) while the iodine value was determined by using Wijs' solution (iodine monochloride in glacial acetic acid solution) as outlined by Oderinde and Ajayi (2000).

2.6. Mineral content

Samples were digested by using conc. nitric acid and perchoric acid (1:1, v/v). Sodium, potassium, calcium, magnesium, copper, iron, zinc and manganese were determined by atomic absorption spectrophotometry (Perkin–Elmer) as described by Ajayi, Dawodu, Adebowale, and Oderinde (2002).

2.7. Fatty acid analysis

Fatty acid analysis of the oils was done by the use of gas–liquid chromatography at the Institute of Tuebingen, Germany (Ajayi, Dawodu, Adebowale, & Oderinde, 2004; Lutz, Esuoso, Kutubuddin, & Bayer, 1998). T_0 0.1 g of the oil was added 5 ml of CH_3OH and 1 ml of CH_2Cl_2. The mixture was cooled in ice and 0.6 ml of CH_3COCl was added. One millilitre of the solution was withdrawn into a hydrolysis tube and heated for 1 h at 110 °C. The solution was cooled and discharged into 10 ml of 1% NaCl solution in a separating funnel. The organics were extracted with 3 × 4 ml hexane and volume was reduced to 0.5 ml using a rotary evaporator. This was eluted on silica gel column successively with 5 ml hexane and 4 ml CH_2Cl_2. The CH_2Cl_2 fraction was separated on a DB5 30 m × 0.25 m capillary installed on a GC Chrompack 900 equipped with computer software and Mosaic integration J&W Scientific, Köln, Germany. Flame ionization detector was used. The temperature was programmed as follows: 35 °C for 3 min, temperature was then increased at 20 °C per minute, up to 230 °C for 5 min. Heptadecanoic acid was used as internal standard.

2.8. Statistical analysis

Results are expressed as the mean of three separate contents, except for mineral elements and fatty acid. The data were statistically analyzed by one way analysis of variance (ANOVA). Means were compared by the Duncan's (1955) multiple range test; significance was accepted at 5% level ($P \leqslant 0.05$).

3. Results and discussion

3.1. Physical characterization

The physical properties of *B. eurycoma*, *T. indica* and *M. flagellipes* seeds with regards to the weight, length and width are listed in Table 1. The weight of 50 of each seed ranged from 28.50 g for TI to 37.50 g for MF. The average length and width of the seeds also ranged from 0.89 ± 0.3 mm and 0.18 ± 0.08 mm for TI to 3.90 ± 0.37 mm and 3.70 ± 0.50 mm for MF. They are all significantly different from each other.

Table 1
Physical characterization[a] of seed from *Brachystegia eurycoma*, *Tamarindus indica* and *Mucuna flagellipes*

Property	Species		
	B. eurycoma	*T. indica*	*M. flagellipes*
Weight of 50 seeds (g)	37.50	28.50	31.65
Seed length (mm)[a]	2.20 ± 0.20	0.89 ± 0.3	3.90 ± 0.37
Seed width (mm)[a]	1.80 ± 0.30	0.18 ± 0.08	3.70 ± 0.50

[a] Mean of 50 seeds.

3.2. Proximate analysis

The moisture content of the seeds of *B. eurycoma* (BE), *T. indica* (TI) and *M. flagellipes* (MF) are 3.80 ± 0.16 g/100 g dry matter, 10.75 g/100 g dry matter and 9.38 ± 0.5 g/100 g dry matter, respectively. BE with low moisture level could be stored for a longer time without spoilage than TI and MF since a higher moisture content could lead to food spoilage through increasing microbial action (Onyeike, Olungwe, & Uwakwe, 1995). Ash content was higher, 6.22 ± 0.20 g/100 g dry matter, in MF than BE and TI.

The crude protein content for BE was 11.82 ± 0.25 g/100 g dry matter, a value within the range 8.40–14.8 g/100 g dry matter found for cereal seeds, such as corn, triticale and wheat (Heger & Eggum, 1991) and protein animals such as pork and oyster, 10.0 and 11.0 g/100 g dry matter, respectively. The data for TI (24.28 ± 0.50 g/100 g dry matter) and MF (24.94 ± 0.18 g/100 g dry matter) are higher than the protein contents in seeds of important legumes, 18.0–25.0 g/100 g dry matter (Singh & Singh, 1992) and also the protein content of high protein animals such as lamb, marine fishes and beef, 16.0–18.0 g/100 g dry matter (Bhuiyan, Ratnayake, & Ackman, 1986) but are close to the seed contents of underutilized legumes such as *Ganavalia ensiforms*, 26 g/100 g dry matter (Ajah & Madubuike, 1997). The protein content concentration of the seeds of TI and MF suggest that they can contribute to the daily protein need of 23.6 g/100 g for adults as recommended by the National Research Council (1974).

The oil contents of the seeds varied between 3.77 ± 0.21 g/100 g dry matter for TI. These values even though low are higher than the oil content reported for 10 wild legumes which ranged from 1.16 g/100 g dry matter to 1.85 g/100 g dry matter (Viano et al., 1995) and they fairly agree with the findings of Groenewald and Joubert (1982), Snook (1982) and Marta Vargas (1982) that the lipid content of aerial part of legumes is about 4–5 g/100 g dry matter. All the seeds have fairly high crude fibre content ranging from 16.45 ± 0.42 g/100 g dry matter for MF to 18.00 ± 1.10 g/100 g dry matter for TI. This is of nutritional significance since fibre helps to maintain the health of the gastro-intestinal tract. As a result, the awareness for fibre consumption has been growing among the general public (Vijayakumari, Siddhuraju, & Janardhanan, 1997). The data for carbohydrate content shows that BE has the highest value of 57.83 ± 0.28 g/100 g dry matter (see Table 2).

Table 3 shows the physical properties of oil extracts from the seed of BE, TI and MF. The colours of the oils are yellow, dark-yellow and golden yellow, respectively. The state at room temperature (29.0 ± 1 °C) was generally liquid. The specific gravity of the oils ranged from 0.86 ± 0.02 for BE to 0.88 ± 0.15 for TI. These values are lower than the values reported by Omode, Fatoki,

Table 2
Proximate composition[a] (g/100 g dry matter) of seeds from *Brachystegia eurycoma*, *Tamarindus indica* and *Mucuna flagellipes*

Component	Species		
	B. eurycoma	*T. indica*	*M. flagellipes*
Moisture	3.80 ± 0.16^{d}	10.75 ± 0.53^{c}	9.38 ± 0.15^{c}
Ash ($N \times 6.25$)	3.68 ± 0.12^{c}	1.50 ± 0.01^{d}	6.22 ± 0.20^{c}
Protein ($N \times 6.25$)	11.82 ± 0.25^{d}	24.28 ± 0.50^{c}	24.94 ± 0.18^{c}
Oil yield	5.87 ± 0.30^{c}	7.20 ± 0.45^{c}	3.77 ± 0.21^{d}
Crude fibre	17.00 ± 0.30^{c}	18.00 ± 1.10^{c}	16.45 ± 0.42^{c}
Carbohydrate[b]	57.83 ± 0.28^{d}	38.27 ± 0.41^{c}	39.24 ± 0.35^{c}

Values in the same horizontal row sharing the same letter are not significantly different at the 5% level.
[a] Means of triplicate analysis.
[b] Calculated by difference.

Table 3
Physical properties[a] of oil extracts from *Brachystegia eurycoma*, *Tamarindus indica* and *Mucuna flagellipes*

Property	Species		
	B. eurycoma	*T. indica*	*M. flagellipes*
State at RT	Liquid	Liquid	Liquid
Colour	Yellow	Dark-yellow	Golden-yellow
Specific gravity	0.86 ± 0.02^{b}	0.88 ± 0.15^{b}	0.86 ± 0.03^{b}
Refractive index at RT	1.45 ± 0.01^{b}	1.48 ± 0.01^{c}	1.47 ± 0.022^{b}

Values in the same horizontal row sharing the same letter are not significantly different at the 5% level. RT, room temperature (29.0 ± 1 °C).
[a] Values are means ± SD of triplicate determination.

and Olaogun (1995) for *B. refescens*, *B. monandra*, *C. pulcherrina*, *C. escluentus* and *H. barteri.* TI had the highest value of refractive index (1.48 ± 0.01).

Presented in Table 4 is the result of the chemical composition of the oil extracts from BE, TI and MF seeds. Two of the oils, BE and TI, have iodine values below 100 mg/100 g which place them in the non-drying group of oil. MF, however, belongs to the semi-drying group as its iodine value is 110 ± 2 mg/100 g. The oil could be utilized for cooking and may find application as a raw material in industries for the manufacture of vegetable oil-based ice-cream (Ibiyemi, Adepoju, Okanlawon, & Fadipe, 1992).

The total acidity expressed as acid value was low in all the seed oils 4.59 ± 0.20 mg NaOH/g (MF) oil to 7.81 ± 0.21 mg NaOH/g oil (BE). A previous report by Ekpa and Ekpe (1995) has shown that, unlike free fatty acid content, which is a measure of free fatty acid present in a fat or oil, acid value is a measure of total acidity of the lipid, involving contributions from all the constituent fatty acids that make up the glyceride molecule.

Each of the oils had a free fatty acid concentration below the maximum limit of 5.0% reported for high-grade Nigerian palm oil (NIFOR, 1989). The nutritional value of a fat depends, in some respects, on the amount of free fatty acids (e.g., butyric acid in butter) which develop. In the tropics, where vegetable oils are the most common dietary lipids, it has been shown that it is desirable that the free fatty acid content of cooking oil lies within limits of 0.0–3.0% (Bassir, 1971; Onyeike & Acheru, 2002). The low levels of % FFA in all the oils investigated indicate that the oils could probably be good edible oils that may be stored for a long time without spoilage via oxidative rancidity.

The peroxide values of the oils are BE (8.40 ± 0.62 mg/g oil), TI (11.00 ± 0.35 mg/g oil) and MF (6.60 ± 0.18 mg/g oil). Fresh oils have been shown to have peroxide values lower than 10 mg/g oil and oils become rancid when the peroxide value ranges from 20.0 to 40.0 mg/g oil (Pearson, 1976). Ojeh (1981) reported that oils with high peroxide values are unstable and easily become rancid (having a disagreeable odour). It can thus be inferred that oils from BE and MF would store for a longer time without deterioration than oil from TI. The high saponification values of the oils 251 ± 2 mg KOH/g oil, 221 ± 1.4 mg KOH/g oil and 228 ± 1.8 mg/KOH oil for BE, TI and MF, respectively, suggest that the oils could be good for soap making and in the manufacture of lather shaving creams (Eka, 1980; Hilditch, 1949).

The role of trace elements in human nutrition and disease cannot be over-emphasized. Even though the mineral elements form a small proportion of the total composition of most plant materials and total body weight and do not contribute to the energy value of food, they are of great physiological importance particularly in body metabolism (Schwart, 1975). It is of interest to note that the most prevalent mineral element in

Table 4
Chemical properties[a] of oil extracts from seeds of *Brachystegia eurycoma*, *Tamarindus indica* and *Mucuna flagellipes*

Component	Species		
	B. eurycoma	*T. indica*	*M. flagellipes*
Acid value (mg NaOH/g oil)	7.81 ± 0.20^{b}	6.40 ± 0.20^{c}	4.59 ± 0.20^{d}
Saponification number (mgKOH/g oil)	251 ± 2^{b}	221 ± 1.4^{c}	229 ± 1.8^{d}
Iodine value (mg/100 g)	91.2 ± 0.3^{b}	37.5 ± 1.5^{c}	110.4 ± 2.1^{d}
% FFA as oleic acid	3.92 ± 0.25^{b}	3.22 ± 0.20^{b}	2.31 ± 0.20^{c}
Peroxide value (mg/g oil)	8.40 ± 0.62^{b}	11.00 ± 0.35^{c}	6.60 ± 0.18^{b}
Ester value (mg/KOH)	244 ± 1.8^{b}	214 ± 1.2^{c}	224 ± 1.6^{d}

Values in the same horizontal row sharing the same letter are not significantly different at 5% level. % FFA, % free fatty acid.
[a] Values are means ± standard deviations of triplicate determinations.

Table 5
Mineral composition of *Brachystegia eurycoma*, *Tamarindus indica* and *Mucuna flagellipes* (mg/100 g of dry matter)

Element	Species		
	B. eurycoma	*T. indica*	*M. flagellipes*
Potassium	521	1308	1322
Calcium	90	36.6	12.8
Magnesium	175	104	58.3
Sodium	23.7	8.90	11.10
Zinc	4.80	7.00	7.30
Copper	3.10	2.10	2.60
Manganese	17.2	12.1	11.9
Iron	42.0	45.5	82.0

the three seeds is potassium which is as high as 1322 mg/100 g dry matter in MF (Table 5). This is nutritionally significant considering the fact that potassium plays a principal role in neuro-muscular function. The high quantity of potassium, magnesium and calcium together with the quantity of sodium plus the content of the essential elements iron, manganese, zinc and copper allow the seeds to be considered as excellent sources of bioelements (Saura-Calixto & Canellas, 1982). It is recommended that these seeds be used in the preparation of diets of individuals with low levels of these mineral elements (see Table 5).

The fatty acid composition of the seed oils investigated revealed oleic acid as the predominant unsaturated fatty acid 24.13% (TI) to 60.68% (MF) (see Table 6). Linoleic acid, undoubtedly one of the most important polyunsaturated fatty acids in human food because of its prevention of distinct heart vascular diseases (Omode et al., 1995) is present in all the seed oils. It is well known that dietary fat rich in linoleic acid, apart from preventing cardiovascular disorders such as coronary heart diseases and atherosclerosis, also prevents high blood pressure and also linoleic acid derivatives serve as structural components of the plasma membrane and as a precursors of some metabolic regulatory compounds (Vles & Gottenbos, 1989). The presence of one of the three essential fatty acids in the seed oils make them nutritionally valuable. Palmitic acid and stearic acid are also present in high proportion in the oils. Two of the oils, TI and MF have higher percentage of unsaturated fatty acids than saturated ones; of special interest is MF seed oil whose percentage of unsaturated fatty acid is 77.97%. This is of nutritional significance.

Table 6
Fatty acid composition[a] of *Brachystegia eurycoma*, *Tamarindus indica* and *Mucuna flagellipes*

Fatty acid (%)	Species		
	B. eurycoma	*T. indica*	*M. flagellipes*
$C_{16:0}$	26.19	27.41	10.71
$C_{18:2}$	5.73	24.75	15.03
$C_{18:1}$	31.50	24.13	60.68
$C_{18:0}$	7.47	13.86	3.39
$C_{20:3}$	–	1.45	–
$C_{20:2}$	1.59	2.12	2.26
$C_{20:1}$	2.40	3.13	–
$C_{20:0}$	3.47	2.25	–
$C_{22:0}$	4.24	0.39	1.37
$C_{24:0}$	13.27	0.51	3.85
$C_{26:0}$	4.14	–	2.71
Total saturated	58.78	44.42	22.03
Total unsaturated	41.22	55.58	77.97

[a] Percent by weight of total fatty acids identified by GC as FAME.

4. Conclusion

The three seeds studied are, in general, good sources of protein, crude fibre and carbohydrate. They can all be stored for a long time without spoilage because of their low moisture content, in particular BE. The knowledge of protein and carbohydrate content seems interesting for nutritional applications for example in feeding supplementation. In addition, the seeds could be considered as good sources of dietary fibre. The mineral concentrations are high especially those of K, and Mg. Oil extracts of BE contain higher amounts of saturated fatty acids than those of TI and MF and are therefore valuable in the manufacture of confectionary. Percent free fatty acids in the oils were below the maximum desirable limit of 5.0%, acid and peroxide values were low and these qualify them as good edible oils. Values of saponification number indicate the presence of many fatty acids of low molecular weight, making possible the utilization of these oils in the manufacture of soaps and lather shaving cream, the high iodine value of MF seed oil makes it suitable to find usage in the manufacture of vegetable oil-based cream. Because of the high contents of unsaturated fatty acids in two of the seed oils and in the light of the beneficial effects of such unsaturated fatty acids in health and disease, the oils which are rich in linoleic acid might be acceptable as substitutes for unsaturated oils and could be exploited for nutritional advantage. The overall results of this work may offer a scientific basis for use of the seeds and oils both in human diet and some commercial products. Finally, the utilization of BE, TI and MF seeds and their oils could provide extra income and at the same time help to minimize waste disposal problems.

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