Petroleum Technology Development Journal

Extraction and Characterization of *Chrysophyllum albidum* and *Luffa cylindrica* Seed Oils

By

T. O. K. Audu*
(Chair Holder)
E. O. Aluyor**
S. Egualeona**
S. S. Momoh**

Abstract
The studies were undertaken in order to determine the physico-chemical properties of oils extracted from the seeds of Chrysophyllum albidum (CA) (African star apple) and Luffa cylindrical (LC).CA fruits were bought from Uselu Market in Egor Local Government Area of Edo State while LC fruits were collected from a bush in Ekosodin Village in Ovia North-East Local Government Area, also in Edo State.. The oils were extracted from the corresponding seeds in a soxhlet extractor with hexane (boiling point range: 55^0C-65^0C), and analyzed for moisture content, pH, specific gravity, saponification value, refractive index, peroxide value, acid number, free fatty acid and iodine value. Results showed that the oil contents were 21.57% and 14.08% respectively, for Chrysophyllum albidum and Luffa cylindrica. The acid values were 2.87 and 3.72mgKOH/g, respectively. Flash points (139^0C, 190^0C) and kinematic viscosities ($4.04mm^2/s$, $3.94mm^2/s$) of bio-diesel from the purified oils are within the ASTM standards (130^0C minimum, 1.9 mm^2/s to $6.0mm^2/s$).

Key words: *Characterization, Chrysophyllum albidum, Luffa cylindrica, oil extraction, bio-diesel*

Introduction

Nigeria, as a tropical country, has a wide variety of domestic plants that produce oil-bearing seeds of sufficient volume potential; for example, edible seeds like soya bean[1], peanuts, and corn. According to Oderinde et al[2], Nigeria has one of the most extensive flora in continental Africa. Unfortunately, however, the vast majority of the seed oils have not been adequately characterised. Examples include *Hura crepitans*, (otherwise known as sandbox tree), neem, castor, rubber seed, et cetera[3]. Others are *Chrysophyllum albidum CA and Luffa cylindrical LC.*

* Professor of Chemical Engineering, PTDF Professorial Chair in Renewable Energy, University of Benin, Benin City, Nigeria
** Department of Chemical Engineering, University of Benin, Benin City Nigeria
[1] Aluyor E. O. and Audu T. O.K. (2009) Effect of lubrication additives on thephysical and chemical properties of soybean oil: Advanced Material Reseach: Vols 62-64, 374-379
[2] Oderinde R.A, Ajayi I.A, Adewuyi A, (2009): Characterization of seed and seed oil of hura *crepitans* and the kinetics of degradation of the oil during heating. EJEAFChe Electronic Journal of Environmental Agricultural and Food Chemistry 8 (3) 201-208
[3] Otoikhian, S. K. (2008): Synthesis of Alkyl Ester (Bio-diesel) from Jatropha curcas, Hura crepitans, and Neem seed oils; M. Eng. Dissertation, Department of Chemical Engineering, University of Benin, Benin City, Nigeria

Plants use photosynthesis to convert solar energy into chemical energy which is stored as proteins, oils, carbohydrates etc. Oils and fats are basically similar in composition. They are substances used by plants and animals mainly as an energy store. Some of their components are essential to metabolic processes. Many seeds are rich in fats which act as a food supply to the young seedling. The main difference between oil and a fat is that oil is usually liquid at ambient temperature while a fat is solid. However, there are some exceptions; coconut oil, for example, with a melting range of 22-24°C, is usually liquid oil in the tropics but a solid fat in temperate climates.[4] Each oil and fat has its own individual properties[5], but of the same chemical type. The backbone of a fat is glycerol which has three arms each of which can combine with another substance known as fatty acid, to build up a molecule, known as triglyceride. All oils and fats are made up of a mixture of these triglycerides. The character of a particular oil or fat depends on the actual fatty acids present in the individual triglyceride molecules. Some of these fatty acids have longer carbon chains than others, and exist in three forms: saturated, mono-unsaturated and polyunsaturated. They can all combine with a glycerol 'arm'.

In their simplest form, saturated fatty acids are made up of a linear chain of carbon atoms linked to a group which provides the acidic properties. The most common examples are lauric, myristic, palmitic, and stearic acids. They have the following number of carbon atoms and melting points: 12, 44^0C; 14, 54^0C; 16, 63^0C; and 18, 70^0C; respectively. The acids are solid at ambient temperatures and their presence in high proportions in a triglyceride mixture is likely to make it a solid.

Monounsaturated fatty acids contain one double bond; the most common example is oleic acid which, like stearic acid, has 18 carbon atoms but a melting range of $13\text{-}16^0$C. Polyunsaturated fatty acids have two or three double bonds. Linoleic and linolenic acids are common examples. They have the same number of carbon atoms as stearic acid, but linoleic acid has two double bonds, (18, -5^0C), and linolenic acid has three, (18, -11^0C)[6]. It can be seen that the presence of a double bond lowers the melting point. Thus, a triglyceride mixture containing a high proportion of monounsaturated or polyunsaturated fatty acids is likely to be liquid. The fatty acid composition of oil tends to be a characteristic of the oilseed from which it is extracted.

Chrysophyllum albidum (African star apple) is a Sapotaceae. It is a small-to-medium tree species, up to a height of 25-37 m having a mature girth varying from 1.5 to 2.0 m[7]. It is found in many eco-zones of Africa[8]. Seedlings require good tending and shade until well established. In Nigeria it is found in urban and rural centres in the months of December to April[9]. The fruit is a

---

4 Bodger D. et al. (1982): An investigation of the extraction, refining and composition of oil from winged bean (Psophocarpus tetragonolobus [L.] D.C) Journal of the American oil chemist's society, 59(12): 523-530.

5 Bookock, D. G. B. et al (1998): "Fast formation of high-purity methyl esters from vegetable oils", Journal of the American oil chemists' society, 75(9): 1167 – 117

6 Bodger D, et al. (1982), op. cit

7 Orwa C., Mutua A., Kindt R., Jamnadass R., and Simons A., (2009): Agro-forestry Database: a tree reference and selection guide, Version 4.0 (http://www.worldagroforestry.org/af/tree db/)

Pearson, D. (1976): *Chemical Analysis of Foods*. (7th Edition) London: Church Hill Livingstone, 488-496

8 Bada, S.O. (1997) Preliminary information on the ecology of *Chrysophyllum albidum* in West and Central Africa; Proceedings of National Workshop on the potentials of the star apple in Nigeria, 16-25

9 Amusa, N A., Ashaye O A., and Oladapo, M O., (2003): Bio-deterioration of African star apple (*Chrysophyllum albidum*); African J Bio-technol. 2 (3) 56-59

large berry whose pulp is said to be rich in iron and vitamin C[10], and also unsaturated fatty acids[11]. 'It is almost spherical, slightly pointed at the tip, about 3.2 cm in diameter, greenish-grey when immature, turning orange-red, yellow-brown or yellow, sometimes with speckles, 5 celled, with 5 brown seeds in yellowish, pleasantly acid pulp. Seeds 1-1.5 x 2 cm, beanlike, shiny when ripe, compressed, with one sharp edge and a star-shaped arrangement in the fruit. The generic name is based on Greek words for 'gold' and 'leaf' and refers to the leaves of some species that are often covered with golden hairs underneath'[12]. It contains 4 to 5 flattened seeds or sometimes fewer due to seed abortion.

The seeds are usually discarded after the endocarp has been consumed. Some earlier studies showed that the seeds were not particularly rich in lipids, just 16.6%, with unsaturated fatty acids accounting for 74% of the oil extracted from the seeds[13]. However, Essien et al.[14] reported that the lipid content was 3.2% and the unsaturated fatty acid content was 68% (oleic, 29.6%; linoleic, 38.4%).

Luffa cylindrica is a Curcurbitaceae, a sub-tropical plant, which requires warm summer temperatures and long frost-free growing season when grown in temperate regions. It is popular in Asia and Africa[15]. In Nigeria, *Luffa cylindrica* plant grows in the wild and on abandoned building structures and fenced walls in towns and villages[16]. Indo-Burma is reported to be the centre of diversity for the sponge gourd. The main commercial production countries are China, Korea, India, Japan and Central America[17]. It is an annual climber which produces smooth and cylindrically-shaped fruits containing fibrous vascular system and seeds. Two species, *Luffa cylindrica* (L.) Roem syn *L. aegyptiaca* Mill, commonly called sponge gourd, loofa, vegetable sponge, bath sponge or dish cloth gourd, and ribbed or ridge gourd [*L. acutangula* (L.) Roxb] are domesticated[18].

The fruits are harvested before maturity, and eaten as a vegetable. The ripe dried fruit is also the source of the luffa or plant sponge. The sponge contains at least 30 seeds; some may produce more. The fibres contain 60% cellulose, 30% hemicelluloses and 10% lignin[19]. A lot of studies

---

[10] Asenjo CF (1946): The high ascorbic acid content of the West Indian Cherry. Science 103: 219.
[11] Essien, E.U., Esenowo, G.J. & Akpanabiatu, M.I. (1995): Lipid composition of lesser known tropical seeds, Plant Foods Hum. Nutr, 48, 135-140.
[12] Dr. A. I. Aigbodion, Director, Rubber Research Institute of Nigeria – His comment on this paper as assessor of the paper.
[13] Ajewole, K. & Adeyeye, A. (1991): Seed oil of white star apple (*Chrysophyllum albidum*) - Physicochemical characteristics and fatty acid composition, J. Sci. Food Agric., 54, 313-315.
[14] Op. Cit.
[15] Iqbal M., (1993): International trade in non-wood forest products: an overview, Rome FAO.
[16] Ndukwe, G. I., Amupitan, J. O. and Badmus, N. K.,(2001): Preliminary investigation on the antibiotic and fungicidal activities of the extracts from the seeds of *Luffa cylindrical;* Journal of Engr. Tech., 8(2), 3202 – 3207
[17] Bal K J., Hari B K C., Radha K., Ghale G M., Bhuwon R S., and Madhusudan P U., (2004): Descriptors for sponge guord (*Luffa cylindrical (L) Roem.*), NARC, LIBIRD & IPGRI
[18] Oboh I. O. and Aluyor E. O., (2009): *Luffa cylindrica* - an emerging cash crop Review African Journal of Agricultural Research Vol. 4 (8), pp. 684-688, August Available online at http://www.academicjournals.org/AJAR ISSN 1991-637X © 2009 Academic Journals
[19] Mazali I O and Alves O L (2005): Morphosynthesis: high fidelity inorganic replica of the fibrous network of loofa sponge (*Luffacylindrica*);Anais da Academia Brasileira de Ciências, Vol. 77, No. 1, 25-31.; Oboh I O (2011): Evaluation of *Luffacylindrica* as a biosorbent in heavy metal sorption from aqueous solutions; Ph.D Chemical Engineering Thesis, University of Benin, Benin City, Nigeria.

have been done on the luffa sponge, but very little on the seeds which are usually discarded. For example, the sponge can be used as bathroom sponge, as a component of shock absorbers, sound proof linings, inner cloth of bonnets, filters in factories and as a part of soles of shoes. [20] In Nigeria, *Luffa cylindrica* plant grows in the wild and on abandoned building structures and fenced walls in towns and villages. The sponge in the whole fruit holds the seeds, as many as 25 – 30 together. The young fruit is used as a cooked vegetable although some Gardeners grow *Luffa cylindrica* for the fibrous interior only. The fibrous netting is an excellent sponge but there are also industrial applications such as water–filters. The leaves are used for the treatment of diseases like anaemia. A tea of the leaves is used as a diuretic while juice of the fruit is used against internal hemorrhage. The seeds have laxative properties. The sponge is used in the rural areas of Nigeria for washing and scrubbing of household utensils while the seeds are discarded.
Accordingly, the objectives of the present studies are to extract the oils from the seeds and characterize them.

Materials and Methods
Chrysophyllum albidum (CA) seeds were obtained from the fruits bought from Uselu Market in Egor Local Government Area of Edo State. *Luffa cylindrica (LC)* seeds were extracted from the fruits collected from a bush in Ekosodin Village in Ovia North-East Local Government Area, also in Edo State. The seeds were separated manually from the fruits, and dried for 5 days in the sun at ambient temperature for easy removal of the shells from the seeds. After the shells were removed from the seeds, they were further dried in the oven for 180 minutes at 60^o C to reduce the moisture content, before grinding to increase the surface area for oilextraction.

Oil extraction: The resulting flour from each of the two types of seeds was subjected to solvent extraction in a soxhlet extractor with n- hexane *(boiling point range: 55^0C-65^0C)*. Subsequently, the oils were purified prior to physic-chemical analyses, by degumming to remove phosphatides that would make the oil turbid, during storage, and promote the accumulation of water (MITTELBACH, 2005). In addition, the degummed oils were de-acidified and neutralized.

Degumming
Water was added to the oil at 60-90°C to dissolve the phosphatides in the oil. The mixture was allowed to settle. Thereafter, the oil was separated from the water phase in a centrifuge.

De-acidification
The free fatty acids FFA's were saponified with 1 M sodium hydroxide solution and the resulting soap, was separated from the oil.

Characterization of the oil
The physico-chemical properties, of the oils, such as the saponification value, iodine value, acid value, viscosity, peroxide value and refractive index were determined by standard methods[21]. The same procedure was repeated for *Luffa cylindrica.*

---

[20] Bodger D. et al. (1982), Op. Cit.; Mazali I O and Alves O L (2005), Op Cit.; Lee S and Yoo J G (2006): Method for preparing transformed *Luffa cylindrical* Roem. World Intellectual Property Organization (WO/2006/019205)
[21] Pearson, 1976, Op. Cit; AOAC, (1990): Official Methods of Analysis, Method 945.16; 15th Edition, Association of Official Analytical Chemists, Washington DC

Results and Discussion

The analyses revealed the following results presented in Table 1

Table 1: Properties of *Chrysophyllum albidum CA* & *Luffa cylindrica LC* seed oils.

Property	*CA*	*CA**	*LC*	*LC**
Oil content (%)	21.57		14.08	
Specific gravity @29^{0}C	0.886	0.906	0.896	0.926
Saponification value(mg KOH/ g oil)	193.7	195.0	148.50	149.0
Viscosity @ 32^{0}C (P)	1.077	1.079	1.045	1.045
Acid value(mgKOH/g)	2.87	3.97	3.72	3.82
Peroxide value(meq/kg)	1.96	-	5.43	-
Iodine value(mg/g)	33.18	-	82.56	-
Free fatty acid FFA (%)	1.79	2.09	2.18	2.52
Refractive Index	1.396	-	1.474	-

**Crude seed oil*

A sample from each of the purified oils was used to produce bio-diesel via alkali-catalyzed trans-esterification, to test its suitability as feed-stock for bio-diesel production[22].

Discussion

Oil yields of *Chrysophyllum albidum (CA)* and *Luffa cylindrica (LC)* seeds were 21.57% and 14.08% respectively; their specific gravity was 0.886 and 0.896 respectively, close to the standard range of 0.87–0.90 for biodiesel.[23]

The saponification value is inversely proportional to the molecular weight of the oil; the higher the value the lower the molecular weight. Thus *CA* oil has a lower molecular weight than *LC* oil. *CA* oil has a high potential for liquid soap and shampoo industry.[24] Saponification value148.5 mgKOH/g is more than twice the value,65.92 mgKOH/g, reported for *LC* oil in Ibeto et al.[25]

---

[22] Audu T.O.K. (2012): Development of a viable technology for the production of bio-diesel from oils of non-edible seeds. PTDF Professorial Chair Lecture Series, University of Benin, April 5,62 pages.

[23] Ejikeme, P M., Egbonu, C. A. C., Anyaogu, I. D. and Eze, V. C., (2008): Fatty acid methy esters of melon seed oil: characterization for potential diesel fuel application, Chemical Society of Nigeria, Enugu Chapter, Coal City Chemistry Conference Proceedings, 37–41

[24] Akbar E, Yaakub Z, Kamarudin SK, Ismail M, Salimon J., (2009): Characteristics and composition of *Jatropha curcas* oil seed from Malaysia and its potential as biodiesel Feedstock. European J. Scientific Res., 29(3): 396-403.

[25] Ibeto, C N., Okoye, C O B. and Ofoefule, A U., (2012): Comparative Study of the Physicochemical Characterization of Some Oils as Potential Feedstock for Biodiesel Production ISRN Renewable Energy Volume 2012 (2012), Article ID 621518, 5 pages doi:10.5402/2012/621518

With acid values in the range 2.87 to 3.72mgKOH/g, the oils will not be as corrosive as paw-paw and orange seed oils which have acid values of 47.12 and 51.4,mgKOH/g, respectively, reported by Okoye et al.[26] The *CA*and *LC* oils may even be edible because the values are less than 10. Both oils can also be trans-esterified to biodiesel by the acid catalyzed system because of the relatively low values of the acid value.They can also be used in the paint industry (Pearson, 1976).

The peroxide values were low, 1.96meq/kg and 5.3meq/kg, respectively. These values suggest that the oils are stable and may not readily become rancid during storage.

The iodine value is a measure of the unsaturation of fats and oils; therefore, the values: 33.18gI_2/100g oil and 82.56gI_2/100g oil, do not suggest high unsaturation. Oils with values less than 112gI_2/100 g oil may find use in the confectionery and biofuels industries. Oilshaving high unsaturation of fatty acids, when heated are prone to polymerization of the glycerides, causing formation of deposits, and thereby compromising oxidative stability.[27]

With an iodine value of 82.56gI_2/100g, the oil from *Luffa cylindrical* seed is non-drying; it can therefore be used in the paint industry.[28] The iodine value according to EN 14214 (European committee for standardization) should be less than 120g I_2/100g sample for the seed oil to be suitable as feed-stock for biodiesel production. Thus with an iodine value of 82.56g iodine/100g sample *Luffa cylindrica* seed oil may be a possible candidate for biodiesel feed-stock.

The refractive index for the two oils: 1.396 and 1.474: are within values reported by some researchers for soybean and corn.[29] The higher values of the properties obtained for the crude oils reveal the necessity to purify the oils.

The flash points and kinematic viscosities of the produced bio-diesel were determined to confirm, the suitability of the oils as feed-stocks for the bio-diesel process. The flash point, which correlates the ignitability of a fuel, is the lowest temperature at which the vapor of a combustible liquid (fuel) can be made to ignite (flash) momentarily in air on application of an ignition source; while kinematic viscosity is the resistance of a fluid to flow under gravity. Viscosity is important in determining optimum handling, storage, and operational conditions. Fuels need to have suitable flow characteristics to ensure that an adequate supply reaches injectors at different operating temperatures.

[26] Okoye C O B and Ibeto C N (2010): Analysis of different brands of fruit juice with emphasis on their sugar and trace metal content, Bioresearch 7, 493-495

[27] Mittelbach M, (1996): Diesel fuel derived from vegetable oils. 6. Specification and quality control of biodiesel, Bioresource Technol. 56, 7-11

[28] Dosumu O. O., (2005): Thermal response and frying performance of *Thevetiaperuviana* seed oil; Nigerian Journal of Science, 39, 81-85

[29] Sodeke V A (2005): Extraction of oil from water melon seed and analysis; Quarterly Res. Service, 25-30

The corresponding values of the two properties for *Chrysophyllum albidum* bio-diesel *(CAB)* the *Luffa cylindrica* Bio-diesel (*LCB),* produced from alkali-catalyzed trans-esterification of the two seed oils are shown in Table 2:

Table 2: Properties of the Biodiesel, *CAB* and *LCB* and Standard Values (ASTM)

	CAB	*LCB*	ASTM D6751
Flash point (^{0}C)	139	190	130 minimum
Kinematic Viscosity @40^{0}C (mm^2/s)	4.04	3.94	1.9-6.0

The values compare very well with those specified by ASTM D 6751

Conclusion

Oils extracted from *Chrysophyllum albidum (CA)* and *Luffa cylindrica (LC)* seeds can be exploited for use in the bio-fuels industries for bio-diesel production.