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Full Length Research Paper

Optimum conditions for expression of oil from *Allanblackia floribunda* seeds and assessing the quality and stability of pressed and solvent extracted oil

S. Wilfred[1], J. Adubofuor[2]* and J. H. Oldham[2]

[1]Department of Hotel, Catering and Institutional Management, Kumasi Polytechnic, Kumasi, Ghana.
[2]Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology Kumasi, Ghana.

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The study was carried out to establish the optimum conditions for the extraction of oil from *Allanblackia floribunda* nuts and also assess the quality and stability of both the crude pressed oil (CPO) and solvent extracted oil (SEO).The optimum conditions of extraction were established by varying the moisture levels of the milled seed samples under different temperatures. The oil was expressed using a manual screw press and the soxhlet apparatus was used to extract the oil using petroleum ether as the solvent. Quality parameters assessed included specific gravity, refractive index, free fatty acids, acid value, melting range, unsaponifiable matter, saponification value, iodine value, peroxide value and calorific value. The results showed the seeds were high in oil. The oil yields from manual expeller and solvent extraction were 48.60 and 67.59% respectively. The oils had a melting point ranging between 42 - 44°C. There were no significant differences in the quality parameter such as refractive index, specific gravity, iodine value, saponification value, peroxide value, free fatty acid, acid value and ester value. There were however, significant differences in the moisture and volatile matter as well as unsaponifiable matter of the oils. The peroxide value and free fatty acid content were used as the indicators for stability of the oil. The pressed oil was more stable during storage of the oil in plastic containers than the solvent extracted oil. *Allanblackia* seeds can be used commercially in the food sector and also for non food purposes.

Key words: *Allanblackia floribunda* seeds, mechanical extraction, optimum conditions, quality characteristics.

INTRODUCTION

Many indigenous Ghanaian trees species, which have little importance as timber trees, are becoming increasingly recognized as valuable sources of raw materials for various food and industrial uses. These uses include extraction of vegetable oils from the seeds for various purposes, alkaloids from several parts of the plants for medicinal purposes and fibre for pulp. In Ghana and other countries within the sub-region, there are several forest plant species which have seeds from which oil could be produced (Ellis et al., 2007). Vegetable oils are are derived from seeds and fruits of plants which grow in different parts of the world. Several varieties of plants are known to have oil bearing seeds or fruits but only a few are commercially significant. Some of these include soybeans cottonseed, groundnuts, sunflower oil palm nuts, shear nuts and rapeseed (Ihekoronye and Ngoddy, 1985). The demand for low-priced common edible fats and oils has been on a steady increase in most countries, including Ghana. This is partly due to the competition between the industrial requirement for oil and their use for edible purposes. It has therefore become imperative to find alternative sources of oils from unexploited and underutilized plants which can also serve both domestic and industrial purposes. The tallow tree (*Allanblackia*

*Corresponding author. E-mail: jkwab@yahoo.de.

floribunda) is a woody dicotyledonous and underutilized plant belonging to the family *Guttiferae* and the genus *Allanblackia.* It is an evergreen plant that thrives well in wet places especially in the rainforest regions. The trees are widely distributed in certain parts of Africa, mostly in Sierra Leone to Cameroon and Gabon, Congo Brazzaville and Uganda. In Ghana it is found growing in the Western, Central, Ashanti and Eastern Regions in forest stands as well as on cocoa farms. (Irvine, 1961).

Traditionally, the oil extracted from seeds has been used locally for cooking, preparing medicines and making soap at a subsistence level. It has recently been found that the oil could be used in the manufacturing of spreads (margarine), soap and beauty products. Several properties of this oil, for example high melting point and better food value among others, make it superior to alternatives like palm oil (Novella Partnership, 2008). The seeds of A. floribunda contain 6.0% water, 2.2% ash, 3.6% crude protein, 3.1% crude fibre, 20.7% carbohydrate and 64.4% oil (www.fao.org/docrep/003/×6877E/×6877E09.htm).

Oilseeds are generally processed to extract oil by employing various extraction techniques. In the developing countries oils are mostly extracted by using traditional expellers. This results in significant losses of edible oil in the cake. The oil content of the cake ranges from 4 to 6% or even up to 10%, depending upon the oilseed and the processing equipment used. Modern technology for the processing of oilseeds to separate oil from meal has been evolved from the development and utilization of continuous expeller. Currently, three types of commercial processing systems are employed for oilseeds in the developed countries. These include expeller pressing, pre-pressing followed by solvent extraction, and direct solvent extraction (Salunkhe et al., 1992).

Inadequate knowledge of the commercial value of *Allanblackia* seeds, inefficient method of extraction of *Allanblackia* oil and the relative abundance of the trees in Ghana coupled with the high oil content of *Allanblackia* seeds provides a sound basis for undertaking this project.The study was therefore, carried out to determine the optimum conditions for expression of oil from *A. floribunda* nuts and assess the quality and stability of pressed and solvent extracted oils.

MATERIALS AND METHODS

Sources of raw materials

Matured seeds of *A. floribunda* were obtained from the Plant Genetic Resource Institute-Bunso in the Eastern Region of Ghana, Forestry Research Institute of Ghana (FORIG) - Kumasi and some selected cocoa farms in New-Edubease in the Ashanti Region of Ghana.

Sample preparation

The seeds used for the study were removed from ripe mature fruits manually through maceration. The extracted seeds were dried in the sun for three days. The seeds were then manually dehulled and were further sun–dried until a constant weight was obtained. The dehulled dried seeds were then stored at room temperature prior to milling and oil extraction (Plate 1).

Solvent and mechanical extraction

The seeds of *A. floribunda* were milled to fine particle sizes (72.69% passing through a 1.18 mm standard sieve) using a Disc miller. Solvent extraction was carried out using petroleum ether as solvent for the Soxhlet apparatus. The oil extracted was dried and weighed and percentage yield determined. In establishing the optimum conditions for mechanical expression using a manual screw press, extraction of oil was carried out on the dehulled-milled seeds at different moisture (3.1, 5.0, 7.0, 9, 11, 13, 15, 17, 19, 21 and 23%) and temperatures levels (60, 70, 80, 90, 100 and 110°C). The desired (*x*) moisture levels in the milled seeds samples were calculated by first, determining the amount of moisture in the milled seeds samples through proximate analysis. This value then became the initial moisture content (a) in the milled sample. 400 g of milled seeds was then accurately weighed and mixed (kneaded) with the calculated amount of warmed water (y) to obtain the desired moisture level. The following relation was used:

$$x = (aw + y) / (w + y)$$

Where, x = desired moisture content in milled *Allanblackia* seeds; w = weight of sample (400g); y = water added to sample to achieve desired moisture content; a = initial moisture content in milled sample, which is 3.1% (from proximate analysis).

The samples were then placed in linen cloth-bags and heated in a thermostatically controlled oven (Gallenkamp Hotbox with fan, size 1) for 2 h at the different temperature conditions specified. The oil was expressed using a low pressure (40 kg/cm^2) manual screw – press. The oil obtained was dried in an oven for 10 min at 105°C and weighed. The yield was then calculated using the relation:

$$\% \text{ Yield} = \frac{\text{Weight of oil obtained}}{\text{Weight of sample}} \times 100$$

The seed meal residue (cake) was dried at 105°C in an oven for 12 h after the oil has been expressed at each temperature and moisture condition. The Soxhlet method was then used to determine residual oil in the meal (cake). The Oil Extraction Efficiency (OEE) of the mechanical extraction process was then calculated using the relation:

$$OEE\ (\%) = 100\ [1 - (R_{(kernels)} / R_{(cake)})]$$

Where, $R_{(kernels)}$ is (100 - proximate composition of oil in kernels) / (proximate composition of oil in kernels); $R_{(cake)}$ is (100 - % oil in the pressed cake) / (% oil in the pressed cake).

The sample Crude Pressed Oil (CPO) with the highest yield and the Solvent Extracted Oil (SEO) were subjected to physicochemical analyses.

Physicochemical properties of extracted oil

The extracted oils are indicated in plate 2. The physicochemical properties of the oil were determined using the official methods and recommended practices of the American Oil Chemists' Society (AOCS). The melting range was determined using the AOCS capillary tube method Ccl-25 (AOCS, 1993) while the specific gravity was measured at 60 / 25°C using the specific gravity bottle based

Plate 1. The fruits and kernels of *A. floribunda.*

gravity bottle based on AOCS method Cc 10a-25 (AOCS, 1993). The refractive index was determined at 60°C using Abbe refractometer (model: Bellingham + Stanlay limited, 60/70). The free fatty acids and acid value were determined using the AOCS method Ca 5a-40, (AOCS, 1993) and the procedure described by Kirk and Sawyer (1991) respectively. The peroxide value was determined using the AOCS method Cd 8-53, (AOCS, 1993). The iodine value and saponification value were determined using the AOCS methods Cd 1-25, (AOCS, 1993) and Cd 3-25, (AOCS, 1993) respectively. The unsaponifiable matter and calorific value were determined using the AOCS method Ca 6a-40, (AOCS, 1993) and the Bomb calorimeter (model M482, England).

Statistical analysis

All experiments were carried out in triplicates. Data obtained were subjected to analysis of variance (ANOVA). Differences among means were determined using Duncan's multiple range test

RESULTS AND DISCUSSION

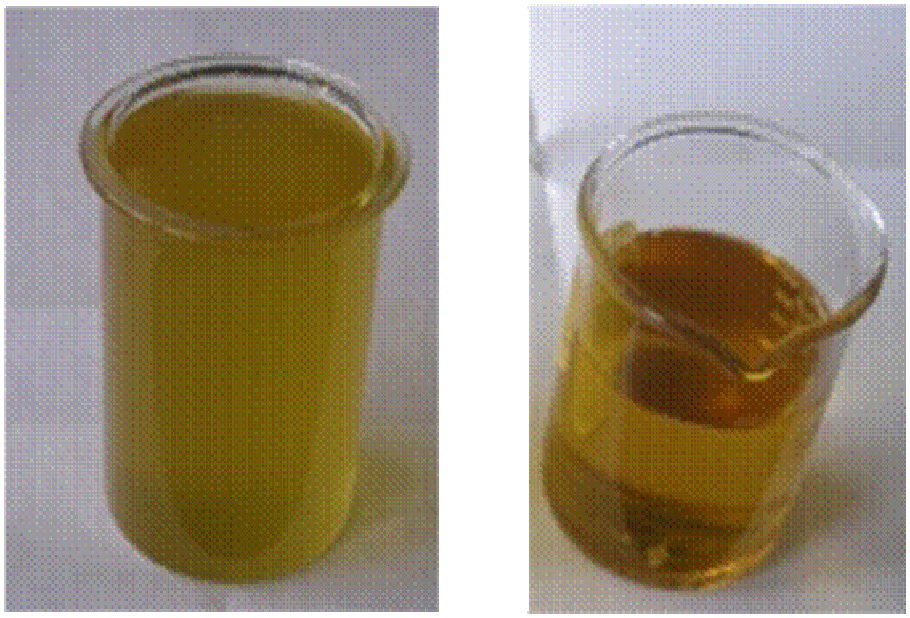
The yield of pressed crude oil obtained at temperatures ranging from 60 to 110°C and moisture contents of dehulled-milled seeds from 3.1 to 23% are shown in Table 1. The preliminary analyses of the three selected pressed oils are represented in Table 2.

Preliminary analyses on three selected samples of extracted oil

From the results of the preliminary analyses to select a optimum yield of pressed oil sample for further analysis, the three samples selected; 100°C at 3.1% , 90°C at 11% and 100°C at 13% were not significantly ($p > 0.05$) different in quality. As indicated in Table 2, the OEE at 100°C and at 3.1% moisture was significantly low ($p < 0.5$) whilst the OEE at 100°C and 13% moisture was significantly higher than the OEE at 90°C and 11% moisture content. Thus, the oil obtained at 100°C and at 13% moisture content was selected and its properties compared with the solvent extracted oil.

Determination of the optimum condition for extraction of oil

Generally, the results in Table 1 show that at each specific temperature and varied increases in the moisture contents, the yield of oil increased gradually to a maximum value after which there was a decline. The yield of oil obtained at 60, 70 and 80°C for each of the varied moisture contents were all lower than the yields at 90 and 100°C. This may be due to high viscosities of the oils and relatively lower heating temperatures. According



(a) Pressed crude oil (b) Solvent extracted oil

Plate 2. Samples of pressed and solvent extracted oils.

Table 1. Yield of pressed crude *A. floribunda* seed oil obtained at different temperatures and varied moisture contents of milled seed kernels.

Temperature (℃)	Moisture content (%)										
	3.1	5	7	9	11	13	15	17	19	21	23
	Yield of oil (%)										
60	28.7	30.2	30.6	31.7	32.2	32.8	33.4	34.6	36.9	35.1	34.3
70	29.3	30.9	29.6	31.4	31.9	32.5	36.7	37.4	37.0	36.3	35.8
80	30.5	33.1	34.8	35.9	39.2	39.2	39.6	42.3	43.5	42.7	41.8
90	31.8	33.9	35.3	44.8	46.01	42.7	42.5	42.9	43.8	43.1	42.7
100	32.5	40.9	41.2	43.4	45.2	48.6	46.5	47.1	46.6	45.4	43.9
110	30.9	31.7	32.5	35.7	36.9	37.1	38.2	38.9	44.6	42.3	41.8

Table 2. Preliminary analyses to select a suitable pressed sample for further analysis.

Properties	*Samples			LSD (5%)	SED
	90℃ at 11%	100℃ at 3.1%	100℃ at 13%		
% Yield	46.01[a]	32.60[b]	48.57[c]	1.908	0.687
% OEE	66.44[a]	40.92[b]	80.22[c]	4.002	1.442
Melting Range (ºC)	42-44	42-44	42-44	-	-
Refractive index @60℃	1.46[a]	1.46[a]	1.46[a]	0.000	0.000
Specificgravity (60 /25℃)	0.8852[a]	0.8948[a]	0.8860[a]	0.018	0.007
%FFA (Calc. as oleic acid)	0.25[a]	0.26[a]	0.25[a]	0.030	0.011
Acid value (mgKOH/g)	0.55[a]	0.60[a]	0.56[a]	0.087	0.031
Peroxide value (mEq/kg fat)	3.00[a]	3.00[a]	3.00[a]	0.02	0.010

LSD: Least significant differences of means. SED: Standard error of differences of means.

Table 3. Physicochemcal properties of *A. floribunda* oil.

Properties	Sample		LSD (5%)	SED
	PCO	SEO		
Yield (%)	48.60	67.59	-	-
Oil extraction efficiency (%)	80.22	-	-	-
Melting range (°C)	42-44	42-44	-	-
Refractive index at 60°C	1.46[a]	1.46[a]	0.000	0.000
Specific gravity (60 /25°C)	0.89[a]	0.88[a]	0.012	0.03
Free fatty acid (%)	0.25[a]	0.25[a]	0.008	0.002
Acid value (mg KOH/g)	0.55[a]	0.54[a]	0.004	0.001
Peroxide value (mEq/kg fat)	3.00[a]	3.00[a]	0.000	0.000
Saponification value (mg KOH/g)	199.39[a]	200.56[a]	3.620	0.841
Ester value (mg KOH/g)	199.17[a]	200.02[a]	4.726	1.098
Unsaponifiable matter (%)	0.64[a]	0.54[a]	0.115	0.027
Calorific value (kJ/g)	39.65[a]	39.74[a]	0.959	0.223
Iodine value (Wijs)	38.84[a]	35.65[a]	1.012	0.235
Moisture and volatile matter at 105°C	0.18[a]	0.02[b]	0.043	0.010
MIU (%)	2.50[a]	1.47[b]	0.823	0.191
Colour	Yellow		Yellowish-Brown	

*Values with different superscripts in the same row are significantly different ($p < 0.05$), LSD: Least significant differences of means, SED: Standard errors of differences of means, PCO: Pressed crude oil, SEO: Solvent extracted oil, MIU: Moisture, Insoluble and Unsaponifiable matter.

to Fellows (1996), temperature influence the yield of oil and better extraction is achieved by heating, which reduces the oil viscosity, releases oil from the intact cells and removes moisture. However, moisture also lubricates the seed meal during pressing and increases the flow of oil through the pores of the press cake. Thus reducing the amount of oil entrained in the cake and increasing the oil yield. The lower yields at 110°C than the corresponding values at 100°C may be due to loss of moisture at 110°C resulting in low moisture availability in the paste, leading to a decrease in the amount of oil displaced from the oil cells of the seed meal.

Maximum oil yields obtained were 46.01 and 48.60% at the moisture level of 11% at 90°C and 13% at 100°C respectively. Analysis on these samples indicated that there was no significant difference ($p > 0.05$) in the quality parameters analyzed. However, as shown in Table 2 the oil extraction efficiency at 100°C and 13% moisture content was significantly ($p < 0.05$) higher than the oil extraction efficiency at 90°C and 11% moisture level. It has been reported that there is an optimum moisture content for each type of oil seed to obtain a maximum yield of oil (Fellows, 1996). The optimum condition for maximum yield of *A. floribunda* seed oil (48.60%) was achieved at 100°C and 13% moisture content of seed meal .This sample was therefore selected and compared with the solvent extracted oil. The 48.60% oil yield obtained from the kernels, was comparatively high since most commercial oil bearing seeds have oil contents of about 30 - 40% and above (Abbiw, 1990; Ellis et al., 2007). Table 3 shows the physicochemical properties of pressed crude oil and solvent extracted oil.

Physicochemical properties of pressed and solvent extracted oils

The properties of the pressed crude oil and solvent extracted oil are presented in Table 3. The specific gravity, refractive index, free fatty acid, acid value, peroxide value, saponification value, ester value, unsaponifiable matter, and calorific values of the two samples were not significantly different ($p > 0.05$). The melting point of both samples ranged between 42 - 44°C and were both solid at room temperatures ranging between 28-30°C. The melting point is relatively very high compared with cocoa butter and palm kernel oil which have been reported to be between 32 - 36 and 25 - 30°C respectively, Shea butter has been reported to have a melting point of 32 - 42°C and may be comparable to *A. floribunda* oil (Bockish, 1993). The relatively high melting point is a good property in the confectionary industry as far as the stability of products are concerned. The oil could effectively replace palm oil in the manufacture of products like margarine and soap (www.worldagroforestry.org/treesandmarkets/allanblacki). The specific gravity of the *Allanblackia* oil at 60°C was 0.886, indicating that the oil is higher than water and will form an upper layer in a water-oil mixture. The refractive index value obtained was 1.46. There exist a close relationship between average molecular weight and refractive index. Refractive index increases with increasing chain

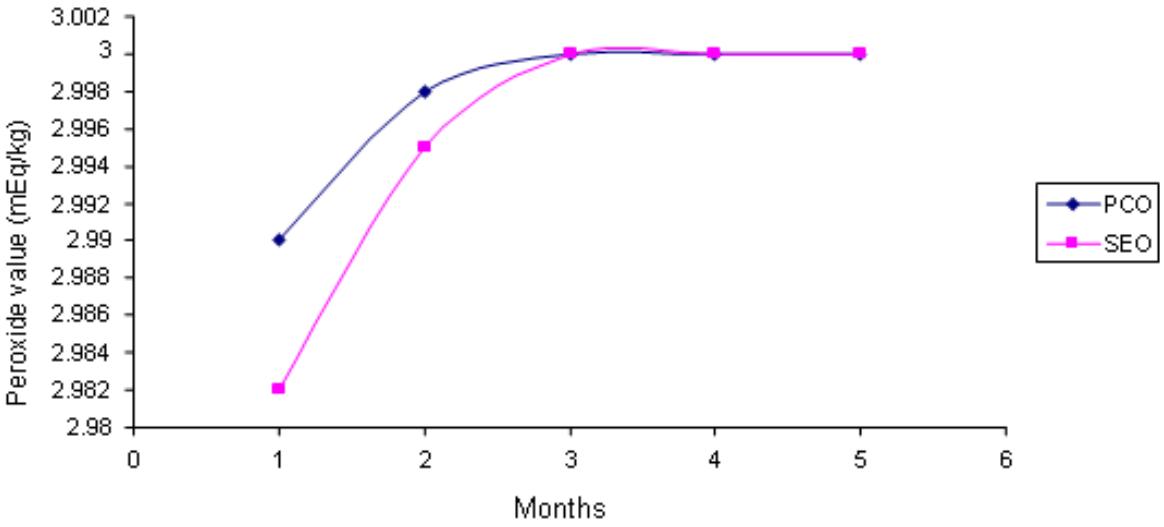


Figure 1. Changes in the peroxide value of *Allanblackia* oil during storage.

length and also with the number of double bonds present in the oil (Nielsen, 1994); The refractive index value obtained falls within the range reported for some fats in the nut family (1.45 -1.49) (Eckey, 1954).

The Free Fatty Acids (FFA), acid value and peroxide value are important parameters in evaluating the quality of fats and oils with respect to rancidity and oxidation. The acid value is usually twice as large as the FFA and this was the case in this work. The mean Peroxide Value (PV) of *Allanblackia* oil was 3.00. This value is within the range of peroxide values (<10) generally reported for fresh fats and oils (Kirk and Sawyer, 1991). The value also falls within the standards (PV<10mEq/kg fat or oil) stated by Codex Alimentarius for edible oils. The acid value for virgin fats and edible oils, as indicated by the Codex Alimentarius (www.codexalimentarius.net/ standard) is up to a maximum level of 4.0 mg KOH/g fat or oil. The low FFA of 0.25%, acid value of 0.54/0.55 mg KOH/g fat or oil and peroxide value of 3 are good indicators of the stability of the oil against oxidation and rancidity. Even though there was no significant difference in the saponification values of the two samples, the saponification value of the solvent extract was a bit higher than the pressed crude oil. This is because the ester value (glyceride content) was a bit higher and the oil also had lower percent moisture, insoluble and unsaponifiable matter (MIU). The low value of unsaponifiable matter suggest that the fat contains low level of sterols, paraffin hydrocarbons, alcohols and mineral oil and contaminants such as heavy metals (Boekenoogen, 1964).

Generally, fats and oils with high proportion of shorter carbon chain lengths of the fatty acids have high saponification values (Kirk and Sawyer, 1991). Low molecular weight fatty acids have more glyceride molecules per gram of fat than high molecular weight acids and hence greater saponification value. Coconut oil contains appreciable quantities of low-molecular weight fatty acids and has high saponification value (251 - 264) (Aurand et al., 1987). The saponification value obtained in this work was lower than that of coconut oil but close to that stated for palm oil (190 - 209) by (Bockish, 1993), indicating relatively higher molecular weight acids (Ellis et al., 2007).The Iodine Value (IV) of fats and oils is an important characteristic which determines the degree of unsaturation. The IV of the pressed crude oil (38.78) and solvent extracted oil (35.75) were significantly ($p < 0.05$) different from each other and they were lower than the range of 50 - 55 specified by Codex Alimentarius (Codex Standard 210, 2003) The values were relatively low indicating a low degree of unsaturation or high degree of saturation of the *Allanblackia* oil. Oils have been classified into three groups based on IV, oil is classified as non-drying if the IV is less than 100, as semi-drying if the IV is between 100 and 130, or as drying if the IV is between 130 - 200 (Cocks and Rede, 1966). The iodine values obtained for the *A. floribunda* oil were below 100 indicating that the oil is non-drying. Thus, the oil will not be suitable for the production of industrial products such as paints, varnishes and surface coatings (Ellis et al., 2007).

Stability of *A. floribunda* oil during storage

Figures 1 and 2 shows the changes in the peroxide values and FFA of the pressed crude oil and the solvent extracted oil over a period of 5 months of storage in plastic containers under ambient conditions. The peroxide values of the pressed crude fat and the solvent extract ranged between 2.9 to 3.0 and 2.9 to 3.0 mEq/kg oil respectively. These low values are acceptable within the period of study without causing any instability to the

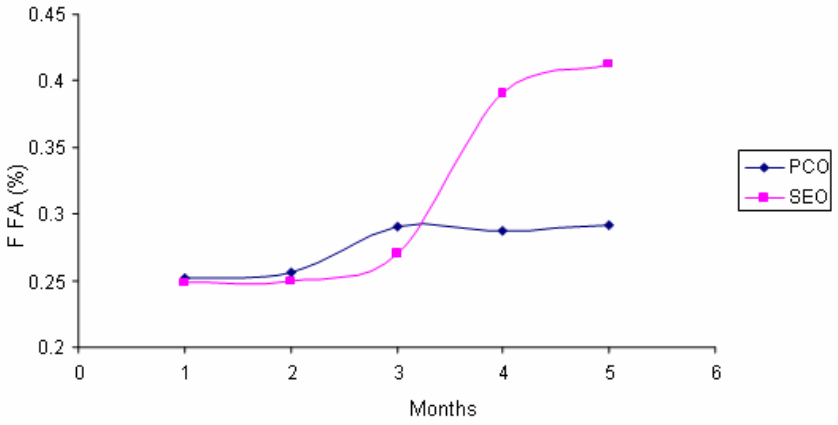


Figure 2. Changes in the free fatty acids content of *Allanblackia* oil during storage.

oils. A rancid taste is often noticeable in many oils when the peroxide value is between 20 and 40 mEq/kg oil (Kirk and Sawyer, 1991). The percentage FFA levels of pressed crude oil and solvent extracted oil were observed to vary and were between 0.25 to 0.30% and 0.25 to 0.41% respectively as shown in Figure 2. Even though, the changes in FFA level were significant ($p < 0.05$) at 5% level of significance, the levels of FFA were still within the permissible values (acid value < 4 mg KOH/g fat) .The pressed oil was however more stable on storage than the solvent extracted oil. Igbo et al. (2005) also made a similar observation for solvent extracted and mechanical pressed benniseed oil stored for a period of four months. The increase in the FFA of solvent extracted oil may be attributed to the heating process during solvent extraction, since in the presence of heat and water triglycerides break up through hydrolysis to form FFA (www.andrew.cmu.edu/user/jitkangl/). Thus, the *Allanblackia* oil, if stored in sealed plastic containers under ambient conditions can remain wholesome for at least five months without spoilage. The high stability of *Allanblackia* oil may be due to the low degree of unsaturation in the oil since a low level of unsaturation in a oil makes it less susceptible to rancidity.

Conclusion

The study has shown that *Allanblackia* seeds are high yielding oilseeds and serve as a commercially rich source of vegetable oil. The maximum yield of approximately 49% of the *Allanblackia* oil was best extracted from the milled seeds at an optimum temperature of 100°C and moisture content of 13%. The oil has the qualities suitable for the production of soaps, confectionaries and margarine. The relatively high melting range of the *Allanblackia* oil is a good attribute for the oil to be used in the confectionary industry to enhance the stability of products. Thus, the oil may serve as a best alternative to supplement oils in both the food and the non food sectors. In view of the low degree of unsaturation, acid and peroxide values the oil can be stored in plastic containers for a period of at least five months without deterioration.

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