

Full Length Research Paper

# Physico-chemical properties of *Blighia sapida* (ackee) oil extract and its potential application as emulsion base

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Oil extracted from the ripe ackee (*Blighia sapida* L) aril was characterized by the classical titrimetric and gravimetric analyses following the British Pharmacopoeia (BP) procedures. Dynamic and kinematic viscosities as well as the true density of the lipid were determined. The sample was subjected to instrumental polarimetric and gas chromatographic analyses. In each test, arachis oil (BP) and/or oleic acid was used as reference. The extraction and purification method produced  $37.0 \pm 4.9\%$ , on dry weight basis, of bright-yellow oil with characteristic roasted ackee scent. Acid, ester, hydroxyl and saponification values were  $1.83 (\pm 0.01)$ ,  $64.52 (\pm 0.18)$ ,  $28.01 (\pm 0.04)$  and  $743 (\pm 0.19)$  respectively. Its specific gravity was  $0.905 (\pm 0.008)$  while the optical rotation was 1.453. The gas chromatography showed several well-defined peaks with two peaks at elution times of 15.41min (n-hexane) and 17.44 min (oleic acid). The sample has comparable specific gravity, viscosities and true density values as arachis oil BP. On the other hand, it contains higher levels of saponifiable matters, free acid and hydrolysable matters than arachis oil. The characteristic properties of ackee oil suggest potential for its application as pharmaceutical base and may satisfy some of the deficiencies of arachis and, possibly, some other vegetable oils.

**Key words:** Ackee oil, extraction, characterization, pharmaceutical base.

## INTRODUCTION

Ackee (*Blighia sapida*, L.; Family: *Sapindaceae*) is a perennial herbaceous plant introduced to Jamaica in the 16th century mainly as a food for residents. It gained scientific recognition in 1793 when Captain William Bligh introduced it to England in honor of whom it was named '*Blighia sapida*' (Lancashire, 2004). It is an evergreen tree, which grows to a height of between 7 and 25 m. Ackee tree grows well in Jamaica with little cultural

attention and is cultivated mainly in the parishes of Clarendon and St. Elizabeth. It produces good yield of 7.5 to 10 cm long, lipid-bearing fruits almost all the year round, with two peak fruiting seasons of January to March and June to August (Lancashire, 2004). Ackee is widely consumed in Jamaica as part of the national dish. It is also popular among Jamaicans in the United States and Canada, countries where it was previously prohibited.

The main drawback to its application is the toxicity which manifests as diarrhea, hypoglycemia, nausea and vomiting commonly known as Jamaican vomiting sickness (JVS) or toxic hypoglycemic syndrome (Mitchell et al., 2008). The toxicity is now known to be due to the

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toxic amino acids hypoglycin A and B present in the unripe arils but which have now been shown to decrease by 13 and 7 folds respectively on ripening (Mitchell et al., 2008), hence, self-opened ackee fruits have been found to be quite safe for consumption. In addition, hypoglycin is water-soluble (Wellington, 1999); boiling ackee before consumption and use of extraction methods that are selective to the lipophilic components would enhance the elimination of hypoglycin from extracted oil.

Although, literature shows some chemical and biological studies on ackee (Brooks and Audretsch, 1970; Ogutuga et al., 1992; Singh et al., 1992; Wellington, 1999), information on the potential application as industrial/pharmaceutical base appears to be unavailable. The aim of this study therefore was to develop and standardize an extraction method for the lipid content of *Blighia sapida* (Ackee) arils and to perform qualitative and quantitative tests on the lipid in order to characterize its physicochemical properties that may be useful in its application as an industrial and pharmaceutical base.

## MATERIALS AND METHODS

Samples of plant materials (cheese ackee) were collected in batches of six dozens from a single source (farmer) in the parish of St. Catherine, Jamaica, during the peak fruiting seasons of January to March and June to August 2008 and 2009. Samples' identity was confirmed with botanist at the Botany Department of the University of the West Indies uwi herbarium 35575.

### Chemicals and reagents

Acetone, ethyl ether, potassium hydroxide, petroleum ether and phenolphthalein were products of Fisher scientific (N.J., USA) while acetic anhydride, chloroform, oleic acid and pyridine were obtained from BDH (Poole, UK). Arachis oil (BP) was a product of Halewood Chemical (England, UK). All materials were used without further purification.

### Preparation of the Ackee aril

For each batch of six dozens, the arils were freed from the fruits, cleaned and dried in a gravity convection cabinet oven (BTL, USA) at approximately 60°C for about 72 h. The powdered dried aril ( $421.31 \pm 6.20$  g per batch of 12 dozens) was combined and stored in tightly-closed bottle until extracted. Extraction was done in batches of approximately  $150 \pm 5$  g with 500 ml of petroleum ether in a Soxhlet extractor (Corning, USA). The extract obtained was cleaned by the addition of 1% w/w activated charcoal and hot filtration at 60°C, using Whatman 1 filter paper. The extract was concentrated using a rotary evaporator (Buchi rotavapor R-200/water bath B-450) at  $50 \pm 5^\circ\text{C}$ .

### Gas chromatography of Ackee oil

Gas chromatography (GC) was used to establish the purity of the oil and to identify the main fatty acid content of the oil. The GC comprised of a Hewlett Packard 5890 series II. The column material consists of cross-linked polyethylene glycol 30 m  $\times$  0.25 mm  $\times$  0.25

$\mu\text{m}$  film thickness at 50 to 120°C. Chloroform and acetone (5 ml) were used as cleaning solvents. One microlitre of Ackee oil solution was injected and the analysis was allowed to run for 30 min.

## Physical characterization of Ackee oil

### Freezing point determination

The apparatus and the procedures described in the BP (2007) were adopted. Ackee oil (15 ml) was transferred into the inner tube covering the thermometer bulb and the freezing point was determined by cooling rapidly. The inner tube was placed in a bath maintained at 15°C. The beaker was filled with a saturated solution of sodium chloride, at a temperature about 2°C, the inner tube was inserted into the outer tube, and was stirred thoroughly until solidification occurred. The highest temperature during solidification was noted.

### Melting point determination

The European Pharmacopoeia apparatus and procedures described in the BP 2007 were used with slight modifications. A 400 ml Pyrex<sup>®</sup> glass beaker was fitted with a thermometer and 100 ml of water added (Apparatus 1). The apparatus was placed on a Fisher Thermix<sup>®</sup> model 3107 stirring hot plate at low temperature (27°C). Ackee oil (15 ml) was placed in a pycnometer with a thermometer attached and the sample was solidified at 5°C. The solidified sample was placed in a 150 ml Pyrex<sup>®</sup> glass beaker fitted with a stirring rod and containing ice cubes and water that was maintained at 5°C (Apparatus II). Apparatus II was placed in Apparatus I and the liquid observed for the temperature at which all the solids were melted.

### Specific gravity

A 25 ml pycnometer was cleaned and dried, filled with water and weighed at room temperature ( $-27^\circ\text{C}$ ). The pycnometer was emptied, dried, cooled and weighed again on an electronic balance (Ohaus, USA). The apparatus was filled with Ackee oil and weighed. The specific gravity at 27°C was calculated using the Equation (1):

$$S.G. = \frac{\text{Mass of ackee oil}}{\text{Mass of water}} \quad (1)$$

The values obtained were adjusted to 25°C using the formula:

$$G = G' + 0.00064(t - 25^\circ\text{C}) \quad (2)$$

where  $G$  is the corrected specific gravity,  $G'$ , calculated specific gravity (27°C), and  $t$  is the temperature (Cunniff, 1999). The determination was done in triplicates along with arachis oil as reference standard.

### Determination of optical rotation of Ackee oil

Sample of purified Ackee oil previously cooled to 22°C was fed into the cell of a polarimeter (Carl Zeiss<sup>®</sup>, Germany). The angle of refraction was determined following established procedures. The test was replicated for at least three consistent readings, and repeated with Arachis oil (BP). The refractive index was determined from the table of reference standard provided by AOAC (Cunniff,

1999).

### Viscometry

Ackee oil (2.5 ml) was loaded into a Stabinger viscometer model SVM3000 (Anton Paar®, Austria). Kinematic and dynamic viscosities as well as the true density were measured at a range of temperatures (50, 45, 40, 35, 30 and 25°C). The tests were replicated in parallel with Arachis oil BP under similar conditions.

### Acid value

Twenty-five milliliters of both ethyl ether and absolute alcohol were measured into a conical flask and 10 g of Ackee oil was added. The mixture was shaken and 0.5 ml of phenolphthalein was added and agitated vigorously. The mixture was then titrated with 0.1 M potassium hydroxide until a pink colour that persisted for 15 s was observed. The test was repeated with arachis oil BP following random assignment. The acid value was calculated using the expression:

$$a = 5.610 \frac{v}{w} \quad (3)$$

where,  $a$ , is the acid value,  $v$  is the difference in volume of potassium hydroxide consumed in the titration and  $w$ , the mass of the sample used.

### Ester value

One gram of Ackee oil was weighed into a 200 ml flask and 5 ml of ethanol (95%) added. To the mixture was added 5 drops of phenolphthalein indicator, and titrated with 0.1 M ethanolic potassium hydroxide until the colour turn just pink. Twenty milliliters of 0.5 M potassium hydroxide was added along with 2 glass beads. A reflux condenser was turn on and the content was boiled for one hour. The mixture was removed from the heat source and 25 ml of distilled water was added along with 0.2 ml of phenolphthalein. The mixture was titrated to neutrality with 0.5 M hydrochloric acid. The ester value was determined by the expression (BP, 2007):

$$E = 2805 \frac{v}{w} \quad (4)$$

where  $E$ , is the ester value,  $v$  is the difference in volume of hydrochloric acid consumed by the blank compared with the actual titrations and  $w$  is the weight of the sample.

### Hydroxyl value

To 2 g of oil was added 5 ml of acetic anhydride. The mixture was boiled in a reflux condenser for 1 h, removed from heat source and 5 ml of water was used to rinse the condenser unit. Fifteen milliliters of pyridine was added to render the mixture clear. The unit was returned to the bath and refluxed for an additional 10 min. The product was removed from the heat source, allowed to cool and 10 ml of absolute alcohol was used to rinse the unit. Phenolphthalein (0.2 ml) solution was added. The mixture was titrated with 0.5 M

KOH until a slight pink color was observed. A blank run containing no oil was performed and the hydroxyl value was calculated according to the expression (BP, 2007):

$$H = a + 28.05 \frac{v}{w} \quad (5)$$

where  $H$  is the hydroxyl value,  $a$  is the acid value,  $v$  is the difference in volume of potassium hydroxide consumed by the blank compared with the sample titrations and  $w$  is the weight of the sample.

### Saponification value

Two grams of oil was weighed into a round-bottom flask, 25 ml of 0.5 M ethanolic potassium hydroxide was added followed by two dispersion beads and the mixture was boiled for 30 min in reflux condenser. The mixture was removed from the heat source and 1 ml of phenolphthalein was added. The mixture was then titrated with 0.5 M hydrochloric acid until a pink colour persisting for more than 15 s was observed. Blank titrations excluding the oil were performed. The saponification values were calculated using the expression (BP, 2007):

$$S = 2805 \frac{v}{w} \quad (6)$$

where  $S$ , is the saponification value,  $v$  is the difference in volume of hydrochloric acid consumed by the blank compared with the actual titrations.

### Statistical analysis

All quantitative observations and measurements were average of at least three consistent values and are reported with their standard deviation. Paired samples t-test was used to compare test parameters with control using the SPSS 16 software. Significance of any effect of test against the respective control standards were tested at 95% confidence level ( $p \leq 0.05$ ) (Bryman and Cramer, 1997).

## RESULTS

### Yield and physical characteristics of the purified oil

Ackee arils produced an average yield of  $37.01 \pm 4.90\%$  purified Ackee oil. The yield was significantly higher than those reported in the literature for well-known oil seeds such as sunflower (35%), safflower (30%), olive (30%), and soybean (20%), cotton seed (15%) and corn (3.0 to 6.5%) in the whole kernel (Alexander, 2009). The purified oil obtained was a bright yellow, clear, viscous liquid, with a characteristic roasted ackee scent. Upon storage for about two-week period, crystals start to appear in the liquid, indicative of rancidification process. This may be due to the high content of oleic acid having double bonds (unsaturation) with predisposition to autoxidation.

Sample Name: ackee oil  
 Misc Info : using cedar method 70-180-280  
 Vial Number: 1

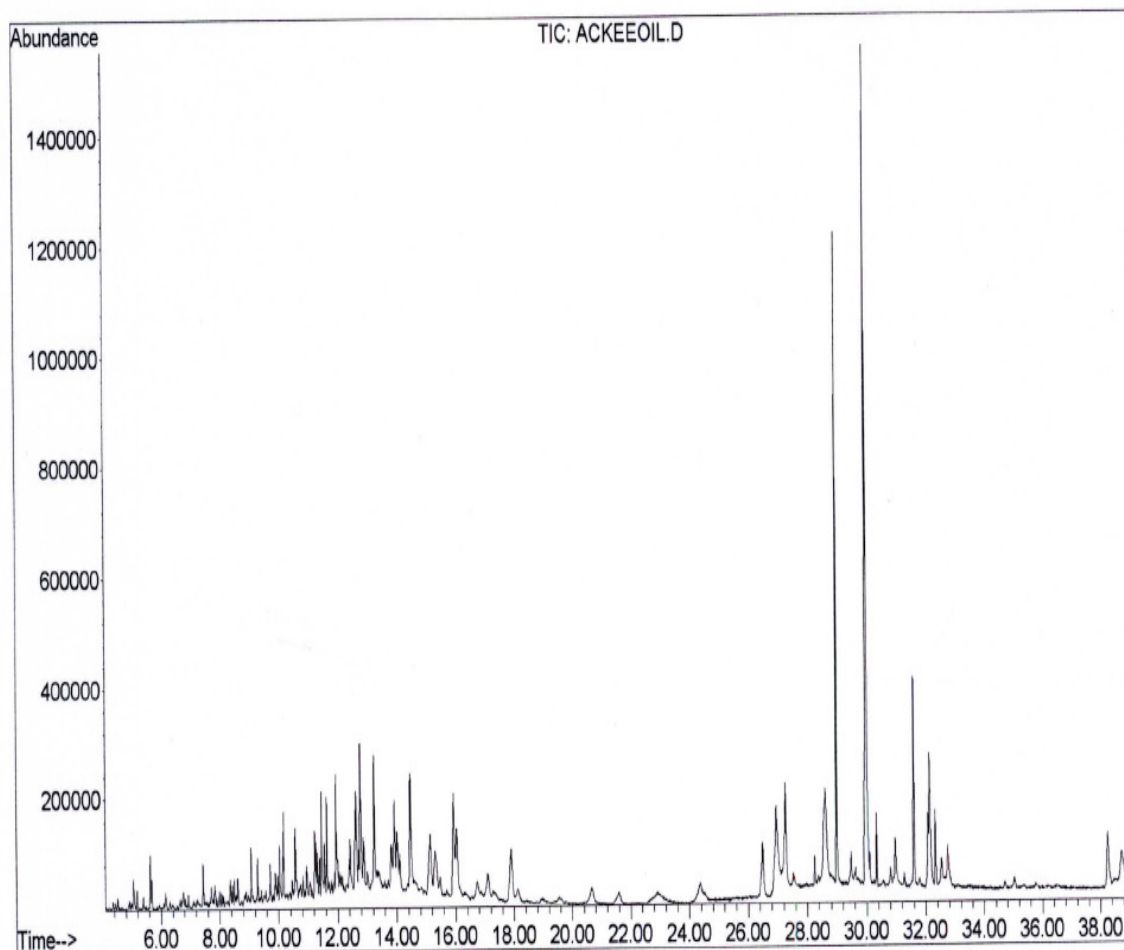


Figure 1a. Gas chromatogram of Ackee oil.

## Instrumental analysis

### Gas chromatography (GC) of Ackee oil

The GC spectroscopy of Ackee oil, oleic acid and preparation solvent (n-hexane) are shown in Figure 1a, b and c, respectively. Several peaks were resolved at elution times between 10 and 16 min and between 26.5 and 33 min (Figure 1a) reflecting the numerous fatty acids present in ackee oil. When the analysis was carried out under similar conditions with pure oleic acid reference standard, peaks appearing at elution times of 15.41 min (ascribable to n-hexane) and 17.44 min (oleic acid) could be found in Figure 1a but in low abundance, indicating that oleic acid is not a major constituent of ackee oil. The major peak observed in n-hexane spectrogram has an elution time of 15.43 min.

## Freezing and melting points

Table 1 gives the freezing point of Ackee oil and Arachis oil as 9 and 5.5°C and of the melting point of Ackee oil and Arachis oil as 25.7 and 18.4°C respectively.

## Density and specific gravity

The densities of Ackee oil, Arachis (test), Arachis BP and corn oil are 0.907, 0.913, 0.916 and 0.916 respectively (Table 1). The differences were not statistically significant ( $p > 0.05$ ). As expected, density of the samples decreased with increase in temperature (Figure 2). The specific gravity of Ackee oil determined by the pycnometry method is shown in Table 1. The oil has a specific gravity of 0.9044 g/cm<sup>3</sup> which is almost equal to

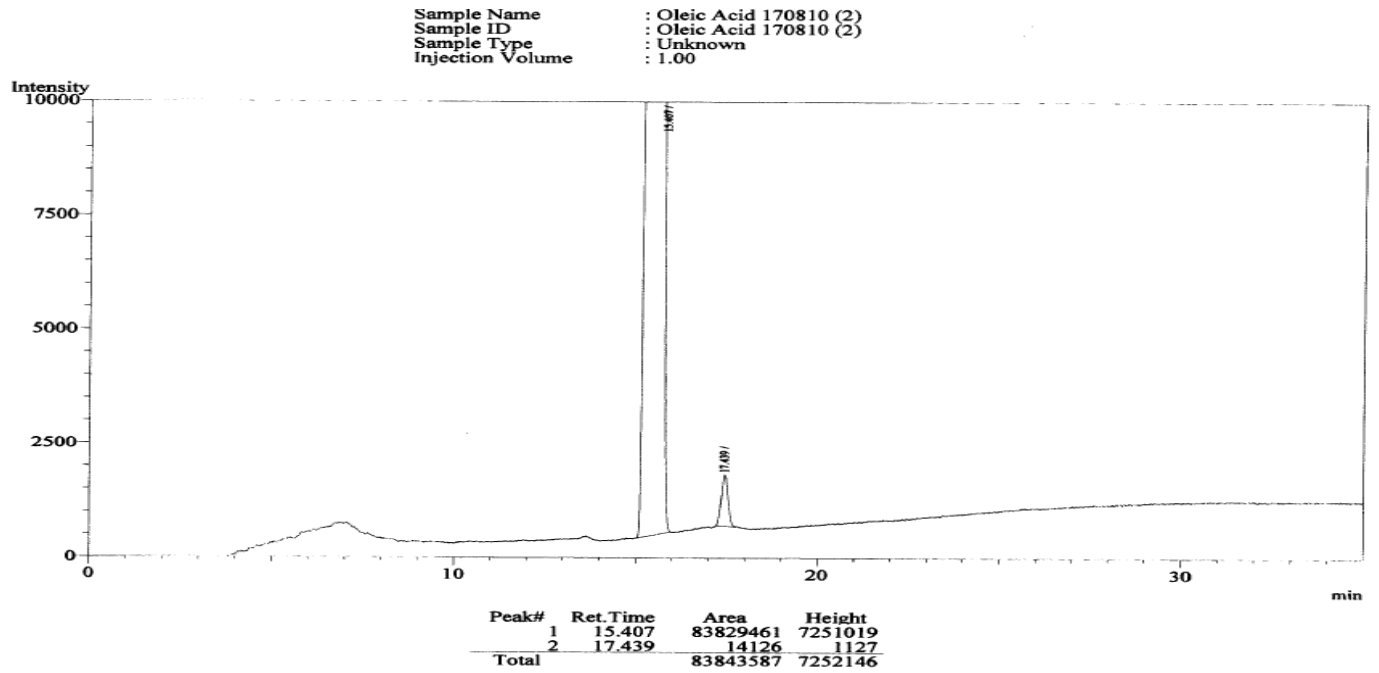


Figure 1b. Gas chromatogram of pure oleic acid.

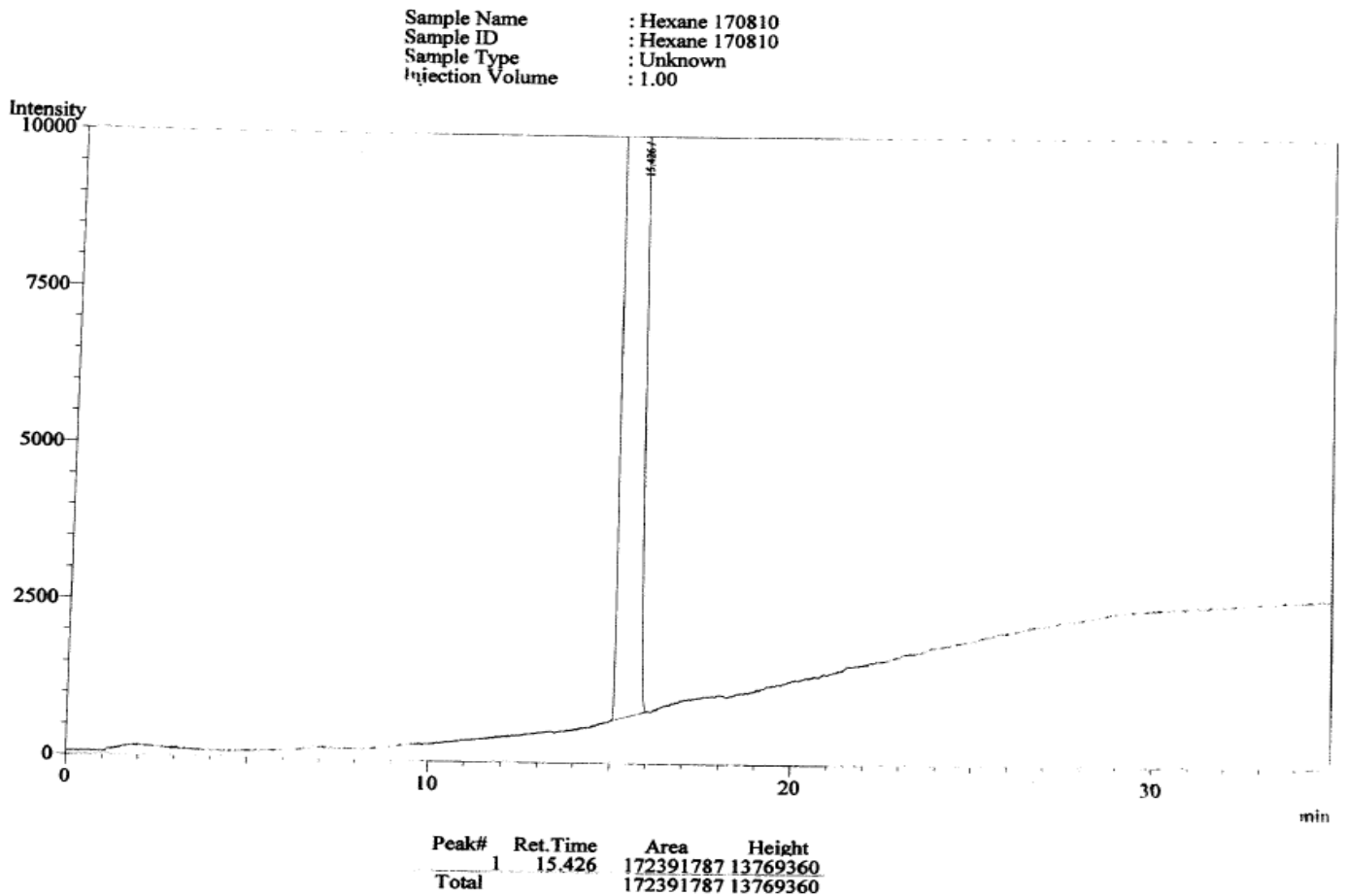
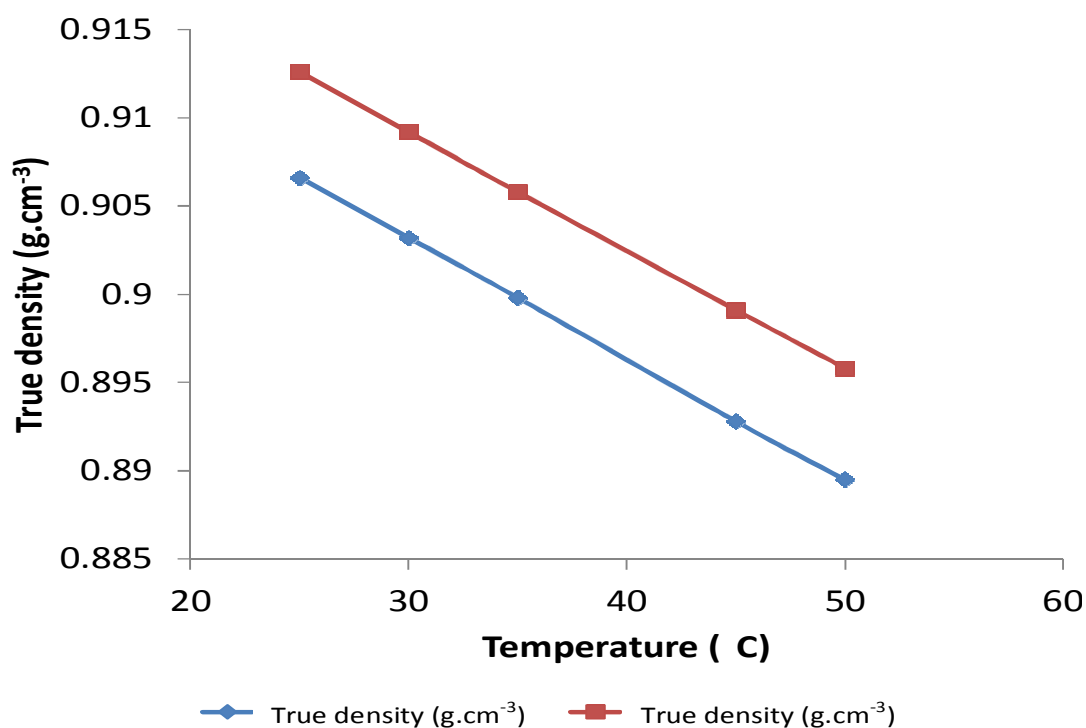


Figure 1c. Gas chromatogram of solvent N-hexane.

**Table 1.** Physio-chemical properties of Ackee oil in comparison with other pharmaceutical oils.

Property	Ackee oil	Arachis (Peanut oil)	Arachis (Peanut oil) (USPNF23/PhEur 2005)	Corn oil (Pharm. Excip.)
Acid value	1.8326 (0.006)	0.4488 (0.11)	≤ 0.5	2 - 6
Ester value	64.5200 (0.18)	33.6600(0.05)	-	-
Hydroxyl value	28.0100 (0.037)	4.9952(0.07)	2.5-9.5	8 - 12
Saponification value	197 (0.19)	190 (0.03)	185-195	187 - 196
Freezing point (°C)	9.0 (1)	5.5(0.7)	-5	-
Melting point (°C)	25.7(0.6)	18.5(0.7)	-	-18 to 10
Specific gravity	0.9045 (0.008)	0.9191(0.05)	0.912-0.920	0.915 - 0.918
Poliarmetry (25 °C)	1.4532	1.1011	1.462-1.464	1.474

**Figure 2.** True density of ackee and arachis oils over a range of temperatures. SD of density values were generally below 0.001, making error bars non-conspicuous.

the density determined by the instrumental method.

### Viscosity

Comparative kinematic and dynamic viscosities of Ackee oil and arachis oil as a function of temperature are shown in Figure 3. The oils displayed Newtonian flow, with a curvy-linear decrease in rate of flow with increasing temperature. Parameters for the regression of viscosity on temperature are presented in Table 2. Kinematic viscosity is normally higher than the dynamic viscosity as the former incorporates the material density (Table 2).

### Polarimetry

Table 1 shows the specific rotation (SR) of plane polarized light by the Ackee oil. The SR value of 1.453 is lower than for arachis oil of 4.463. This result establishes that the oil is optically active.

### Physico-chemical properties of Ackee oil

Some physical properties of Ackee oil are shown in Table 1. All the parameters determined stoichiometrically are significantly higher than those of Arachis oil BP. Ackee

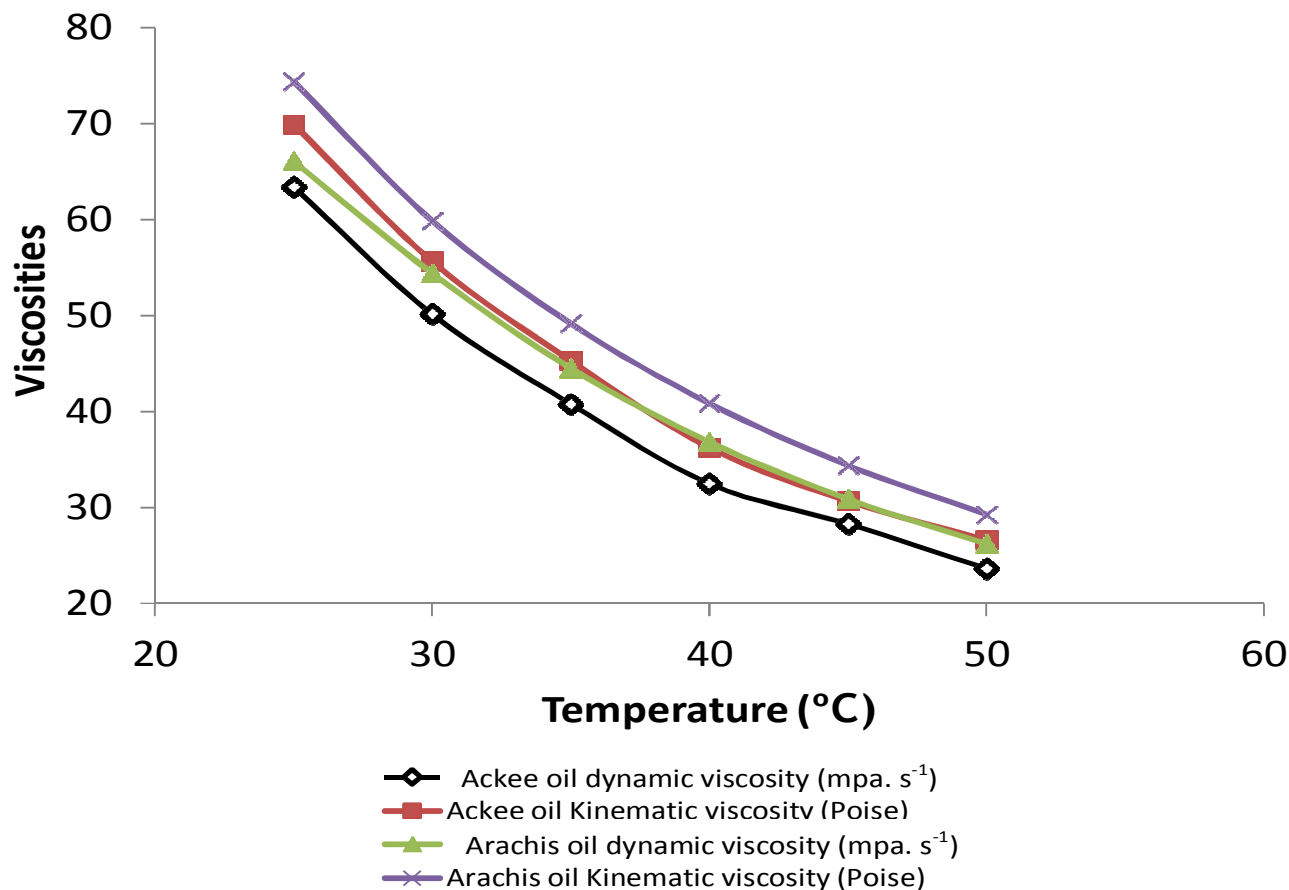


Figure 3. Dynamic and kinematic viscosities of ackee and arachis oils as a function of temperature.

Table 2. Parameters of the regression equation of viscosity and density on temperature.

Parameter	Ackee oil			Arachis oil		
	Slope	Intercept	R	Slope	Intercept	R
Kinematic viscosity (cSt)	-1.700	108.00	0.997	-1.715	112.07	0.987
Dynamic viscosity (mPa.s)	-1.558	98.21	0.977	-1.586	102.67	0.986
Density (g/cm <sup>3</sup> )	-0.008	0.928	0.990	-0.009	0.929	0.814

oil's acid value of 1.8 is intermediate between arachis oil ( $\leq 0.5$ ) and corn oil (2 – 6). On the other hand, the relative density and refractive index are comparable to those of other pharmaceutical lipids (Alexander, 2009; Shah and Thassu, 2009).

#### Acid value

Ackee oil has an acid value of approximately 1.8 (Table 1). Acid value is the number of grams of potassium hydroxide required to neutralize one gram of oil (BP, 2007). It is indicative of the quantity of fatty acids in the oil and may show evidence of rancidification.

#### Ester value

Table 1 presents the ester value of Ackee oil as 64.5 compared with 33.7 for arachis oil BP. The ester value obtained is consistent with difference in values of saponification between Ackee oil and arachis oil.

#### Hydroxyl value

Table 1 shows the hydroxyl value of Ackee oil to be 28.01 compared with arachis oil of 4.995. Hydroxyl value is the number of milligrams of potassium hydroxide required to neutralize the acid combined by acylation in one gram of

substance (BP, 2007). It is the number of milligrams of potassium hydroxide equivalent to the hydroxyl content of one gram of sample. Ackee oil has a hydroxyl value of 28 indicating that it has a high proportion of hydrolysable matter.

### Saponification value

The saponification value of Ackee oil is shown in Table 1. Its saponification value of 197 is slightly higher than those of corn oil and Arachis oil USP/NF respectively. This is indicative of higher fatty acid content and potential for application in soft soap manufacturing.

### DISCUSSION

Ackee oil is a naturally occurring mixture of lipids with glycerol backbone and fatty acid esters (R) on hydroxyl functional groups (R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> respectively). GC analysis indicates the presence of oleic acid in Ackee oil. In addition, other fatty acids are present in Ackee extracts including linoleic [CH<sub>3</sub>(CH<sub>2</sub>)<sub>4</sub>CH=CH-CH<sub>2</sub>-CH=CH(CH<sub>2</sub>)<sub>7</sub>COOH], palmitic [CH<sub>3</sub>(CH<sub>2</sub>)<sub>14</sub>COOH] and stearic [CH<sub>3</sub>(CH<sub>2</sub>)<sub>16</sub>COOH] with linoleic acid (elution time 30 min) accounting for 55% of the total fat. This observation is consistent with the available literature information (Ogutuga et al, 1992). Linoleic and  $\alpha$ -linolenic acids are poly-unsaturated fatty acids (PUFAs) classified as essential fatty acids (EFA) because they are principally derived from vegetable oils and seeds in the diets as human system lacks the enzyme to synthesize them (Mason, 2004; Evans, 2005). Rancidification appears to be a feature of most pharmaceutical oils and fats (Alexander, 2009; Alexander and Milallos, 2009; Cable, 2009; Kibbe, 2009; Sha and Thassu, 2009). In line with the recommended storage conditions for most pharmaceutical oils and fats, it is necessary that Ackee oil be packaged in airtight, light resistant containers and stored in a cool, dry place. The container should be fully filled, while incompletely filled containers should be flushed with nitrogen. In addition, antioxidants such as esters of gallic acid and  $\alpha$ -tocopherol, may be added to retard rancidification by autoxidation.

Repeated analysis of several batches of oil indicated that GC analysis could be used in both qualitative identification and quantitation of the oil in sample extracts. Although there were several peaks each indicative of different types of fatty acids and other minor constituents, the sharp clean peaks are indicative of absence of interfering substances and the GC analysis could serve as fingerprint for the quality assessment of the oil. By running standard PUFAs acids with successive Ackee oil samples from different batches, it was possible to establish qualitative (elution time) and quantitative (peak areas) standard limits for routine QC of the Ackee

oil extraction processes.

The freezing or melting point of a pure substance is the temperature at which the solid and liquid states exist in equilibrium at 1 atm (Knipp et al., 2006). The BP also considers the freezing point of a liquid substance as the point at which the liquid begins to solidify (cloud point), not necessarily when it becomes complete solid, but considers the melting point to be the point at which all the solid matters in the solid liquefy. The chemical nature of the oil such as degree of bond saturation affects the melting and freezing points of the oil. The parameter can be used to assess the purity of a substance (Speight, 2006), since products contaminated with a foreign matter will deviate from the standard melting point and freezing points established for the substance. Additionally, they are important since changing from one state to another may affect the stability of emulsions in which the oils are used as base, thereby causing creaming or cracking. Also, as oils approach their freezing points their viscosity increased and this is an important factor when handling or formulating products that contain oils (Speight, 2006). Ackee oil is lighter than sesame oil (0.916 to 0.920 g/cm<sup>3</sup>), canola oil (0.913 to 0.917 g/cm<sup>3</sup>), corn oil (0.915 to 0.918 g/cm<sup>3</sup>) and cottonseed oil (0.916 g/cm<sup>3</sup>) and, like most oils, is lighter than water (1.0001 g/cm<sup>3</sup> at 20 °C). The specific gravity of a substance is indicative of its comparative miscibility (BP 2007) with water and other oils. In emulsion stability, it could serve a useful guide in the choice of formulation components that would retard creaming, cracking or phase separation.

The density of the component phases of an emulsion can contribute significantly to its physical stability and potentials for creaming or cracking. As shown by the Stokes equation, the rate of creaming, that is, separation of globules from dispersion medium is related to the difference in density of the dispersed ( $\rho_1$ ) and continuous phases ( $\rho_2$ ), and the viscosity of the continuous phase ( $\eta$ ) according to the equation (7):

$$v = \frac{2r^2(\rho_1 - \rho_2)}{9\eta} \quad (7)$$

where  $v$  is the terminal velocity of creaming (cm/s),  $r$  is the radius of the globules (cm),  $\rho_1$  and  $\rho_2$  are the densities (g/cm<sup>3</sup>) of the dispersed phase and the dispersion medium respectively,  $g$  is the acceleration due to gravity (980.7 cm/s<sup>2</sup>), and  $\eta$  is the Newtonian viscosity of the dispersion medium in poise (g.cm<sup>-1</sup>.s<sup>-1</sup>).

The viscosity of mixtures of solvents is an additive property defined by the equation:

$$\frac{1}{\eta} = \frac{1}{\eta} v_1 + \frac{1}{\eta} v_2 \quad (8)$$

where  $\eta$  is the viscosity of the solution,  $v_1$  and  $v_2$  are the



**Table 3** Parameters of the regression equation of viscosity and density on temperature.

Parameter	Ackee oil			Arachis oil		
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volume fractions of the pure liquids (Allen et al., 2005). Therefore, the overall viscosity of a formulation of oil-in-water or water-in-oil would be determined by the volume fraction of the oil phase in the mixture. For instance, Jayakrishnan et al. (1983) observed that the kinematic viscosity of a micro-emulsion formulation increased steadily with an increase in the water-to-oil phase volume ratio. This is consistent with literature observations that viscosity tends to increase with increase in volume fraction of the dispersed phase, which, in most cases, is the more viscous phase. Above certain fraction, phase inversion would occur in order to sustain the thermodynamic stability of the system (Jayakrishnan et al., 1983; Billany, 2007).

Dynamic viscosity ( $\eta$ ) of a substance is the constant of proportionality that links the rate of flow ( $\frac{\delta v}{\delta r}$ ) of the substance to the stress ( $\sigma$ ) applied to produce the flow according to the expression (Marriott, 2007):

$$\sigma = \eta \frac{\delta v}{\delta r} \quad (9)$$

Substances that obey this relationship are referred to as Newtonian while those that deviate from it are said to be non-Newtonian (Marriot, 2007; Allen et al, 2005). As shown in Table 3, the intrinsic viscosity, represented by the intercept on the viscosity axis of the viscosity versus temperature plot, is higher for arachis than for Ackee oil ( $p < 0.05$ ). However, the sensitivity of both the dynamic and kinematic viscosities of the oils to change in temperature are not significantly different ( $p > 0.05$ ). In addition, the two oils show no significant difference in sensitivity of their densities to temperature change. The dynamic and kinematic viscosity of a fluid are affected by temperature, since most liquids flow more freely at higher temperatures where the molecules are more energetic and the intermolecular bonds are much weaker.

Ackee oil is optically active. Optical activity refers to the interaction of plane polarized light with the electrons within a molecule to produce electronic polarization (Knipp et al., 2006). Polarimeter measures the extent to which a substance interacts with the plane polarized light, rotating it to the left or right. A substance that rotates plane polarized light to the left or right is optically active. Considering optical activity as a kind of birefringence,

linear polarization of light can be resolved as an equal combination of right-hand (R) and left-hand (L) circularly polarized light according to Equation (10):

$$E_o^\theta = E_R^\theta + e^{i2\theta} E_L^\theta \quad (10)$$

where E is the electric field of the light. In an optically active material, the two circular polarizations experience different refractive indices and the difference gives the strength of the optical activity according to Equation (11)

$$\Delta n = \Delta n_R - \Delta n_L \quad (11)$$

This difference is a characteristic of the material and, for substances in solution, expressed as the specific rotation. All molecules have optical activity in the presence of a magnetic field and knowledge of a specific rotation of a substance can be applied in the determination of its purity using the measured optical rotation at a fixed wavelength in a polarimeter.

In addition, optical rotation ( $\alpha$ ) depends on the density of an optically active substance because each molecule contributes an equal but small part to the rotation. The specific rotation ( $\alpha_\lambda^t$ ) at a specific temperature ( $t$ ) and wavelength ( $\lambda$ , usually the D line of sodium), is characteristic for a pure optically active substance, and is given by Equation 12:

$$\alpha_\lambda^t = \frac{\alpha v}{lg} \quad (12)$$

where,  $l$  is the length (dm) of light path through the sample,  $g$  is the number of grams of optically active substance in a known volume ( $v$ ) of sample (Knipp et al., 2006). The principle of polarimetry is based on the chiral arrangement of the atoms in the substance and since no two substances have exactly the same arrangement of atoms, the optical rotation is unique for each substance and therefore is a useful tool for checking its identity and purity.

Generally, entries in the Handbook of Pharmaceutical Excipients (HPE) on parameters for pharmaceutical lipids vary widely and appear to be related to the source of the material and the intended applications. Vegetable oils comprise a variety of glycerides with various arrangements

of fatty acids: it is this arrangement that determines various properties of these fats and oils. For example, most vegetable oils such as Ackee oil are liquid at room temperature and this is attributable to the degree of unsaturation of the fatty acids present (Perona and Ruiz-Gutierrez, 2004). Oils with high content of saturated fatty acids such as myristic, lauric, stearic, and palmitic acids are generally solid at ordinary temperatures while those high in unsaturated fatty acids such as oleic, linolic and linoleic acids are generally liquid at ordinary temperatures (Alsberg and Taylor, 1992). According to Alsberg and Taylor (1992), the arrangement of fatty acids within a particular plant may vary slightly from plant to plant or even from fruit to kernel of the same plant. This, in turn, may result in slightly different chemical and physical properties of the oils. In addition, Mitchell et al. (2008) noted that the propagation of ackee plant is most successful from seeds however this method produces slight variability in the nature of fruits. Therefore, to maintain the quality of oils, the source should be carefully controlled. In addition, since the fatty acid components of a fat can significantly impact its physical properties and potential application, analysis of fats to determine the type and relative abundance of its acid content would provide a useful guide in their selection for different applications.

Acid value of the ackee oil is much higher than that of *Arachis* but much lower than corn oil (Alexander, 2009). Oleic acid, the principal fatty acid in Ackee oil, may be responsible for the relatively high acid value. Since corn oil of acid value 2 to 6 is used in pharmaceutical formulations as solvent for intramuscular injections, oral nutritional supplement (at up to 67%) and vehicle for veterinary vaccines (Alexander, 2009), Ackee oil of much lower acid value should be applicable in similar formulations provided all other formulation variables are satisfied.

The difference between saponification value and acid value is related to the ester value (BP, 2007). However, in all oils, which contain aldehydes, the ester determination by saponification cannot be made because some amount of alkali is used up due to the decomposition of the aldehyde. Although this decomposition increases with the duration of the reaction, it gives no information as to the amount of aldehyde decomposed. It may therefore lead to an overestimation of the saponification value. Hence, caution must be exercised in the application of this parameter in the selection of oil for formulation work. Although data produced with the instrumental methods tend to be more reliable, there are still many of the parameters for which no satisfactory instrumental techniques are currently available.

The high fatty acid content of Ackee oil may be an indication of its instability at room temperature, probably a function of autoxidation, and may limit the application of the oil in parenteral preparations. On the other hand, saponification value is of significance to the soap industry since the higher the value of an oil/fat free from moisture

and unsaponifiable matter, the more soluble the soap that would be produced (Alsberg and Taylor, 1992). Coconut oil and lard, two popular ingredients of soap formulae, have saponification values of 250 to 264 and 192 to 198 respectively (Evans, 2005).

## Conclusion

Ackee arils produced an average yield of  $37.0 \pm 4.9\%$  on dry weight basis. This is consistent with the literature and indicates a much higher yield than has been reported for well known seed oils such as sunflower (35%), safflower (30%), olive (30%), soybean (20%), cotton seed (15%) and corn (3.0 to 6.5% in the whole kernel). The purified oil is a clear, viscous liquid, with a bright yellow colour and a scent characteristic of roasted ackee. The study compiled a number of parameters similar to those documented in the monograph of related substances in pharmaceutical references. The differences in physico-chemical properties of Ackee oil suggest some potential for its application in areas where arachis and some other vegetable oils have shown some deficiencies. For instance, its high saponification value may suggest suitability for self-emulsification process while the high acid value may imply suitability as a base in formulation of drugs of low pH values.

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