Physicochemical Properties Yield and Fatty Acid Profile of Allanblackia (*Allanblackia floribunda*), African Walnut (*Tetracarpidium conophorum*) and Fluted Pumpkin (*Telfairia occidentalis*) Seed Oils as Suitable Raw Materials for Table Margarine and Bakery Shortening Production

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Abstract

The objective of this work was to extract and characterize vegetable oils from Allanblackia, African walnut and fluted pumpkin seeds, as suitable raw materials in table-margarine and bakery shortening production. Oils were extracted using solvent (ethanol and hexane) and hot water floatation methods. Using hexane, higher yield of 62.19, 55.04 and 53.94 % were recorded respectively for Allanblackia, African walnut and fluted pumpkin seeds. Melting point and density were respectively 35.43 ^{0}C and 0.9145 g/ml, 17.13 ^{0}C and 0.9107 g/ml, 18.33 ^{0}C and 0.9166 g/ml for Allanblackia, African walnut and fluted pumpkin seed oils. Refractive index (1.4750) of African walnut oil was significantly higher ($p<0.05$) than those of Allanblackia and fluted pumpkin seed oils. Fluted pumpkin seed oil showed wider plasticity with solid fat content of 44.96 to 0.99 % at 5 to 50 ^{0}C. Iodine value, free fatty acid and saponification value ranged from 40.27 to 128.69 g/100g, 0.17 to 0.58 % and 152.03 to 199.98 mgKOH/g respectively. Iodine value of African walnut and fluted pumpkin seed oils were significantly ($p<0.05$) higher than that of Allanblackia seed oil. African walnut oil contained 15.44 % omega-3 fatty acid. Use of Allanblackia, African walnut and fluted pumpkin seed oils in wide range of domestic and industrial applications, for cooking and food product development is highly recommended, based on their high content of polyunsaturated fatty acids (omega-6 and omega-3) which have cholesterol lowering properties.

Keywords: *Allanblackia, African walnut, fluted pumpkin, Physicochemical, Fatty Acid Profile, Shortening*

Main Text Introduction

The predominant source of fat and oil for commercial bakery fat and margarine production in Nigeria is from Palm stearin and palm kernel oil. The vegetable oil is extracted, refined, fractionated, and hydrogenated to produce saturated fats, which are further blended with approved additives, to enhance texture, consistency and stability (Chibor *et al.*, 2017). The quest to minimizing trans-fats in fat-based products such as margarine and bakery shortenings has focused attention on sourcing vegetable oil with high melting properties, as solid base in place of hydrogenated fats (O'Brien, 2009). Allanblackia seed contains a stable fat at room temperature (28±2^{0}C), with slip melting point above 33^{0}C (Akusu and Wordu, 2019). The incorporation of Allanblackia seed oil by the Dutch group Unilever as a natural component for use in the manufacture of shortenings, margarine and spreads has added great value to this indigenous crop of Africa. The oil has received the approval of the European Union (EU) Novel Food Regulations that certify its safe usage in food products (Hermann, 2009), clearing an important bottleneck to high future demand in EU markets (Jamnadass *et al*., 2010).

Allanblackia floribunda, known in English as 'tallow tree' is a specie of flowering plant in the Clusiacease family mainly found in the rainforest belt of Western and Eastern Africa, has long been used in traditional African medicine, with high nutritive and economic values (Bilanda *et al*., 2010). In Nigeria, Allanblackia floribunda grows as an indigenous wild tree species and thrives well in the Niger–Delta region of Edo, Bayelsa, Akwa Ibom, Rivers State (one season) and Cross Rivers States (two seasons). The tree bears large brown fruits that contain seeds rich in edible vegetable oil (60-67 %) with a neutral odour and taste (Sefah *et al*., 2010). Allanblackia seed oil contains a hard fat consisting mostly of stearic and oleic acids which makes it extremely stable for use as lip balm, soaps, body butters and shortenings. The unusual fatty acid composition of Allanblackia floribunda gives a sharp melting point around 34-35 degrees Celsius. This means that the fat remains solid and stable at room temperature, but melts in the mouth which is exactly what is required of fat–based spread like margarine or shortenings used in baking.

Other oil seeds that have great potential for industrial use and whose values have not been maximally exploited in Nigeria are the low melting oils extracted from the seeds of fluted pumpkin (*Telfairia occidentalis*) and African walnut (*Tetracarpidium conophorum*). They are needed to provide wide plasticity and spreadability in blends. With a melting point of 18.5 ^{0}C (Eddy *et al*. 2011) and about 66% polyunsaturated fatty acid content (Bello et al. 2011) fluted pumpkin seed oil in the blend is expected to improve functionalities, nutrition and health value of the shortening. Fluted Pumpkin, a tropical cucurbit (Giami and Bekebain, 1992) is grown in Nigeria as a source of leafy vegetable, and for its oil bearing seeds. Common names for this plant in Nigeria include 'ugu', and fluted gourd. *Telfairia occidentalis* grows in many countries of West Africa, but cultivated mainly in Nigeria where it is used primarily in soups and herbal medicines. It is said to be indigenous to southern Nigeria (Akorada, 1990). The fruit pulp is not edible, but the seeds are rich in fat and protein, and can therefore be used in nutrient fortification, to enhance a well-balanced diet. Giami *et al*. (1999) reported that fluted pumpkin seeds contained 54% fat. Aiyelaagbe and Kintomo (2002) also reported high fat content of 53%. The non-defatted fluted pumpkin flour has the potential for use as a functional agent in many formulated foods (Giami and Barber, 2004).

African walnut contains 55 to 70% edible oil, with about 54% omega 6 and 14% omega 3 fatty acids (Cindric *et al*., 2018). The benefits of walnuts on cholesterol in human diet have been proven (Jehangir et al. 2010). It is proved that a balanced consumption of walnuts reduces cholesterol or low-density lipoprotein levels to about 16 percent in men (Jehangir *et al*., 2010). Walnut is rich in two unsaturated fatty acids with polyunsaturated bonds including linoleic acid and linolenic acid (Dogan and Akgui, 2005). Blending of Allanblackia seed fat, which is stable at room temperature with African walnut and fluted pumpkin seed oils, rich in essential polyunsaturated fatty acids will produce margarine and bakery shortenings with improved functional properties, and enhanced nutrition and health values.

Bakery shortenings and margarines are tailored fat systems whose functional and nutritional properties have been modified so as to deliver desired consumer needs. In margarine and bakery shortening, the functional characteristics of natural fat systems have been manipulated so as to provide the needed consistency and storage stability in the end product. By these modification processes, bakery fats and margarine offer special functional utility to confectionery, baking and culinary applications (Ghotra *et al.*, 2002). Shortening or bakery margarine is one of the basic food ingredients, having wild applications in cookies, pastry, bread, cakes and icing, and for filler purposes. As such, it has to satisfy a host of functional, nutritional, physical and health requirements (Ghotra *et al.*, 2002). Considering the potentials and acceptance of this modified fat system in the food process industry, it becomes absolutely necessary to select ingredients that will deliver desired functionalities with zero harmful consequences. Thus, the need to discourage the use of potentially harmful hydrogenated fats which are associated with cardiovascular disorders, while those health-enhancing triacylglycerols such as oleic acid and other essential polyunsaturated fatty acids are included (Ghotra *et al.*, 2002). The objective of this study was to determine the yield, physicochemical properties and fatty acid profile of Allanblackia, African walnut and fluted pumpkin seed oils, as suitable blend in table-margarine and bakery shortening production.

2.0 Material and Methods

2.1 Materials

Mature fruits of Allanblackia floribunda were obtained from the Rivers State Allanblackia Project farm, Mgbu-Azuogu in Oyigbo Local Government Area of Rivers State, Nigeria. Fresh fruits were stored in a covered bag for five days to allow the fruit pulp to disintegrate and enhance seed extraction. Seeds were cleaned and, sundried to 10% moisture content before storing in an airtight polythene bag for further analysis. Freshly harvested fluted pumpkin fruits were procured from Bori market in Rivers State, Nigeria. Mature and good quality African Walnut seeds were procured from Oil mill market in Port Harcourt, Rivers State, Nigeria.

2.2 Oil Extraction and Yield

2.2.1 Oil extraction (hot water flotation method)

Allanblackia, African walnut and fluted pumpkin seeds were dehulled and cleaned separately, then oven dried at 60^0C for 24h (Giami *et al.*, 1999) in a hot air oven (model QUB 305010G, Gallenkamp, UK), milled using a laboratory mill (model MXAC2105, Panasonic, Japan). Oil extraction was done using hot water floatation method as described by Rosenthal *et al.* (1996), with slight modification. Here, the milled seeds were made into paste by adding warm and cold water intermittently. The paste was placed in boiling water and allowed to boil for 6 hours. Oil floated to the surface and kept standing overnight in the refrigerator. This allowed the oil to crystallize out, making it easier to be skimmed from the mixture and washed after which the oil was heated to 100 ^{0}C to remove any trace of moisture before storing in airtight plastic containers.

2.2.2 Oil extraction (solvent extraction)

The Ether extract method of AOAC (2012) was used to determine the percentage lipid in the Allanblackia, African Walnut and fluted pumpkin seeds. Fat was extracted using the micro Soxhlet extraction equipment. Flour samples (0.5g) was weighed into an extraction thimble, placed in a Soxhlet extractor and fat extracted with 200ml each of hexane and ethanol (separately) for six hours using a reflux condenser (boiling point 60 to 80 ^{0}C). The solvent was evaporated by heating the receiving flask at 80^{o}C on a hot plate and the extract dried, cooled and weighed.

Calculation:

$$\text{Oil Yield (\%)} = \frac{\text{weight of extract (g)} \times 100}{\text{weight of sample (g)}} \quad (1)$$

2.3 Physicochemical Properties

Physicochemical properties including; density, Refractive index, melting point, cloud point, smoke point, colour, Iodine value, free fatty acid, saponification value, peroxide values, unsaponifiable matter ester values were determined by the method of AOAC (2012). Viscosity measurement (in centistokes, cSt) was performed using an Ubbelohde glass capillary viscometer (size 2. A149, Cannon instrument, PA, USA) (ASTM D445 2009).

2.4 Fatty Acid Profile

The individual fatty acids in the fats were determined using Gas chromatography (GC) with flame ionization detector (FID), following AOAC (2012) standard procedures. To separate round bottom flasks (50ml capacity) were measured 50 mg each of the fat sample, 3 ml of methanolic sodium hydroxide solution (0.5mol/l solution of NaOH in methanol) was added. The reaction medium was refluxed for 10 min; 3 ml of Acetyl chloride then added; mixture was refluxed again for 10 minutes then cooled to ambient temperature; 8 ml Hexane and 10 ml of distilled water were added and allowed to stand for 5 min to establish a two-phase solution. The upper organic phase was recovered into a vial for Gas Chromatography (GC) analysis.

2.5 Solid Fat Content

The solid fat content was determined using the density method (Onwuka, 2018). The glass pycnometer was used to measure density at the following temperatures range: 5^{o}C to 50^{o}C, at an interval of 5^{o}C. Percentage SFC was calculated using the following equation:

$$\text{SFC (\%)} = \frac{\rho - \rho l}{\rho s - \rho l} \times \frac{100}{1} \quad (2)$$

ρ = density of fat at the desired temperature

ρl =density of fat when completely liquid.

ρs =density of fat when completely solid.

2.6 Statistical Analysis

All the analyses were carried out in triplicate. Data obtained were subjected to Analysis of variance (ANOVA), differences between means were evaluated using Tukey's multiple comparison test, and significance accepted at $p \leq 0.05$ level. The statistical package in Minitab 20 computer program was used.

3 Results and Discussion

3.1 Percentage oil yield

The percentage yield of edible vegetable oil extracted from Allanblackia, African walnut and fluted pumpkin seeds using hexane, ethanol and hot water, as extracting medium, is shown in Table 1. Significantly high ($p<0.05$) oil recovery was shown using hexane as solvent. Oil content of Allanblackia seed was significantly ($p<0.05$) higher. Higher oil content of 67.60 and 48.60 % had earlier been reported for Allanblackia seed, extracted with hexane and hot water, respectively (Balogun and Uku 2019). Akusu and Wordu (2019) also reported higher oil recovery of 65.30 %. Differences in oil recovery from Allanblackia seed and those of earlier researchers was probably due to seed source and varietal differences. The oil recovery from all the seeds studied were higher than 50 % when extracted with hexane (African walnut 55.045 %, fluted pumpkin seed oil 53.94 %). This showed that Allanblackia, African walnut and fluted pumpkin seeds are rich sources of vegetable oil and can be declared as oil seeds. Oil content of 53.94 %, identified in fluted pumpkin seed corroborated with 54.00 % oil content reported by Giami *et al*. (1999), but higher than 46.20 % reported by Okashi *et al*. (2013). Oil contents of walnut had earlier been reported to vary from 52 to 70 % depending on the cultivar, location and irrigation rate (Ozkan and Koyuncu, 2005).

Table 1: Percentage (%) Oil Yield of Allanblackia, African Walnut and Fluted Pumpkin Seeds

Sample	Hexane	Ethanol	Hot Water Floatation
Allanblackia Seed	$62.19^{a}\pm0.210$	$53.95^{a}\pm0.278$	$43.40^{a}\pm0.520$
African Walnut Seed	$55.04^{b}\pm0.542$	$49.84^{b}\pm0.165$	$34.73^{b}\pm0.238$
Fluted Pumpkin Seed	$53.94^{c}\pm0.125$	$44.51^{c}\pm0.423$	$32.00^{c}\pm0.140$

Values are mean ± standard deviation of triplicate samples.
Mean values bearing different superscripts in the same column differ significantly ($p<0.05$)

3.2 Physical Properties of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

Density of the vegetable oil samples ranged from 0.9107 to 0.9166 g/ml, with fluted pumpkin seed oil significantly ($p<0.05$) higher, followed by Allanblackia seed oil (Table 2). Density provides information on the solid content of the oil as well as its weight at a particular temperature (Aremu et al. 2015). It is the ratio of the weight of the oil to its volume (Rodenbush *et al*. 1999). Density of 0.9166 g/ml for fluted pumpkin seed oil was higher than 0.87g/ml and 0.83g/ml reported by Eddy et al. (2011), and Akubugwo *et al*. (2008). Density values as high as 0.943g/ml and 0.921g/ml had been reported for fluted pumpkin seed oil (Okashi *et al*., 2013; Agatemor 2006). Density of 0.9145 g/ml seen in Allanblackia seed oil agreed with 0.914 g/ml reported by Maduelosi et al. (2019), but higher than 0.889 g/ml reported by earlier researchers (Akusu and Wordu, 2019). The higher the density of a fat, the higher the presence of solid fats (Nazzaruddin, 2013), which enhance plasticity in margarine and shortenings. Low density seen in African walnut oil (0.9107 g/ml) showed that the oil is low in solid fats. This property enhances product spreadability and flow consistency. Lower density (0.873 g/ml) had been reported for African walnut oil (Folaranmi *et al*. 2016).

Significantly ($p<0.05$) higher Refractive index seen in African walnut oil was probably due to high content of polyunsaturated fatty acids. Refractive index had been shown to provide hint on oxidative damage in vegetable oils (Hoffman, 1986). Refractive index of fat had been reported to increase with increase in chain length of the fat, and with the number of unsaturated bonds present in the fat (Nielson, 1994). Saxena *et al*. (2009) also reported Refractive index of 1.477 for African walnut oil. There was no significant ($p>0.05$) difference in the Refractive index of Allanblackia and fluted pumpkin seed oils. Fluted pumpkin seed oil gave Refractive index of 1.4648, this value compared with 1.463 reported by Bwade *et al*. (2013) and higher than 1.462 and 1.461 reported by Eddy et al. (2011) and Muibat *et al*. (2011), respectively. Refractive Index depends on the degree of conjugation as well as the degree of unsaturation of the oil (Shahidi, 2005).

Higher melting point of Allanblackia seed oil (35.43 °C) at room temperature (28±2 °C) makes it suitable for use in bakery shortening and margarine production. Melting point of 35.43 °C agreed with slip melting point of 35.40 °C presented earlier by Akusu and Wordu (2019), but lower than 42.5 °C reported by Maduelosi et al. (2019), probably due to varietal differences. Fluted pumpkin seed oil and African walnut oil with slip melting points of 18.33 and 17.13 °C, respectively are liquid at room temperature. High cloud point of Allanblackia seed oil corroborated with 25 °C cloud point reported by Maduelosi *et al*. (2019). Higher cloud point indicates higher crystallization potential. Low Cloud point of 4.60 ^{0}C seen in African walnut oil showed that the oil could stay liquid with less crystals at a wide range of temperature. This property will enhance the consistency and spreadability of margarine, when used in supplementation.

Smoke point of fluted pumpkin seed oil was significantly ($p<0.05$) high. This was higher than 223 °C reported by earlier researchers (Ikya *et al*., 2013). followed by Allanblackia seed oil with smoke point of 220.23 °C. Relatively lower smoke point (190.07 °C) seen in African walnut seed oil was probably due to the presence of hydrocolloids and free fatty acids. Smoke point has a negative correlation with the percentage free fatty acid of the oil (Thomas 2002). Smoke point serves as an indicator to the temperature limit which oil can be used (Thomas, 2002). Lower smoke point of 219.85 ^{0}C and 210.0 °C were reported earlier by Akusu and Wordu (2019) and Maduelosi et al. (2019), for Allanblackia seed oil. The temperature at which oil gives off a steel bluish smoke when heated is termed smoke point (O'Brien, 2009).

High viscosity of Allanblackia seed oil at 40°C indicates that it contains more saturated fatty acids, and thus demonstrates more resistance to flow. This also indicates that it has more solid fats at 40 °C. This makes Allanblackia seed oil suitable as a source of stable solid fat for margarine and bakery shortening production. Viscosity of African walnut oil was lower at 40 °C, with value of 19.25 cSt, probably due to significant presence of low melting Triacylglycerol. Fluted pumpkin seed oil gave 23.94 cSt, which was significantly ($p<0.05$) lower than the viscosity of Allanblackia seed oil. Higher viscosity of 32.22 cP and 45 cSt had been reported for fluted pumpkin seed oil (Bello et al. 2012; Bwade *et al*. 2013). Differences in viscosity was probably due to oil extraction methods and differences in temperature of determination. The relatively low viscosity value of fluted pumpkin seed oil showed that the oil is light and probably highly unsaturated (Nangbes *et al*., 2013).

showed that the oils have bright colours and might not require further bleaching before use. Red shade of 2.5 had earlier been reported for Allanblackia seed oil (Akusu and Wordu, 2019). The intensity of red pigments (R) in all the oil samples were within the standard range of 5R – 20R (max) for crude vegetable oil (IS:8323 2014; MS:814 2007). Relatively higher red (5 and 6) shown in fluted pumpkin and African walnut seed oils indicated that the oils contained more monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). Monounsaturated and polyunsaturated fatty acids had been reported to play significant role in the colour of nut oils (Hasnul-Hadi *et al.*, 2021). Polyunsaturated fatty acid content of vegetable oils plays an essential role in human nutrition and health (El-Nagger, 2016).

Table 2 Physical Properties of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

parameters	Allanblackia seed oil	African walnut oil	Fluted pumpkin seed oil
Density (g/ml)	$0.9145^{b}\pm0.000$	$0.9107^{c}\pm0.001$	$0.9166^{a}\pm0.001$
Refractive Index	$1.4627^{b}\pm0.001$	$1.4750^{a}\pm0.005$	$1.4648^{b}\pm0.000$
Slip Melting Point (°C)	$35.43^{a}\pm0.058$	$17.13^{c}\pm0.058$	$18.33^{b}\pm0.115$
Cloud Point (°C)	$20.00^{a}\pm0.000$	$4.60^{c}\pm0.173$	$7.70^{b}\pm0.265$
Smoke Point (°C)	$220.23^{b}\pm0.153$	$190.07^{c}\pm0.115$	$242.47^{a}\pm0.115$
Viscosity (cSt)	$30.00^{a}\pm0.000$	$19.25^{c}\pm0.081$	$23.94^{b}\pm0.079$
Colour	2R, 20Y	6R,20Y	5R,20Y

Values are mean ± standard deviation of triplicate samples.
Mean values bearing different superscripts in the same row differ significantly ($p<0.05$)

3.3 Effect of Temperature on the Solid fat of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

Result in Fig 1 showed the effect of temperature change on the percentage solid fat of Allanblackia, African walnut and fluted pumpkin seed oils. The percentage solid fat of Allanblackia seed oil was significantly ($p<0.005$) high at 5 °C (99.18 %), but dropped to 5.01 % at 35 °C. The solid fat content of African walnut and fluted pumpkin seed oils dropped steadily with increase in temperature from 99.18 to 65.02 % at 5 to 30 °C and shapely dropped to 5.01 % at 35 °C giving a steep curve. Steep curve of percentage solid fat seen in Allanblackia seed oil, due to temperature changes corroborated with earlier report by Naeli *et al.* (2018) for palm stearin. High solid fat content at 30 °C will provide the needed solid base desired in shortening. The steady sloppy curve of solid fat seen in fluted pumpkin seed oil corroborated with earlier reported by Naeli *et al.* (2018) for soybean oil. The steady sloppy plastic behaviour of fluted pumpkin seed oil will enhance the desired plasticity of shortening when used in blend with high solid Allanblackia seed fats. Shape of the curve of SFC is a function of temperature and showed the expected melting profile of the final product (Kodali, 2005). Low solid fat oil in the blend will enhance the spreadability and consistency of shortenings and margarine.

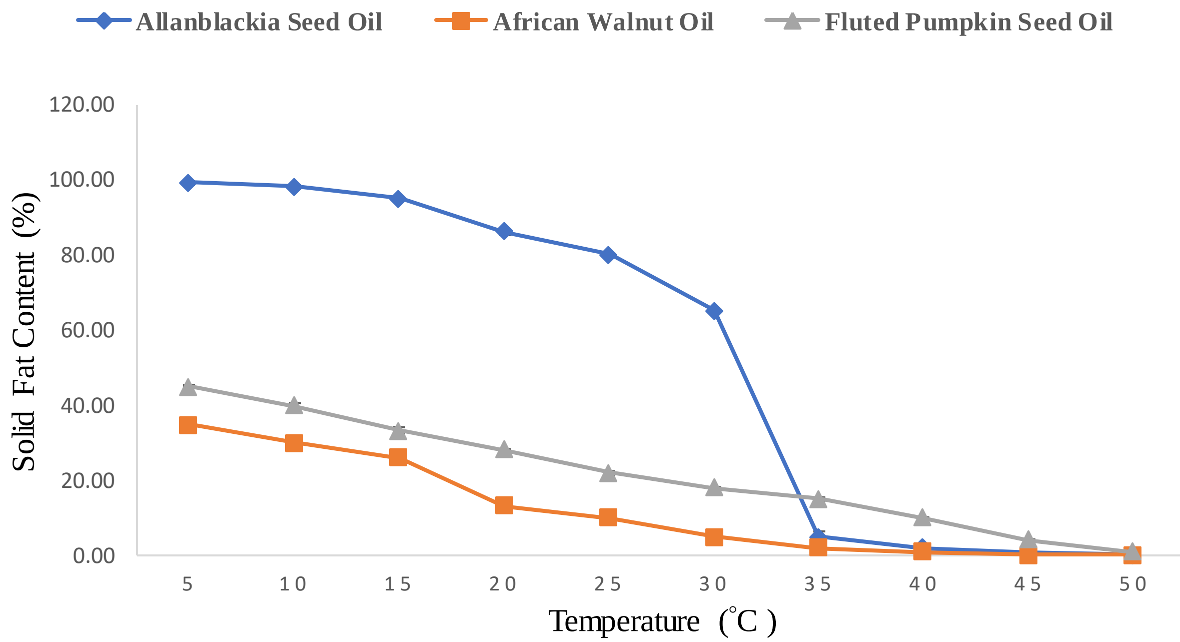

Figure 1: Effect of Temperature on the Solid fat of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

3.4 Chemical Properties of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

The iodine value, percentage free fatty acids, peroxide value, saponification value, unsaponifiable matter, ester value and moisture content of Allanblackia, African walnut and fluted pumpkin seed oils are presented in Table 3. The low iodine value of Allanblackia seed oil (40.27 g/100g) is an indication that the oil is rich in saturated fatty acids (Aremu *et al*., 2006). which acts as a good source of solid fat for shortening and margarine production. High iodine value of 128.69 g/100g and 121.67 g/100g seen respectively in African walnut and fluted pumpkin seed oil indicates that the oil is rich in polyunsaturated fatty acids, which enhances the nutritional value of the bakery shortening, and food products in which they are used. Iodine value is a simple chemical constant used to measure the degree of unsaturation or the average number of double bonds in an oil sample. It is the number of grams of iodine that could be used to halogenate 100 g of oil (Shahidi, 2005). Iodine value of fluted pumpkin seed oil in this work compared with 123.83g/100g reported earlier by Nwabanne (2012), but higher than 104.7 g/100g reported by Okashi *et al*. (2013).
Percentage free fatty acid of Allanblackia, African walnut and fluted pumpkin seed oils were significantly ($p<0.05$) different. Free fatty acids of all the oil samples were within the recommended standard of ≤ 2.00% for virgin oils (CODEX 1999; NIS:289 1992). The amount of free acids presents in a given amount of fat gives an indication of the extent of oxidation of fats and the degree of hydrolysis by lipolytic enzymes (Gordon 1993). Free fatty acids are formed from the hydrolysis of an ester by lipase or moisture (Choe and Min 2006). According to Raghavendra and Raghavarao (2010), hydrolytic rancidity could be due to hydrolysis of

triglycerides of fats and oils by enzymes resulting in an increase in free fatty acid of the fats and oil. Percentage free fatty acid of fluted pumpkin seed oil (0.58 %) seen in this work was higher than 0.38 % reported by Eddy *et al.* (2011), but lower than 1.74 %, and 1.74 % reported by Bello *et al.* (2011), and Muibat et al. (2011), respectively. Percentage free fatty acid of 0. 55 in African walnut oil agreed with 0.56 % reported earlier by Yangomodou *et al.* (2020) but lower than 0.71 % presented by Oloko (2019). Differences in percentage free fatty acid was probably due to differences in freshness of seeds and mode of analysis. The suitability of fluted pumpkin seed oil, African walnut and Allanblackia seed oil for margarine and bakery fat production, and other food product formulations is greatly enhanced by the low free fatty acid value. With low free fatty acid, the cost and energy required for refining and modifications will be drastically reduced. The oil samples need some level of refining to further reduce the free fatty acid to ≤0.25%, which is the standard value of free fatty acid for refined vegetable oil (IS:8323 2014; CODEX 1999). Significantly low free fatty acid of 0.17% seen in Allanblackia seed oil is an indication that it is chemically safe for use and need no further refining.

There was no significant difference ($p>0.05$) in the Peroxide value of African walnut and fluted pumpkin seed oils. Peroxide value gives an indication of the degree of oil oxidization (Okashi *et al.*, 2013). Oxidation of an unsaturated oil takes place through the formation of hydroperoxides. The hydroperoxides being the primary products of oxidation. Peroxide value of the oil samples were lower than 10.00 mEq/kg and 3.00 mEq/kg recommended maximum for virgin and refined vegetable oil, respectively (CODEX 1999; NIS:289 1992).

Saponification value of Allanblackia seed oil was significantly ($p<0.05$) higher (199.98 mgKOH/g). The saponification value of fluted pumpkin seed oil corroborated with 179.04 mgKOH/g reported earlier by Muibat *et al.* (2011), and Bello *et al.* (2011). Lower saponification value of 158.40 and 154.40 mgKOH/g had also been reported (Akubugwo *et al.*, 2008; Okashi *et al.*, 2013). Saponification value is a measure of the alkali-groups in fats and oil and is defined as the mg KOH needed to saponify 1g of oil (Shahidi 2005). It is a measure of all the saponifiable fatty acids (including the esters) present in oil (Aremu *et al.*, 2015). A higher saponification value of 183.44mgKOH/g was reported earlier by Agatemor (2006). Saponification value of 199.98 mgKOH/g for Allanblackia seed oil compared favourably with 199.67 and 198 mgKOH/g reported by earlier researchers (Akusu and Wordu 2019; Maduelosi *et al.*, 2019). Saponification value of the African walnut oil was significantly low (152.03 mgKOH/g). It was also lower than 189.88 and 308 mgKOH/g reported by Oloko (2019) and Folaranmi *et al.* (2016). Disparity in result was probably due to seed varietal differences and high acid value of oil. Relatively low saponification value noticed in these oil samples is an indication of the presence of long chain triacylglyceride. Saponification value is an indication of the molecular weight and the percentage concentration of fatty acids components presents in oil (Jan et al. 2010). Saponification value is a measure of the content of ester linkages (Wypych, 2017). It is an indicator for fat/oil suitability for industrial use. High saponification value is suitable for soaps and shampoo, pharmaceutical, and food processing (Aremu et al. 2015), low saponification value is also suitable for food processing.

Result for Saponification value compared with the range 0.2 to 0.8% reported for groundnut, and 0.5% reported for soybean by Hamilton and Rossel (1986). The Unsaponifiable fraction comprises only a small part of Allanblackia, African walnut and fluted pumpkin seed oils compared to their triglyceride fraction. Unsaponifiable matter shows the presence of desirable bioactive components such as antimicrobial, antioxidants, and anti-inflammatory substances, including the fat-soluble vitamins (Nahm 2011).

Ester value of fluted pumpkin seed oil was 178.42 mgKOH/g, this corroborated with ester value of 175.56mgKOH/g reported by Muibat *et al.* (2011), and higher than 171.65mgKOH/g reported by Bwade *et al.* (2013) for the same oil. The high ester value of Allanblackia seed and fluted pumpkin seed oil is an indication that the oils have good flavour suitable for culinary purposes. The ester value of a fat is determined by the saponification value and the acid value. It is an indication of the saponifiable fatty acids excluding the free acids of the fat (Aremu *et al.* 2015).
Moisture content of the oils ranged from 0.012 to 0.09 %. These values were within the recommended moisture level of < 0.20%, which is the maximum allowable moisture content for refined vegetable oil (CODEX-STAN-192, 2009). Low moisture content of oil enhances oxidative stability.

Table 3 Chemical Properties of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

Parameters	**Allanblackia seed oil**	**African walnut oil**	**Fluted pumpkin seed oil**
Iodine Value (g/100g)	$40.27^{c}\pm0.029$	$128.69^{a}\pm0.150$	$121.67^{b}\pm0.181$
Free Fatty Acids (%)	$0.17^{c}\pm0.000$	$0.55^{b}\pm0.006$	$0.58^{a}\pm0.006$
Peroxide Value (mEq/kg)	$0.58^{b}\pm0.000$	$1.22^{a}\pm0.021$	$1.19^{a}\pm0.012$
Saponification Value (mgKOH/g)	$199.98^{a}\pm0.136$	$152.03^{c}\pm0.064$	$179.59^{b}\pm0.401$
Unsaponifiable Matter (%)	$0.64^{a}\pm0.006$ (%)	$0.25^{c}\pm0.030$	$0.55^{b}\pm0.012$
Ester Value (mgKOH/g)	$199.65^{a}\pm0.136$	$150.93^{c}\pm0.069$	$178.42^{b}\pm0.401$
Moisture (%)	$0.09^{a}\pm0.015$	$0.07^{a}\pm0.012$	$0.08^{a}\pm0.006$

Values are mean ± standard deviation of triplicate samples.
Mean values bearing different superscripts in the same row differ significantly ($p<0.05$)

3.5 Fatty Acid Profile of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

The percentage fatty acid content of Allanblackia, African walnut and fluted pumpkin seed oils is presented in Table 4 and the chromatograms in Figs 2, 3 and 4. Total saturated fatty acid content of Allanblackia seed oil was 57.5%, predominantly of the very-long-chain specie. This accounts for its high melting point. High content of stearic (61 %) and oleic acids (36 %) had been reported for Allanblackia seed oil by earlier researchers (Loumouamou et al. 2014). High molecular weight TAG is associated with formation of HDL (high density lipoprotein) which is known to be heart friendly and reduces cardiovascular complications (Nicholls and Nelson, 2019). Kanu *et al.* (2015) reported 80 % of polyunsaturated fat in African walnut, with proven cholesterol lowering properties. Chauhan and Chauhan (2020) reported that walnut extracts which are rich in dietary omega-3-fatty acids play a role in the prevention of some disorders including depression as well as dementia. The beauty of fluted pumpkin seed oil is the omega-6 (polyunsaturated) fatty acid content. Bello et al. (2011) also reported high linoleic acid content (64.4%) in fluted pumpkin seed oil. The linoleic acid content of fluted pumpkin seed oil was observed to be higher than that earlier reported for other vegetable oil noted for high linoleic acid content, such as maize (58.5%), and soybean oil (54.3%). African walnut and fluted pumpkin seed oils are rich sources of essential fatty acids owing to their high content of polyunsaturated fatty acids (omega-6 and omega-3), with great potentials to enhance the nutritional value of food products. Alpha linolenic acids (ALA omega-3) was reported to lower insulin resistance, aid neural and brain development and support maintenance of heart and eye health (Ndife, 2016).

Table 4: Fatty Acid Profile of Allanblackia, African Walnut and Fluted Pumpkin Seed Oils

	Oil Samples		
Fatty Acids (%)	**Allanblackia seed oil**	**African walnut oil**	**Fluted pumpkin seed oil**
C14:0 (Myristic)			0.31
C16:0 (Palmitic)	1.77	5.20	17.06
C16:1 (Palmitoleic)	0.25	0.22	4.14
C18:0 (Stearic)	28.01	1.94	0.78
C18:1 (Oleic)	37.70	18.49	13.81
C18:2 (Linoleic)	0.15	55.19	61.75
C18:3 (Linolenic)	1.37	15.44	
C20:0 (Arachidic)	23.49	0.01	0.20
C20:1 (Eicosenoic)	0.23	0.07	1.95
C20:2 (Eicosadienioc)	0.28		
C20:3 (Eicosatrienioc)	0.59		
C20:4 (Arachidonic))	0.60		
C22:0 (Behenic)		0.04	
C22:1 (Erucic)	1.33	0.03	
C24:0 (Ignoceric)	4.23	3.37	
Total Saturated	**57.5**	**10.56**	**18.35**
Total Unsaturated	**42.5**	**89.44**	**81.65**
Omega-9	**39.51**	**18.81**	**19.90**
Omega-6	**1.03**	**55.19**	**61.75**
Omega-3	**1.96**	**15.44**	**0**

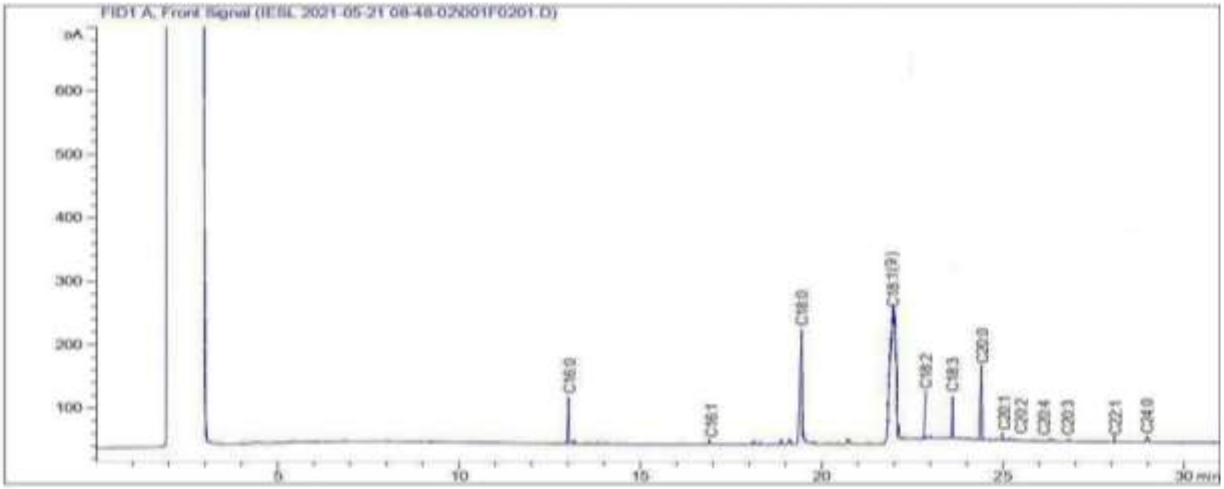

Figure 2: Fatty Acid Chromatogram of Allanblackia Seed Oil

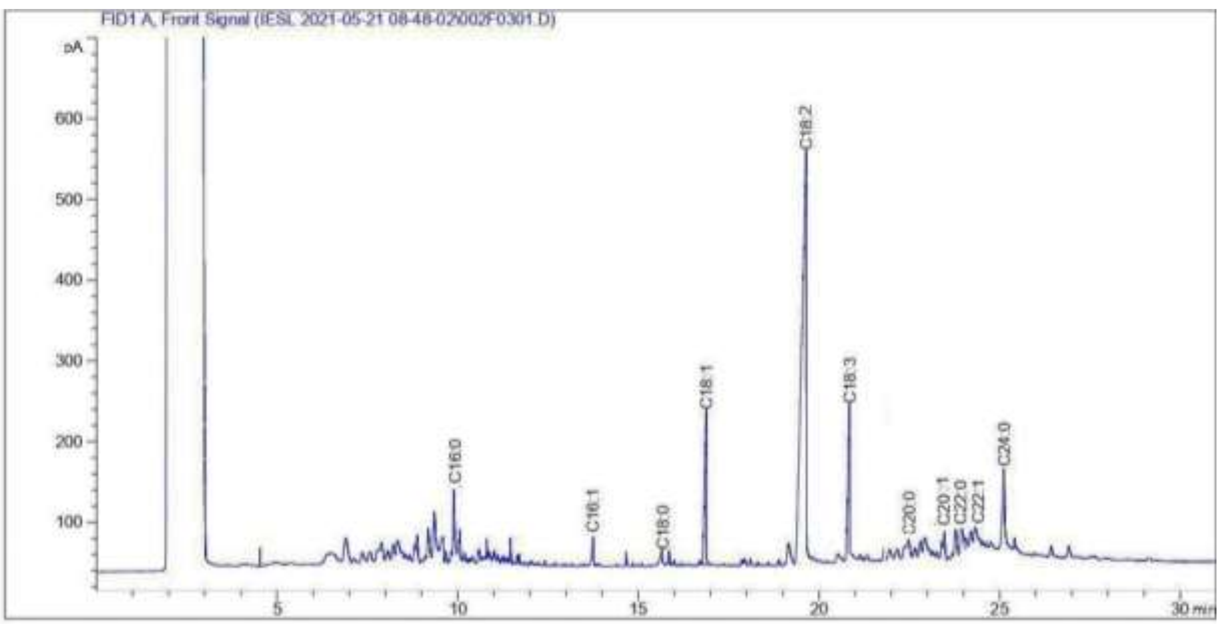

Figure 3: Fatty Acid Chromatogram of African Walnut Oil

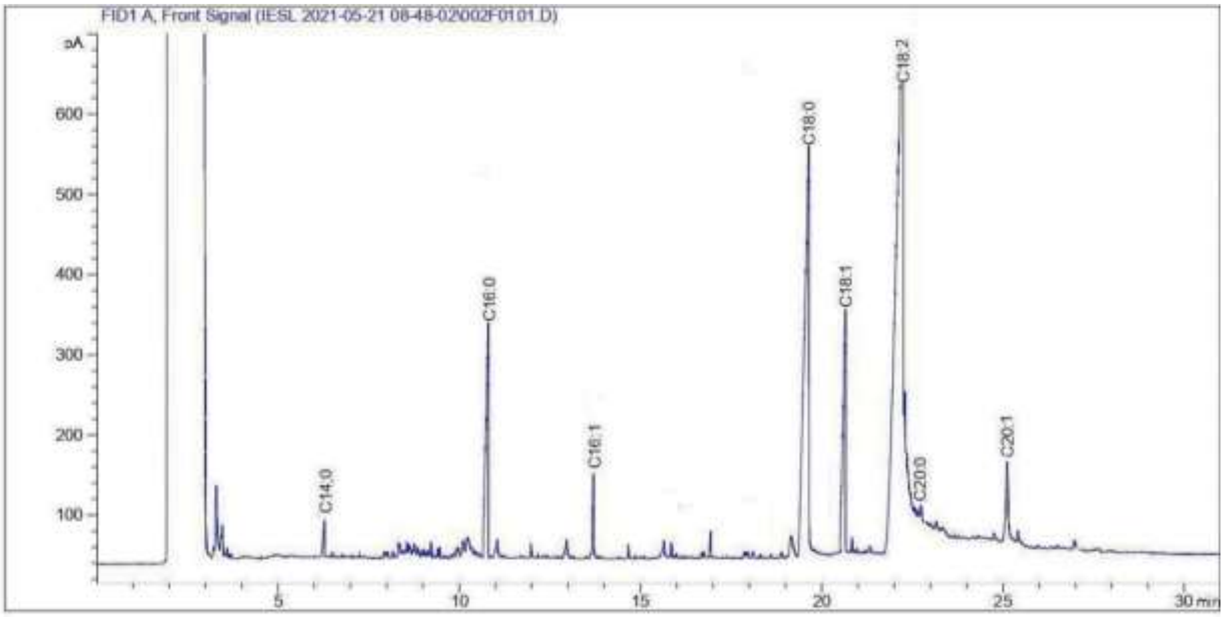

Figure 4: Fatty Acid Chromatogram of Fluted Pumpkin Seed Oil

4. Conclusion and Recommendation

The results revealed that Allanblackia, African walnut and fluted pumpkin seed had 62.19 %, 55.04 % and 53.94 % yield of oil, indicating that the seeds are good sources of vegetable oil. High iodine value of African walnut (128.69 g/100g) and fluted pumpkin seed oil (121.67 g/100g) indicated that the oils are rich in polyunsaturated fatty acids (omega-6 and 3), which will enhance the nutritional value of the bakery shortening and table margarine. African walnut oil had 89.44 % unsaturated fatty acids, out of which 55.19 and 15.44 % are linoleic and linolenic acids, respectively. While fluted pumpkin seed oil has 81.65 % unsaturated fatty acids. Linoleic and linolenic acids are safe, heart friendly and nutritionally desirable. Allanblackia seed oil has 51.50 % long and very-long-chain (stearic and arachidic) fatty acids and less palmitic acids (1.77 %) making it a healthy source of solid base fat for shortening and table-grade margarine.

African walnut and fluted pumpkin seed oils have high iodine values, high smoke points and are rich in polyunsaturated fatty acid (linoleic and linolenic acids), which are essential fatty acids, and thus should be used in wide range of domestic and industrial applications, for cooking and food product development. Allanblackia seed oil is a stable solid fat at room temperature ($28\pm2^{0}C$) and rich in the high molecular weight tryacylglyceride (TAG). High molecular weight TAG is associated with formation of HDL (high density lipoprotein) which is known to be heart friendly and reduces cardiovascular complications. Allanblackia seed oil is therefore recommended for use in bakery shortenings, table-grade margarine, and cocoa butter equivalents (CBEs) in chocolate manufacturing.

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