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Lipid Composition of Black Variety of Raw and Boiled Tigernut (*Cyperus esculentus* L.) Grown in North-East Nigeria

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Abstract: A comprehensive study was conducted on oils from raw and boiled black variety of tigernut (*Cyperus esculentus* L), in order to evaluate their potential uses. The quality of the extracted oils was assessed in terms of acid value, iodine value, saponification value, peroxide value, specific gravity, flash point, kinematic viscosity and unsaponifiable matter with the mean range values of 9.03-9.12 mg KOH/g, 57.30-92.60 mg of I/100 g, 179.40-180.30 mg KOH/g, 6.90-7.50 meqO_2/kg, 0.90-0.91 g/cm, 275.00-282.00°C, 8.30-8.42 mm^2/s at 100°C and 0.50-0.82%, respectively. The major fatty acids of the tigernut oil were oleic acid (32.14-50.85%)> linoleic acid (24.08-46.71)> palmitic acid (12.96-15.84%)> stearic acid (4.35-4.60%). Palmitoleic, eicosenoic, erucic, nervonic, elaidic, eicosadienoic, docosadienoic, α-linolenic, γ-linolenic, dihomo-γ-linolenic, eicosatrienoic, eicosapentaenoic and docosahexaenoic acids were present in small quantities with none of them recording up to 1.0% in either of the samples while lauric and myristic acids in the boiled sample were not at the detectable range of GC. The boiling process reduced the content of lauric, myristic, arachidic, behenic, palmitoleic, pentacosylic and oleic acids by 100, 100, 98.72, 99.21, 99.76, 1.47 and 36.79%, respectively. Unsaturated fatty acids predominated in all the samples with an adequate amount of essential fatty acid (linoleic acid). Generally, the boiling method showed deviations in fatty acid components from the raw sample. Phosphatidylethanolamine had the highest content (223.08 mg/100 g) in raw tigernut while the lowest was lysophosphatidylcholine (3.83 mg/100 g) also in the raw sample. However, the total phytosterols were of low values with range of 1.59e-3 to 9.74e-3 mg/100 g except that of stigmasterol and sitosterol. The high percentage PUFA and the low sterols particularly cholesterol may make processed black variety of tigernut a good food source on health wise basis.

Key words: Processed tigernut, physicochemicals, fatty acids, phospholipids, phytosterols

INTRODUCTION

Poverty and food insecurity seriously constrain the accessibility of nutritious diets that have high adequate essential fatty acids and high nutrient density. The typical diets of vulnerable populations in Nigeria with high prevalence of malnutrition and under nutrition consist predominantly of starch-rich staples, such as a cereal or tuber, with limited amounts of fruits, vegetables, legumes and pulses (Solomon and Owolawashe, 2007; Aremu and Amos, 2010). Such diets are bulky, have low nutrient density and poor bioavailability of minerals, vitamins and fatty acids and therefore result in impaired growth, development and a host of chronic diseases. Investigations on economically viable indigenous food ingredients as alternative strategies to curb under nutrition and food insecurity in developing countries are of utmost importance to broaden the essential nutrient sources for human beings (Barba de la Rosa *et al*., 2009). In order to secure food supply for the Nigerian population, research efforts are being directed towards the study of under exploited plant foods that are well adapted to adverse environmental conditions and highly resistant to disease and pests (Aremu *et al*., 2006a,b; Aremu *et al*., 2015a).

Tigernut (*Cyperus esculentus*) is an underutilized and non-conventional crop of the family *Cyperaceae* which produces rhizomes from the base and tubers that are somewhat spherical. It is known in Nigeria as "Ayaya" in Hausa, "Ofio" in Yoruba and "Akiausa" in Igbo where three varieties (black, brown and yellow) are cultivated. Among these, only two varieties, yellow and brown, are readily available in the market. The yellow variety is preferred over others because of its inherent properties like its large size, attractive colour and fleshier nature. The yellow variety also yields more milk, contains lower fat and higher protein and less anti-nutritional factors especially polyphenols (Okafor *et al*., 2003). Tigernut can be consumed raw, roasted, dried, baked or made into a refreshing beverage.

Tigernuts are valued for their highly nutritious starch content, dietary fibre and carbohydrate (Umerie and Enebeli, 1997) and are rich in sucrose (17.4-20.0%), fat

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(25.5%), protein (8.0%) (Kordyias, 1990; Temple *et al*., 1990). Tigernut is also rich in mineral content such as calcium, potassium, magnesium, zinc and traces of copper (Omode *et al*., 1995; Oladele and Aina, 2007). The dietary fibre content of tiger nut is effective in the treatment and prevention of diseases such as colon cancer, coronary heart diseases, obesity, diabetes and gastro-intestinal disorders (Anderson *et al*., 1994). Tigernut tubers are diuretic and can be used as stimulant and tonic and in the treatment of flatulence, indigestion, diarrhea, dysentery and excessive thirst (Chopral *et al*., 1986). In addition, tigernut has been demonstrated to contain higher essential amino acids than those proposed in the protein standard by FAO/WHO (1995) for satisfying adult needs for protein (Bosch and Alegna, 2005; Aremu *et al*., 2014).

Edible oils from plant sources are of interest in various food and application industries. They provide characteristic flavours and textures to foods as integral diet components (Odoemelam, 2005) and can also serve as a source of oleo chemicals (Morrison *et al*., 1995). Vegetable oils had made an important contribution to the diet in many countries, serving as a good source of protein, lipid and fatty acids for human nutrition including the repair of worn-out tissues, new cells formation as well as a useful source of energy (Gaydon *et al*., 1983; Grosso and Guzman, 1995; Grosso *et al*., 1997, 1999).

Fatty acids (FA) are a substantial part of lipids, one of the three major components of biological matter (along with proteins and carbohydrates) which play a number of key roles in metabolism-major metabolic fuel (storage and transport of energy). It is an essential component of all membranes and as gene regulators. In addition, dietary lipids provide polyunsaturated fatty acids (PUFAs) that are precursors of powerful locally acting metabolites, i.e., the eicosanoids. As part of complex lipids, fatty acids are also important for thermal and electrical insulation and for mechanical protection (Katan *et al*., 1995; Mensink and Katan, 1992).

The relationship between dietary fats and CVD, especially coronary heart disease, has been extensively investigated, with strong and consistent associations emerging from a wide body of evidence accrued from animal experiments, as well as observational studies, clinical trials and metabolic studies conducted in diverse human populations (Kris-Etherton, 2001). Saturated fatty acids raise total and low-density lipoprotein (LDL) cholesterol, but individual fatty acids within this group have different effects (Grundy and Vega, 1988). Myristic and palmitic acids have the greatest effect and are abundant in diets rich in dairy products and meat. Stearic acid has not been shown to elevate blood cholesterol and is rapidly converted to oleic acid *in vivo*. The most effective replacement for saturated fatty acids in terms of coronary heart disease outcomes are polyunsaturated fatty acids, especially linoleic acid. This finding is supported by the results of several large randomized clinical trials, in which replacement of saturated and *trans* fatty acids by polyunsaturated vegetable oils lowered coronary heart disease risk (Hu, 1997).

There are a few scientific reports and technological interests about the fatty acids composition of oil from tigernut (Glew *et al*., 2006). However, literature reports about the detailed composition of the FA components, in the oils of tigernut (black variety), a plant grown in Nigeria are rather lacking. The aim of this study was to collect comprehensive data on the physicochemical parameters, fatty acids composition, phospholipid and phytosterol contents of non-conventional black variety of Nigerian tigernut oils of different preparation methods. Such data will give information on the nutritive value of the nut and will also be useful in evaluating the oils for other potential uses in food and industrial applications.

MATERIALS AND METHODS

Collection of samples: The black variety of tigernut (*Cperus esculentus*) tubers were purchased from new market in Wukari, Taraba State, Nigeria. The tubers were thoroughly sorted to remove the stones, pebbles and bad ones before washing with tap water.

Preparation of samples

Raw tubers: Five hundred grams of the cleaned nuts were oven dried at 50°C for 48 h to a moisture content of about 12%. The dried nuts were ground into powder with a food blender and sieved through 600 µm aperture size. The powdered sample was packed and sealed in polythene bags and kept at 4°C prior to analyses.

Cooked tubers: The cleaned nuts (500 g) were also cooked for 1 h 20 min in distilled water at 100°C. The cooked nuts were drained using a perforated basket and then dried in an oven at 55°C for 48 h. Powdered sample was obtained as described earlier and stored at 4°C prior to analyses.

Extraction of oils: The sample of black variety of tigernut was oven dried and extracted in Soxhlet apparatus with redistilled n-hexane of Analar grade (British Drug Houses, London) for the recovery of undiluted oil. The crude oil extract was made to be free of water by filtering through the anhydrous sodium sulphate salt. The hexane was removed from the oil/hexane mixture by using a rotary evaporator.

Fatty acid analysis: The oil extracted was converted to the methyl ester using the method described by Akintayo and Bayer (2002). About 2 mg crude oil sample was transferred into a 5-10 mL glass vial and 1 mL of diazomethane ether solution added. The mixture was

shaken thoroughly and allowed to stand for 1 min. Then 16 µL of 3.33 M CH_3CONa/CH_3OH solution was added; mixture shaken and allowed to stand for 10 min after which 10 µL acetic acid was added. The fatty acid methyl esters were analyzed using a HP 6890 gas chromatograph powered with HP Chemistation Rev. a 09.01 (1206) software fitted with a flame ionization detector and a computing integrator. Nitrogen was used as the carrier gas. The column initial temperature was 250°C rising at 5°C/min to a final temperature of 310°C while the injection port and the detector were maintained at 310 and 350°C, respectively. A polar (HP INNO Wax) capillary column (30 m x 0.53 mm x 0.25 micrometre) was used to separate the esters. The peaks were identified by comparison with standard fatty acid methyl esters obtained from Sigma Chemical Co. (St. Louis MO, USA).

Phospholipids analysis: A modified method of Raheja *et al.* (1973) was employed in the analysis of the extracted oil phospholipids content determination. 0.01 g of the extracted fats was added to the test tube. To ensure complete dryness of the oil for phospholipids analysis, the solvent was completely removed by passing the stream of the nitrogen gas on the oil. 0.04 mL of chloroform was added to the content of the tube and it was followed by the addition of 0.10 mL of chromogenic solution. The content of the tube was heated at a temperature of 100°C in a water bath for about 1 min. The content was allowed to cool, 5 mL of the hexane was added and the tube with its content shook gently several times. The solvent and the aqueous layers were recovered and allowed to be separated. The hexane layer was recovered and allowed to be concentrated to 1.0 mL for gas chromatography using flame photometric detector. The conditions for phospholipid analysis include H.P 5890 powered with HP ChemStation REV. A 09.01 (1206) and split injection ratio of 20: 1; nitrogen as carrier gas; inlet temperature, 250°C; column type, HP5; column dimension: 30 m x 0.25 mm x 0.25 µm; oven program: Initial temperature at 50°C; first ramping at 10°C/min for 20 min, maintained for 4 min while second ramping at 15°C/min for 4 min, maintained for 5 min. Detector: PFPDDetector temperature: 300°C; hydrogen pressure, 20 psi; compressor air: 35 psi.

Phytosterol analysis: The phytosterol analysis was done as described by AOAC (2005). The aliquots of the extracted fat were added to the screw-capped test tubes. The samples were saponified at 90°C for 30 min, using 3 mL of 10% KOH in ethanol, to which 0.20 mL of benzene had been added to ensure miscibility. Deionized water (3 mL) was added and 2 mL of hexane was added in extracting the non-saponifiable materials. Three extractions, each with 2 mL of hexane were carried out for 1 h, 30 and 30 min, respectively. The hexane was concentrated to 1 mL in the vial for gas chromatography analysis and 1 µL was injected into the injection pot of GC. The GC conditions of analyses were similar to the GC conditions for methyl esters analyses.

RESULTS AND DISCUSSION

The mean physicochemical properties of the oils extracted from *Cyperus esculentus* are presented in Table 1. The acid values were 9.12 (raw) and 9.03 (boiled) though higher than those reported for bambara groundnut (1.38), groundnut seed oil (5.99) and moringa seed oil (7.09) by Aremu *et al.* (2013); Atasie *et al.* (2009); Abiodun *et al.* (2012), respectively, but comparable to those reported for melon (9.36) and almond (9.66) seeds oils (Akpambang *et al.*, 2008) and cashew nut seed oil (10.70) (Evbuowman *et al.*, 2013). These values however accounted for the presence of free fatty acids in the oils as an indicator of the presence and extent of hydrolysis by lipolytic enzymes and oxidation (Gordon, 1993). Low acid value in oil indicates that the oil will be stable over a long period of time and protect against rancidity and peroxidation. This could be attributed to presence of natural antioxidants in the seeds such as vitamins C and A as well as other possible phytochemicals like flavonoids (Aremu *et al.*, 2015a). The acid values obtained were lower when compared with those reported by Elizabeth *et al.* (2012); Aremu *et al.* (2010); Bwade *et al.* (2013); Nangbes *et al.* (2013); Igwenyi (2014) for *Jatropha curcas* (35.80), luffa gourd (68.88), pumpkin (62.60), castor (14.80) and African bush mango (20.10) seeds oils, respectively. Acid value is also used as an indicator for edibility of an oil and suitability for use in the paint and soap industries (Aremu *et al.*, 2006a,b). High acid value in an oil showed that the oil may not be suitable for use in cooking (edibility), but however, be useful for production of paints, liquid soap and shampoos (Akintayo, 2004). Also appreciable acid value of oils is an indication that the plant might be poisonous for livestock (Aremu *et al.*, 2006a,b). The iodine values obtained for all the samples place them in the non-drying group oil since drying oils have an iodine value above 100 (Aremu *et al.*, 2015b). The iodine value is a measure of the degree of unsaturation and it is an identity characteristic of seed oils, qualifying tigernut oils as an excellent raw material for soaps cosmetics industries (Edmond *et al.*, 2009). Mathew *et al.* (2014) reported that the lower the iodine value the lesser the number of unsaturated bonds; thus the lower the susceptibility of such oil to oxidative rancidity. Therefore, the extracted oils particularly from the raw sample will have low contents of unsaturated fatty acids and they will be easily stored for a long time without spoilage. Thus these oils are expected to be suitable for the manufacture of soaps, lubricating oil and candles due to their non-drying characteristics there by making them attractive options for commercial purpose

and minimizing the dependence on use of known edible oils for making such products. The iodine values of *Cyperus esculentus* oil were 57.30 (raw) and 92.60 (boiled). These values are lower than 130.96 (African pear), 136.89 (cashew nut), 153.00 (melon seed) and 152.44 (horse eye seed) as reported by Akanni *et al.* (2005), Aletor *et al.* (2007), Olaofe *et al.* (2012) and Oyeleke *et al.* (2012a), respectively.

The peroxide values of 7.50 (raw) and 6.90 (boiled) were recorded for *Cyperus esculentus* oil. These values obtained are lower than the reported 135.00 (ackee apple), 56.00 (*Jatropha curcas*), 280.00 (luffa gourd) and 158.64 (castor seed) by Kyari (2008); Belewu *et al.* (2010); Abayeh *et al.* (2013); Nangbes *et al.* (2013), respectively. They are however higher than the values of 1.42, 2.25 and 4.47 reported for cotton seed (Andrew *et al.*, 2012), almond seed (Ogunsuyi and Daramola, 2013) and sesame seed (Ogbonna and Ukaan, 2013), respectively. Peroxide value (PV) is the most common indicator of lipid oxidation. High values of PV are indicative of high levels of oxidative rancidity of the oils and also suggest absence or low levels of antioxidant; certain antioxidants may, however, be used to reduce rancidity such as propygadlate and butyl hydroxyl anisole (Kyari, 2008). The WHO/FAO (1994) stipulated a permitted maximum peroxide level of not more than 10 equivalent of oxygen/kg of the oils, therefore, the extracted oils from the samples will be suitable for consumption. The saponification value is in the range of 180.30 to 179.40 for raw and boiled tiger nut oils, respectively. Saponification value is a measure of oxidation during storage and also indicates deterioration of the oils. An increase in saponification value in oil increases the volatility of the oils. It enhances the quality of the oil because it shows the presence of lower molecular weight components in 1 g of the oil which will yield more energy on combustion (Engler and Johnson, 1983). The high saponification value in the extracted oils is an indication that the oil may be suitable for soap making, oil-based ice-cream and shampoos. It has been reported that oils with high saponification values contain high proportion of lower fatty acids (Pearson, 1976). Therefore, the high saponification value of the oils under investigation indicated that they contained low proportion of higher fatty acid and can be regarded as edible oils.

The unsaponifiable matter values (0.50-0.82) are low and favourably compared with 0.84 reported for soy bean oil (Akanni *et al.*, 2005). High unsaponifiable matter content of fats and oils has been reported to be an indication of adulteration or contamination. This may be due to the presence of fuel or lubricating oils in the oil sample (Ihekoronye and Ngoddy, 1985). The specific gravity ranged from 0.91 in raw to 0.90 in boiled *Cyperus esculentus* oil. The result showed that the extracted oils are less dense than water and therefore would be useful in cream production as it will make the oils flow and spread easily on the skin (Oyeleke *et al.*, 2012b). Specific gravity is commonly used in conjunction with other parameters in assessing the purity of oil (Yahaya *et al.*, 2012). Viscosity increased with the molecular weight and decreased with increasing unsaturated level and high temperature (Nourrechni *et al.*, 1992). The viscosities of the extracted oils were 8.42 and 8.30 for raw and boiled *Cyperus esculentus* oils, respectively. The more viscous oil is, the better its use as lubricant (Belewu *et al.*, 2010), hence the raw *Cyperus esculentus* oil will have higher lubricating property than the boiled *Cyperus esculentus* oil. The oil with low viscosity value indicates that it is light and so probably highly unsaturated; the high value might be as a result of suspended particles still present in the crude oil sample (Nangbes *et al.*, 2013). The flash points values were 282.00 (raw) and 275.00 (boiled) *Cyperus esculentus* oil while the oils colours were light yellow and slightly yellowish green for raw and boiled *Cyperus esculentus* samples, respectively. The coefficient of variation (CV%) ranged from 0.25% in saponification value to 24.24 in unsaponifiable matter. Table 2 displays the differences in the physicochemical properties between raw and boiled. The unsaponifiable matter and iodine value were enhanced by the processing method (boiling). Kinematic viscosity, specific gravity, saponification value, peroxide value and acid value were all reduced by boiling method.

The fatty acid composition of the oils extracted from raw and boiled *Cyperus esculentus* are presented on Table 3. Oleic acid (C18:1) has the highest concentration of 50.85% in boiled *Cyperus esculentus* sample. This is comparable with the report of Aremu *et al.* (2015c) on African locust bean and mesquite bean. In their result, oleic acid was the highest with 32.24 and 30.96% in both African locust and mesquite beans, respectively. The oleic acid content of tiger nut tuber oil is much greater than that of most other vegetable oils, such as sunflower oil (23.6%), soybean oil (24.9%), or corn oil (23.8%), but comparable to that of olive oil (Warner and Knowlton, 1997; Romero *et al.*, 1998; Chung and Choe, 2001). Tiger nut oil with its high percentage of oleic acid should be relatively stable and resistant to oxidation (Oderinde and Tairu, 1988). Unlike the raw sample, linoleic acid had the highest concentration of fatty acid in the processed (boiled) sample with the value of 46.71%. It has been also shown that linoleic acid was the most concentrated fatty acid in soy beans (52.0%) (Paul and Southgate, 1985), corn oil (55.7%) and safflower oil (72.6%) (Ihekoronye and Ngoddy, 1985), pigeon pea (54.8%) (Oshodi *et al.*, 1993) and harms seed (47.95) (Ajayi *et al.*, 2014). The observation in this report is also comparable with the earlier reports by some researchers (Branch *et al.*, 1990; Adeyeye *et al.*, 1999; Akintayo and Bayer, 2002; Aremu *et al.*, 2007; Audu *et al.*, 2011) that linoleic was the most concentrated fatty acid

Table 1: Physicochemical parameters of *Cyperus esculentus* oils

	---------- Tiger nut ----------				
Parameters	Raw	Boiled	Mean	SD	CV%
Kinematic viscosity (mm^2/s) at 100°C	8.42	0.8.30	8.36	0.06	0.72
Specific gravity (g/cm^3)	0.91	0.90	0.91	0.01	0.63
Unsaponifiable matter (%)	0.50	0.82	0.66	0.16	24.24
Flash point (°C)	282.00	275.00	278.50	3.50	1.26
Saponification value (mgKOH/g)	180.30	179.40	179.85	0.45	0.25
Peroxide value ($meqO_2/kg$)	7.50	6.90	7.20	0.30	4.17
Iodine value	57.30	92.60	74.95	12.83	17.12
Acid value	9.12	9.03	9.08	0.05	0.55
Colour	LY	SLG			

LY: Light yellow, SLG: Slightly yellowish green, SD: Standard deviation, CV: Coefficient of variation

Table 2: Differences in physicochemical parameters between raw and boiled *Cyperus esculentus* oils

Parameters	Raw-Boiled	(%) Differences
Kinematic viscosity (mm^2/s) at 100°C	0.12	1.43
Specific gravity (g/cm^3)	0.01	1.10
Unsaponifiable matter (%)	-0.32	-64.00
Flash point (°C)	7.00	2.48
Saponification value (mgKOH/g)	0.90	0.50
Peroxide value ($meqO_2/kg$)	0.60	8.00
Iodine value	35.30	38.12
Acid value	0.09	0.99

in legume seed oils. Oleic (32.14%) and linoleic (24.08%) acids were the second highest concentrated fatty acids in raw and boiled samples, respectively.

Palmitic and stearic acids were the third and fourth concentrated fatty acid in both raw and boiled samples. The values of palmitic acids (12.96% in raw and 15.84% in boiled) and stearic (4.35% in raw and 4.60% in boiled) are lower than the reported composition in bambara groundnut (22.38 and 11.20%) (Aremu *et al*., 2013), African locust bean (17.26 and 18.09%) (Ijarotimi and Keshinro, 2012), *Adenanthera pavonina* (13.99 and 17.99%) (Ogbuagu and Odoemelam, 2013) and mesquite bean (27.54 and 8.04%) (Aremu *et al*., 2015c), but comparable with the compositions in harms seed (11.51 and 4.52%) (Ajayi *et al*., 2014, respectively. Stearic acid values in the samples are higher than those of *Moringa oleifera* (2.96%) (Olaofe *et al*., 2013), *Parinari curatellifolia* (2.91%) (Ogungbenle and Atere, 2014), soy beans (4.0%) (Paul and Southgate, 1985) and kidney bean (2.3%) (Olaofe *et al*., 2010).

Our data are in accord with those of Kim *et al*. (2007) and Yeboah *et al*. (2012) which show that four fatty acids (oleic, palmitic, linoleic and stearic acid) account for >97% of the total fatty acid in tiger nut tuber and this plant food is a good source of essential fatty acid linoleic acid. The variability in the fatty acid composition of the oils, as reported by the different investigators, may be due to the age of the tissue analyzed, genetic history, climate, nutrition, temperature and oxygen tensions, any of which can profoundly alter the composition of the endogenous lipid of a plant (Stump, 1980).

The differences in the fatty acid composition between raw and boiled *Cyperus esculentus* are shown in Table 4. Palmitic acid (C16:0), stearic (C18:0), eicosenoic acid (C20:1), erucic acid (C22:1), nervonic acid (C24:1), elaidic acid (C18:1), linoleic acid (C18:2), eicosadienoic acid (C20:2), docosadienoic acid (C22:2), α-linolenic acid (C18:3), γ-linolenic acid (C18:3), dihomo-γ-linolenic acid (C20:3), eicosatrienoic acid (C20:3), eicosapentaenoic acid (C20:5) and docosahexaenoic acid (C22:6) recorded increase in the processed (boiled) sample. The percentage increase varied from 5.69 to 509.09%.

The distribution of results in Table 3 into TSFA, MUFA, PUFA TUFA, TEFA, TNEFA and oleic to linoleic (O/L) ratio is shown in Table 5. TSFA ranged from 20.50% in boiled *Cyperus esculentus* to 24.80% in raw *Cyperus esculentus*. These values are lower than TSFA value of 54.51% reported for dehulled African yam bean (Adeyeye *et al*., 1999), 31.98% reported for *Adenanthera pavonina* (Ogbuagu and Odoemelam, 2013), 34.68% reported for bambara groundnut (Aremu *et al*., 2013), 40.20 and 43.00% reported for African locust and mesquite bean, respectively (Aremu *et al*., 2015b). The reported values of 12.3% for groundnut (Hilditch and Williams, 1964), 15.2% for soybean (McLeod and Ames, 1988), 9.0-12.9% for pinto bean (Audu *et al*., 2011) and 17.06% for *B. eurycoma* (Ajayi *et al*., 2014) are lower. However, *Cyperus esculentus* oil with 75.20% (in raw) and 79.50% (in boiled) of total unsaturated fatty acid is higher than that of *Parkia biglobosa* with a reported value of 33.69% (Ijarotimi and Keshinro, 2012), *Adenanthera pavonina* with a reported value of 66.67% (Ogbuagu and Odoemelam, 2013), bambara groundnut with a reported value of 65.32% (Aremu *et al*., 2013) and mesquite bean with a reported value of 56.90% (Aremu *et al*., 2015c). TUFA in this study is of good concern because report has shown that fats and oils with high unsaturation are particularly susceptible to oxidation and intakes of food containing oxidized lipid increased the concentration of secondary proxidation products in liver (Hegested *et al*., 1993). High amount of TUFAs makes *Cyperus esculentus* as a special tuber suitable for nutritional applications.

Table 3: Fatty acids composition (%) of raw and boiled tigernut

	---------- Tiger nut ----------				
Fatty acid	Raw	Boiled	Mean	SD	CV
Lauric acid C12:0	0.0240	0.0000	0.0120	0.0120	100.00
Myristic acid C14:0	0.0201	0.0000	0.0101	0.0101	100.00
Palmitic acid C16:0	12.9578	15.8439	14.4009	1.4430	10.02
Stearic acid C18:0	4.3513	4.5990	4.4752	0.1239	2.77
Arachidic acid C20:0	2.3413	0.0299	1.1856	0.1557	97.48
Behenic acid C22:0	3.6788	0.0276	1.8532	1.8256	98.51
Pentacosylic acid C25:0	1.4240	0.0034	0.7137	0.7103	99.52
Palmitoleic acid C16:1	0.0340	0.0335	0.0338	0.0000	0.00
Oleic acid C18:1	50.8485	32.1416	41.4951	9.3534	22.54
Eicosenoic acid C20:1	0.0386	0.0503	0.0445	0.0058	13.03
Erucic acid C22:1	0.0309	0.0403	0.0356	0.0047	13.02
Nervonic acid C24:1	0.0026	0.0034	0.0030	0.0003	10.00
Elaidic acid C18:1	0.0090	0.0118	0.0104	0.0014	13.46
Linoleic acid C18:2	24.0840	46.7139	35.3990	11.3150	31.96
Eicosadienoic acid C20:2	0.0033	0.0042	0.0038	0.0003	7.89
Docosadienoic acid C22:2	0.0148	0.0192	0.0170	0.0022	12.94
α-Linolenic acid C18:3	0.0328	0.1690	0.1009	0.0681	67.49
γ-Linolenic acid C18:3	0.0363	0.2211	0.1287	0.0924	71.79
Dihomo-γ-linolenic acid C20:3	0.0268	0.0350	0.0309	0.0041	13.27
Eicosatrienoic acid C20:3	0.0141	0.0183	0.0162	0.0021	12.96
Eicosapentaenoic acid C20:5	0.0155	0.0202	0.0179	0.0023	12.85
Docosahexaenoic acid C22:6	0.0111	0.0145	0.0128	0.0017	13.28

Table 4: Differences in the fatty acids composition (%) between raw and boiled tigernut

Fatty acid	Raw-boiled	Differences (%)
Lauric acid C12:0	0.0240	100
Myristic acid C14:0	0.0201	100
Palmitic acid C16:0	-2.8861	-22.27
Stearic acid C18:0	-0.2477	-5.69
Arachidic acid C20:0	2.3114	98.72
Behenic acid C22:0	3.6512	99.25
Pentacosylic acid C25:0	1.4206	99.76
Palmitoleic acid C16:1	0.0005	1.47
Oleic acid C18:1	18.7069	36.79
Eicosenoic acid C20:1	-0.0117	-30.31
Erucic acid C22:1	-0.0094	-30.42
Nervonic acid C24:1	-0.0008	-30.77
Elaidic acid C18:1	-0.0028	-31.11
Linoleic acid C18:2	-22.6299	-93.96
Eicosadienoic acid C20:2	-0.0009	-27.27
Docosadienoic acid C22:2	-0.0044	-29.73
α-Linolenic acid C18:3	-0.1362	-415.24
γ-Linolenic acid C18:3	-0.1848	-509.09
Dihomo-γ-linolenic acid C20:3	-0.0082	-30.60
Eicosatrienoic acid C20:3	-0.0042	-29.79
Eicosapentaenoic acid C20:5	-0.0047	-30.32
Docosahexaenoic acid C22:6	-0.0034	-30.63

Table 5: Fatty acids distribution to saturation and unsaturation of components (%) in raw and boiled tiger nut

Fatty acid	Raw	Boiled
TSFA	24.80	20.50
TSFA (%)	24.80	20.50
MUFA	50.96	32.28
DUFA	24.10	46.74
PUFA	0.14	0.48
TUFA	75.20	79.50
TUFA (%)	75.20	79.50
TEFA (%)	24.12	46.88
TNEFA	75.88	53.12
O/L ratio	2.11	0.69

TSFA: Total saturated fatty acid, MUFA: Monounsaturated fatty acid, DUFA: Diunsaturated fatty acid; TUFA: Total unsaturated fatty acid, TEFA: Total essential fatty acid, TNEFA: Total non-essential fatty acid, O/L: Oleic/Linoleic ratio, PUFA: Polyunsaturated fatty acid

Table 6: Differences in the fatty acids distribution to saturation and unsaturation of components (%) in raw and boiled tiger nut

Fatty acid	Raw-boiled	Differences (%)
TSFA	4.30	17.34
TSFA (%)	4.30	17.34
MUFA	18.68	36.66
DUFA	-22.64	-93.94
PUFA	-0.34	-242.86
TUFA	-4.30	-5.72
TUFA (%)	-4.30	-5.72
TEFA (%)	-22.76	-94.36
TNEFA	22.76	29.99
O/L ratio	1.42	67.30

These findings imply that black variety of *Cyperus esculentus* oil is as good as soybean and cowpea seed oils in the supply of essential fatty acids. Linoleic and alpha-linolenic acids called omega-6-fatty acids and omega-3-fatty acids, respectively are the most important essential fatty acids required for growth, physiological functions and body maintenance (Salunkhe *et al*., 1985). These two fatty acids work together in a competitive balance to regulate blood clotting, immune response and inflammatory processes. Deficiency of linoleic acid leads to dry hair, hair loss (Cunnane and Anderson, 1997) and poor wound healing (Ruthig and Meckling-Gill, 1999). It also leads to poor growth, fatty liver, skin

Table 7: Phospholipid levels (mg/100 g) of tiger nut

	---------- Tiger nut ----------				
Phospholipids	Raw	Boiled	Mean	SD	CV
Phosphatidylethanolamine	223.08	151.31	187.20	35.88	19.17
Phosphatidylcholine	185.09	195.26	190.18	5.09	2.68
Phosphatidylserine	11.62	18.18	14.90	3.28	22.01
Lysophosphatidylcholine	3.83	8.61	6.22	2.39	38.42
Phosphatidylinositol	107.34	21.56	64.45	42.89	66.55

Table 8: Differences in the phospholipids level (mg/100 g) between raw and boiled tiger nut

Phospholipids	Raw-boiled	Differences (%)
Phosphatidylethanolamine	71.77	32.17
Phosphatidylcholine	-10.17	-5.49
Phosphatidylserine	-6.56	-56.45
Lysophosphatidylcholine	-4.78	-124.80
Phosphatidylinositol	85.78	79.91

lesions and reproductive failure (Connor *et al*., 1992). It has been reported that linolenic acid plays a role in lowering the risk of cardiovascular disease (Mozaffarian, 2005). It has also been found that the intake of linolenic acid in the diet protects against fatal ischemic heart disease (Hu *et al*., 1999). Processed *Cyperus esculentus* had the highest TEFA (46.88) contents. It has also been reported that linoleic acid moderately reduces serum cholesterol and low density lipoprotein levels (LDL) (WHO/FAO, 1994). The oleic/linoleic (O/L) acid ratio has been associated with high stability and potentiality of the oil for deep frying fat (Branch *et al*., 1990). The O/L level ranged from 0.69% in boiled to 2.11% in raw tuger nut. These values are lower than that of *Anarcadium occidentale* (12.28%) (Aremu *et al*., 2007), but compared favourable with that of peanut oil 1.48% (Branch *et al*., 1990) hence tiger nut oil (raw) may be stable compared with peanut oil and may also be useful as frying oil.

The differences in the distribution of fatty acids composition into saturated and unsaturated for the raw and processed *Cyperus esculentus* are shown in Table 6. DUFA PUFA, TUFA and TEFA (%) recorded increase of 93.94, 242.86, 5.72 and 94.36%, respectively in processed (boiled) *Cyperus esculentus* while there were reductions of 17.34, 36.66, 29.99 and 67.30% in TSFA, MUFA, TNEFA and O/L (%), respectively in boiled tigernut.

Table 7 shows the phospholipids content of black variety of *Cyperus esculentus*. From the result phosphatidyethanolmine showed a greater concentration with the value of 223.08 mg/100 g in raw while in boiled sample, phosphatidycholine (PC) had the highest value of 195.26 mg/100 g. Phosphatidyethanolmine followed phosphatidycholine in processed tiger nut whereas phosphatidycholine followed Phosphatidyethanolmine in raw sample with the concentrations of 151.31 and 185.09 mg/100 g, respectively. Phosphatidyserine and lysophosphatidycholine were the minor phospholipids with concentrations ranging between 11.62 to 18.18 mg/100 g and 3.83 to 8.61 mg/100 g, respectively.

The oral application of dietary glycerophospholipids GPLs with a specific FA composition has the potential to cause defined alterations of the FA composition of membrane phospholipids (PLs) within a certain cell type. As a consequence, cellular functions, including signaling and transport, as well as the activity of membrane bound enzymes, could be modulated by dietary PLs and hence contribute to the health benefits (Kullenberg *et al*., 2012). Phosphatidythanolamine is usually the most abundant phospholipid in animals and plants, often amounting to almost 50% of the total and as such they are building block of membrane bilayer (Wirtz, 1991). The phosphatidycholine values for raw and processed *Cyperus esculentus* were high. This may be as a result of the shelf life of the sample, because researchers had found that phosphatidycholine (PC) concentration is high at infancy but slowly deplets throughout the age of life and may drop to as low as 10% of the cellular membrane in the elderly plants and animals (Adeyeye *et al*., 2012), As a result of this, researchers have recommended daily supplementation of PC as a way of improving brain functioning memory capacity (Chung *et al*., 1985). The US Food and Drug Administration (USFDA) have stated that consumption of phosphodyserine (PS) may reduce the rate of dementia and cognitive dysfunction in the elderly people, in young people it reduces mental stress and increases mental accuracy and stress resistance (Alter, 2006). PS supplementation promotes a desirable hormonal balance for athletes and might reduce the physiological detorations that accompanies over training and/or overstretching (Starks *et al*., 2008). Therefore, consumption of *Cyperus esculentus* may participate well in these functions.

Table 8 gives the difference in phosphoplipids level (mg/100 g) of black variety of *Cyperus esculentus*. Boiled sample was more concentrated in all the phospholipids than the raw *Cyperus esculentus* except in phosphatidythanolamine and phosphatidylinositol. The CV% varied from 2.68 to 66.55.

Phytosterols are natural components of plant origin forming cell membrane and occur in small quantities in many fruits, vegetables, nuts, seeds, cereals, legumes, vegetable oils and other plants. They are abundantly present in the fat soluble fractions of all plants and foods containing plant based raw materials including

Table 9: Phytosterols level (mg/100 g) of tiger nut

	---------- Tiger nut ----------				
Phospholipids	Raw	Boiled	Mean	SD	CV
Cholesterol	5.17 e-2	5.17 e-2	0.70	0.000	0.00
Cholestanol	1.60 e-3	1.59 e-3	0.08	0.000	0.00
Ergosterol	1.60 e-3	1.60 e-3	0.08	0.000	0.00
Campesterol	9.39 e-3	9.74 e-3	0.48	0.007	1.47
Stigmasterol	1.34	1.46	1.40	0.060	4.29
5-Avena sterol	5.62 e-3	8.07 e-3	0.34	0.060	17.65
Sitosterol	17.21	57.50	37.36	20.145	53.92

Table 10: Differences in the phytosterols level (mg/100 g) between raw and boiled tiger nut

Phospholipids	Raw-boiled	Differences (%)
Cholesterol	0.0000	0.00
Cholestanol	0.0005	0.63
Ergosterol	0.0000	0.00
Campesterol	-0.0174	-3.72
Stigmasterol	-0.1200	-8.96
5-Avena sterol	-0.1220	-43.60
Sitosterol	-40.29	-234.11

principally oils, cereals, pulses and dried fruits (Piironen *et al*., 2000). Phytosterols may exist as free sterols (FS's), esterified with fatty acids (SE's) or phenolic acids (SPHE's) or as glycosides (SG's) and acylated glycosides (Moreau *et al*., 2002; Piironen and Lampi, 2003). Table 9 displays the phytosterols level of raw and boiled *Cyperus esculentus*.

Systematic reviews studying the efficacy of phytosterols have shown that phytosterols enriched foods can significantly lower LDL cholesterol (Law, 2000). Daily intake of phytosterols helps to prevent heart disease by lowering HDL cholesterol levels by as much as 14% (Normen *et al*., 2005). A number of studies using phytosterols have been carried out and showed significant lowering of blood cholesterol levels. A summary of 52 studies revealed that an average of 13±1g of phytosterol intake daily for 3-5 weeks, showed a 20% decrease in blood cholesterol level (Pollak and Kritchevsky, 1981). Phytosterols compete with cholesterol absorption and uptake in the small intestine thereby reducing the supply of cholesterol in the blood stream. Since high blood total cholesterol and low-density lipoprotein (LDL) cholesterol levels are the main risk factors for coronary heart disease (CHD) and other diseases related to atherosclerosis, thus reducing cholesterol levels reduces the risk of CHD as well.

The difference in the phytosterols level the raw and processed *Cyperus esculentus* are shown in Table 10. Campesterol, stigmasterol, 5-Avena sterol and sitosterol recorded increase of 3.72, 8.96, 43.60 and 234.11.36%, respectively in processed (boiled) *Cyperus esculentus* while there were no significant changes in the cholesterol, cholestanol and ergosterol between the raw and boiled samples. As plant components, phytosterols (PS) may offer protection against cancer by several different means (Rao and Koratkar, 1997; Awad and Fink, 2000). These include inhibiting cell division, stimulating tumor cell death and modifying some of the hormones that are essential to tumor growth (Awad *et al*., 2000).

Phytosterols have been found useful in treating other conditions, including rheumatoid arthritis, but their widest application is in protecting the heart. However, reports also suggest that excessive intake of dietary phytosterols and stanols in plasma and tissues may contribute to the increased blood pressure (Chen *et al*., 2010).

Conclusion: The black variety of tigernut tuber was a rich source of oil and contained moderate amount of phospholipids and phytosterols. It was also a rich source of fiber and carbohydrates. Twenty two different individual fatty acids were identified, with oleic and linoleic predominating in the studied raw and boiled samples, respectively. The edible and stable oil obtained from the tuber is said to be superior oil that compares favorably with olive oil. The results of this study have provided much justification for the use of tiger nut oil in food products. The high content of oleic and linoleic acids makes tiger nut oil a very nutritious and health enhancing oil. Thus black variety of tiger nut oil should be developed into a commercial product for use in food products. The suitability of the oils for domestic use and utilization in the production of paints, liquid soap and shampoos are also revealed.

REFERENCES

Abayeh, O.M., I.H. Garba, H.M. Adamu and O.J. Abayeh, 2013. Quality Characteristics of *Luffa aegyptiaca* seed oil. Int. J. Sci. and Eng. Res., 4: 11-16.

Abiodun, O.A., J.A. Adegbite and A.O. Omolola, 2012. Chemical and Physicochemical Properties of Moringa Flours and Oil. Global J. Sci. Frontier Res. Biol. Sci., 12: 12-18.

Adeyeye, E.I., A.A. Oshodi and K.O. Ipinmoroti, 1999. Fatty acid composition of six varieties of dehulled African yam bean (*Sphenostylis stenocarpa*) flour. Int. J. Food Sci. and Nutr., 50: 357-365.

Adeyeye, E.I., A.Y. Adesina, M.C. Ginika and H.E. Ariyo, 2012. Great Barracuda: Its skin and muscle fatty acids, phospholipids and zoosterol's composition. Int. J. Chem. Sci., 5: 18-28.

Ajayi, F.A., M.O. Aremu, Y. Mohammed, P.C. Madu, B.O. Atolaiye, S.S. Audu and O.D. Opaluwa, 2014. Effect of Processing on Fatty Acid and Phospholipid Compositions of Harms (*Brachystegia eurycoma*) Seed Grown in Nigeria. Chem. and Proc. Eng. Res., 22: 18-25.

Akanni, M.S., A.S. Adekunle and E.A. Oluyemi, 2005. Physicochemical Properties of Some Non-Conventional Oilseeds. J. Food Technol., 3: 177-181.

Akintayo, E.T., 2004. Characteristics and composition of *Parkia biglobbossa and Jatropha curcas* oils and cakes. Bioresour. and Technol., 92: 307-310.

Akintayo, E.T. and E. Bayer, 2002. Characterization and some possible uses of *Phikenetia conophora* and *Adenopus brevilorus* seeds and seed oils. Bioreso. Technol., 85: 95-97.

Akpambang, V.O.E., I.A. Amoo and A.A. Izuagie, 2008. Comparative compositional analysis on two varieties of melon (*Colocynthis citrullus* and *Cucumeropsis edulis*) and a variety of almond (*Prunus amygdalus*). Res. J. Agric. and Biolog. Sci., 4: 639-642.

Aletor, O., J.O. Agbede, S.A. Adeyeye and V.A. Aletor, 2007. Chemical and Physio-Chemical Characterization of the Flours and Oils from Whole and Rejected Cashew Nuts Cultivated in Southwest Nigeria. Pak. J. Nutr., 6: 89-93.

Alter, T., 2006. More than you wanted to know about fats and oils. Sundance National Food Online Retrieved, 31-08-2006.

Anderson, J.W., B.M. Smith and N. Gustafon, 1994. Health benefits and practical aspects of high fibre diets. Am. J. Chem. Nutr., 59: 12425-12476.

Andrew, C., A.A., Buba, A.U. Itodo and E.E. Etim, 2012. Thermoxidative Degradation of Commonly Used Vegetable Oils: A Comparative Study. J. Emerging Trends in Eng. and Appl. Sci., 3: 924-928.

AOAC, 2005. Official Methods of Analysis, 18th edn. Association of Analytical Chemists.

Aremu, M.O. and V.A. Amos, 2010. Fatty Acids and Physicochemical Properties of Sponge Luffa (*Luffa cylindrical*) Kernel Oils. Int. J. Chem. Sci., 3: 161-166.

Aremu, M.O., H. Ibrahim and T.O. Bamidele, 2015a. Physicochemical Characteristics of the Oils Extracted from Some Nigerian Plant Foods-A Review. Chem. and Proc. Eng. Res., 32: 36-52.

Aremu, M.O., H. Ibrahim, E.Y. Awala, A. Olonisakin and O.J. Oko, 2015b. Effect of Fermentation on Fatty Acid Compositions of African Locust Bean and Mesquite Bean. J. Chem. Eng. Chem. Res., 2: 817-823.

Aremu, M.O., O.J. Oko, H. Ibrahim, S.K. Basu, C. Andrew and S.C. Ortutu, 2015a. Compositional evaluation of seed and pulp of blood plum (*Haematostaphis barteri*); a wild tree found in Taraba State. Adv. in Life Sci. and Technol., 33: 9-17.

Aremu, M.O., I.M. Ohale, A.M. Magomya, D.B. Longbap and O.A. Ushie, 2014. Compositional evaluation of raw and processed harms (*Brachystegia eurycoma*) seed flour. Appl. Food Biotechnol., 2: 9-18.

Aremu, M.O., I. Ogunlade and A. Olonisakin, 2007. Fatty acid and amino acid composition of cashew nut (*Anarcadium occidentale*) protein concentrate. Pak. J. Nutr., 6: 419-423.

Aremu, M.O., O. Olaofe and E.T. Akintayo, 2006a. A comparative study on the chemical and amino acid composition of some Nigerian under-utilized legume flours. Pak. J. Nutr., 5: 34-38.

Aremu, M.O., O. Olaofe and E.T. Akintayo, 2006b. Chemical composition and Physicochemical Characteristics of Two Varieties of Bambara Groundnut (*Vigna subterrenea*) Flours. J. Appl. Sci., 6: 1900-1903.

Aremu, M.O., O. Olaofe, S.K. Basu, G. Abulazeez and S.N. Acharya, 2010. Processed cranberry bean (*Phaseolus coccineus* L.) seed flour for the African diet. Canadian J. Plant Sci., 90: 719-728.

Aremu, M.O., S. Mamman and A. Olonisakin, 2013. Evaluation of fatty acids and physicochemical characteristics of six varieties of bambara groundnut (*Vigna subterranea* L. Verdc) seed oils. La Rivista Italiana Delle Sostanze, 90: 107-113.

Atasie, V.N., T.F. Akinhanmi and C.C. Ojiodu, 2009. Proximate analysis and physioco-chemical properties of Groundnut *(Arachis hypogaea* L.). Pak. J. Nutr., 8: 194-197.

Audu, S.S., M.O. Aremu and L. Lajide, 2011. Effect of procession on fatty acid composition of pinto bean (*Phaseolus vulgaris* L.) seeds. Int. J. Chem. Sci., 4: 114-119.

Awad, A.B. and C.S. Fink, 2000. Phytosterols as anticancer dietary components: evidence and mechanism of action. J. Nutr., 130: 2127-2130.

Awad, A.B., C.C. Karen, A.C. Downie and C.S. Fink, 2000. Peanuts as a Source of B-sitosterol, a Sterol with Anticancer Properties. Nutr. and Cancer, 36: 238-241.

Barba de la Rosa, A.P., I.S. Fomsgaard, B. Laursen, A.G. Mortensen, L. Olvera-Martinez, L. Silva-Sanchez, A. Mendoza-Herrera, J. Gonzalez-Castaneda and A. De Leon-Rodriguez, 2009. Amaranth (*Amaranthus hypochondriacus*) as an alternative crop for sustainable food production: Phenolic acids and flavonoids with potential impact on its nutraceutical quality. J. Cereal Sci., 49: 117-121.

Belewu, M.A., F.A. Adekola, G.B. Adebayo, O.M. Ameen, N.O. Muhammed, A.M. Olaniyan, O.F. Adekola and A.K. Musa, 2010. Physico-chemical characteristics of oil and biodiesel from Nigerian and Indian *Jatropha curcas* seeds. Int. J. Biol. Chem. Sci., 4: 524-529.

Bosch, L. and A. Alegna, 2005. Reverse-phase High Pressure Liquid Chromatography (RP-HPLC) determination of tigernut and orgeal amino acid contents. Food Sci. Technol. Int., 10: 30-40.

Branch, W.D., T. Nakayama and M.S. Chennan, 1990. Fatty acid rariation among US runner type peanut cultivars. J. Am. Oil Chem. Soc., 67: 591-596.

Bwade, K.E., B. Aliyu and A.M. Kwaji, 2013. Physicochemical Properties of Pumpkin Seed Oil Relevant to Bio-diesel Production and other Industrial Applications. Int. J. Eng. Bus. and Enterprise Appl., 4: 72-78.

Chen, Q., H. Gruber, E. Swist, K. Coville, C. Pakenham, W.M.N. Ratnayake and K.A. Scoggan, 2010. Dietary phytosterols and phytostanols decrease cholesterol levels but increase blood pressure in WKY inbred rats in the absence of salt-loading. Nutr. and Metabol., 7: 11-20.

Chopral, R.N., S.I. Naya and I.C. Chopra, 1986. Glossary of Indian medicinal plants (including the supplement). Canal of Scientific and Industrial Research, New Delhi, pp: 18-30.

Chung, J. and E. Choe, 2001. Effects of sesame oil in thermooxidative stability of soybean oil. Food Sci. Biotechnol., 10: 446-450.

Chung, S., M. Tomoe, U. Eiko, U. Kayoko, H. Rieko, Y. Noviko, M. Yasnuoby, K. Toyohite and Y. Shigeru, 1985. Administration of phosphatidycholine increases brain actylcholine concentration and improves memory in mice with dementia. J. Nutr., 125: 1484-1489.

Connor, W.E., M. Neuringer and S. Reisbick, 1992. Essential Fatty Acids: The Importance of n-3 Fatty Acids in the Retina and Brain. Nutr. Rev., 50: 21-29.

Cunnane, S. and M. Anderson, 1997. Pure Linoleate Deficiency in the Rat: Influence on Growth, Accumulation of n-6 polyunsaturates and (1-14C) linoleate Oxidation". J. Lipid Res., 38: 805-812.

Edmond, A.D., B.L.Z. Herve Cesar, P.E.N.K. Jean and P.K. Lucien, 2009. Fatty acid composition and properties of skin and digestive fat content oils from *Rhynchophorus palmarum* L. larva. Afr. J. Biochem. Res., 3: 089-094.

Elizabeth, F.A., O.D. Michael, V.O. Tunde, O.A. Mujidat, K.L. Stephen and O.S. Bamidele, 2012. Nigerian Jatropha Curcas Oil Seeds: Prospect for Biodiesel Production in Nigeria. Int. J. Renewable Energy Res., 2: 317-325.

Engler, C.R. and L.A. Johnson, 1983. Effects of processing and chemical characteristics of plant oils on performance of an indirect-injection diesel engine, J. Am. Oil Chem. Soc., 60:1592-1596.

Evbuowman, B.O., J.N. Lawson and M.M. Atuka, 2013. Some Physicochemical Properties of Cashew Nut (*Anacardium occidentale*) and Palm Kernel (*Elaeis guineensis*) Oil using Straight Run Gasoline. Int. J. Sci. and Eng. Investigations, 2: 82-84.

FAO/WHO, 1995. Energy and Protein requirement Genera Report of a Joint FAO/WHO/UWU expert consultation. WHO Technical Report Series No., 724.

Gaydon, E.M., J.P. Bianchini and J. Ratovogery, 1983. Triter pene alcohols, methyl sterols and fatty acid five Malagasy legume seed oils. J. Agric. Food Chem., 31: 833-836.

Glew, R.H., R.S. Glew, L.T. Chuang, Y.S. Huang, M. Millson and D. Constans, 2006. Amino acid, mineral and fatty acid content of pumpkin seeds (*Cucurbita* spp.) and *Cyperus esculentus* nuts in the Republic of Niger. Plant Foods for Human Nutr., 61: 51-56.

Gordon, M., 1993. Fats, Fatty Foods, In: Ranken MD, Kill RC. (Eds), Food Industries Manual, 23rd edition. Blackie Academic and Professional, London, pp: 179-186.

Grosso, N.R. and C.A. Guzman, 1995. Chemical composition of Aboriginal Peanut (*Arachis hypogaea* L.) seeds from Peru. J. Agric. Food Chem., 43: 102-105.

Grosso, N.R., E.I. Lucini, A.G. Lopez and C.A. Guzman, 1999. Chemical composition of aboriginal peanut (*Arachis hypogaea* L.) seeds from Uruguay. Grasasy Aceites, 50: 203-207.

Grosso, N.R., J.A. Zygadlo, A.L. Lamarque, D.M. Maestri and C.A. Guzman, 1997. Proximate, fatty acid and sterol compositions of aboriginal peanut (*Arachis hypogaea* L.) seeds from Bolivia. J. Sci. Food Agric., 73: 249-356.

Grundy, S.M. and G.L. Vega, 1988. Plasma cholesterol responsiveness to saturated fatty acids. Am. J. Clin. Nutr., 47: 822-824.

Hegested, D.M., L.M. Dusman, J.A. Johnson and G.E. Dallal, 1993. Dietary fat and serum lipids: An evaluation of the experimental data. Am. J. Clin. Nutr., 57: 875-883.

Hilditch, T.P. and P.N. Williams, 1964. The Chemical Constitution of Natural Fats. Chapman and Hall: London, UK, pp: 58-69.

Hu, F.B., 1997. Dietary fat intake and the risk of coronary heart disease in women. New Engl. J. Med., 337: 1491-1499.

Hu, F.B., M.J. Stampfer and J.E. Manson, 1999. Dietary Intake of Linolenic Acid and Risk of Fatal Ischemic Heart Disease Among Women. Am. J. Clin. Nutr., 69: 890-897.

Igwenyi, I.O., 2014. Comparative Study of the Physicochemical Properties of Vegetable Oil from *Irvigna gabonesis* and *Citrullus colocynthis* Dried Seeds Samples. Int. J. Biochem. Res. and Rev., 4: 568-573.

Ihekoronye, A.I. and P.O. Ngoddy, 1985. Integrated food science and technology for the tropics. Macmillan Publishers Ltd., London, pp: 28-50.

Ijarotimi, O.S. and O.O. Keshinro, 2012. Comparison between the amino acid, fatty acid, mineral and nutritional quality of raw, germinated and fermented African locust bean (*Parkia biglobosa*) fl our. Acta Sci. Pol., Technol. Aliment, 11: 151-165.

Katan, M.J., P.L. Zock and R.P. Mensink, 1995. Dietary oils, serum lipoproteinsandcoronary heart disease. Am. J. Clin. Nutr., 61: 1368-1373.

Kim, M., Siwon, N. and S.H. Yoon, 2007. Stereospecific analysis of fatty acid composition of chufa (*Cyperus esculentus* L.) Tuber Oil. J. Am. Oil Chem. Soc., 84: 1079-1080.

Kordyias, J.M., 1990. Processing and Preservation of Tropical and subtropical food. J. Agric. Food Technol., 12: 28-40.

Kris-Etherton, P.M., 2001. Summary of the scientific conference on dietary fatty acids and cardiovascular health: conference summary from the nutrition committee of the American Heart Association. Circulation, 103: 1034-1039.

Küllenberg, D., L.A. Taylor, M. Schneider and U. Massing, 2012. Health effects of dietary phospholipids. Lipids in Health and Dis., 11: 1-16.

Kyari, M.Z., 2008. Extraction and characterization of seed oils. Int. Agrophysics, 22: 139-142.

Law, M., 2000. Plant sterol and stanol margarines and health. Br. Med. J., 320: 861-864.

Mathew, T.J., M.M. Ndamitso, E.Y. Shaba, S. Mustapha, S.S. Muhammed and A.S. Salihu, 2014. Physicochemical and Phytochemical Composition of locust bean tree emperor moth larvae (*Bunaea alcinoe)* from Gurara Local Government Area, Niger state, Nigeria. Int. J. Eng. Sci. Invention, 3: 14-18.

McLeod, G. and J. Ames, 1988. Soy Flavor and its Improvement. Crit. Rev. Food Sci. and Technol., 27: 219-259.

Mensink, R.P. and M.B. Katan, 1992. Effect of dietary fatty acids on serum lipids and lipoproteins. A meta-analysis of 27 trials: Arteriosclerosis and Thrombosis, 12: 911-919.

Moreau, R.A., B.D. Whitaker and K.B. Hicks, 2002. Phytosterols, phytostanols and their conjugates in foods: structural diversity, quantitative analysis and health-promoting uses. Prog. in Lipid Res., 41: 457-500.

Morrison, W.H., R.J. Hamilton and C. Kalu, 1995. Sun flower seed oil. In: R.J. Hamilton (ed.) Developments in oils and fats. Blackie Academic and Professional, Glasgow, pp: 132-152.

Mozaffarian, D., 2005. Does α-linolenic acid intake Reduce the Risk of Coronary Heart Disease? A Review of the Evidence. Alternative Therapies in Health and Med., 11: 24-30 quiz 31, 79.

Nangbes, J.G., J.B. Nvau, W.M. Buba and A.N. Zukdimma, 2013. Extraction and Characterization of Castor (*Ricinus communis*) Seed Oil. Int. J. Eng. and Sci. (IJES), 2: 105-109.

Normen, L.D. Holmes and J. Frohlich, 2005. Plant sterols and their role in combined use with statins for lipid lowering. Curr. Opin. Invest. Drugs, 307-316.

Nourrechni, H., B.C. Teoh and L.D. Clement, 1992. Viscocity of vegetable oils and fatty acids. J. Am. Chem. Soc., 69: 1184-1188.

Oderinde, R.A. and O.A. Tairu, 1988. Evaluation of the properties of yellow nutsedge (*Cyperus esculentus*) tuber oil. Food Chem., 28: 233-237.

Odoemelam, S.A., 2005. Proximate Composition and selected physicochemical properties of the seeds of African oil bean (*Pentaclethra marcrophylla*). Pak. J. Nutr., 4: 382-383.

Ogbonna, P.E. and S.I. Ukaan, 2013. Chemical composition and oil quality of seeds of sesame accessions grown in the Nsukka plains of south eastern Nigeria. Afr. J. Agric. Res., 8: 797-803.

Ogbuagu, M.N. and S.A. Odoemelam, 2013. Fatty Acid and Amino Acid Profiles of an Under-Utilized Tropical African Seed: *Adenanthera pavonina*. Pac. J. Sci. and Technol., 14: 310-318.

Ogungbenle, H.N. and A.A. Atere, 2014. The Chemical, Fatty Acid and Sensory Evaluation of *Parinari curatellifolia* Seeds. Br. Biotechnol. J., 4: 379-386.

Ogunsuyi, H.O. and B.M. Daramola, 2013. Evaluation of almond (*Prunus amygdalus*) seed oil as a viable feedstock for biodiesel fuel. Int. J. Biotechnol. Res., 1: 120-127.

Okafor, J.N.C., J.U. Mordi, A.U. Ozumba, H.M. Solomon and I. Olatunji, 2003. Preliminary studies on the characterization of contaminants in tigernut (yellow) variety. In Proceedings of the 27th Annual Conference of Nigerian Institute of Food Science and Technology, 13-17th Oct., pp: 210-211.

Oladele, A.K. and J.O. Aina, 2007. Chemical composition and functional properties of flour from two varieties of tigernut. Afr. J. Biotechnol., 6: 2473-2476.

Olaofe, O., E.I. Adeyeye and S. Ojugbo, 2013. Comparative study of proximate amino acids and fatty acids of Moringa oleifera tree. Elixir Appl. Chem., 54: 12543-12554.

Olaofe, O., H.N. Ogungbenle, B.E. Akhadelor, A.O. Idris, O.V. Omojola, O.T. Omotehinse and O.A. Ogunbodede, 2012. Physicochemical and fatty acids composition of oils from some legume seeds. IJBPAS, 1: 355-363.

Olaofe, O., J.A.V. Famurewa and A.O. Ekwagbere, 2010. Chemical functional properties of kidney bean seed flour. Int. J. Chem. Sci., 3: 51-69.

Omode, A., O. Fatoki and K.A. Olaogun, 1995. Physico-chemial properties of some under-exploited and non-conventional oil seed. J. Agric. Food Chem., 11: 50-53.

Oshodi, A., O. Olaofe and G.M. Hall, 1993. Amino acid, fatty acid and mineral composition of pigeon pea (*Cajanus cajan*). Int.J. Food Sci. Nutr., 43: 187-191.

Oyeleke, G.O., E.O. Olagunju and A. Ojo, 2012a. Functional and physicochemical properties of watermelon (*Citrullus lanatus*) seed and seed-oil. J. Appl. Chem., 2: 29-31.

Oyeleke, G.O., O. Afolabi, O.A. Olayiwola and R.O. Adetoro, 2012b. Oil quality characteristics and effects of temperaturevariations on some functional properties of horse eye (*Dioclea reflexa*) seed flour. J. Environ. Sci. Toxicol. and Food Technol., 2: 38-42.

Paul, A.A. and D.A.T. Southgate, 1985. McCance and Widdowsen's The Composition of Foods, Royal Society of Chemistry, London.

Pearson, D., 1976. The chemical analysis of foods. 7th edition, Churchill Living Stone Edinburgh, London NY, pp: 6-14.

Piironen, V. and A.M. Lampi, 2003. Occurrence and levels of phytosterols in foods: phytosterols as functional food components and neutraceuticals. Edited by Paresh C. Dutta CRC Press, pp: 1-32.

Piironen, V., D.G. Lindsay, T.A. Miettinen, J. Toivo and A.M. Lampi, 2000. Plant sterols: biosynthesis, biological function and their importance to human nutrition. J. Sci. Food and Agric., 80: 939-966.

Pollak, O.J. and D. Kritchvesky, 1981. Sistosterol. Monograph Atherosclerosis, 10: 1-219.

Raheja, R.K., C. Kaur, A. Singh and I.S. Bhatia, 1973. New colorimetric method for the quantitative estimation of phyospholipids without acid digestion. J. Lipid Res., 14: 695-697.

Rao, A.V. and R. Koratkar, 1997. Anticarcinogeniceffects of saponins and phytosterols. ACS Symposium Series, 662: 313-324.

Romero, A., C. Cuesta and F.J. Sanchez-Muniz, 1998. Effect of oil replenishment during deep-fat frying of frozen foods in sunflower oil and high-oleic acid sunflower oil. J. Am. Oil Chem. Soc., 75: 161-167.

Ruthig, D.J. and K.A. Meckling-Gill, 1999. Both (n-3) and (n-6) Fatty acids stimulate wound healing in the rat intestinal epithelial cell line, IEC-6. J. Nutr., 129: 1791-1798.

Salunkhe, D.K., S.S. Kadam and J.K. Chavan, 1985. CRC Postharvest Biotechnology of Food Legumes. CRC Press, Bola Raton, FL.

Solomon, M. and H. Owolawashe, 2007. The analyses of amino acid, fatty acid and mineral in a legume-cereal based complementary food blend used in Jos, Nigeria. The Internet J. Nutr. and Wellness, 4: 12-19.

Starks, M.A., S.L. Starks, M. Kingsley, M. Purpura and R. Jager, 2008. The effects of phosphatidylserine endocrine response to moderate intensity exercise. Int. Soc. Sports and Nutr., 5: 11-16.

Stump, P.K., 1980. Lipids: Structure and function-the biochemistry of plants. A Comprehensive Treatise, Academic Press, New York, 4: 2-261.

Temple, V.J., T.O. Ojobe and N.M. Kapu, 1990. Chemical analysis of tigernut (*Cyperus esculenta*). J. Sci. Food Agric., 50: 262-263.

Umerie, S.C. and J.N. Enebeli, 1997. Malt caramel from the nuts of *Cyperus esculentus*. J. Bio. Resour. Technol., 8: 215-216.

Warner, K. and S. Knowlton, 1997. Frying quality and oxidative stability of high-oleic corn oils. J. Am. Oil Chem. Soc., 74: 1317-1322.

WHO/FAO, 1994. Fats and Oils in Human Nutrition (Report of a Joint Expert Consultation). FAO Food and Nutrition Paper 57, Rome.

Wirtz, K.W., 1991. Phosphoslipid transfer of proteins. Ann. Rev. Biochem., 60: 73-99.

Yahaya, A.T., O. Taiwo, T.R. Shittu, L.E. Yahaya and C.O. Jayeola, 2012. Investment in Cashew Kernel Oil Production; Cost and Return Analysis of Three Processing Methods. Am. J. Econ., 2: 45-49.

Yeboah, S.O., Y.C. Mitei, J.C. Ngila, L. Wessjohann and J. Schmidt, 2012. Compositional and structural studies of the oils from two edible seeds: Tiger nut, *Cyperus esculentum* and asiato, *Pachira insignis*, from Ghana. Food Res. Int., 47: 259-266.