COMPARATIVE E VALUATION OF THE LIPID PROFILES OF TWO SOUP INGREDIENTS (*TETRACARPIDIUM ONOPHORUM* AND *IRVINGIA GABONENSIS* SEEDS) USED IN NIGERIA

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Abstract

Lipid compositions of the seed oils of Tetracarpidiumconophorum (conophornut) and Irvingiagabonensis (dika nut) used in Nigeria as soup ingredients were determined by gas chromatography. Crude fat level ranged from 63.5–61.6 g/100 g and the corresponding total fatty acids ranged from 60.7–58.9 g/100 g. SFA level ranged from 20.3–98.8 % total fatty acids. MUFA was very much wide apart with a range of 26.9–1.07 % with trans–MUFA predominating as 16.9–0.605 % respectively. PUFA range was 52.8–0.142 % with n–6 PUFA predominating as 49.2–0.142 % total fatty acids. PUFA/SFA range was 2.60–0.00144, MUFAA +PUFA range was 79.7–1.21, MUFA/SFA range was 1.33–0.0183 and EPSI range was 1.96–0.133. The fatty acid levels as food gave these values g/100 g: SFA, 12.3–58.2; MUFA, 16.3–0.629; PUFA, 32.1–0.083; MUFA+PUFA, 48.4–0.711. Energy contribution in kJ/100 g of fatty acids as food gave the values: SFA, 469–2210; MUFA, 620–23.9; PUFA, 1219–3.17 and total range was 2308–2237. The total phospholipid level range was 1369–276 mg/100 g with phosphatidylinositol (PI) predominating in T. conophorum (385 mg/100 g) while phosphatidylcholine predominated in I. gabonensis (128 mg/100 g). The total sterol level range was 306–253 mg/100 g with sitosterol predominating in the two samples. On the whole T. conophorum was more concentrated than I. gabonensis in crude fats; total fatty acids; MUFA; PUFA; PUFA/SFA; n–6/n–3; LA/ALA; MUFA+PUFA; MUFA/SFA; EPSI; MUFA, PUFA and MUFA+PUFA (as food); MUFA, PUFA as energy source and total energy; phospholipids and sterols. On the other hand, I. gabonensis was better concentrated than T. conophorum in SFA (fat), SFA (as food), SFA (in energy contribution) and cholesterol. On health ground T. conophorum is a better soup ingredient because it is better in unsaturated fatty acids, higher level of phospholipids and lower of cholesterol.

Keywords: *Lipid profiles, Tetracarpidiumc onophorum, Irvingia gabonensis, health ground.*

INTRODUCTION

Although tree nuts have been used for food since antiquity, the potentials of most tree nuts have not been fully exploited. In Nigeria, the situation is not different for conophor nut (*Tetracarpidium conophorum*), although there is no yield record of its annual production. Conophor nut is a tropical climbing shrub. It belongs to the family euphobiaceae. This exotic, perennial wild fruit is grown in the traditional farming system of the lowland humid tropics of Nigeria between 4º 15´ and 8 ºN of the equator (Okafor, 1983).

The fruit is a four–winged and ribbed capsule, containing subglobose seeds with thin brown shell and yellowish kernel. Ogunsua and Adebona (1983) stated that the oil from the shelled nut contains over 60 % linolenic acid which predisposes it for use as edible oil and industrial production of valuable products (soap, varnish, etc.). This indigenous snack food is harvested at the same time as fresh maize between May and August. Like other edible nuts, it can serve in food fortification and as a special treat to be added to candy, cakes, cookies or prepared as salted snacks (Adesioye, 1981). Ige *et al*. (1984) had worked on the functional properties of conophor seeds. Asaolu (2009) reported the amino acid composition of T. *conophorum*. *Irvingia gabonensis* belongs to the Irvingiaceae family. Recent work has shown that this family is closely related to the Ixonanthaceae and in some works the two families are combined (Keay, 1989). *Irvingia gabonensis* (O' Rorke), the wild mango or Dika Nut, with mango–like fruits. The tree may be readily recognised by its dense dark green evergreen foliage and characteristic stipules which are similar to those of *Klainedoxa* but smaller. The plant extends from Senegal to Sudan and south to Angola.

The fruit is widely used as a complement to other foods in most parts of southern Nigeria. Its kernels are a major raw material in the preparation of *ogbono* soup or as a condiment in the preparation of sauces used with African foods prepared from major staples such as *amala*, *eba*, pounded yam. Some reported pioneering works on the *I. gabonensis* included: the nutritional studies of pulp and kernel, uses (Irvinge, 1961), ecological studies, nutritional values of the pulp (Adeyeye and Arogunjo, 1977), determination of amino acid contribution of the hull of *I. gabonensis* seed as food ingredient (Adeyeye and Akinyeye, 2011) and the comparative evaluation of amino acid

profiles of the dehulled and hull parts of *Irvingia gabonensis* seeds (Adeyeye & Kenni, 2011). The vast majority of Nigerians are not only improperly fed but underfed (Oyenuga, 1968) and the widespread use of wild fruits, vegetables and nuts to supplement the traditional diets helps to alleviate this problem. The objective of this study was to determine the lipid profiles (crude fat, fatty acids, sterols and phospholipids) of *Tretracarpidiumc onophorum* and *Irvingia gabonesis* on comparative basis.

MATERIALS AND METHODS

Collection and Treatment of Samples

The seeds of the fruits were purchased from Ado–Ekiti, Nigeria, market. The seeds were dried, separately pulverised, sieved and kept in freezer (–4ºC) in McCartney bottles pending analysis. The samples were purchased between the months of June and August, 2011. The samples are common and well known; hence, no special identification was required.

Extraction of Lipid

A quantity of 0.25 g of each sample was weighed into the extraction thimble. 200 ml of petroleum ether (40–60ºC boiling range) was measured and then added to the dried 250 ml capacity flask. The covered porous thimble with the sample was placed in the condenser of theSoxhlet extractor arrangement that has been assembled (AOAC, 2005). The extraction flask with the oil was oven dried at 105ºC for 1 h. The flask containing the dried oil was cooled in the desiccator and the weight of the cooled flask with the dried oil was taken.

Preparation of Methyl Esters and Analysis

A weight of 50 mg of theextracted oil was saponified for 5 min at 95ºC with 3.4 ml of 0.5 M KOH in dry methanol. The mixture was neutralised by 0.7 MHCl. 3 ml of 14 % boron triflouride in methanol was added (AOAC, 2005). The mixture was heated for 5 min at 90ºC to achieve complete methylation process. The fatty acid methyl esters (FAMEs) were thrice extracted from the mixture with distilled n–hexane. The content was concentrated to 1.0 ml for analysis and 1 µl was injected into the injection pot of the GC. The FAMEs were analysed using an HP 5890 powered with HP gas chromatograph (HP 5890 powered with HP ChemStation rev. A09.01[1206] software [GMI, Inc, Minnesota, USA]) fitted with a flame ionization detector. Nitrogen was the carrier gas with a flow rate of 20–60 ml/min. The oven programme was: initial temperature at 60ºC, first ramping at 10ºC/min for 20 min, maintained for 4 min, second ramping at 15ºC/min for 4 min and maintained for 10 min. The injection temperature was 250ºC whilst the detector temperature was 320ºC. A capillary column (30 m x 0.25 mm) packed with a polar compound (HP INNOWAX) with a diameter (0.25 µm) was used to separate the esters. Split injection type was used having a split ratio of 20:1. The peaks were identified by comparison with standard fatty acid methyl esters.

Sterol Analysis

Sterol was analysed as described by AOAC (2005). The aliquots of the extracted fat were added to the screw–capped test tubes. The sample was saponified at 95ºC for 30 min, using 3 ml of 10 % KOH in ethanol, to which 0.20 ml of benzene had been added in extracting the non–saponifiable materials. Three extractions, each with 2 ml hexane, were carried out for 1 h, 30 min and 30 min respectively. The hexane was concentrated to 1 ml in the vial for gas chromatographic analysis and 1 µl was injected into injection pot of GC. The peaks were identified by comparison with standard sterols. The sterols were analysed using similar conditions as for FAME analyses.

Phospholipids Analyses

The modified method of Raheja *et al*. (1973) was employed in the analysis of phospholipids. A weight of 0.01 g of the extracted fat was added to each test tube. To ensure complete dryness of the fat for phospholipids analyses, the solvent was completely removed by passing stream of nitrogen gas on the fat. 0.40 ml chloroform was added to the tube followed by the addition of 0.10 ml chromogenic solution. The tube was heated at 100ºC in water bath for 1 min 20 sec. The content was allowed to cool to the laboratory temperature and 5 ml hexane added and the tube shaken gently several times. The solvent and the aqueous layers were allowed to be separated. The hexane layer was recovered and concentrated to 1.0 ml for analysis. The phospholipids were analysed using an HP 5890 powered with HP gas chromatograph (HP 5890 powered with HP ChemStation rev. A09.01 [1206] software [GMI, Inc, Minnesota, USA]) fitted with a pulse flame photometric detector. Nitrogen gas was used as the carrier gas with a flow rate of 20–60 ml/min. The oven programme was: initial temperature at 50ºC, whilst the detector temperature was 320ºC. A capillary column (30 m x 0.25 mm) packed with a polar compound (HP) with a diameter (0.25 µm) was used to separate the phospholipids. Split injection type was used having a split ratio of 20:1. The peaks were identified by comparison with standard phospholipids.

Quality Assurance

Standard chromatograms were prepared for sterols, phospholipids and FAMEs which were then compared with respective analytical results; calibration curves were prepared for all the standard mixtures and correlation coefficient determined for each fatty acid parameter, same for sterols and phospholipids. Correlation coefficient should be > 0.95 for any result to be acceptable. It was performed with Hewlett Packard Chemistry (HPCHEM) software (GMI, Inc, 6511 Bunker Lake Blvd Ramsey, Minnesota, 55303, USA).

Calculation of Fatty Acid per 100 g in Sample

At the data source and reference database levels, values for individual fatty acids (FAs) are usually expressed as percentages of total FAs. At the user database levels, values per 100 g of food are required. A conversion factor derived from the proportion of the total lipid present as FAs is required for converting percentages of total FAs to FAs per 100 g of food. Total lipid level was multiplied by a conversion factor of 0.956 to convert it to total fatty acids (Anderson, 1976). (0.956 is a conversion factor to convert total lipid to total fatty acids.) For fatty acids, precision is best limited to 0.1 g/100 g of fatty acids (Greenfield & Southgate, 2003).

Statistical Analysis

Statistical analysis (Oloyo, 2001) was carried out to determine coefficient of variation in per cent (CV%), linear correlation coefficient (r_{xy}), coefficient of determination (r_{xy}^2), linear regression coefficient (R_{xy}), coefficient of alienation (C_A) in per cent and index of forecasting efficiency (IFE) in per cent. The r_{xy} was subjected to the Table (criticall) value at $r_{=0.05}$ to see if significant differences existed in the values of FAs, sterol and phospholipids between conophor and dika seeds.

RESULTS AND DISCUSSION

Results in Table 1 depict the total lipid and the calculated total fatty acid levels on dry weight basis. The values of total lipids between the two samples were very close with the CV% of 2.19. The total fat of 63.5–61.6 g/100 g were favourably comparable with some of these animal fats (g/100 g): 42.5 (bull brain), 45.2 (hen brain) (Adeyeye, 2012), duck's meat and skin (43), beef fat (67), lamb fat (72) and pork fat (71) (Bender, 1992); cattle brain (47.3), sheep brain (38.1) and pig brain (42.6) (Fornias, 1996); in groundnut seeds (raw, cooked and roasted) the range was 47.6–49.6 (Adeyeye and Agesin, 2012) but much higher than in two other snack nuts: *Cola acuminata* (15.7) and *Garciniakola* (18.9) (Adeyeye & Ayejuyo, 1994).

Table 1: Crude fat and total fatty acid levels of *Tetracarpidiumc onophorum*and *Irvingiaga bonensis* seeds (g/100 g)

Parameter	*T. conophorum*	*I. gabonensis*	Mean	SD	CV%
Crude fat	63.5	61.6	62.6	1.37	2.19
Total fatty acids*	60.7	58.9	59.8	1.31	2.19

***Crude fat x 0.956; **SD =** standard deviation; **CV% =** coefficient of variation

In Table 2, the saturated fats (SFAs), the monounsaturated fats (MUFAs) and the polyunsaturated fats (PUFAs) of samples are shown. In the samples the following SFA recorded 0.00 % value: C5:0, in MUFA, there was 0.00 % in C24:1 (both samples) and C22:1 (*cis*–13) for conophor nut, in PUFA, 0.00 % was observed for C20:3 (*cis*–8, 11, 14) (for conophor), C20:3 (*cis*–11, 14, 17) (for conophor), C20:4 (*cis*–5, 8, 11, 14) (for conophor), C22:2 (*cis*–13, 16) (for conophor), C20:5 (*cis*–5, 8, 11, 14,17) (for conophor) and C22:6n–3 (both nuts). Values recorded not detected (–) in C2:0, C3:0, C6:0, C8:0 (all in both nuts) but only dika nut in C18:1 (*cis*–6), C18:2 (*trans*–9, 11), C18:3 (*cis*–9, 12, 15), C20:3 (*cis*–8, 11, 14), C22:1 (*cis*–13), C20:3 (*cis*–11, 14, 17), C20 : 4 (*cis*–5, 8, 11, 14), C22:2 (*cis*–13, 16), C24:0 and C20:5 (*cis*–5, 8, 11, 14, 17).

The most concentrated SFA was palmitic acid in conophor (10.2 % total fatty acid in sample) but it was the myristic acid (51.9 %) in dika nut. Most concentrated polyunsaturated acids were: linoleic acid (LA) (23.3 %) and rumenic acid (22.4 %) both in conoplor seed. In dika nut most concentrated monoenoic FAs were elaidic acid (0.598 %) and oleic acid (0.462 %) whereas most concentrated monoenoic acids in conophor were petroselinic acid (6.03 %) and elaidic acid (7.47 %). The LA and rumenic acids were close in values in conophor with respective values of 23.3 % and 22.4 %. The palmitic acid being the most concentrated SFA in conophor followed the usual trend in literature. This is true in groundnut seeds (Adeyeye & Agesin, 2012; Oyenuga, 1968) and cashew (roasted and unroasted) (Adeyeye, 2011). It is unusual in plant oils finding myristic and lauric acids constituting about 91.4 % of the total fatty acids with respective values of 51.9 % and 39.5 %; actually the two constituted a total of 92.5 % of the SFA in dika nut. In the comparative values of SFA in the two samples, the values were highly varied as demonstrated by the values of the CV% which varied from 35.4–14.1. The second most concentrated SFA in conophor was stearic acid (5.07 %) as seen in groundnut seeds and cashew kernel (roasted and unroasted). Among the monoenoic acids, elaidic acid was the most concentrated (7.47 %) followed closely by petroselinic acid (6.03 %) and vaccenic acid (4.98 %); all in conophor seeds. The DUFA levels in conophor ranged from 0.00007–23.3 % but mainly constituted by LA and rumenic acid with total composition of 45.7 % or 99.9998 % of the total DUFA. In the TUFA, the two acids present in conophor were close at 3.57–3.61 % as contained in gamma–linolenic acid (GLA) and alpha–linolenic acid (ALA), respectively.

Table 2: Fatty acid composition of the conophor and dika nut seeds (% total fat in sample)

Fatty acid	*T. conophorum*	*I. gabonensis*	CV%
C4:0 (Butyric acid)	0.0005	0.0003	35.4
C10:0 (Decanoic acid)	0.068	1.43	129
C12:0 (Lauric acid)	0.029	39.5	141
C14:0 (Myristic acid)	4.94	51.9	117
C16:0 (Palmitic acid)	10.2	5.30	44.7
C18:0 (Stearic acid)	5.07	0.678	108
C20:0 (Arachidic acid)	0.014	0.0008	126
C22:0 (Behenic acid)	0.017	0.0003	137
C24:0 (Lignoceric acid)	0.003	–	–
C14:1 (*cis*–9) (Myristoleic acid)	0.0001	0.0002	47.1
C16:1 (*cis*–9) (Palmitoleic acid)	0.00004	0.00009	54.4
C18:1(*trans*–6) (*trans*–Petroselinic acid)	4.50	0.006	141
C18:1(*cis*–6) (Petroselinic acid)	6.03	–	–
C18:1(*trans*–9) (Elaidic acid)	7.47	0.598	120
C18:1(*cis*–9) (Oleic acid)	3.88	0.462	111
C18:1(*trans*–11) (*trans*–Vaccenic acid)	4.98	0.0008	141
C20:1 (*cis*–11) (Gondoic acid)	0.00007	0.0002	68.1
C18:2 (*cis*(*n*–6)–9,12)(Linoleic acid, LA)	23.3	0.141	140
C18:2 (*cis*(*n*–6)–9,*trans*–11(Rumenic acid)	22.4	–	–
C20:2 (*cis*(*n*–6)–11, 14)(Eicosadienoic acid)	0.00007	0.0002	68.1
C18:3(*cis*(*n*–6)–6,9,12,)(Gamma–linolenic acid, GLA) 3.570.0003	141	–	–
C18:3(*cis*(*n*–3)–9,12,15)(Alpha–linolenic acid, ALA)	3.61	–	–

Table 3: Summary of information on the fatty acid profiles of the samples from Table 2

Fatty acid	*T. conophorum*	*I. gabonensis*	CV%
Saturated fatty acid (SFA)	20.3	98.8	93.2
Monounsaturated fatty acid (MUFA)	26.9	1.07	131
–*cis* MUFA	9.92	0.462	129
–*trans* MUFA	16.9	0.605	132
Polyunsaturated fatty acid (PUFA)	52.8	0.142	141
n–6 PUFA	49.2	0.142	141
n–3 PUFA	3.61	–	–
Total fatty acid (SFA+MUFA+PUFA)	100	100	–
Ratio of total fatty acid	1 :	1	–
PUFA/SFA	2.60	0.00144	141
n–6/n–3	13.6	–	–
LA/ALA	6.45	–	–
MUFA + PUFA	79.7	1.21	137
MUFA/SFA	1.33	0.0183	137
EPSI (PUFA/MUFA)	1.96	0.133	123

The summary of Table 2 into SFA, MUFA (*cis* and *trans*) and PUFA (*cis* and *trans*) levels (% total fatty acids) was depicted in Table 3. SFA range was 20.3–98.8 % and CV % of 93.2; in MUFA, total range was 26.9–1.07 % with *trans*– MUFA being higher than *cis*–MUFA as shown: *cis*–MUFA (9.92–0.462 %) and *trans*–MUFA (16.9–0.605 %); in PUFA, total range was 52.8–0.142 % with the *n*–6 PUFA predominating as 49.2–0.142 % but no *n*–3 PUFA was detected in dika nut. The results showed that while SFA (98.8 %) predominated in the dika nut, PUFA (52.8 %) predominated in the conophor seed. The SFA in conophor (20.3 %) related closely to the levels in groundnut: raw (19.0 %), roasted (20.0 %) and cooked (23.4 also the *trans*–MUFA in the groundnut was more concentrated than in the *cis*–MUFA (Adeyeye & Agesin, 2012).

Both lauric and myristic FAs are related to human health issues. Both are responsible for raising bad cholesterol levels in blood serum (Grundy, 1994) and have been shown to be strongly correlated with early heart attack (Kromhout *et al.*, 1995). This observation may lead to a suggestion that dika nut should be eliminated as one of the soup ingredients or in any other use that involves food for human consumption. The percentages of lauric (< 1%) and myristic (2–3 %) acids in beef are small. Palmitic acid (C16:0) formed 10.2–5.30 % in the samples. There is very strong evidence that palmitic acid raise serum cholesterol levels (Grundy, 1994) and that this occurs predominantly by increasing bad cholesterol (LDL) levels. This acid forms 27 % of the FAs in beef where it accounts for most of the cholesterol–raising activity from beef, thereby increasing the risk of atherosclerosis, cardiovascular disease and stroke (Nicolosi *et al.*, 1998). With the palmitic acid levels in the samples, it may be a less hypercholesterolemic FA than in the beef. Stearic acid (C18:0) accounted for 5.07–0.678 % in the samples. Several studies have shown that C18:0 effect on total cholesterol is minimal and not detrimental to human health (Bonanome *et al*., 1988; Zock *et al*., 1992; Kris–Etherton *et al.*, 1993; Judd *et al.*, 2002). For practical purposes, stearic acid is essentially neutral in its effects on serum total cholesterol, similar to oleic acid (Grundy, 1994). It is not clear why C18:0 does not raise cholesterol level as do other SFAs. A possible reason could be that it is rapidly absorbed into body tissue compared with other SFAs (Grundy, 1994). However, it has been observed in dogs, rats and hamsters that stearic acid or stearic acid–rich glycerides are absorbed less efficiently than SFAs of shorter chain length or their glycerides (Kitchevsky, 1994). Some investigators have speculated that C18:0 may be thrombogenic (causes blood clotting). This effect has not been proven (Grundy, 1994). Also, the effects of C18:0 on hypertension, cancer, obesity and other illnesses are unknown (Hu *et al*., 1999). Accumulation of certain long–chain FAs is associated with degenerative diseases of the central nervous system, such as behenic acid (C22:0; about 1 % in beef fat) and lignoceric acid (C24:0; about 1 %) as well as that of the unsaturated members of the C22 and C24 group (Whetsell, 2003). Other reasons other than the one stated above may be responsible for the formation of C22:0 and C24:0 since some traces were also detected in the samples: C22:0 (0.017–0.0003 %) and C24:0 (0.003 % in conophor only). Accumulation occurs because enzymes needed to maintain turnover of those FAs are lacking (Lord and Braloley, 2001); this might be responsible for the presence of those acids in the samples. Behenic acid has been detected to be a cholesterol–raising SFA factor in humans (Cater & Denke, 2001).

Elaidic acid [C18:1 (*trans*–9)] (7.47–0.598 %) is a monounsaturated *trans*–fatty acid which can raise bad cholesterol (LDL) in serum (Abbey and Nestel, 1994; Muller *et al*., 1999; Judd *et al*., 2002). *Trans*–fatty acids, may behave similar to SFAs. Studies have shown that foods enriched in C18:1–*trans* resulted in higher cholesterol (LDL) levels compared with C18:1–*cis* (Nicolosi *et al*., 1998; Judd *et al*., 2002). Whereas C18:1–*trans* raised bad cholesterol (LDL) equivalent to SFAs, it had no effects on good cholesterol (HDL) (Judd *et al*., 2002). Other MUFAs were palmitoleic acid (C16:1 *cis*–9) (0.00004–0.00009 %), *trans*–vaccenic acid (C18:1 *trans*–11) (4.98–0.0008 %) and myristoleic acid (C14:1 *cis*–9) (0.0001–0.0002 %). *Trans*–vaccenic acid is important in the human bodies' production of conjugated linolenic acid (CLA) which is discussed later. Palmitoleic acid is also found in rich amounts in macadamia nuts, olive, canola and peanut oils. C16:1 *cis*–9 is beneficial in reducing bad cholesterol (LDL). Petroselinic acid (C18:1 *cis* –6) occurs up to the level of 50 % or more in seed oils of the Umbelliferae family, including carrot, parsley and coriander. Kleiman and Spencer (1982) gave the levels of petroselinic acid (PA) as 24–37 % in the various species of Umbelliferae and Araliaceae. The unusual position of the double bond in this FA provides an opportunity for production, through cleavage of this bond, of valuable raw materials–lauric and adipic acids. Petroselinic acid range in the present samples was 6.03–ND %. The data of Weber *et al*. (1995) on fat absorption and fecal excretion indicate thatpetroselinc acid from dietary triacylglycerols is absorbed as readily as oleic acid. Reduction in the concertration of arachidonic acid in the lipids of heart, liver and blood with concomitant increase in the concentration of linoleic acid suggests petroselinic acid–mediated inhibition of arachidonic acid synthesis.

Oleic acid (C18:1 *cis*–9) is the primary MUFA in beef and accounts for about 33 % of the FA in beef. It is also found in rich amounts in olive, canola and peanut oils. Available evidence indicates that while

most SFAs raise serum cholesterol concentrations the monounsaturated oleic acid does not (Denke, 1994). For practical purposes, it is convenient to use the neutrality of oleic can acid as baseline with which to judge the responses of other FAs. The fact that the body synthesizes a large quantify of oleic acid suggests that it has a variety of biological uses, and to this extent the concept of the neutrality of oleic canbe extended to imply safety (Grundy, 1994). In several studies on the relative carcinogenicity of FAs or their ability to suppress the immune system, oleic acid was the fatty acid with the least negative effect (Grundy, 1994). One reason why oleic acid may not raise serum cholesterol concentrations is because it is a favoured substrate for the liver enzyme that converts cholesterol to an inactive form (the Acyl CoA transferase: cholesterol acyltransferase) (Grundy, 1994). Oleic acid was low in all in the samples with a value range of 3.88–0.462 %. The major important polyunsaturated fatty acids are linoleic acid (LA) (C18:2, *cis*–9, 12) (23.3–0.142 %); rumenic acid (C18:2 *cis*–9, *trans*–11, rumenic acid) (22.4–ND %); gamma–linolenic acid (GLA) (C18:3 *cis*–6, 9, 12) (3.57–0.0003 %) and alpha–linolenic acid (ALA) (C18:3 *cis*–9, 12, 15) (3.61–ND %). ALA is classified as a short–chain omega–3 FA and is also found in nuts and seeds. The meat and milk of grazing animals has been reported to contain significantly more omega–3 FAs than does meat and milk of animals fed conserved forages and grains. This higher content of omega–3 FAs may be beneficial to human health (Kelly *et al*., 1988; Dhiman, 1999). LA is also found in corn, sunflower oil, safflower oil and soybeans. LA is in omega–6 family. For many years linoleic acid (C18:2; omega–6) was thought to be the preferable fatty acid for the diet because it was considered to be the most effective cholesterol–lowering FA. However, despite an increase in linoleic acid intake (from about 4 % to 7 %), there has been a growing reservation about recommending its consumption, due to no proven long–term safety (Grundy, 1994). In humans, high supplemental intakes of linoleic fatty acids can lower good cholesterol concentration and may increase the risk of cholesterol gallstones. In addition, the presence of linoleic acid in bad cholesterol lipids makes them more prone to oxidation, which could promote atherosclerosis. Because of these detrimental effects, current recommendations have been moderated and now caution that intakes of this FA should not exceed current concentrations (about 7 % of total energy intake) (Grundy, 1994). However, recent information from the American Heart Association indicates that linoleic acid has a noticeable effect on lowering cholesterol further than oleic and palmitic acids when plasma cholesterol levels are high (> 200 mg/dl). They suggest that at a 10 % calorie intake in the form of PUFAS, linoleic acid achieves a maximal effect on cholesterol lowering. It also has been suggested (Iso *et al*., 2002) that a higher intake of linoleic acid appear to protect against stroke, possibly through potential mechanism of decreased blood pressure, reduced platelet aggregation and enhance deformability of erythrocyte cells.

The omega–3 FAs present in pastures, like the ALA (C18:3), appear to have little direct value for human health. However, the human body can add 2 or 4 carbons to these 18–carbon chains fats to produce 20– or 22–carbon chain omega–3 FA. Thus, ALA (C18:3) is a precursor for EPA (C20:5) and DHA (C22:6) FAs, which are important for human health. It has been suggested that ALA has a beneficial effect on cardiovascular heart disease (Ascherio *et al.*, 1999; Hu *et al*., 1999). However, other studies reported no evidence of ALA having a positive effect on cardiovascular heart disease (Renaud *et al.*, 2002; Sanderson *et al*., 2002). Although ALA supplementation causes an increase in the blood and plasma levels of ALA, EPA and DPA, no benefit has shown on either risk factors for cardiovascular diseases or on the secondary prevention of cardiovascular heart disease (Sanderson *et al.*, 2002). ALA (C18:3) may help balance linoleic acid (C18:2) and be beneficial. Linoleic acid (C18:2, omega–6) and alpha–linolenic acid (C18:3; omega–3), are plant FAs that can be transformed to CLA (conjugate linolenic acid) by bacteria in the rumen (Kepler *et al*., 1966). CLA is a collective term describing a mixture of positional and conjugated isomers of linoleic acid (C18:2) involving a double bond at positions 8 and 10, 9 and 11, 10 and 12, or 11 and 13 (Eulitz *et al.*, 1999). Each of these positional C18 isomers can occur in *cis–trans*, *trans–cis*, *cis–cis and trans–trans* forms (Eulitz *et al*., 1999). In beef and milk samples, the *cis*9–*trans* 11 and the *cis10–trans* 12 CLA are the predominant forms.

Interest in CLA (rumenic acid) research has increased in the past few years as a result of reports of CLA consumption providing several health benefits (Kramer, 1998). Because plants do not synthesize CLA, ruminant fats in milk or meat are the primary dietary CLA sources for humans (Herbein *et al*., 2000). This literature information may not be true with the observation in conophor seed where CLA value was 22.4 % which was very close to LA value of 23.3 % in conophor seed. The predominant CLA in ruminant fats is the *cis*–9, *trans*–11 isomer that accounts for more than 80 % of total CLAs (Chin *et al*., 1992). It has been found that CLA is an antioxidant, which also reduces circulating cholesterol in mice (West *et al*., 1998). Other literature reports that CLA has a positive effect by reducing cardiovascular risk, protects against atherosclerosis, is anti–carcinogenic, reduces body content of adipose tissue and lipid, and enhances the immune system (Lee *et al*., 1994; Nicolosi *et al*., 1997; Ip *et al*., 1991, 1994; West *et al*., 1998; Cook

et al., 1993). It has been found that stearic acid (C18:0) cannot be stored well in tissue. It is converted to oleic acid (*cis*–18:1) apparently so body fat can be maintained in a "liquid state" at body temperature (Herbein *et al.*, 2000). The enzyme that adds a double bond to stearic acid to form oleic acid is SCD (stearoyl–CoA desaturase– or Δ^9–desaturase). Most tissues of ruminants, mice, rat and chicken, have SCD, especially in the intestines, liver, adipose tissue and mammary glands. This enzyme has also been detected in humans. However, the distribution of SCD in humans is unknown. In humans, the liver is the principal tissue containing SCD and presumably also has the highest SCD activity (Turpeinen *et al*., 2001). SCD is important because it can add a *cis*–9 double bond to convert *trans*– vaccenic acid (TVA) (*trans* –11, 18:1) to CLA. Therefore, conophor fat is not only an excellent source of CLA, but also contains reasonable amounts of TVA, which can be converted to CLA in the human body (Adlof *et al*., 2000). Moreover, some studies confirmed that when a diet rich in TVA was fed to humans, mice or rats, accumulation of CLA in serum fat or body tissue was detected in a much higher conversion pattern than feeding CLA itself (Salmine *et al*., 1998; Santora *et al*., 2000; Banni*et al*., 2001). Turpeinen *et al*. (2001) showed that the conversion rate over a range of TVA intakes (1.5, 3 and 4.5 g TVA/day) in human subjects was 19 %, and that interindividual differences were prominent ranging from one non–responder to a conversion rate greater than 30 % in another subject. Whether the amount of CLA formed from TVA in the diet will result in positive human health benefits remains to be seen. Banni *et al*. (2001) showed that the CLA levels formed from TVA sources reduced the total number of cancer pre malignant lesions by about 50 % in rats. TVA is a *trans* fatty acid that raise bad cholesterol in serum (Judd *et al*., 2002), however, the conversion to CLA is a benefit for human health.

Petroselinic acid (6–18:1) in seed oils of the Umbelliferae is synthesised by an enzyme that removes hydrogens from position 4 of palmitate, before the resulting 4–16:1 is elongated by two carbon atoms.

16:0 *desaturation* 4–16:1 *elongated* 6–18:1 petroselinic acid

Petroselinic acid was the second largest MUFA (6.03 %) in conophor seed.

Table 3 further contains some calculated ratio parameters, all from Table 2 results. The relative amounts of PUFA and SFA in dietary oils is important in nutrition and health. The ratio of

determining the detrimental effects of dietary fats. The higher the P/S ratio the more nutritionally useful nutritionists as being beneficial in the human diet. The essential PUFA status index (EPSI), (ratio of sum of all n–3 and n–6 FAs and the sum of all *n*–7 is the dietary oil. This is because the severity of atherosclerosis is closely associated with the proportion of the total energy supplied by SFAs and PUFAs (Honatra, 1974). The present PUFA/SFA was good in conophor seed (2.60) but poor in dika nut (0.00144). From several *in vivo* and *in vitro* studies with different animal species it is well known that ALA, LA and oleic acid (18:1*n*–9) compete for the same Δ^6–desaturase in the metabolic cascade. Dietary studies on rats and other animals have shown that ALA is a strong suppressor of *n*–6 FA metabolism, whereas 10 times as much LA is required to give an equal suppression of *n*–3 metabolism (Holman, 1998). The *n*–6 and *n*–3 FAs have critical roles in the membrane structure (Kinsella, 1990) and as precursors of eicosanoids, which are potent and highly reactive compounds. Since they compete for the same enzymes and have different biological roles, the balance between the *n*–6 and *n*–3 FAs in diet can be of considerable importance (WHO/FAO, 1994). The ratio of *n*–6 to *n*–3 or specifically LA/ALA in the diet should be between 5:1 and 10:1 (WHO/FAO, 1994) or 4–10 g of *n*–6 FAs to 1.0 g of *n*–3 FAs (CGPC, 1990). As LA is almost always present in foods, it tends to be relatively abundant in animal tissues. C18:2 (*n*–6) and C18:3 (*n*–3) FAs are the biosynthetic precursors in animal systems of C20 and C22 PUFAs, with 3–6 double bonds, via sequential desaturation and chain–elongation steps (desaturases in animal tissues can only insert a double bond on the carboxylside of an existing double bond (Berg *et al*., 2007). On the overall *n*–6/*n*–3 ratios, the value of 13.6 (conophor) showed that the PUFA composition was skewed towards *n*–6 much more than *n*–3; however, LA/ALA of 6.45 fell within 5:1 and 10:1 in conophor seeds. Whilst it would be easy for the body to synthesise AA[20:4(*n*–6)], it may be difficult to synthesise the *n*–3 PUFA series especially eicosapentaenoic acid [20:5(*n*–3) or EPA] because of the relative lower level of C18:3 (*n*–3) and so the seed might need enhancement in this PUFA. The MUFA/SFA levels in the samples ranged from 1.33–0.0183 which were less than in the P/S levels particularly in conophor seeds. The relative proportion of MUFA/SFA is an important aspect of phospholipids compositions and changes to this ratio have been claimed to have effects on such disease states as cardiovascular disease, obesity, diabetes, cancer and neurophatological conditions. For example, MUFA/SFA have been shown to have cytoprotectiveactions in pancreatic β–cells. *cis*–Monoenoic acids have desirable physical properties for membrane lipids in that they are liquid at body

rature, yet are relatively resistant to oxidation. They are now recognised by

and *n*–9 FAs) is an indicator of essential PUFA status. The higher the EPSI the better the essential

PUFA status. The EPSI values in the samples ranged between 1.96–0.133.

Table 4: Statistical analysis of the fatty acid profiles in Table 2

Parameter	Value
Correlation coefficient (r_{xy})	–0.6620
Coefficient of determination (r_{xy}^2)	0.4383
Regression coefficient (R_{xy})	106
Mean±SD due to *T. conophorum*	33.3±17.2
Mean±SD due to *I. gabonensis*	33.3±56.7
Coefficient of alienation (C_A %)	74.9
Index of forecasting efficiency (IFE %)	25.1
Statistical decision at $r_{=0.05}$ (0.997)	Result not significant

The statistical analysis of the results in Table 2 is shown in Table 4. The r_{xy} was low (–0.6620); the R_{xy} showed that for every unit increase in the FA of conophor seed, there was a corresponding increase of 106 in dika nut; the mean values were close but values were differently scattered with levels of 33.3±17.2 % (conophor) and 33.3±56.7 % (dika nut). The C_A was high (74.9 %) leading to low IFE (25.1 %) and the overall result not being significantly different. The IFE showed that prediction of relationship between conophor and dika nut FAs would be difficult because reduction in the error of prediction of relationship was just 25.1 %.

In Table 5, the various fatty acid levels as food were shown. All the values reflected the pattern as seen in Table 2 for the fatty acids. The results in Table 5 were summarised into their groups as depicted in Table 6. In Table 7, the energy contribution per each group of the FAs was shown. Although a very close observation will reveal that the percentage energy contribution was equivalent to fatty acid levels, this type of result could only be accurately obtained if the fat could be calculated as food (as shown in Table 5). The *trans*–MUFA energy contribution was high at 16.9 % > 9.92 % *cis*–MUFA in conophor; this could be dangerous on health reasons. A sum of 98.8 % of the energy was produced by SFA in dika nut. Table 8 shows the levels of various phospholipids in the samples. Phospholipids are not essential nutrients: they are just another lipid and, as such, contribute 9 kcalories per gram of energy. The total phospholipids ranged between 1369–276 mg/100 g.

Table 5: Fatty acid (g/100 g) *T. conophorum and I. gabonensis* as food

Fatty **acid**	***T. conophorum***	***I. gabonensis***	CV %
Butyric acid	0.0003	0.0002	28.3
Decanoic acid	0.041	0.841	128
Lauric acid	0.018	23.2	141
Myristic acid	3.00	30.6	116
Palmitic acid	6.18	3.12	46.5
Stearic acid	3.08	0.399	109

Lignoceric acid	0.002	–	–
Myristoleic acid	0.00006	0.00014	56.6
Palmitolec acid	0.00002	0.00005	60.6
trans–Petroselinic acid	2.73	0.004	141

Petroselinic acid	3.66	–	–
Elaidic acid	4.54	0.352	121
Oleic acid	2.36	0.272	112
Vaccenic acid	3.02	0.0005	141
Gondoic acid	0.00004	0.00009	54.4
Linoleic acid, LA	14.1	0.083	140
Rumenic acid	13.6	–	–
Eicosadienoic acid	0.00004	0.00009	54.4
Gamma–linolenic acid, GLA	2.17	0.0002	141
Alpha–linolenic acid, ALA	2.19	–	–

Table 6: Summary of information of the fatty acid (g/100 g) levels as food from Table 5

Fatty **acid**	**T. *Conophorum***	***I. gabonensis***	**CV%**
SFA	12.3	58.2	92.1
MUFA	16.3	0.629	131
– *cis* MUFA	6.02	0.272	129
– *trans* MUFA	10.3	0.356	132
PUFA	32.1	0.083	141
n–6 PUFA	29.9	0.083	141
n–3 PUFA	2.19	–	–
MUFA + PUFA	48.4	0.711	137

Cephalin, lecithin, lysophosphati–dylcholine and phosphatidylinositol were all better concentrated in the conophor sample than the dika nut whereas phosphatidylserine was more concentrated in dika nut than the conophor seed. Lecithin is usually the most abundant phospholipid in animals and plants, often amounting to almost 50 % of the total, and as such it is the key building block of membrane bilayers. This observation was true for lecithin in the dika nut [128 mg/100 g, 46.4 %)] but not so in the conophor nut; it is a distant third position in the conophor [302 mg /100 g, 22.1 %)]. Phosphatidylcholines (PC) are a class of phospholipids that incorporate choline as a headgroup. They are a major component of biological membranes and can be easily obtained from a variety of readily available sources such as egg yolk or soy beans from which they are mechanically extracted or chemically extracted using hexane. They are also a member of the lecithin group of yellow–brownish fatty substances occurring in animal and plant tissues. Phosphatidycholines are such a major component of lecithin that in some contents the terms are sometimes used as synonyms. However, lecithin extract consists of a mixture of phosphatidylcholine and other compounds.

Lysophosphatidylcholine (LPC) was the highest concentrated in conophor (398 mg/100 g, 29.1 %) but closely followed by phosphatidylinositol (PI) (385 mg/100 g, 28.1 %), a difference of 1.0 %; in fact no particular phospholipid could be said to be major in concentration in the conophor because the rest three members occupied 22.1%, 18.6 % and 2.21 %. While phosphatidylcholine (PC) could be said to be major (46.4 %) in dika nut, the rest members were also close with values of 16.8 %, 14.6 %, 11.2 % and 10.9 %. Cephalin is found in all living cells, although in human physiology it is found particularly in nerves, such as the white matter of brain, nerves, neural tissue and in spinal cord. The US Food and Drug Administration (USFDA) has stated that consumption of PS may reduce the risk of cognitive dysfunction in the elderly (Adeyeye & Oyarekua, 2011). In addition to the increased caloric burden of a diet rich in fats like phosphatidylcholine, a recent report has linked the microbial catabolites of phosphatidylcholine with increased atherosclerosis through the production of choline, trimethylamine oxide and betaine (Wang *et al*., 2011). The statistical analysis of Table 8 is shown in Table 9. The r_{xy} was low at 1.910348e–3 with high R_{xy} of 55.1. The results in the conophor were wide apart (272±149 mg/100 g) than in dika nut (55.1±41.3 mg/100 g). The C_A was high (99.9998175) but very low IFE (1.825 e–4) thereby making prediction of relationship almost impossible in the phospholipid levels of the samples and the results were however not significant different.

Table 7: Energy distribution as contributed by the Fatty acid groups in conophor and dika nut seeds (values in kJ and kCal/100 g food)

Fatty acid group	*T. conophorum*	*I. gabonensis*	CV %
SFA	469 kJ (20.3 %)	2210 kJ (98.8 %)	91.9
	(111 kCal)	(524 kCal)	
MUFA	620 kJ (26.9 %)	23.9 kJ (1.07 %)	131
	(147 kCal)	(5.66 kCal)	
–*cis* MUFA	229 kJ (9.92 %)	10.3 kJ (0.462 %)	129
	(54.2 kCal)	(2.45 kCal)	
–*trans* MUFA	391 kJ (16.9 %)	13.5 kJ (0.606 %)	132
	(92.6 kCal)	(3.21 kCal)	
PUFA	1219 kJ (52.8 %)	3.17 kJ (0.141 %)	141
	(289 kCal)	(0.750 kCal)	
n–6 PUFA	1136 kJ (49.2 %)	3.17 kJ (0.141 %)	141
	(269 kCal)	(0.750 kCal)	
n–3 PUFA	83.4 kJ (3.61 %)	–	–
	(19.7 kCal)	–	–
Total energy	2308 kJ	2237 kJ	2.21
	(547 kCal)	(533 kCal)	

Table 8: Phospholipid levels (mg/100 g) of conophor and dika nut seeds

Phospholipid	*T. conophorum*	*I. gabonensis*	CV %
Phosphatidylethanolamine (PE)	254 (18.6 %)	46.4 (16.8 %)	97.7
Phosphatidylcholine (PC)	302 (22.1 %)	128 (46.4 %)	57.2
Phosphatidylserine (PS)	30.2 (2.21 %)	40.4 (14.6 %)	20.4
Lysophosphatidylcholine (LPC)	398 (29.1 %)	31.0 (11.2 %)	121
Phosphatidylinositol (PI)	385 (28.1)	30.2 (10.9 %)	121
Total	1369	276	94.0

The phytosterol results in Table 10 showed the results to be close (total basis) between the samples with values of 306–353 mg/100 g and CV % of 10.1. The following phytosterols: cholestanol and ergosterol had 0.00 mg/100 g each and 0.00 mg/100 in 5–Avenasterol in dika nut. Sitosterol was highest in both samples with 126–304 mg/100 g (or 41.2–86.1 %) followed by campesterol (93.9 mg/100 g or 30.7 %) in conophor but stigmasterol (25.7 mg/100 g or 7.28 %) in dika nut. Sitosterol in conophor was less than ½ of the value in dika nut. In the samples of groundnut (*Arachis hypogaea*) seeds, cholestanol and 5–avenasterol recorded 0.00 mg/100 g in raw, roasted and cooked seeds. Also sitosterol occupied the first position in concentration among all phytosterols in all the samples of raw, roasted and cooked groundnut seeds (Adeyeye & Agesin, 2012). β–sitosterol is one of several phytosterols with chemical structures similar to that of cholesterol. It is widely distributed in the plant kingdom and is found in cumin seed, *Nigella sativa*, pecans, corn oils, wheat germ, etc. Alone and in combination with similar phytosterols, β–sitosterol reduces blood levels of cholesterol and is sometimes used in treating hypercholesterolemia. In Europe, β–sitosterol plays a major role in treatment of herbal therapy of being prostatic hypertrophy; it is also used in Europe for the treatment of prostatic carcinoma and breast cancer although the benefits are still being evaluated in the USA (Prager *et al*., 2002). β–sitosterol was also the major sterol in the three seed oils of *Collocyn thiscitrullus* (CLCT), *Cucurbita moschata* (CCBT) and *Cyperuse sculentus* (CYP) (Akintayo, 2004). While β–sitosterol occupied the second position in *Plukenetia canophora* (PKCP); it occupied the first position in *Adenopus breviflorus* (ADB) seed oils (Akintayo & Bayer, 2002). Both CLCT, CCBT, CYP (Akintayo, 2004); raw, roasted and cooked groundnut seeds (Adeyeye & Agesin, 2012) also contained some quantities of cholesterol, campesterol and stigmasterol just like they were present in the two nut samples. The cholesterol levels in the nut samples (2.92–8.87 mg/100 g) could be favourably compared with the levels in the three different groundnut seeds with a range of 8.93–9.28 mg/100 g. The lowest varied phytosterol was sitosterol (CV% = 58.5) whereas campesterol was the most varied (CV% = 103) between the two samples.

Table 9: Statistical analysis of the phospholipid profiles in Table 8

Parameters*	Value
$_{xy}$	1.910348 e–3
r_{xy}^2	3.649e–6
R_{xy}	55.1
Mean±SD due to *T. Conophorum*	272±149
Mean±SD due to *I. Gabonensis*	55.2±41.3
C_A	99.9998175
IFE	1.825 e–4
Statistical decision at $r_{=0.05}$(0.878)	Result not significant

***See Table 2**

Table 10: Sterol levels (mg/100 g) of conophor and dika nut seeds

Sterol	*T. conophorum*	*I. gabonensis*	CV%
Cholesterol	2.92 (0.954 %)	8.87 (2.51 %)	71.4
Cholestanol	0.00 (–)	0.00 (–)	–
Ergosterol	0.00 (–)	0.00 (–)	–
Campesterol	93.9 (30.7 %)	14.7 (4.16 %)	103
Stig– masterol	6.10 (1.99 %)	25.7 (7.28 %)	87.2
5–Avenasterol	77.5 (25.3 %)	0.00 (–)	–
Sitosterol	126 (41.2 %)	304 (86.1 %)	58.5
Total	306	353	10.1

Quality assurance: The correlation determined for all the standards: fatty acids, phospholipids and phytosterols, all had values ranging as follows: 0.99833–0.9997 (fatty acids), 0.99909 – 0.99999 (phospholipids) and 0.99920 –0.99994 (phytosterols); all the correlation values were greater than 0.95 which is the critical correlation for acceptance of these types of analytical results, thus attesting to the quality assurance of the determinations.

CONCLUSION

The results of these analyses and other calculations showed that the samples contained unequal distribution of most parameters determined. *T. conophorum* was better in crude fat (and total fatty acids), MUFA, PUFA, PUFA/SFA, *n*–6/*n*–3, LA/ALA, MUFA + PUFA, MUFA/SFA, EPSI and total phospholipids than the corresponding values in *I. gabonensis* whereas *I. gabonensis* was better in SFA and total phytosterol particularly in cholesterol and sitosterol. From the overall observation *Tetracarpidium conophorum* would serve as a better soup ingredient or food because of its dietary qualities as shown by high linoleic acid, high rumenic acid, high GLA and ALA, low SFA, high phospholipids and low cholesterol; on the other hand *Irvingia gabonensis* should be avoided nutritionally because of its high level of SFA (almost the only FA present as 98.8 %) particularly serum cholesterol enhancing SFA like lauric acid (C12:0, 39.5 %), myristic acid (C14:0, 51.9 %) and palmitic acid (C16:0, 5:30 %); and relatively higher level of cholesterol (8.87 mg/100 g).

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