LIPID COMPOSITION OF RAW, ROASTED AND COOKED DEHULLED (*Treculiaafricana*) SEEDS: DIETARY IMPLICATIONS

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Abstract: The following determinations were carried out on the raw and processed *Treculiaafricana* seed samples using standard analytical methods: crude fat, fatty acids, phytosterols and phospholipids analyses and the results were subjected to analysis of variance (ANOVA). The results were: crude fat range (g/100g): 10.4, raw dehulled flour (RDF), 2.75, roasted dehulled flour (RSDF) and 3.12, cooked dehulled flour (CDF); SFA range (% total fat): 20.3 – 33.6; MUFA, 32.1 – 38.4; total polyunsaturated unsaturated fatty acid (PUFA = DUFA + TUFA) was RDF (36.6%) <RSDF (41.5%) <CDF(42.2%); PUFA/SFA was 1.02 – 2.03; *n*-6/*n*-3 range was 6.95 – 29.8. The following phospholipids were highest in the samples (mg/100g): lecithin, raw dehulled seed flour (110), phosphatidylinositol, roasted and cooked dehulled seeds flour (716, 772, respectively). Among the phytosterols, sitosterol was highest in each sample with a range of 127 – 293 mg/100 g. The analysis of variance (ANOVA) showed that there were significant differences between the results of fatty acids (g/100g as food), energy contributions from various fatty acids groups; phospholipids and phytosterols contents.

Keywords: Lipid profiles, processed, raw, *Treculiaafricana*

Introduction

Many fruits, vegetables, nuts, grains, fish, dairy and meat products contain several natural components that deliver benefits beyond basic nutrition, such as lycopene in tomatoes and omega-3 fatty acids in soy and other foods from plant sources. Lipids in the diet have been associated with the rising prevalence of many chronic diseases. There is an increasing incidence of life-style related diseases such as obesity, hyperlipidemia, hypertension and obesity and cancer worldwide. It is also noted that quantity and quality of dietary lipids could be important modulators associated with the morbidity and mortality of these diseases. There have been recent developments with regard to functional lipids (such as omega-3 and omega-6 fatty acids, conjugated linoleic acids, medium chain triglycerides) and phytosterols have many beneficial effects on human health such as in obesity, bone health, and in treating and managing depression, blood pressure, cardiovascular health (Buang*et al.,* 2004). One of such fruits containing these functional components is *Treculiaafricana* (African breadfruits), its seeds have been reported severally to be highly nutritious and constitute a cheap source of vitamins, minerals, proteins, carbohydrates and lipids (Adesina and Adeyeye, 2015).

*Treculiaafricana*tree produces large, usually round compound fruits covered with pointed outgrowths and the seeds are buried in the spongy pulp of the fruits (Nwokolo, 1996). It is considered as an important natural resource for the poor, contributing significantly to their income and dietary intake and as animal feed (Ejidike and Ajileye, 2007). The seeds are seldom eaten raw but can be baked, boiled, roasted and fried before consumption, or they can also be ground into flour which can be used as a substitute for wheat flour in bakery products and as a thickener in soup making (Ijeh*et al.*, 2011). The need to establish the nutritional values of under-utilized plant foods was recognized by Fetuga *et al.* (1977) while working on the nutritional potentials of some plant seed meals. They pointed out "many protein and lipids sources which could not find use as human foods and could have potentials as feed sources in the livestock industry, but that their effective utilization had been hampered by a lack of precise knowledge of their nutrient status and processing conditions that could lead to optimization of these nutrients" (Fetuga *et al.,* 1977).

Due to its numerous applications, this research was designed to investigate the lipids (fatty acids, phospholipids and phytosterols) content of the raw, roasted and cooked dehulled seeds flour of *Treculiaafricana.* It is hoped that the results would encourage a wider applications of the seeds flour both domestically and industrially.

Materials and Methods

Collection of samples

The samples of African breadfruit (*Treculiaafricana*) seeds were obtained from a local farm in Odo-Ayedun town in Ekiti State, Nigeria. The samples were identified in the Department of Plant Science and Biotechnology, Ekiti State University, Ado-Ekiti. The seeds were properly sorted to remove the defected ones.

Treatment of samples

A quantity of 450 g of the *Treculiaafricana*seeds used for the analysis was divided into three parts (about 150 g each for raw, roasted and cooked samples). These forms of samples were prepared following the method described by Adeyeye (2010).

Determination of ether extract

An aliquot (0.25 g) of each part was weighed into an extraction thimble and 200 ml of petroleum ether (40 – 60°C boiling point range) was added. The covered porous thimble containing the sample was extracted for 5 h using a Soxhlet extractor. The extraction flask was removed from the heating mantle when it was almost free of petroleum ether, oven dried at 105°C for 1 h, cooled in a desicator and the weight of dried oil was determined.

Preparation of fatty acid methyl esters and analysis

A 50 ml aliquot of the dried oil was saponified for 5 min at 95°C with 3.4 ml of 0.5 M KOH in dry methanol. The mixture was neutralized by 0.7 M HCl and 3 ml of 14% boron tri-fluoride in methanol was added. The mixture was heated for 5 min at 90°C to achieve complete methylation. The fatty acid methyl esters were thrice extracted from the mixture with redistilled n-hexane and concentrated to 1 ml for analysis. The fatty acid methyl esters were analyzed using an HP 5890 gas chromatograph (GMI, Inc., Minnesota, USA) fitted with a flame ionization detector and using ChemStation software. Nitrogen was used as the carrier gas with a flow rate of 20-60 ml/min. The oven programme was: initial temperature at 60°C, ramping at 10°C/min for 20 min, held for 4 min, with a second ramping at 15°C/min for 4 min and held for 10 min. The injection temperature was 250°C and the detector temperature was 320°C. A polar (HP INNOWAX) capillary

column (30 m x 0.25 mm x 0.25 µm) was used to separate the esters. A split injection was used with a split ratio of 20:1. The peaks were identified by their relative retention time compared with known standards.

Phytosterol analysis

Aliquots of the dried oil were added to screw-capped test tubes. The sample was saponified at 95°C for 30 min, using 3 ml of 10 % KOH in ethanol, to which 0.20 ml of benzene was added to ensure miscibility. Deionizer water (3 ml) was added and 2 ml of hexane was used in extracting the non-saponifiable materials. Three extractions, each with 2 ml of hexane, were carried out for 1 h 30 min and 30, min respectively, to achieve complete extraction of the phytosterols. Hexane was concentrated to 1 ml for gas chromatographic analysis.

Phospholipids analysis

Using a modified method of Raheja*et al*. (1973), 0.01 g of the dried oil was added to test tubes. Any remaining solvent was removed by passing a stream of nitrogen gas over the oil. Then 0.40 ml of chloroform was added, followed by addition of 0.10 ml of the chromogenic solution.

The tube was heated to 100°C in a water bath for 1 min 20 sec, cooled to room temperature; 5 ml of hexane was added and the tube was shaken gently several times. After separation of the solvent and aqueous layers, the hexane layer was recovered and concentrated to 1.0 ml for analysis. Analysis was performed using the gas chromatograph with a polar (HP5) capillary column (30 m x 0.25 mm x 0.25 µm). The oven programme was: initial temperature was 50°C, ramping at 10°C/min for 20 min, held for 4 min, a second ramping at 15°C /min for 4 min and held for 5 min. The injection temperature was 250°C and the detector temperature was 320°C. As previously described, a split injection type was used having a split ratio of 20:1. Peaks were identified by comparison with known standards.

Statistical analysis

The results were subjected to analysis of variance (Anova) and the level of significance was determined at $p<0.05$, df=n-1.

Results and Discussion

In Table 1, crude fat levels of the samples (dry weight) were shown. The range was 2.75 – 10.4 g/100g with roasted dehulled seed flour (RSDF) being the lowest (2.75 g/100g) and raw dehulled seed flour (RDF) being the highest (10.4 g/100g). The variation was high between the three samples with the coefficient of variation (CV %) being 79.5. The calculated total fatty acids (crude fat x 0.80) and calculated energy levels followed the trend as in the crude fat results in CV %. The present crude fat results were comparably less than the values in the lipid composition of the seeds of three types of chillies consumed in Nigeria whose values ranged as 10.8-12.1 g/100g (Adeyeye*et al.,* 2013), three types of citrus seeds oils in Nigeria (Adeyeye and Adesina, 2015) whose values ranged from 21.6-26.2 g/100g. However the crude fat values were highly comparable to literature cereal results: millet (1.10%), maize (1.72%) and rice (0.63%) (Adeyeye and Ajewole, 1992). The general trend in the concentration of parameters from Table 1 was raw dehulled seed flour (RDF) > cooked dehulled seed flour (CDF) > roasted dehulled seed flour (RSDF). The cooking effect might have reduced the total lipids level in roasted and cooked samples.

Table 1: Levels of crude fat, total fatty acid (g/100g) and Total energy (kJ/100g) in the raw (RDF), roasted (RSDF) and cooked (CDF) dehulled seeds flour of *Treculiaafricana*

Parameter	RDF	RSDF	CDF	Mean	SD	CV%
Crude fat (g/100g)	10.4	2.75	3.12	5.42	4.31	79.5
*Total fatty acid (g/100g)	8.32	2.20	2.50	4.34	3.45	79.5
Energy (kJ/100g)	308	81.4	92.5	161	128	79.5

*Crude fat x 0.8 (Greenfield and Southgate, 2003)

The total fatty acids in per cent levels (%) for the three samples were shown in Table 2. These fatty acids recorded 0.00% (of total fatty acid): butyric, pentanoic, hexanoic, octanoic, decanoic, vaccenic and arachidonic acid. The most concentrated SFA was palmitic acid in all the samples: 19.1% (RDF), 16.1% (RSDF) and 16.7% (CDF); most concentrated monoenic acids was oleic acid (C18:1*cis*-9) in all the samples with values: RDF (27.7%), RSDF (28.1 %) and CDF (25.5%) followed by petroselinic acid (C18:*cis*-6) (RDF, 4.23%; RSDF, 8.00% and CDF, 7.91%).

The levels of linolenic acid were very close, viz: RDF (31.6%), RSDF (37.2%) and CDF (37.5%) with a CV % of 9.40, conjugated linoleic acid (CLA), 0.096 – 0.185% with CV % of 31.4. alpha-linoleic acid, RDF (2.26%), RSDF (1.18%) and CDF (1.12%) and a wide variation of 42.2% .The most varied saturated fatty acid was stearic acid (C18:0) with a CV % of 93.2 whereas oleic acid (C18:1*cis*-9) was the least varied with a CV % of 5.17.

Palmitic acid (16.1 – 19.1%) in the present report were comparably higher than those reported by Oyenuga (1978) with a lower value of 8.6% (Nigeria) and the mean value in the West African groundnut oil from raw seeds with a level of 9.2%. The present stearic acid level in RSDF and CDF (2.63 and 3.77%, respectively) were close to the level of 3.70% reported for groundnut (Nigerian) and 5.5% (West African). The most concentrated MUFA in all the samples was oleic acid (C18:1*cis*-9) (25.5 – 28.1%). These values were comparably higher than the values reported for raw and processed groundnut seeds (Adeyeye and Agesin, 2012). The trend among the samples was: RSDF>RDF>CDF. The present stearic acid level in RDF was 14.3% which was comparably higher than the level of groundnut seeds of 3.70% (Nigerian) and 5.5 % (West African) Oyenuga (1978). However, the values were drastically reduced by roasting and cooking as depicted in the results (RSDF, 2.63%; CDF, 3.77%). These values were comparably close to the levels reported for bambara groundnut seeds (Adeyeye*et al.,* 2015). The difference could have been due to the levels of oxidation by the heat treatments.

Linoleic acid (C18:2*cis*-9,12) in the present report ranged from 31.6 - 37.5%. These values were comparably higher than the values reported for groundnut seeds flour in the literature within the range of 19.7-20.6 % (Adeyeye and Agesin, 2012). Humans can synthesize saturated and monounsaturated fatty acids but cannot synthesize polyunsaturated omega-3 (also referred to as *n*-3) and omega-6 (also referred to as *n*-6) fatty acids de novo. This is because humans like other animals, lack the desaturase enzymes required to produce the simplest members of these families (ALA and LA, respectively). Thus ALA and LA are considered "essential fatty acids" (EFAs) that need to be included in the diet. EFAs act as precursors for the synthesis of more highly unsaturated and longer- chain omega-3 and omega-6 fatty acids (Tapiero*et al.*, 2002). Omega-3 and omega-6 fatty acids are essential components of cell-membrane phospholipids and they have several other functional roles (Hardman, 2004). Alpha linoleic acid (ALA) levels in the present report ranged between 1.12 – 2.26% with least value occurring in the cooked dehulled seeds flour and the highest in the raw dehulled seed flour. Roasting and cooking reduced the levels of ALA in the raw samples. This might probably be due to oxidation or leaching.

ALA is mainly of plant origin and is the precursor of two functionally important longer-chain *n* -3 fatty acids, eicosapentaenoic acid (EPA; 20:5 (*n*-3)) and docosahexaenoic acid (DHA; 22:6 (*n* -3)). Conversion efficiency of ALA to EPA and DHA is low (Igarashi, 2006) and is estimated to be approximately 4–5% in men, but greater than this in women (Burdge, 2004). More generally, there are several ways to

express the conversion rate and it probably depends on the tissues which are investigated.

Eicosapentaenoic acid (C20:5 (*n*-3); all-*cis*-5,8,11,14,17, EPA) and docosahexaenoic acid (C22:6 (*n* -3); all-*cis*-4,7,10,13,16,19, DHA) in the present report were within the following ranges respectively: 7.9e-3 – 0.024% and 0.015 – 0.020%. The levels were apparently low in the samples but higher in the heat treated samples, particularly the roasted dehulled flour. These are long-chain, polyunsaturated fatty acids naturally found in aquatic foods, especially oily fish and in fish oil supplements. DHA is highly abundant in brain and retina (Dratz and Holte, 1993) where it plays important structural and functional roles. Consequently, DHA status is important to ensure optimum neural and visual functions (Birch *et al*., 2007; Eilander*et al*., 2007). EFAs are the precursors of a family of prostaglandins and leukotrienes, which control blood clotting and other arterial functions and inflammation (Simopoulos, 2002). This may be important in reducing the risk of cardiovascular disease. Prostaglandins produced from EPA constitute a minor group compared to eicosanoids produced from arachidonic acid (AA) and may be as much as one hundred fold less potent biologically for inducing pro-inflammatory cellular responses than those derived from AA (Robinson *et al*., 1988). EPA and DHA also lower blood triglyceride concentrations and are substrates for the synthesis of resolvins, which are believed to play a key role in terminating inflammatory processes (Kohli and Levy, 2009). Thus, these *n*-3 fatty acids could be important in treating inflammatory diseases.

Table 2: Fatty acids (%) composition of the raw (RDF), roasted (RSDF) and cooked (CDF) dehulled seeds flour of *Treculiaafricana*

SFA	Names	RDF	RSDF	CDF	Mean	SD	CV %
C3:0	Propionic acid	0.00	0.00	0.00	0.00	0.00	0.00
C4:0	Butyric acid	0.00	0.00	0.00	0.00	0.00	0.00
C5:0	Pentanoic acid	0.00	0.00	0.00	0.00	0.00	0.00
C6:0	Hexanoic acid	0.00	0.00	0.00	0.00	0.00	0.00
C8:0	Octanoic acid	0.00	0.00	0.00	0.00	0.00	0.00
C10:0	Decanoic acid	0.00	0.00	0.00	0.00	0.00	0.00
C12:0	Lauric acid	0.008	0.864	1.07	0.65	0.56	87.1
C14:0	Myristic acid	0.052	0.576	0.749	0.46	0.36	79.1
C16:0	Palmitic acid	19.1	16.1	16.7	17.3	1.59	9.18
C18:0	Stearic acid	14.3	2.63	3.77	6.90	6.43	93.2
C20:0	Arachidic acid	0.069	0.054	0.046	0.056	0.012	21.1
C22:0	Behenic acid	0.064	0.046	0.039	0.050	0.013	26.0
C24:0	Lignoceric acid	0.008	5.7 e-3	0.005	0.006	0.002	24.5
Total SFA		33.6	20.3	22.4	25.4	7.15	28.1
C14:1(*cis*-9)	Myristoleic acid	0.023	0.006	0.005	0.011	0.010	87.3
C16:1(*cis*-9)	Palmitoleic acid	0.034	2.12	2.36	1.50	1.28	85.0
C18:1(*cis*-6)	Petroselenic acid	4.23	8.00	7.91	6.71	2.15	32.0
C18:1(*cis*-9)	Oleic acid	27.7	28.1	25.5	27.1	1.40	5.17
C20:1 (*cis*-11)	Gondoic acid	0.071	0.092	0.078	0.080	0.011	13.3
C22:1(*cis*-13)	Erucic acid	0.081	0.068	0.058	0.069	0.012	16.7
C24:1(*cis*-15)	Nervonic acid	7.9 e-3	5.7 e-3	0.005	0.006	0.002	24.5
Total MUFA*cis*		32.1	38.4	35.9	35.5	3.17	8.94
C18:1 (*trans*-6)	*Trans*-petroselenic acid	0.025	0.018	0.015	0.019	0.005	26.5
C18:1 (*trans*-9)	Elaidic acid	2.3 e-3	1.6 e-3	1.4 e-3	0.0018	0.0005	25.7
C18:1 (*trans*-11)	Vaccenic acid	0.00	0.00	0.00	0.00	0.00	0.00
Total MUFA*trans*		0.027	0.02	0.016	0.021	0.006	27.1
MUFA Total		32.1	38.4	35.9	35.5	3.17	8.9
C18:3 (*cis*-9,12, 15)	Alpha-linolenic acid (aLA)	2.26	1.18	1.12	1.52	0.642	42.2
C20:2 (*cis*-11,14)	Eicosadienoic acid	2.26	0.087	0.430	0.926	1.17	126
C20:3 (*cis*-11,14,17)	Eicosatrienoic acid (ETE)	0.043	0.031	0.026	0.033	0.008	25.5
C20:5 (*cis*-5,8,11,14,17)	Timinodonic acid or EPA	7.9 e-3	0.024	0.021	0.018	0.009	48.5
C22:6 (4,7,10,13,16,19)	Docosahexaenoic acid (DHA, Cervonic acid)	0.015	0.020	0.017	0.017	0.003	14.8
Total (*n*-3)		4.59	1.34	1.61	2.51	1.80	71.6
C18:2 (*cis*-9,12)	Linoleic acid (LA)	31.6	37.2	37.5	35.4	3.32	9.4
C18: 2 (*trans*-9,11)	Rumenic acid (CLA)	0.096	0.185	0.167	0.149	0.047	31.4
C18:3 (*cis*-6,9,12)	Gamma-Linolenic acid (GLA)	0.183	1.88	1.75	1.27	0.944	74.3
C20:3 (*cis*-8,11,14)	Dihomo-Gamma-Linolenic acid (DGLA)	0.022	0.651	0.667	0.45	0.368	82.4
C20:4 (*cis*-5,8,11,14)	Arachidonic acid (AA)	0.00	0.00	0.00	0.00	0.00	0.00
C22:2 (*cis*-13,16)	Docsadienoic acid	7.9e-3	0.033	0.017	0.019	0.013	65.8
Total (*n*-6)		31.9	39.9	40.1	37.3	4.69	12.6
PUFA Total		36.6	41.5	42.2	40.1	3.05	7.61

Gamma linoleic acid (18:3 (*n*-6); all-*cis*-6,9,12 octadecatrienoic acid; GLA) in the samples ranged as follows: 0.183 – 1.88 %, with the highest value in RSDF and the least value occurring in the RDF. GLA is produced in the body as an intermediate in the metabolism of LA by the enzyme delta-6 desaturase. This reaction is the rate limiting step in the conversion of LA into its more unsaturated and longer chain derivatives (Cheng, 2004). GLA is also found in some plant oils. GLA is rapidly elongated to dihomo-gamma-linolenic acid (20:3 (*n*-6); DGLA) by the enzyme elongase. Subsequently, DGLA may be incorporated into cell-membrane phospholipids or may be converted into arachidonic acid (20:4 (*n*-6); AA) by the enzyme delta-5-desaturase. AA is one of the most important fatty acids associated with membrane phospholipids. AA can be oxidized to a variety of eicosanoid compounds. In the present report the DGLA levels are as follows: RDF (0.022%), RSDF (0.651%) and CDF (0.667 %) with a CV % of 82.4, indicating that the values were widely varied. The values reported for both GLA and DGLA were comparably lower than those reported for raw and processed groundnut seed flours (Adeyeye and Agesin, 2012).

Conjugated linolenic acid (CLA) refers to a group of polyunsaturated fatty acids (PUFA) that exist as positional and stereo-isomers of linoleic acid with a conjugated double bond. In the present report, CLA levels were as follows: RDF (0.096%), RSDF (0.185%) and CDF (0.167%) and a CV % of 31.4. These values were comparably lower than those reported for raw and processed bambara groundnut seed flour (Adeyeye*et al.,* 2015). The major naturally occurring CLA is cis-9, trans-11 CLA, found in ruminant milks, dairy products and ruminants' meats and also in CLA supplements. Animal models suggest that some CLA isomers have a role in preventing cancer (Ip*et al*., 1994). There are suggestions that CLA has a role in treating some human diseases (Nagao and Yanagita,2005).

The Table 3 explained the distribution of the fatty acid levels to SFA, MUFA, DUFA and TUFA. The relative proportion ofSFA to MUFA is an important aspect of phospholipid compositions and changes to this ratio have been claimed to have effects on such disease states as cardiovascular disease, obesity, diabetes, neuropathological conditions and cancer (Christie, 2011). For example, they have been shown to have cytoprotective actions in pancreatic cells. *Cis*-monoenoic acids have desirable physical properties for membrane lipids in that they are liquid at body temperature, yet are relatively resistant to oxidation. They are now recognised by nutritionists as being beneficial in the human diet. *Cis*-MUFA ranged between 32.5 – 38.4% and MUFA/SFA range was 0.955 (RDF), 2.91 (RSDF), 1.60 (CDF). The SFAs had been ascribed with some benefits in nutrition: SFA constitute at least 50% of the cell membranes giving our cells necessary stiffness and integrity; for calcium to be effectively incorporated into the skeletal structure, at least 50% of the dietary fats should be saturated (Watkins *et al.,* 2009); they are needed for proper utilization of EFAs, elongated omega-3 FAs are better retained in tissues when the diet is rich in SFA; saturated 18-carbon stearic acid and 16-carbon palmitic acid are preferred foods for the heart, which is why the fat around the heart muscle is highly saturated (Lawson and Kummerow, 1979). The n-6/n-3 range was very much in favour of n-6 such as 6.95-29.8. Problems associated with an excess of polyunsaturated are exacerbated by the fact that most polyunsaturatates in commercial vegetable oils are in the form of double unsaturated (DUFA) omega-6 linoleic acid, with very little of vital triple (TUFA) unsaturated omega-3 linolenic acid.

Recent research has revealed that too much omega-6 in the diet creates an imbalance that can interfere with production of important prostaglandins. This disruption can result in increased tendency to form blood clots, inflammation, high blood pressure, irritation of the digestive tract, depressed immune function, sterility, cell proliferation, and cancer and weight gain (Adeyeye and Agesin, 2012). Omega -3 linolenic acid is necessary for cell oxidation, for metabolizing important sulphur-containing amino acids and for maintaining proper balance in prostaglandin production. Deficiencies have been associated with asthma, heart disease and learning deficiencies. The present oils contained much omega-6 than omeg-3, hence must be supplemented with omega-3 when it serves as the only dietary oil. The PUFA/SFA and EPSI levels were favourable with levels range of 1.02 – 2.03 and 0.7 – 1.16, respectively.

Total fatty acids (g/100g as food) and subsequent energy (kJ/100g) contributions by FA groups were shown in Tables 4 and 5 respectively. Fatty acids level in dehulled*Treculiaafricana* seed flour per 100 g raw, roasted and cooked samples as food were shown in Table 4. Fatty acids group levels were in the following ranges (for RDF, RSDF and CDF): SFA, 0.447 – 2.80 (CV % of 105); MUFA, 0.845 – 2.67 (CV % of 70.6) and PUFA, 0.908 – 3.03 (CV % of 71.6), with the highest values being from RDF sample, respectively.

In Table 5, the energy contributions of the various FA fractions were shown. For RDF, the range of energy contributions (kJ/100g) was 7.98 – 116, RSDF (1.12 – 34.5) and CDF (1.52 – 39.5) whilst the CV % ranged between 59.6 and 133. The calculation accounted for all the calculated total fatty acid in each of the samples. Contribution of energy due to SFA was: RDF (106), RSDF (17) and CDF (21.2); whereas PUFA was: RDF (116), RSDF (34.5) and CDF (39.5). However, *n*-3 contributed 14.5 (RDF), 1.12 (RSDF) and 1.52 (CDF) whereas *n*-6 contributed 101 (RDF), 33.4 (RSDF) and 38.1 (CDF). Research evidence indicates that our intake of polyunsaturated should not be much greater than 4% of the caloric total; in approximate proportions of 1.5% omega -3 and 2 .5% omega- 6 (Lasserre*et al.,* 1985). The present results were outside this range.

Table 3: Summary of the quality parameters of fatty acids of the raw (RDF), roasted (RSDF) and cooked (CDF) dehulled seeds flour of *Treculiaafricana*

Quality parameters	RDF	RSDF	CDF	Mean	SD	CV %
SFA	33.6	20.3	22.4	25.4	7.15	28.1
MUFA*cis*	32.1	38.4	35.9	35.5	3.17	8.94
MUFA*trans*	0.027	0.020	0.016	0.021	0.006	26.9
MUFA Total	32.1	38.4	35.9	35.5	3.18	8.97
n-3 PUFA	4.59	1.34	1.61	2.514	1.799	72
n-6 PUFA	31.9	39.9	40.1	37.3	4.69	12.6
Total PUFA	36.6	41.5	42.2	40.1	3.05	7.6
DUFA*cis*	31.6	37.3	38.0	35.6	3.51	9.85
DUFA*trans*	0.096	0.185	0.167	0.149	0.047	31.5
DUFA total	31.7	37.5	38.2	35.8	3.57	10.0
TUFA *cis*	2.55	3.74	3.56	3.28	0.641	19.5
TUFA *trans*	-	-	-	-	-	-
TUFA total	2.55	3.74	3.56	3.28	0.641	19.5
MUFA/SFA	0.955	2.91	1.60	1.82	1.00	54.7
PUFA/SFA	1.02	2.03	1.86	1.64	0.54	33.0
n-6/*n*-3	6.95	29.8	24.9	20.6	12.0	58.5
EPSI	1.07	0.70	1.16	0.977	0.244	25.0
LA/ALA	173	31.5	33.5	79.3	81.1	102
EPA/DHA	0.530	1.20	1.24	0.99	0.40	40.3

SFA=saturated fatty acid, MUFA=monounsaturated fatty acid, DUFA= double unsaturated fatty acid, TUFA= triple unsaturated fatty acid, PUFA=polyunsaturated fatty acid, EPSI=essential PUFA Status index

Table 4: Total fatty acids (g/100g as food) of the raw (RDF), roasted (RSDF) and cooked (CDF) dehulled seeds flour of *Treculiaafricana*

Fatty Acid groups	RDF	RSDF	CDF	Mean	SD	CV%
SFA	2.80	0.447	0.559	1.27	1.33	105
MUFA	2.67	0.845	0.898	1.47	1.04	70.6
n-3 PUFA	0.382	0.0295	0.040	0.151	0.201	133
n-6 PUFA	2.65	0.878	1.003	1.51	0.989	65.5
Total PUFA	3.03	0.908	1.04	1.66	1.19	71.6
DUFA	2.64	0.75	0.955	1.45	1.04	71.6
TUFA	0.210	0.075	0.089	0.125	0.074	59.5

Table 5: Energy contributions (kJ/100g) from fatty acids of the raw (RDF), roasted (RSDF) and cooked (CDF) dehulled seeds flour of *Treculiaafricana*

Fatty acids	RDF	RSDF	CDF	Mean	SD	CV %
SFA	106	17	21.2	48.1	50.2	104
MUFA	101	32.1	34.1	55.7	39.2	70.4
n-3 PUFA	14.5	1.12	1.52	5.71	7.61	133
n-6 PUFA	101	33.4	38.1	57.5	37.7	65.6
Total PUFA	116	34.5	39.5	63.3	45.7	72.1
DUFA total	100	28.5	36.3	54.9	39.2	71.4
TUFA total	7.98	2.85	3.38	4.74	2.82	59.6

Table 6: Levels (mg/100g) of phospholipids in the raw (RDF), roasted (RSDF) and cooked (CDF) dehulled seeds flour of *Treculiaafricana*seeds

Phospholipids	RDF	RSDF	CDF	Mean	SD	CV%
Phosphatidylethanolamine (PE)	36.6	315	342	231	169	73.1
Phosphatidylcholine (PC)	110	87.4	93.9	97.1	11.6	12.0
Phosphatidylserine (PS)	2.78	254	295	184	158	86.0
Lysophosphatidylcholine (LPC)	27.2	3.61	4.83	11.9	13.3	112
Phosphatidylinositol (PI)	16.3	716	772	501	421	84.0
Total	192	1375	1508	1025	724	70.7

Table 7: Levels of phytosterols (mg/100g) in the raw (RDF), roasted (RSDF) and cooked (CDF) dehulled seeds flour of *Treculiaafricana*

Phytosterol	RDF	RSDF	CDF	Mean	SD	CV%
Cholesterol	1.2e-5	2.5 e-6	1.8 e-6	5.52 e-6	5.89 e-6	107
Cholestanol	2.4 e-3	4.6 e-4	6.9 e-4	1.19 e-3	1.08 e-3	90.4
Ergosterol	1.3 e-3	1.5 e-4	6.2 e-6	4.80 e-4	7.05 e-4	147
Campesterol	12.6	101	106	73.2	52.5	71.8
Stigmasterol	0.257	21.3	24.2	15.3	13.1	85.7
5- Avenasterol	0.096	5.92	9.66	5.23	4.82	92.2
Sitosterol	127	266	293	229	89.1	39.0
Total	140	394	433	322	159	49.4

In animal body, function of phospholipids includes its role as an intermediary metabolite in fat metabolism and also it plays a role in oxidation-reduction system. Total level of phospholipids range was 192 - 1508 mg/100 g with ratio of RDF/RSDF (0.140), RDF/CDF (0.127) with CV % of 70.7. Lecithin (phosphatidylcholine) was the most concentrated in RDF with a value of 110 mg/100 g. However, lecithin was likely oxidized in roasting and cooking and therefore had reduced values among the samples (87.4 and 93.9 mg/100g). In like manner, lysophosphatidycholine was also likely highly oxidized by roasting and cooking, leading to reduced values in the samples. The following phospholipids were highly enhanced by roasting and cooking: phosphatidylethanolamine (RDF, 36.6; RSDF, 315 and CDF, 342 mg/100g), phosphatidylserine (RDF, 2.78; RSDF, 254 and CDF, 295 mg/100g) and phosphatidylinositol (RDF, 16.3; RSDF, 716 and CDF, 772 mg/100g). The CV % levels ranged between 12.0 and 112 which actually showed that the values were widely varied.

Lecithin is usually the most abundant phospholipid in animal and plants, often amounting to almost 50 % of the total, and as such it is the key building block of membrane bilayers. This observation is true of lecithin only in the raw sample (RDF). Roasting and cooking had positive effects on the following phospholipids: phosphatidylethanolamine, phosphatidylserine and phosphatidylinositol.

Lecithin is the principal phospholipid circulating in plasma, where it is an integral component of the lipoproteins, especially the HDL. Lecithin is used as (additive) emulsifier in the food industry; as a wetting and stabilizing agent in pharmaceutical industry; it protects cells from oxidation and largely comprises the protective sheaths surrounding the brain. It is possible that it is this property of protecting cell from oxidation that had enhanced lecithin in the cooked sample. Cephalin is a major phospholipid in nervous tissue such as the white matter of brain, neural tissue, nerves and in spinal cord. Phosphatidylserine (Ptd- L-Ser or PS) is a phospholipid usually kept on the inner-leaflet, the cytosolic side, of cell membranes by an enzyme called flippase. When a cell undergoes apoptotic cell death, PS is no longer restricted to the cytosolic part of the membrane, but becomes exposed on the surface of the cell. PS has been demonstrated to speed up recovery, prevent muscle soreness, improve well-being, and might possess ergogenic properties in athletes involved in cycling, weight training and endurance running (Adeyeye and Agesin, 2012). The US Food and Drug Administration (USFDA) had stated that consumption of PS may reduce the risk of dementia and cognitive dysfunction in elderly persons (Adeyeye, 2011). PS range in the samples was 2.75 – 295 mg/100 g (1.43 – 19.6%); being enhanced by both roasting and cooking. Phosphatidylinositol (PtdIns or PI) occupied the highest position in RSDF and CDF (716 and 772 mg/100 g or 52.1 and 51.2%); it showed that PI was a major component in the samples and probably enhanced by roasting and cooking treatments.

Phytosterols (plant sterols) are common plant and vegetable constituents. They are normal constituents of the human diet and are considered to be biologically active (Pirronen*et al.*, 2000). They are structurally related to cholesterol, but differ from cholesterol in the structure of the side chain. Examples are campesterol, stigmasterol and beta-sitosterol. Phytosterols inhibit cholesterol absorption and so help to control blood total cholesterol, LDL and HDL levels and so modify the risk of cardiovascular disease (Lichtenstein and Deckelbaum, 2001).

The phytosterols levels of the samples were shown in Table 7. Sitosterol was highest in all the samples with values in RDF (127 mg/100 g); higher in RSDF (266 mg/100 g); highest in CDF (293 mg/100g). On the total, the phytosterol levels (mg/100g) were: RDF (140), RSDF (394) and CDF (433). Roasting had negative effect on cholesterol, cholestanol and ergosterol whereas its effects on campesterol, stigmasterol, 5-avenasterol and sitosterol were positive. Sitosterol occupied the first position in concentration among all phytosterols and in all the samples. 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, sitosterol reduces blood levels of cholesterol and is sometimes used in treating hypercholesterolemia. In Europe, sitosterol plays a major role in the treatment of herbal therapy of 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). Sitosterol had also been reported as the major sterol in the three seed oils of *Collocynthiscitrullus* (CLCT), *Cucurbitamoschata*(CCBT) and *Cyperusesculentus* (CYP) with levels of (%) 34.6 (CLCT), 53.9 (CCBT) and 55.9 (CYP); these levels were comparably lower than the present results. While sitosterol occupied the second position in *Plukenetiaconophora*(PKCP) with a level of 31.5%, it occupied the first position in *Adenopusbreviflorus*(ADB) seeds oils with a level of 53.3% (Akintayo and Bayer, 2002).

Table 8: Results of the statistical analysis (ANOVA) of the results from all the Tables

Results	Source of variation	*SS*	*Df*	*MS*	F*cal*	*P-value*	F *crit*	Remark
RT1	Rows	48519	2	24259	4.74	0.0880	6.94	NS
	Columns	12242	2	6121	1.20	0.3914	6.94	NS
RT2	Rows	20061	40	502	117	1.18e-56	1.54	S
	Columns	0.590	2	0.295	0.0686	0.934	3.11	NS
RT3	Rows	118230	18	6568	1.25	0.278	1.90	NS
	Columns	7894	2	3947	0.750	0.480	3.26	NS
RT4	Rows	7.86	6	1.31	5.39	0.00649	3.00	S
	Columns	9.79	2	4.90	20.1	0.00015	3.89	S
RT5	Rows	11373	6	1896	5.40	0.00646	3.00	S
	Columns	14138	2	7069	20.1	0.00015	3.89	S
RT6	Rows	2.0e+6	5	418876	5.15	0.0135	3.33	S
	Columns	699446	2	349723	4.30	0.0448	4.10	S
RT7	Rows	329562	7	47080	14.0	2.4e-5	2.76	S
	Columns	25318	2	12659	3.76	0.049	3.74	S

RT1=results from Table 1, RT2=results from Table 2, RT3=results from Table 3, RT4=results from Table 4, RT5=results from Table 5, RT6=results from Table 6, RT7=results from Table 7, S= significant (F*cal*>F*crit*), NS= not significant (F*cal*<F*crit* at $P_{<0.05}$)

As shown in Table 8, the analysis of variance (ANOVA), a statistical summary of the data from Tables 1- 7 with a critical value at p = 0.05 and n-1 degrees of freedom for rows and columns (RDF/RSDF, RDF/CDF and RSDF/CDF). The results showed that there were no significant difference between the comparisons made for results in Table 1 (crude fats, total fatty acids and energy), between the columns in Table 2 (% fatty acids) and for both rows and columns of results in Table 3 (quality parameters from fatty acids) whereas significant differences existed between the results from Tables 4, 5, 6 and 7 (fatty acids g/100g as food, energy contributions from various fatty acids groups, phospholipids and phytosterols contents, respectively).

Conclusion

The findings of this study showed that the samples contained unequal distribution of all the parameters determined. The samples were high in *n*-6 fatty acids but low in *n*-3 fatty acids. The samples had unsaturated acids as the predominant fatty acids. Significant differences occurred in the fatty acids, energy, phospholipids and phytosterols levels. All the samples were good sources of lecithin but much lower in phytosterols. Quality assurances of the determinations were highly satisfactory. In the pair wise comparison among the samples for the quality parameters from fatty acids, it was found that roasting and cooking enhanced 13 /18 or 72.2% and 14/18 or 77.8% parameters, respectively; among the phospholipids and phytosterols, 3/5 or 60% and 4/7 or 57.1% of all the parameters were enhanced by roasting and cooking respectively. It could therefore be concluded that *Treculiaafricana* seeds should not only be dehulled but roasted or cooked when it is being used as food supplement as these processes enhanced most of the nutrients in terms of lipids composition.

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