Available online at www.elixirpublishers.com (Elixir International Journal)

Applied Chemistry

Elixir Appl. Chem. 97 (2016) 42123-42130

ISSN: 2229-712X

Effects of roasting and cooking processes on the lipids composition of raw wholeseed flour of African breadfruit (*Treculia africana*)

Adesina Adeolu Jonathan* and Adeyeye Ilesanmi Emmanuel
Department of Chemistry, Faculty of Science, Ekiti State University, P.M.B 5363, Ado-Ekiti.

ARTICLE INFO

Article history:
Received: 8 July 2016;
Received in revised form:
4 August 2016;
Accepted: 9 August 2016;

Keywords
Lipid composition,
Raw,
roasted and cooked wholeseed,
Treculia africana

ABSTRACT

The levels of fatty acids, phospholipids and sterols were determined in the raw, roasted and cooked wholeseeds flour of *Treculia africana*. Results showed crude fat varied from 2.90 – 8.67 g/100 g; SFA from 18.7 – 31.2 % of total fatty acids, total polyunsaturated unsaturated fatty acids (PUFA) varied from 34.7 – 46.8 % and MUFA/SFA ranged from 0.962 – 2.89, PUFA/SFA ranged from 1.05 – 2.50, *n*-6/*n*-3, EPSI (PUFA/MUFA), LA/aLA and EPA/DHA ranged from 7.80 – 28.8, 0.830 – 1.35, 30.4 – 237 and 0.530 – 1.21 respectively. The samples had high levels of *n*-6 fatty acids but low in *n*-3 fatty acids. In the phospholipids, phosphatidylcholine was highest in the raw wholeseed flour whereas phosphatidylinositol was highest both in roasted and cooked wholeseed flours with respective values of 733 and 733 (mg/100 g). The sterol values in the samples varied from: raw (7.9e-8 – 98.4); roasted (3.1e-7 - 302) and cooked (5.40e-6 – 309) mg/100 g. In all the samples, cholesterol was of the least concentration. In all nutrient parameters considered, roasted and cooked wholeseed flours were better than the raw wholeseed flour. Correlation coefficient was significantly and positively high at r $_{= 0.05}$ in: the crude fats, total fatty acids and energy; fatty acids, fatty acids as food, energy contribution from fatty acids and sterols.

Introduction

African breadfruit (*Treculia africana*) is an edible traditional fruit, consumed, for example in Nigeria, where it is eaten as a main dish. The seeds are of particular interest because of their high nutrition value. Dry seeds contain between 61.3 – 63.6 % carbohydrate, 14.6-16.6% crude protein and 8.68 – 10.4% fat (Adesina and Adeyeye, 2015). Readily available in many developing African countries, *Treculia africana* can be an alternative to rice and yam (Nuga and Ofodile, 2010).The seeds of *Treculia africana* can be ground to flour, pressed for oil and used as flavouring in alcoholic drinks. It is known that African breadfruit is a good adjunct in brewing because it is a source of fermentable sugars. For success with the brewing, see the study of Nwabueze *et al.* (2011). They find that the yield production of ethanol is enhanced when its defatted seeds are used. In most areas, the seeds are variously cooked as pottage or roasted and eaten with palm kernel as roadside snack. The seeds are highly nutritious and constitute a cheap source of vitamins, minerals, proteins, carbohydrates and fats (Okafor and Okolo, 1974).

Meat and meat products are usually known to be high in saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA). SFA are found to elevate cholesterol which is associated with cardiovascular diseases and other chronic diseases. Replacing or reducing animal fat in meat products could create a better image for the industry, but sensory quality as well as product stability could be affected. Animal fat can be replaced or reduced by adding more water in the product or by substituting with vegetable fats and/or oils, or by adding hydrocolloids like dextrins, starches, and gums in the product. Since *Treculia africana* seeds have been reported to contain considerable level of fat, it can be considered a good replacement for the animal fats. In general, any kind of heat processing is widely believed to reduce the nutritional value of foods. On the other hand, thermal processing in general increases digestibility and bioavailability of nutrients and phytochemicals (Slavin *et al*., 2000). Polyunsaturated fatty acids (PUFAs), including omega 6 fatty acids (*n*-6) and omega 3 fatty acids (*n*-3), are delicate and easily oxidized by light, air, or heat. Oxidized fatty acids are what make an oil or fat rancid. Saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs) are less susceptible to being oxidized and can stand up to more cooking heat than PUFAs can. Lipid contents of legumes have been reported to be mobilized by roasting and cooking leading to increased levels (Adeyeye, 2010).

Seeds of *Treculia africana* are usually sold and eating in roasted forms (Adesina and Adeyeye, 2012). Information is needed on the content and variability of the lipids of this seed in both raw and processed form. Thus, the study was undertaken to investigate the effect of ordinary cooking methods (roasting and moist cooking) on the lipid composition (crude fats, fatty acids, phospholipids and sterols) of raw wholeseeds flour of *Treculia africana* as it will help in maximizing its nutritional potentials both domestically and industrially.

Materials and Methods

Collection of Samples

The samples of African breadfruit (*Treculia africana*) 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, Ekiti State University, Ado-Ekiti.

Tele:
E-mail address: unclejoshua2012@gmail.com

The seeds were properly sorted to remove the defected ones.

Treatment of samples

A quantity of 450 g of the *Treculia africana* seeds used for the analysis was divided into three groups (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 in an extraction thimble and 200 ml of petroleum ether (40-60 °C boiling 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 trifluoride 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: initially at 50 °C, ramping at 10 °C/min for 20 min, held for 4 min, a second ramping at 15 oC /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 the known standards.

Statistical Analysis

Calculations made were the mean, standard deviation (SD) and coefficient of variation in percentage (CV %). The data obtained were also subjected to the determination of linear correlation coefficient (r_{xy}), variance (r_{xy}^2), linear regression (R_{xy}) and r_{xy} calculated was compared to r_{xy} table at $r_{=0.05}$ and at n-2 degree of freedom to see if significant difference occurred among the samples (Oloyo, 2001), both the coefficient of alienation (C_A) and index of forecasting efficiency (IFE) (Chase, 1976) were also calculated.

Results and Discussion

Table 1 depicts the total crude fat and the calculated total fatty acid levels (g/100g) and energy (kJ/100g) in the raw, roasted and cooked wholeseed flour of *Treculia africana* on dry weight basis. The values of the total crude fat, total fatty acids and the energy (2.90 – 8.67, 2.32 – 3.06, and 85.8 – 257 respectively) are very different with the coefficient of variation percent of 60.4 with ratios of (RWF: RSWF: CWF) 3:1:2.35, showing that virtually all the fat was concentrated in the raw wholeseed flour (RWF) followed by the cooked wholeseed flour (CWF). The values in the present report were comparably lower than those reported for wholeseed and dehulled flour of bambara groundnut (Adeyeye *et al.*, 2015) and pepper samples consumed in Nigeria (Adeyeye *et al.*, 2013) but comparably higher than those reported for *Corchorous olitorius, Telfaria occidentalis,* and *Amaranthus hybridus* (0.250 – 4.18 g/100g) (Adeyeye *et al.*, 2016) and raw, germinated and steeped grains of guinea corn (Adeyeye and Adesina, 2013).

Table 2 revealed the percent levels of various fatty acids in the raw and processed wholeseeds flour of *Treculia africana* samples. In this report, the following SFAs recorded 0.00%: C6:0, C8:0 and C10:0, C12:0, C14:0, C20:0, C22:0 and C24:0 had values less than 1.00% in all the samples. However, C16: 0 had the highest percentage concentration in all the samples (14.9 – 21.8) second to this was C18: 0 with the following percent values: RWF (15.3), RSWF (2.59) and CWF (2.61) and the total SFA in the samples ranged between 18.7 and 31.2, the highest concentration goes to RWF. Among the SFA, the results showed that RWF was better concentrated in C16:0 and C18:0 than in RSWF and CWF whereas RSWF (12.7%) whereas CWF was better than RSWF (0.20%).

Generally, the SFA values were close to those reported for raw and processed groundnut seeds (Adeyeye, 2012). It has been confirmed that relative to carbohydrates, the saturated fatty acids elevate serum cholesterol for example C12: 0, C14:0 and C16:0 are the primary contributors to cardiovascular disease;

Table 1. Levels of crude fat, total fatty acid (g/100g) and Total energy (kJ/100g) in the raw (RWF), roasted (RSWF) and cooked (CWF) whole seeds flour of *Treculia africana*.

Parameter	RWF	RSWF	CWF	Mean	SD	CV %	RWF - RSWF	RWF - CWF	RSWF - CWF
Crude fat	8.67	2.90	3.82	5.13	3.10	60.4	+5.77	+4.85	-0.92
*Total fatty acid	6.94	2.32	3.06	4.11	2.48	60.4	+4.62	+3.88	-0.74
Energy (kJ/100g)	257	85.8	113	152	92.0	60.6	+171	+144	-27.2

*crude fat x 0.8, + = reduction in the level of crude fat, total fatty acids and energy content of raw due to roasting and cooking, - = enhancement in the crude fat, total fatty acids and energy levels in the roasted and cooked sample.

Table 2. Fatty acids (%) composition of the raw (RWF), roasted (RSWF) and cooked (CWF) whole seeds flour of *Treculia africana*.

Fatty acid	RWF	RSWF	CWF	Mean	SD	CV %	RWF - RSWF	RWF - CWF	RSWF - CWF
C6:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C8:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
C10:0	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.000
C12:0	-	0.727	0.547	0.637	0.13	20.0	0.00	0.00	+0.180
C14:0	0.032	0.511	0.365	0.303	0.25	81.0	-0.48	-0.333	+0.146
C16:0	21.8	14.9	15.0	17.2	3.96	23.0	+6.90	+6.80	-0.100
C18:0	15.3	2.59	2.61	6.83	7.33	107	+12.7	+12.7	-0.020
C20:0	0.049	0.074	0.080	0.068	0.02	24.4	-0.03	-0.031	-0.006
C22:0	0.045	0.063	0.069	0.059	0.01	21.1	-0.02	-0.024	-0.006
C24:0	0.006	7.8e-3	0.008	0.0071	0.00	18.9	0.00	-0.0024	0.000
Total SFA	31.2	18.9	18.7	22.9	7.16	31.2	+12.30	+12.5	+0.200
C14:1(*cis*-9)	0.016	0.009	0.009	0.011	0.00	37.2	+0.01	+0.007	-0.0003
C16:1(*cis*-9)	0.024	2.52	2.08	1.54	1.33	86.4	-2.50	-2.06	+0.440
C18:1(*cis*-6)	2.95	12.3	11.4	8.88	5.16	58.1	-9.35	-8.45	+0.900
C18:1(*cis*-9)	27.0	20.7	20.9	22.9	3.58	15.7	+6.30	+6.10	-0.200
C20:1 (*cis*-11)	0.050	0.127	0.137	0.105	0.05	45.4	-0.08	-0.087	-0.010
C22:1(*cis*-13)	0.016	0.095	0.102	0.071	0.05	67.8	-0.08	-0.087	-0.007
C24:1(*cis*-15)	5.6 e-3	7.8 e-3	0.009	0.0075	0.00	23.3	0.00	-0.003	-0.001
Total MUFA *cis*	30.0	35.8	34.6	33.5	3.06	9.1	-5.80	-4.60	+1.20
C18:1 (*trans*-6)	0.018	0.025	0.027	0.023	0.00	21.3	-0.01	-0.009	-0.002
C18:1 (*trans*-9)	1.6 e-3	2.2 e-3	2.4 e-3	0.0021	0.00	20.4	0.00	-0.001	0.00
C18:1 (*trans*-11)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total MUFA *trans*	0.019	0.027	0.029	0.025	0.01	20.7	-0.01	-0.010	-0.002
Total MUFA	30.0	35.8	34.6	33.5	3.07	9.2	-5.83	-4.60	+1.23
C18:3 (*cis*-9,12, 15)	1.95	1.38	1.33	1.55	0.34	22.2	+0.570	+0.620	+0.050
C20:2 (*cis*-11,14)	1.95	0.111	0.130	0.730	1.06	145	+1.84	+1.82	-0.019
C20:3 (*cis*-11,14,17)	0.030	0.042	0.046	0.039	0.01	21.3	-0.012	-0.016	-0.004
C20:5 (*cis*-5,8,11,14,17)	5.6 e-3	0.034	0.036	0.025	0.02	67.6	-0.028	-0.030	-0.002
C22:6 (*cis*-4,7,10,13,16,19)	0.011	0.028	0.030	0.023	0.01	47.0	-0.018	-0.020	-0.002
Total (*n*-3)	3.95	1.60	1.57	2.37	1.36	57.5	+2.35	+2.37	+0.023
C18:2 (*cis*-9,12)	30.5	42.0	43.4	38.6	7.08	18.3	-11.5	-12.9	-1.40
C18: 2 (*trans*-9,11)	0.062	0.271	0.275	0.203	0.12	60.1	-0.209	-0.213	-0.004
C18:3 (*cis*-6,9,12)	0.129	1.36	1.34	0.943	0.71	74.8	-1.23	-1.211	+0.020
C20:3 (*cis*-8,11,14)	0.057	0.081	0.088	0.075	0.02	21.5	-0.024	-0.031	-0.007
C20:4 (*cis*-5,8,11,14)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:2 (*cis*-13,16)	5.6 e-3	0.045	0.030	0.027	0.02	74.1	-0.039	-0.024	+0.015
Total (*n*-6)	30.8	43.8	45.2	39.9	7.94	19.9	-13.0	-14.4	-1.38
Total PUFA	34.8	45.6	46.9	42.4	6.64	15.7	-10.8	-12.1	-1.30

+ = reduction in the level of the fatty acids content of raw due to roasting and cooking, - = enhancement in the fatty acids levels in the roasted and cooked sample

C14:0 is the major candidate, C18:0 is also thought to increase the risk of cardiovascular disease (Hegsted *et al.*, 1993). The negative effect on the heart is probably due in part to an increase in blood clothing that might be caused by the SFA (Wardlaw, 2003). However, Bonanome and Grundy (1988) opined that C18: 0 may not be as hypercholesterolemic as other SFA (the major reason for this might be because it is converted to oleic acid by desaturation). Reports have also shown that SFA has some benefits in human and animal nutrition, for instance, they constitute at least 50% of the cell membranes which in turns give our cells necessary stiffness and integrity, and it plays a significant role in the incorporation of calcium into the skeletal structure, also a better retention of *n* -3 fatty acids, diets rich in SFAs are highly required (Watkins *et al.*, 1996).

Among the MUFAs, C18: 1 *cis* – 9 was the most concentrated in all the samples (RWF, 27.0; RSWF, 20.7 and CWF, 20.9%), followed by C18: 1 *cis* – 6 with values ranged as: RWF (2.95%), RSWF (12.3%) and CWF (11.4%). The total MUFA *cis* configuration percent values were 30.0 (RWF), 35.8 (RSWF) and 34.6 (CWF). This values were comparably higher than those reported for raw and processed groundnut seeds (Adeyeye, 2012) and raw and treated guinea corn (Adeyeye and Adesina, 2013). The following MUFAs were enhanced by roasting and cooking: C16: 1 *cis* – 9, C18: 1 *cis* – 6, C20: 1 *cis* – 11, C22: 1 *cis* – 13, C24: 1 *cis* – 15, C18: 1 *trans* – 9 while the raw was only better in C_{14}: *cis* – 9 and C_{18}: *cis* – 9. However, RSWF was better concentrated in C16: 1 *cis* – 9 and C18: 1 *cis* – 6 than cooked sample (CWF) whereas CWF was better concentrated in C14: 1 *cis* – 9, C18: 1 *cis* – 9, C20: 1 *cis* – 11, C22: 1 *cis* – 13, C24: 1 *cis* – 15, C18: 1 *trans* – 6 than RSWF. Considering the MUFA total, the percentage enhancement in the roasted (RSWF) was 5.83% and in the cooked sample (CWF) was 4.60%; however, roasted sample (RSWF) was better than the cooked (CWF) sample by a percent value of 1.20%. The reasons for theses enhancement may probably due to mobilization of the lipid within the seeds due to heating.

Table 2 also shows the polyunsaturated fatty acids (PUFA) composition of raw wholeseeds (RWF), roasted wholeseeds (RSWF) and cooked wholeseeds flour (CWF).

Among the n–3 families, C18: 3 (*cis* – 9, 12, 15) had the highest concentration in all the samples (1.95% (RWF), 1.38% (RSWF) and 1.33% (CWF)) followed by C20: 2 (*cis* – 11,14) with percent values of 1.95 (RWF), 0.111 (RSWF) and 1.30 (CWF) whilst the total *n*-3 in the samples were 3.95 (RWF), 1.60 (RSWF) and 1.57 (CWF), the levels were actually better in RWF by 2.35% than RSWF and 2.37% than CWF and RSWF was better by 0.023% than CWF. Among the *n*-6 group, the only fatty acid with major concentration was C18: 2 *cis* – 9, 12 with values of 30.5 (RWF), 42.0 (RSWF), and 43.4 (CWF). These values were adequately enhanced by both roasting and cooking with values of 11.5% and 12.9% differences respectively. Also, the cooked sample (CWF) was better than roasted sample (RSWF) by a difference of 1.40%. PUFA total also followed the same trend as it was enhanced in the roasted sample (RSWF) by 10.8% and in the cooked sample (CWF) by 12.1%. The levels of both C18: 2 (*cis* – 9, 12) (LA) in the present report was comparably higher than the levels obtained in the raw and processed groundnut seeds (Adeyeye and Agesin, 2012). The eicosanoids help to regulate blood clot formation, blood pressure, blood lipid (including cholesterol) concentrations, the immune response, the inflammation response to injury and infection and many other body functions (Whitney *et al.*, 1994). The present samples would be good sources of the PUFA when seen as a combination.

In Table 3, the summary of the quality parameters of fatty acids of the raw, roasted and cooked wholeseed flours of *Treculia africana* were depicted. Total unsaturated fatty acids in the samples were: RWF (34.7%), RSWF (45.4%) and CWF (46.8%). The essential fatty acids (EFA) are not unique in their ability to supply energy. EFA, SFA and monoenoic fatty acids are all equally utilized for energy production. The relative amounts of PUFA and SFA in oils is important in nutrition and health. The ratio of PUFA/SFA (P/S ratio) is very important for the determination of the detrimental effects of dietary fats. Adeyeye *et al*. (1999) reported that the higher the PUFA/SFA ratio the more nutritionally useful is the oil because the severity of atherosclerosis is closely associated with the proportion of the total energy supplied by saturated fats and polyunsaturated fats. The present PUFA/SFA in the samples (1.05 (RWF), 2.40 (RSWF) and 2.50 (CWF)) are good enough to prevent atherosclerosis and its associated conditions.

The ratio of *n*-6/*n*-3 value in RWF was 7.80, RSWF was 27.9 and CWF was 28.8. These two categories of fatty acids (n-6 and n-3) have critical roles in the membrane structure (Lynch and Thompson, 1984) and as precursors of eicosanoids, which are potent and highly reactive compounds. Since they complete for the same enzymes and have different biological roles, the balance between the *n*-6 and *n*-3 fatty acids in the diet can be of considerable importance (Adeyeye, 2012). The ratio of *n*-6 to *n*-3 in the diet should be between 5:1 and 10:1; in the present report, only the raw sample (RWF) has its ratio of *n*-6 to *n*-3 fell within the stated range whereas for roasted and cooked sample the ratios were on a very high side which was due to exceptionally high levels of *n*-6 and low *n*-3 fatty acids. It has been established that too much omega-6 in the diet creates an imbalance that can interfere with production of important prostaglandins (WHO/FAO, 1994). The ratio of linoleic acid (LA) to α-linoleic acid (aLA) (LA/aLA) in the present report were RWF (237), RSWF (30.4) and CWF (32.6). These values were at variance with 7: 1 as recommended by Hayes (2002). The reason had been due to a high level of LA and very low levels of aLA in the samples. The essential PUFA status index (EPSI) values (ratios) were generally low (0.830 – 1.35) showing the closeness between the values of MUFA and PUFA in the samples.

Table 4 contains fatty acid profile (g/100g) of the samples as food source. It showed the level of fatty acids when a particular quantity (g/100g) of seed oil is taken as food. The essence of this type of information is to be able to calculate the energy contribution by individual type of fatty acid. From the results, the trend can be seen as follows:

In RWF, SFA (2.17 g/100g) > MUFA (2.08 g/100g) < PUFA (2.40 g/100g). In RSWF, SFA (0.438 g/100g) < MUFA (1.27 g/100g) < PUFA (1.45 g/100g) and in CWF, SFA (0.571 g/100g) < MUFA (1.06 g/100g) < PUFA (1.43 g/100g). Also as shown in the results, the levels were reduced correspondingly in both the roasted and cooked samples (RSWF and CWF) by a percentage range of 0.810 to 1.73% and 0.966 to 1.60% respectively.

Table 3. Summary of the quality parameters of fatty acids of the raw (RWF), roasted (RSWF) and cooked (CWF) whole seeds flour of *Treculia africana*.

Quality parameters	RWF	RSWF	CWF	Mean	SD	CV %	RWF - RSWF	RWF - CWF	RSWF - CWF
SFA	31.2	18.9	18.7	22.9	7.16	31.2	+12.3	+12.5	+0.200
MUFA *cis*	30.0	35.8	34.6	33.5	3.06	9.1	-5.80	-4.60	+1.20
MUFA *trans*	0.019	0.027	0.029	0.025	0.01	20.7	-0.01	-0.010	+0.002
Total MUFA	30.0	35.8	34.6	33.5	3.08	9.2	-5.83	-4.63	1.20
n-3 PUFA	3.95	1.60	1.57	2.37	1.36	57.5	+2.35	+2.37	+0.023
n-6 PUFA	30.8	43.8	45.2	39.9	7.94	19.9	-13.0	-14.4	-1.38
Total PUFA	34.7	45.4	46.8	42.3	6.58	15.6	-10.7	-12.0	-1.36
DUFA *cis*	30.5	42.2	43.6	38.8	7.19	18.6	-11.7	-13.1	-1.40
DUFA *trans*	0.062	0.271	0.275	0.203	0.12	60.1	-0.21	-0.213	+0.004
Total DUFA	30.6	42.5	43.9	39.0	7.31	18.7	-11.90	-13.3	-1.40
TUFA *cis*	2.20	2.86	2.80	2.62	0.36	13.9	-0.66	-0.600	+0.060
TUFA *trans*	-	-	-	0.00	0.00	0.0	0.00	0.00	0.00
Total TUFA	2.20	2.86	2.80	2.62	0.36	13.9	-0.66	-0.600	+0.060
MUFA/SFA	0.962	2.89	1.85	1.90	0.96	50.8	-1.93	-0.888	+1.04
PUFA/SFA	1.05	2.40	2.50	1.98	0.81	40.8	-1.35	-1.45	-0.10
n-6/*n*-3	7.80	27.4	28.8	21.3	11.7	55.0	-19.6	-21.0	-1.40
EPSI	1.09	0.830	1.35	1.09	0.26	23.9	+0.260	-0.260	-0.520
LA/ALA	237	30.4	32.6	100	119	119	+207	+204	-2.20
EPA/DHA	0.530	1.21	1.20	0.980	0.390	39.8	-0.680	-0.670	+0.010

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, + = reduction in the level of the quality parameters of fatty acids of raw due to roasting and cooking, - = enhancement of the quality parameters of fatty acids in the roasted and cooked sample

Table 4. Total fatty acids (g/100g as food) of the raw (RWF), roasted (RSWF) and cooked (CWF) whole seeds flour of *Treculia africana*.

Parameters	RWF	RSWF	CWF	Mean	SD	CV %	RWF - RSWF	RWF - CWF	RSWF - CWF
SFA	2.17	0.438	0.571	1.06	0.964	91.0	+1.73	+1.60	-0.133
MUFA	2.08	1.27	1.06	1.47	0.539	36.6	+0.810	+1.02	+0.210
PUFA n-3	0.272	0.051	0.048	0.124	0.129	104	+0.221	+0.224	+0.003
PUFA n-6	2.12	1.40	1.38	1.64	0.423	25.8	+0.72	+0.742	+0.019
Total PUFA	2.40	1.45	1.43	1.76	0.551	31.3	+0.94	+0.966	+0.022
DUFA	2.12	0.986	1.34	1.48	0.580	39.1	+1.13	+0.78	-0.354
TUFA	0.150	0.066	0.086	0.101	0.044	43.6	+0.08	+0.064	-0.020
C2:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C4:0	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00
C5:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C6:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C8:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C10:0	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00
C12:0	-	0.017	0.017	0.017	0.00	0.00	0.00	0.00	0.00
C14:0	2.0 e-3	0.012	0.011	0.008	0.006	66.1	-0.010	-0.009	+1.00 e-3
C16:0	1.51	0.346	0.458	0.771	0.642	83.3	1.16	+1.05	-0.112
C18:0	1.06	0.06	0.080	0.400	0.572	143	1.00	+0.98	-0.020
C20:0	3.0 e-3	1.7 e-3	2.5 e-3	0.0024	0.0007	27.3	+0.001	+5.00 e-4	-8.00e-4
C22:0	3.0 e-3	1.5 e-3	2.1 e-3	0.0022	0.0008	34.3	+0.0004	+9.00 e-4	-6.00 e-4
C24:0	4.0 e-4	1.8 e-4	2.8 e-4	0.0003	0.0001	38.4	+0.0004	+1.20 e-4	-1.00 e-4
C14:1(*cis*-9)	1.0 e-3	2.0 e-4	2.8 e-4	0.0005	0.0004	89.2	+0.0004	+7.20 e-4	-7.90 e-5
C16:1(*cis*-9)	2.0 e-3	0.059	0.064	0.042	0.0344	82.7	-0.057	-0.062	-0.01
C18:1(*cis*-6)	0.205	0.285	0.348	0.279	0.0717	25.7	-0.080	-0.143	-0.063
C18:1(*cis*-9)	1.87	0.48	0.639	0.996	0.761	76.4	+1.39	+1.231	-0.159
C20:1 (*cis*-11)	4.0 e-3	3.0 e-3	4.2 e-3	0.0037	0.0007	18.1	1.05 e-3	-2.00 e-4	-1.25 e-3
C22:1(*cis*-13)	1.0 e-3	2.2 e-3	3.1 e-3	0.002	0.0011	50.2	-1.20 e-3	-2.10 e-3	-9.00 e-4
C24:1(*cis*-15)	4.0 e-4	1.8 e-4	2.8 e-4	0.0003	0.0001	38.2	+2.19 e-4	+1.20 e-4	-9.90 e-5
C18:1 (*trans*-6)	0.001	5.8 e-4	8.3 e-4	0.0008	0.0002	26.3	+4.20 e-4	+1.70 e-4	-2.50 e-4
C18:1 (*trans*-9)	1.0 e-4	5.2 e-5	7.4 e-5	7.5 e-5	0.0002	32.1	+4.83 e-5	+2.60 e-5	-2.23 e-5
C18:1 (*trans*-11)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C20:2 (*cis*-11, 14)	2.12	2.6 e-3	4.0 e-3	0.709	1.22	172.4	+2.12	+2.12	-1.42 e-3
C20:3 (*cis*-11,14,17)	2.0 e-3	9.7 e-4	1.4 e-3	0.001	0.0005	35.4	+0.0004	+0.0006	-4.26 e-4
C20:5 (*cis*-5,8,11,14,17)	4.0 e-4	7.9 e-4	1.1 e-3	0.001	0.0004	46.0	+0.0004	-0.0007	-3.11 e-4
C22:6 (4,7,10,13,16,19)	1.0 e-3	6.5 e-4	9.2 e-4	0.001	0.00	21.4	+0.0004	+8.3 e-5	-2.67 e-4
C18:2 (*cis*-9,12)	2.12	9.7 e-1	1.33	1.47	0.59	39.8	+1.15	+0.790	-0.356
C18: 2 (*trans*-9,11)	0.004	6.3 e-3	8.4 e-3	0.006	0.001	35.3	+0.0001	-0.0044	-2.11 e-3
C18:3 (*cis*-6,9,12)	0.009	0.032	0.041	0.027	0.020	60.4	-0.02	-0.032	-9.00 e-3
C18:3 (*cis*-9,12, 15)	0.106	0.032	0.041	0.060	0.04	67.7	+0.070	+0.065	-9.00 e-3
C20:3 (*cis*-8,11,14)	4.0 e-3	1.9 e-3	2.70 e-3	0.003	0.0011	37.4	+0.001	+0.0013	-8.20 e-4
C20:3 (*cis*-11,14,17)	2.0 e-3	9.7 e-4	1.4 e-3	0.001	0.0005	35.4	+0.001	+0.0006	-4.26 e-4
C20:4 (*cis*-5,8,11,14)	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C22:2 (*cis*-13,16)	4.0 e-4	1.0 e-4	1.5 e-3	0.001	0.0007	110.	0.00	-0.0011	+0.001
Total	6.97	2.32	1.43	3.57	2.97	83.2	+4.65	+5.54	+0.89

+ = reduction in the level of the fatty acids as food of raw due to roasting and cooking, - = enhancement of the fatty acids as food in the roasted and cooked sample

As shown in Table 5 which depicted the energy contributions (kg/100g) from the various fatty acids, the energy contributions were relative to the respective values of g/100g fatty acids as food. Table 6 presents the levels (mg/100g) of phospholipid in the raw, roasted and cooked wholeseeds flour of *Treculia africana*. In the raw wholeseeds flour (RWF), phosphatidycholine was the most concentrated with a value of 80.5 mg/100g followed by phosphatidylethanolamine (34.0 mg/100g) and the least concentrated being phosphatidylinositol (3.53 mg/100g). Equal amounts (mg/100g) of the phospholipid profile were recorded in both the roasted and cooked samples (phosphatidylethanolamine (321), phosphatidylcholine (89.3), phosphatdylserine (286), lysophosphatidylcholine (4.00) and phosphatidylinositol (733). From the table, it was clear that both roasting and cooking enhanced all except lysophosphatidylcholine which has its value reduced by about 12.5 mg/100g by the processing methods. However, the values in the present report were compared with those reported for raw and processed groundnut seeds (Adeyeye and Agesin, 2012).

Phosphatidylserine (PS) has been shown 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, 2012). The US Food and Drug Administration (USFDA) has stated that consumption of PS may reduce the risk of dementia and cognitive dysfunction in elderly persons (Adeyeye, 2011). Phytosterols levels (mg/100g) are shown in Table 7. Sitosterol was the highest in all samples with values: RWF (98.4), RSWF (302) and CWF (309) and the lowest concentration goes to cholesterol (the levels were apparently small), the values being: RWF (7.9 e-8), RSWF (3.1 e-7) and CWF (5.4 e-6). From the results, it is evident that roasting and cooking had positive effects on all the phytosterol contents. Also, cooking was better than roasting in respect to the enhancement of sterol content.

Table 5. Energy contributions (kJ/100g) from fatty acids of the raw (RWF), roasted (RSWF) and cooked (CWF) whole seeds flour of *Treculia africana*.

Fatty acids	RWF	RSWF	CWF	Mean	SD	CV %	RWF - RSWF	RWF - CWF	RSWF – CWF
SFA	80.2	16.2	21.2	39.2	35.59	90.8	+64.00	+59.0	-5.00
MUFA	77.1	47.0	39.2	54.4	20.01	36.8	+30.10	+37.9	+7.80
n-3 PUFA	10.1	1.89	1.78	4.58	4.76	104	+8.19	+8.29	+0.109
n-6 PUFA	78.6	51.9	51.2	60.5	15.6	25.8	+26.7	+27.4	+0.706
Total PUFA	88.7	53.7	52.9	65.1	20.4	31.3	+34.9	+35.7	+0.815
Total DUFA	78.6	36.5	49.7	54.9	21.5	39.2	+42.1	+28.9	-13.2
Total TUFA	5.65	2.46	3.17	3.76	1.67	44.5	+3.19	+2.48	-0.71
C2:0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C3:0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C4:0	-	-	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C5:0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C6:0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C8:0	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C10:0	-	-	0.00	0.00	0.00	0.0	0.00	0.00	0.00
C12:0	-	0.629	0.619	0.624	0.007	1.13	0.00	0.00	+0.010
C14:0	0.083	0.439	0.413	0.312	0.20	63.7	-0.36	-0.33	++0.03
C16:0	56.0	12.8	17.0	28.6	23.8	83.3	+43.2	+39.0	-4.20
C18:0	39.3	2.22	2.95	14.8	21.2	143	+37.1	36.4	-0.730
C20:0	0.126	0.064	0.091	0.094	0.03	33.2	+0.06	0.035	-0.027
C22:0	0.116	0.054	0.078	0.083	0.03	37.8	+0.06	0.038	-0.024
C24:0	0.014	6.7 e-3	0.010	0.010	0.00	35.7	+0.01	+0.004	-0.003
C14:1(*cis*-9)	0.041	7.5 e-3	0.010	0.019	0.02	95.9	+0.03	+0.031	-0.003
C16:1(*cis*-9)	0.062	2.16	2.35	1.52	1.27	83.3	-2.10	-2.29	-0.190
C18:1(*cis*-6)	7.58	10.6	12.9	10.4	2.67	25.8	-3.02	-5.32	-2.30
C18:1(*cis*-9)	69.4	17.8	23.6	36.9	28.3	76.5	+51.6	+45.8	-5.80
C20:1 (*cis*-11)	0.129	0.109	0.155	0.131	0.02	17.6	+0.02	-0.026	-0.05
C22:1(*cis*-13)	0.04	0.082	0.115	0.079	0.04	47.6	-0.04	-0.075	-0.033
C24:1(*cis*-15)	0.014	6.7e-3	0.010	0.010	0.00	35.7	+0.01	+0.004	-0.003
C18:1 (*trans*-6)	0.045	0.022	0.031	0.033	0.01	35.5	+0.02	+0.014	-0.009
C18:1 (*trans*-9)	0.004	1.9e-3	0.003	0.003	0.00	38.2	+2.19 e-3	+0.0014	-7.90 e-4
C18:1 (*trans*-11)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C20:2 (*cis*-11,14)	78.4	0.096	0.147	26.2	45.2	172	+78.3	+78.3	-0.051
C20:3 (*cis*-11,14,17)	0.077	0.036	0.052	0.055	0.021	37.6	+0.041	+0.025	-0.016
C20:5 (*cis*-5,8,11,14,17)	0.014	0.029	0.041	0.028	0.014	48.3	-0.015	-0.027	-0.012
C22:6 (*cis*-4,7,10,13,16,19)	0.027	0.024	0.034	0.028	0.005	18.1	0.003	-0.007	-0.010
C18:2 (*cis*-9,12)	78.4	36.1	49.1	54.5	21.67	39.7	42.3	29.3	-13.0
C18: 2 (*trans*-9,12)	0.159	0.233	0.311	0.234	0.076	32.4	-0.074	-0.152	-0.078
C18:3 (*cis*-6,9,12)	0.331	1.18	1.52	1.01	0.612	60.6	-0.849	-1.19	-0.340
C18:3 (*cis*-9,12, 15)	3.93	0.23	1.50	1.89	1.88	99.5	+3.70	+2.43	-1.27
C20:3 (*cis*-8,11,14)	0.147	0.07	0.010	0.076	0.069	90.8	+0.077	0.137	0.060
C20:3 (*cis*-11,14,17)	0.077	0.036	0.052	0.055	0.021	37.6	+0.041	+0.025	-0.016
C20:4 (*cis*-5,8,11,14)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22:2 (*cis*-13,16)	0.014	0.039	0.056	0.036	0.021	58.1	-0.025	-0.042	-0.017
Total	247	85.1	52.9	128	104	81.1	+162	+194	+32.2

+ = reduction in the level of the energy contribution from fatty acids due to roasting and cooking, - = enhancement of the energy contribution from fatty acids in the roasted and cooked sample

Cholesterol was reported to be present in small amounts in vegetable oils (Kochar, 1983). B – sitosterol is one of the several phytosterols with chemical structures similar to that of cholesterol and it is widely distributed in plants. Plants sterols have been suggested to have dietary significance and to protect vegetable oils from oxidative polymerization during heating at frying temperatures (Gordon and Maggos, 1983).

Table 8 depicts the statistical (Pearson's correlation coefficient) analysis between raw wholeseed flour/roasted wholeseeds flour (RWF/RSWF); raw wholeseed flour/ cooked wholeseed flour (RWF/CWF) and roasted wholeseed flour/ cooked wholeseed flour (RSWF/CWF). For results from Tables 1 to 7, significant differences occur between all the paired results except the results from Table 3 (RT3) for

Table 6. Levels (mg/100g) of phospholipids in the raw (RWF), roasted (RSWF) and cooked (CWF) whole seeds flour of *Treculia africana*.

Pospholipids	RWF	RSW	CWF	Mean	SD	CV%	RWF - RSWF	RWF – CWF	RSWF - CWF
Phosphatidylethanolamine	34.0	321	321	225	166	73.5	-287	-287	0.00
Phosphatidylcholine	80.5	89.3	89.3	86.4	5.08	5.88	-8.80	-8.8	0.00
Phosphatidylserine	9.10	286	286	194	160	82.5	-277	-277	0.00
Lysophosphatidylcholine	16.5	4.00	4.00	8.17	7.22	88.4	+12.5	+12.5	0.00
Phosphatidylinositol	3.53	733	733	490	421	86.0	-729	-729	0.00
Total	144	1433	1433	1003	744	74.2	-1289	-1289	0.00

+ = reduction in the level of phospholipids due to roasting and cooking, - = enhancement of the of phospholipids in the roasted and cooked sample

Table 7. Levels of phytosterols (mg/100g) in the raw (RWF), roasted (RSWF) and cooked (CWF) whole seeds flour of *Treculia africana*.

Phytosterols	RWF	RSWF	CWF	Mean	SD	CV %	RWF - RSWF	RWF - CWF	RSWF - CWF
Cholesterol	7.9e-8	3.1 e-7	5.4 e-6	1.9 e-6	3.0e-6	155.8	-0.0001	-5.3 e-6	-0.0001
Cholestanol	5.0 e-6	2.3 e-4	4.7 e-4	2.4 e-4	2.3e-4	99.2	-0.0004	-4.7 e-4	-0.0001
Ergosterol	3.4 e-6	1.0 e-5	2.2 e-5	1.2 e-5	9.6e-6	80.8	-0.0001	-1.9 e-5	-0.0002
Campesterol	8.97	108	137	84.7	67.1	79.3	-99.0	-128	-29.0
Stigmasterol	0.116	23.8	26.6	16.8	14.5	86.4	-23.7	-26.5	-2.80
5- Avenasterol	0.054	11.5	12.7	8.08	6.98	86.3	-11.4	-12.6	-1.20
Sitosterol	98.4	302	309	236	120	50.6	-204	-211	-7.00
Total	108	446	484	346	207	59.8	-338	-376	-38.0

+ = reduction in the level of phytosterol due to roasting and cooking, - = enhancement of the of phytosterol in the roasted and cooked sample

Table 8. Statistical analysis showing the Pearson's Correlation coefficient *r*CV (critical values) for the results from all Tables.

Results	Groups	r_{xy}	r_{xy}^2	R_{xy}	C_A (%)	IFE(%)	*r*CV	Remark
	RWF/RSWF	1.0000	1.0000	1.0000	0.00	100	0.9970	S
RT1	RWF/CWF	1.0000	1.0000	1.0000	0.00	100	0.9970	S
	RSWF/CWF	1.0000	1.0000	1.0000	0.00	100	0.9970	S
	RWF/RSWF	0.934751	0.873759	0.870348	25.5	74.5	0.3490	S
RT2	RWF/CWF	0.932841	0.870192	0.866684	25.9	74.1	0.3490	S
	RSWF/CWF	0.999425	0.998851	0.998819	2.40	97.6	0.3490	S
	RWF/RSWF	0.407661	0.166188	0.117140	77.0	23.0	0.4440	NS
RT3	RWF/CWF	0.424028	0.179800	0.131553	75.9	24.1	0.4440	NS
	RSWF/CWF	0.998975	0.997951	0.997831	3.20	96.8	0.4440	S
	RWF/RSWF	0.902697	0.814861	0.810453	31.2	68.8	0.3040	S
RT4	RWF/CWF	0.816072	0.665973	0.658020	42.9	57.1	0.3040	S
	RSWF/CWF	0.948046	0.898792	0.896382	22.8	77.2	0.3040	S
	RWF/RSWF	0.903368	0.816074	0.811695	31.1	68.9	0.3040	S
RT5	RWF/CWF	0.823959	0.678909	0.671264	42.0	58.0	0.3040	S
	RSWF/CWF	0.949383	0.901328	0.898978	22.5	77.5	0.3040	S
	RWF/RSWF	0.634763	0.402925	0.253656	60.4	39.6	0.7550	NS
RT6	RWF/CWF	0.634763	0.402925	0.253656	60.4	39.6	0.7550	NS
	RSWF/CWF	1.0000	1.0000	1.0000	0.00	100	0.7550	S
	RWF/RSWF	0.973514	0.947730	0.939018	16.3	83.7	0.6660	S
RT7	RWF/CWF	0.960220	0.922022	0.909026	19.9	80.1	0.6660	S
	RSWF/CWF	0.998545	0.997092	0.996607	3.81	96.2	0.6660	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, C_A =coefficient of variation, IFE = index of forecasting efficiency, *r*CV= critical values of r at 0.05, S=significant, NS=not significant

RWF/RSWF and RWF/CWF (summary of quality parameters from fatty acid profiles) and from Table 6 (RT6) for RWF/RSWF and RWF/CWF (phytosterol contents). For instance, taking the results from Table 2 (RT2) row 1 (RWF/RSWF), the result showed r_{xy} as a high positive value (0.934751), r_{xy}^2 (coefficient of determination) of 0.873759 and R_{xy} of 0.870348. This meant that for every one unit rise in the raw wholeseeds flour fatty acids value, there was a corresponding increase of 0.870348 in the roasted wholeseed flour. For the coefficient of alienation (C_A), the value of 25.5 % was low whereas the index of forecasting efficiency (IFE) was high at 74.5 %, signifying that the forecasting efficiency of relationship was high. The IFE is actually the reduction in the error of prediction. The higher the IFE, the lower is the error in the forecasting efficiency. For all the comparisons made, the values of IFE were high except in RT3 and RT6 for RWF/RSWF and RWF/CWF respectively.

Conclusion

This study has revealed that, raw, roasted and cooked wholeseed flours of *Treculia africana* contained useful levels of fatty acids, phospholipids and phytosterols that are good for human nutrition. On the whole from quality parameters of fatty acids, the results showed that the raw wholeseed flour was only better in four parameters (22.2 % or 4/18) whereas roasted wholeseed flour was better in fourteen (77.8 % or 14/18) parameters than the raw wholeseed flour on the other hand, cooked wholeseed flour was in fifteen (15/18 or 83.3 %) parameters better than the roasted wholeseed flour. However, the roasted wholeseed flour was better in ten (55.6 % or 10/18) parameters than the cooked wholeseed flour. Also in the group of phospholipids, both in the roasted and cooked wholeseeds flour were each better in four out of five parameters than the raw wholeseed flour whereas in the group phytosterols, the roasted and cooked wholeseed flour were 100 % better than the raw wholeseed flour. Statistical analysis using the Pearson's correlation coefficient at $r_{=0.05}$ showed that significant differences existed between almost all the parameters from all the results. Generally, for a better or maximum access to the nutritional values in terms of lipid compositions, roasted and cooked wholeseed flour forms would be highly proffered for both domestic and industrial applications.

References

1. Okafor, J.C. and Okolo, H.C. (1974). Potentials of some indigenous fruit trees of Nigeria. Paper Presented to the 5th Annual Conference of the Forestry Association of Nigeria, Jos.
2. Nuga O.O and Ofodile E.A.U. (2010) Potentials of *Treculia africana* Decne - an endangered species of Southern Nigeria. *Journal of Agriculture and Social Research*, 2:12 -21

3. Nwabueze T.U and Uchendu C.B. (2011). African Breadfruit (*Treculia africana*) Seed as Adjunct in Ethanol Production. *European Journal of Food Research & Review*, 1(1): 15-22.
4. Raheja, R.K., Kaur C, Singh A, Bhatia, I.S. (1973) New colorimetric method for the quantitative estimation of phospholipids without acid digestion. *J. Lipid Res*. 14, 695-697.
5. Oloyo, R.A. (2001). “Fundamentals of research methodology for Social and Applied Sciences”. ROA Educ. Press Ilaro.
6. Chase, C.I. (1976). “Elementary statistical procedures”, 2nd edn. McGraw-Hill Kogakusha Ltd, Tokyo, Japan.
7. Adeyeye, E.I., Jimoh, A.O and Adesina, A.J. (2013). Lipid Composition of the Seeds of Three Types of Chillies Consumed in Nigeria. *Open journal of analytical chemistry research* (OJACR), 1(3):69-79.
8. Hayes, K. C. (2002). Dietary fat and heart health: in search of the ideal fat. Asia Pacific *Journal of Nutrition.* 11(Suppl.): S394-S400.
9. Adeyeye. E.I. (2012). Effects of roasting and cooking on the lipid composition of raw groundnut (Arachis hypogaea) seeds: dietary implications. *Elixir Food Science*, 42: 6257-6266.
10. Hegsted, D.M. Ausman, L.M., Johnson, J.A and Dallal, G.E. (1993) Dietary fat and serum lipids: an evaluation of the experimental data. *Am. J. Clin.Nutr.*, 57: 875-883.
11. Bonanome, A and Grundy, S.M. (1988). Effect of dietary stearic acid on plasma cholesterol and lipoprotein levels. *New England J.Med*., 318: 1244-1248.
12. Adeyeye, E.I. Oshodi, A.A and Ipinmoroti, K.O. (1999) Fatty acid composition of six varieties of dehulled African yam bean (*Sphenostylis stenocarpa*) flour. *International Journal of Food Sciences and nutrition*, 50 (5): 357-365.
13. WHO/FAO (1994). Fats and oil in human nutrition (Report of a joint expert consultation FAO food and nutrition). Paper 57, WHO/FAO, Rome.
14. Adeyeye, E.I. (2011). Levels of fatty acids, phospholipids and sterols in the skin and muscle of Tilapia (Oreochromis niloticus) fish. *La Rivista Italiana Delle Sostanze Grasse*, 88 (Gennaio/Marzo): 46-55.
15. Kochar, S.P. (1983). Influence of processing on sterols of edible vegetable oils. *Prog. Lipid Res*., 22: 161-188.
16. Gordon, M.H and Maggos, P. (1983). The effect of sterols on the oxidation of edible oils. *Food Chem*., 10: 141-147.
17. Adeyeye, E.I., Olaleye, A. A., Adesina, A.J**.** (2015). Lipid Composition of Testa, Dehulled Seed and wholeseed of bambara groundnut (*Vigna subterranea* L. Verdc). *Current Advances in Plant Sciences Research*, 2 (1):1-9.
18. Whitney, E.N, Cataldo, C.B and Rolfes, S.R. (1994). Understanding normal and clinical nutrition. New York, USA, West Publishing Company; pp 132-168; 880-909.
19. Wardlaw, G.M.(2003) Contemporary nutrition: issues and insights, 5th ed. Boston, McGraw-Hill; pp 143-186.
20. Lynch, D.V and Thompson, G.A. (1984). Re-tailored lipid molecular species: a tactical mechanism for modulating membrane properties. *Trends Biochem. Sci*. 9: 442-445.
21. Adeyeye, E.I. (2012). Effects of roasting and cooking on the lipid composition of raw groundnut (*Arachis hypogaea*) seeds; dietary implications. *Elixir Food Science*, 42:6257 – 6266.
22. Adeyeye, E.I. (2010). Effect of cooking and roasting on the amino acid composition of raw groundnut (*Arachis hypogaea*) seeds. *Acta Scientarium Polonorum Technologia Alimentaria*,z 9(2): 201-216.
23. Slavin, J.L. Jacobs, D and Marquart, L. (2000). Grain processing and nutrition, *Crit. Rev. Food Sci. Nutr*. 40:309-32.