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Effects of roasting and cooking on the lipid composition of raw groundnut (*Arachis hypogaea*) seeds: dietary implications

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ABSTRACT

The following experimental procedures were carried out on the samples using standard analytical methods: fat, fatty acids, phytosterols and phospholipids analyses, quality assurance determination and the calculation of uncertainty interval percentage (UIP) were undertaken. Statistical evaluations were: linear correlation coefficient (r_{xy}), coefficient of determination (r_{xy}^2), linear regression coefficient (R_{xy}), coefficient of alienation (C_A) and index of forecasting efficiency (IFE). The results were: crude fat range (g/100 g): 47.6 (cooked seeds) – 49.6 (roasted seeds) followed by calculated fatty acid of 45.5-47.4; SFA range (% total fat): 19.0-23.4; MUFA, 54.8-57.9; DUFA, 20.1-23.5; TUFA, 0.50-1.70; total unsaturated fatty acid (TUFA) was raw seeds (81.0 %) > roasted seeds (79.9 %) > cooked seeds (76.6 %); PUFA range was 21.8-24.1 %; PUFA/SFA was 0.93-1.21; 2n-6.3n-3 range was 13.7-43.6. Among the phospholipids, lecithin was highest among the samples with values of 725-1168 mg/100 g or 36.0-57.2 %. Among the phytosterols, sitosterol was highest in each sample with a range of 81.1-111 mg/100 g. Significant relationship existed among the following parameters at $r_{=0.01}$: fatty acids level for raw seeds/roasted seeds (Rs/Rt.s), raw/cooked seeds (Rs/Cs) and Rt.s/Cs; energy contribution by the fatty acids fraction: Rs/Rt.s, Rs/Cs and Rt.s /Cs as well as in phytosterols level.

Introduction

The cultivated species of the groundnut plant, *Arachis hypogaea*, is an annual herb belonging to the Papilionaceae division of the family *Leguminoseae*. It is a spreading, sun-loving plant, widely grown in tropical, sub-tropical, Mediterranean and warm temperate climates. Groundnut is also known as *earth-nut, peanut-monkey-nut, Manilla-nut, Chinese nut, goober pea, pindar, pistache de terre, larachide*. In various Nigerian vernaculars: *epa* (Yoruba); *gya'da* (Hausa); *okpakpa* (Ibo) [1].

The groundnut is a legume with seed rich in oil (48-49 %) and protein (about 26 %). Groundnuts are the main export crop in Nigeria's northern states and the bulk of the crop is produced north of latitude 11°N. The crop does best in light sandy soil, which allows good drainage and ease of harvesting; 500 mm of rain can be sufficient if well distributed. Production in excess of village market sales has varied from less than 100 000 tons in an unfavourable year to 1 000 000 tons of shelled groundnuts in a favourable year. Nearly all this commercial crop is processed in local oil mills and the oil mills and the oil and cake sold at home and abroad[2].

The groundnut is widely consumed in Nigeria and in various other parts of West Africa. Its nutty, agreeable flavour makes it a particularly suitable vegetable food when roasted. It is often cooked and eaten mixed with maize. Its high protein content makes it especially valuable as a tissue builder.

The groundnut is one of the most important sources of edible vegetable oils and it is cultivated principally for this purpose. The oil comprises about 50 % of the total kernel. The content of the oil has been stated to depend on the richness of the soil and the conditions of cultivation rather than on the variety grown [1], the percentage being greater in nuts grown in warm than in temperate climates. It is non-drying, edible oil, liquid at ordinary temperature, golden yellow in colour. About 82 % of the oil consists of the low-melting point glycerides of oleic and linoleic acids, while the remaining 18 % is made up of palmitic, stearic, arachidic and linoceric acids. The oil has an iodine number of 86.8. According to Hilditch and Williams [3], Nigerian and West African groundnut oils have the following mean glyceride components, fatty acids per cent of weight, Nigerian (West African): oleic, 61.8 (59.1); linoleic, 19.7 (20.6); palmitic, 8.6 (9.2); stearic, 3.7 (5.5); arachidic, behenic, lignoceric, 6.3 (5.6). The oil is thus of a high nutritive value readily digestible and, except for its lower vitamin content, has often been ranked as nutritionally the equal of butter fat.

In Nigeria the oil is next only to palm oil as culinary and edible oil being regarded in the South as a relish reserved for cooking on more important occasions instead of palm oil which is cheaper. Groundnut oil is, however, more commonly used than palm oil in Northern Nigeria. It is also used as an illuminant oil and like palm kernel oils, as a basis for pomade. Abroad, groundnut oil is used principally as edible oil especially as salad oil in place of olive oil. Considerable quantities of it are hydrogenated to produce a hardened fat which is employed in the manufacture of margarine. It is used as a lubricant and for oiling wool. Lower quality oils are employed in soap making. Groundnut oil is one of the official oils in the British Pharmacopoeia. It has been successfully used as a fuel in diesel engines [1].

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The chemical composition of groundnut and groundnut products values have been compiled by Oyenuga[1]; the amino acid components of groundnut from three different geographical area have been reported: Sumaru (Nigeria)[4], United States[5] and India[4]. Adeyeye[6] reported on the effects of cooking and roasting on the amino acid composition of raw groundnut (*Arachis hypogaea*) seeds. The effects of processing on the nutritional and anti-nutritional factors of *Arachis hypogaea* Linn. seed flour was reported by Adeyeye [7]. No report is available on the effects of processing (roasting and cooking) on the lipid components of raw groundnut seeds. It is therefore the aim of this research to report on the effects of roasting and cooking on the kernels of dry groundnut and compare the results with raw but also dried groundnut kernels.

Materials and methods

Samples: Groundnut cultivar used: there are three main types:

(a) the long season;

(b) the short season sequentially branched early-maturing types with a more determinate growth pattern;

(c) new types bred from crosses between short and long season forms.

The long season, alternately branched types with indeterminate growth pattern. Erect varieties and runner varieties in this group are capable of giving good yields but the erects are handled more easily with machines. Nearly all the crop grown in Nigeria is of this long season type. The long season runner variety was used for these experiments [2].

Collection of samples: Dried pods of groundnut (approximately 1.0 kg) were collected from Iworoko market, Ekiti State, Nigeria. These sun-dried pods were then further oven-dried to constant weight, and any broken pods were removed.

Treatment of samples*:* The samples were treated as follows: after the groundnut had been divided into three parts.

About 300 g of the groundnut pod was shelled and the kernel collected. The kernels were oven-dried to constant weight and homogenised into flour. The homogenised sample was then packed in plastic bottles and kept in freezer (-4 ^{o}C) pending analysis. This is the raw sample.

About 350 g of the dried groundnut pods were put into an iron pot mixed with clean fine sand and stirred to prevent burning of the samples and to ensure uniform distribution of heat. The groundnut pods were roasted for about 30 min at 120-130 ^{o}C using Gallenkamp thermostat hot plate until a characteristic brownish nutty smell seed was obtained which indicated complete roasting. The sand was then separated from the groundnut using a sieve and the groundnut pods were allowed to cool. Thereafter the pods were shelled and the seeds collected. The seeds were then homogenised and packed in plastic bottles and kept in freezer (-4 ^{o}C) pending analysis. This is the roasted sample.

About 350 g of the dried groundnut pods were put in aluminium pot, tap water added (groundnut pods/water ratio 1:5 w/v), and cooking at 85-90 ^{o}C on a Gallenkamp thermostat hot plate. The groundnut pods got cooked after about 20 min. The seeds were considered cooked when they became soft to touch on pressing between the thumb and fingers. At the end of cooking time, the boiling water was drained and seeds were removed, sun-dried and later oven-dried to constant weight. The seeds were then homogenised and packed in plastic bottles and kept in freezer (-4 ^{o}C) pending analysis. This is the cooked sample.

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 ^{o}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 ^{o}C for 1 h, cooled in a desiccator and the weight of dried oil was determined.

Preparation of fatty acid methyl esters and analysis: A 50 mg aliquot of the dried oil was saponified for 5 min at 95 ^{o}C with 3.4 ml of 0.5 M KOH in dry methanol. The mixture was neutralised 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 ^{o}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 analysed 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 ^{o}C, ramping at 10 ^{o}C/min for 20 min, held for 4 min, with a second ramping at 15 ^{o}C/min for 4 min and held for 10 min. The injection temperature was 250 ^{o}C and the detector temperature was 320 ^{o}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 ^{o}C for 30 min, using 3 ml of 10 % KOH in ethanol, to which 0.20 ml of benzene was added to ensure miscibility. Deionised 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.* [8]. 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 ^{o}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 ^{o}C, ramping at 10^{o}C/min for 20 min, held for 4 min, a second ramping at 15 ^{o}C /min for 4 min and held for 5 min. The injection temperature was 250 ^{o}C, and the detector temperature was 320^{o}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.

Quality assurance: Standard chromatograms were prepared for phytosterols, phospholipids and fatty acid methyl esters which were then compared with respective analytical results; calibration curves were prepared for all the standard mixtures

and correlation coefficient was determined for each fatty acid (28), phytosterol (7) and phospholipids (5). Correlation coefficient > 0.95 was considered acceptable.

Fatty acid values were also subjected to the calculation of uncertainty interval percentage. Some CRMs values were available for phytosterols and phospholipids but none in food samples relevant to this study. The CRMs used here were from Wolf [9].

Calculation of fatty acid per 100 g in samples: Crude fat level was multiplied by a conversion factor of 0.956 to convert it to total fatty acids [10]. For fatty acids expressed in g per 100 g total fatty acids, precision is best limited to the 0.1 g/100 g level, with trace being set at ≤ 0.06 g/100 g to fatty acids [11].

Statistical analysis: Statistical analysis [12] was carried out to determine the mean, standard deviation, coefficient of variation in per cent. Also calculated were linear correlation coefficient (r_{xy}), coefficient of determination (r_{xy}^2), linear regression coefficient (R_{xy}) and 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 (critical) value at $r_{=0.01}$ to see if significant differences existed in the values of fatty acids, phytosterols and phospholipids between the various treated and raw samples of groundnut seeds.

Results

In Table I the crude fat in the samples ranged from 47.6-49.6 g/100 g with cooked seeds being the least and roasted seeds being the highest with low level of coefficient of variation per cent (CV %) of 2.01. This trend was followed by calculated total fatty acid. The low levels of CV % (2.01) showed that the values were close.

The total fatty acids in per cent levels (%) for the three samples were shown in Table II. These fatty acids recorded 0.00 % (of total fatty acid): pentanoic acid; fatty acids not detected were: acetic acid, propionic acid, caproic acid and lignoceric acid; butyric acid was not detected in raw and cooked seeds (Rs and Cs) but low level (0.19 %) was detected in roasted seeds (Rt.s). The most concentrated SFA was palmitic acid in all the samples: 10.1 % (Rs), 13.0 % (Rt.s) and 12.6 % (Cs); most concentrated monoenic acids were: *trans*-petroselinic acid (C18:1 *trans*-6) (15.1 %), in Cs, petroselinic acid (C18:1 *cis*-6) in Rs (13.5 %) and 14.8 % in Rt.s. Oleic acid (C18:1 *cis*-9) was highest in Rt.s (12.0 %) but lowest in Cs (8.28 %). The levels of linoleic acid and conjugated linoleic acid were very close, viz: linoleic acid, 9.90-11.6 % with CV % of 8.15 and conjugated linoleic acid (CLA), 9.19-11.7 with CV % of 12.4. Alpha-linolenic acid was of low levels (0.26-0.72 %) and wide variation of 57.7 %. The most varied fatty acid was caprylic acid (C8:0) with a CV % of 104 whereas *trans*-9 elaidic acid (C18:1 *trans*-9) was the least varied with a CV % of 2.64.

The summary of Table II into SFA, MUFA, DUFA and TUFA levels (% total fatty acid) was depicted in Table III. SFA range was 19.0-23.4 % and CV % of 11.1; in MUFA, total range was 54.8-55.8 % showing that MUFA was the predominant fatty acid (FA) in groundnut oil but the *trans*-MUFA was higher in concentration than the *cis*-MUFA. The DUFA levels were 20.1-22.6 % (for both *trans*-DUFA and *cis*-DUFA). The CV % for SFA, MUFA and DUFA were low at 2.87-13.5. Also of note was that MUFA (*cis*-, *trans*-) and DUFA (*cis*-, *trans*-) levels were lowest in Cs (except in *trans*-MUFA). This could have been due to oxidation at the unsaturated bonds of the fatty acids in the presence of heat, water and oxygen. On the other hand, roasting enhanced the levels of *cis*- MUFA, *cis*-DUFA and *trans*-DUFA. Although TUFA levels were low (0.50-1.70 %), the highest was in Cs, the CV % was high at 70.8. On the whole the trend was this (MUFA + DUFA+TUFA): Cs (76.6 %) < Rt.s (79.9 %) < Rs (81.0 %) showing reduction of unsaturated fatty acids in both dry heating and moist heating, but more pronounced in moist heating.

The differences between the fatty acid levels in Rs and Rt.s, Rs and Cs are shown in Table IV showed that Rt.s was better concentrated in 17/21 (81.0 %) fatty acids than in Rs whereas in Cs, 14/21 (66.7 %) fatty acids were better than in Rs. The Rs was better than Rt.s mostly in SFA like stearic acid (C18:0) by 54.9 %, arachidic acid (C20:0) by 35.5 %, behenic acid (C22:0) by 13.9 % and only one monoenoic acid, vaccenic acid (C18:1 *trans*-11) by 54.1 %. Fatty acids where Cs was better concentrated (7 of them) were mostly in the unsaturated fatty acids (5 unsaturated and 2 saturated fatty acids). For better and easier understanding the values in Table IV was summarised as shown in Table V.

In Table VI, the energy contributions of the various FA fractions were shown. It is interesting to know that MUFA levels were the highest with *trans*-MUFA being higher in the group: *cis*-MUFA kcal (187-246) with CV % of 13.6 and kJ (790-1037) with CV % of 13.5; *trans*-MUFA kcal (257-306) with CV % of 9.16 and kJ (1084-1290) with CV % of 9.19. This was followed by the SFA group of kcal (171-211) with CV % 11.2 and kJ (722-890) with CV % 11.1; TUFA was low with kcal levels of 4.54-15.3 and 19.1-64.6 kJ with CV % of 70.7-70.9.

Fatty acids level in groundnut seeds per 100 g raw, roasted and cooked samples as food were shown in Table VII. Fatty acids with reasonable levels of contribution were palmitic (C16:0), *trans*-petoselinic (C18:1 *trans* -6), petroselinic (C18:1 *cis*-6), elaidic (C18:1 *trans*-6), oleic (C18:1 *cis*-6), linoleic (C18:2 *cis*-9, 12), conjugated linoleic acid (CLA), *trans*-11 vaccenic acid (C18:1 *trans*-11). The CV % ranged between 3.26-102.

Phospholipids level total range was 2012-2141 mg/100 g with ratio of Rs/Rt.s (1.06), Rs/Cs (1.05) with CV % of 0.67. Lecithin (phosphatidylcholine) was the most concentrated with levels ranging from 725-1168 mg/100 g with per cent levels of 36.0 %-57.2 %. However, lecithin was highly oxidised in roasting and therefore had the lowest level among the samples. All the CV % levels were low with levels of 0.67-42.2. Phosphatidylinositol was highly enhanced by cooking with a value of 110 mg/100 g while others ranged from 72.4-75.7 mg/100 g. Table IX depicted the differences in the phospholipids level among the samples. Lecithin and lysophosphatidycholine were highest in Rs than Rt.s whereas cephalin and lysophosphatidylcholine were highest in Rs than Cs.

The phytosterols levels of the samples were shown in Table X. Sitosterol was highest in all the samples particularly in Rs (111 mg/100 g) but reduced in Rt.s (81.1 mg/100 g) but reduction was slight in Cs (110 mg/100 g). There was complete oxidation in campesterol where 0.00 mg/100 g was recorded for Rt.s and reduced by 62.7 % in Cs. Cholesterol was low in all samples and it was also very close in the samples: levels of 8.93-9.28 and CV % 1.93. Both cholestanol and 5-avenasterol had 0.00 mg/100 g in each case. The summary of the differences observed between Rs and Rt.s, Rs and Cs phospholipids depicted in Table X was shown in Table XI. The biggest loss due to roasting was campesterol where there was 100 % loss followed by the same phytosterol in Cs where there was a loss of

62.7 %. In ergosterol, Rt.s gained 257 % but lost 70.6 % in Cs. Whilst Rt.s recorded loss in three phytosterols (campesterol, stigmasterol and sitosterol), Cs recorded loss in four phytosterols (ergosterol, compesterol, stigmasterol and sitosterol) due most likely to oxidation or heat cleavage of the phytosterols concerned.

The statistical summary of the data in Tables III, VI, VIII and X was shown in Table XII. Comparisons made were linear correlation coefficient (r_{xy}), coefficient of determination (r_{xy}^2), linear regression coefficient (R_{xy}), mean (X) and (Y), coefficient of alienation (C_A) and index of forecasting efficiency (IFE) and the r_{xy} was subjected to table value (critical value) at $r_{=0.01}$ at n-2 degrees of freedom for Rs/Rt.s, Rs/Cs and Rt.s/Cs. The r_{xy} levels were highly and significantly positive from Table III, VI and X for Rs/Rt.s, Rs/Cs and Rt.s/Cs at $r_{=0.01}$. Levels from Table VI for Rs/Rt.s, Rs/Cs and Rt.s/Cs were not significantly different at $r_{=0.01}$ and n-2 degrees of freedom. The R_{xy} were positive for all the parameters in Tables III and VI but negative in Table VIII (Rs/Cs and Rt.s) and Table X (Rs/Cs and Rt.s/Cs). The implication of R_{xy} is that for each unit rise in the Rs value (e.g, in Table III), there was an increase of 1.13 in the Rt.s; this explanation goes for all R_{xy} values. For Table VIII (Rt.s/Cs) and Table X (Rs/Cs, Rt.s/Cs), for each unit increase in the X value, there was a negative value for the R_{xy}. The C_A represents the coefficient of alienation or non-relationship, whereas the IFE which is an index of forecasting efficiency denotes a reduction in predicting the error of relationship. The higher the C_A, the lower the value of IFE. For example the data from Table III gave the C_A in Rs/Rt.s as 4.00 % with very high level of IFE as 96.0 %; this meant that reduction in predicting the error of relationship was 100-96.0 = 4.00 % which made prediction very easy. This meant that the levels of FA in Rs would satisfy all the biochemical functions in replacement of Rt.s and vice versa. But in Table VIII, the IFE was low in Rs/Cs (24.6 %) and Rt.s/Cs (7.42 %) thereby making prediction of relationship difficult between the compared samples.

Discussion

The crude fat of the raw and treated groundnut seeds (with skin) varied slightly (2.01 %) being highest in Rt.s (49.6 g/100 g), followed by Rs (48.6 g/100 g) and least in Cs (47.6 g/100 g) (Table I). The cooking effect might have reduced the total lipids level in Cs. Roasting appeared to have mobilised the seeds, hence increase in the lipids level in Rt.s. The sample levels in total lipids were close to the results of data in Oyenuga [1] with comparative levels of present/literature (in g/100 g): Rs (47.5/48.6), Rt.s (49.6/48.7) and Cs (47.6/31.5). The results were less reduced than in the literature just cited.

In Table II was shown the percent levels of the various fatty acids based on total fatty acids. The most concentrated SFA was palmitic acid as also shown in Oyenuga [1] 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 Rs was 3.04 % which was close to the level of 3.7 % (Nigerian) and 5.5 % (West African). Oleic acid was much lower in the present report (8.28 – 12.0 %) than the reported data of 59.1-61.8 % in Oyenuga [1]. The difference could have been due to the difference in the environment in which the samples were grown. Also the linoleic acid in literature ranged between 19.7-20.6 % which was higher than the present 9.90-11.6 %. Butyric acid was only detected in Rt.s (0.19 %). The following SFA were resistant to moist heating: caprylic, capric, myristic, palmitic, arachidic and behenic acids, in fact their levels in Cs were higher than in Rs; such were also seen in Rt.s for caprylic, capric, lauric, myristic and palmitic acids. For the monoenoic FA, the following were enhanced in Cs: myristoleic, palmitoleic, *trans*-petroselinic and *trans*-9 elaidic acid,; in Rt.s: myristoleic, palmitoleic, *trans*-petroselinic, *trans*-9 elaidic and oleic acids. In DUFA and TUFA, enhancement was seen in linoleic (Rt.s), CLA (Rt.s), eicosadienoic acid (Rt.s and Cs), gamma linolenic acid (Rt.s and Cs) and alpha-linolenic acid (Cs). All these results depicted the level of resistance to oxidation at the various types of treatment.

The Table III explained the distribution of the fatty acid levels to SFA, MUFA, DUFA and TUFA. The relative proportion of SFA 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 [13]. For example, they have been shown to have cyto-protective actions in pancreatic β – 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 20.8-27.3 % and MUFA/SFA range was 3.05 (Rs), 2.79 (Rt.s), 2.34 (Cs). Current nutritional thinking appears to be that dietary *trans*-monoenoic fatty acids, both from ruminant and from industrial hydrogenation processes, should be considered as potentially harmful and in the same light as SFA [13]. The SFA 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 [14]; they are needed for proper utilization of EFAs, elongated omega-3 FAs are better retained in tissues when the diet is rich in SFA [15]; 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 [16].

The 2n-6/3n-3 range was very much in favour of 2n-6 such as 13.7-43.6. 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 [17]. 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 [18]. 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[19]. 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 levels were favourable with levels range of 0.93-1.21.

In Table IV, the highest Rs-Rt.s was in myristic acid at -0.093 % (-30.3 %) while the least was stearic acid at +1.67 (+54.9 %); in Rs-Cs, highest change was in capric acid at -0.36 % (-483 %) but least was *trans*-11 vaccenic acid at +5.04 %

(+47.5 %). These results showed that the processing affected both SFA and the unsaturated fatty acids. The results in Table IV were further combined into their various groups as shown in Table V. SFA, DUFA and TUFA with *cis*-MUFA all showed Rs-Rt.s to be negative whereas all DUFA and *cis*-MUFA were positive in Rs-Cs showing that in most cases while roasting enhanced most of the fatty acids, cooking reduced the fatty acids likely due to heating, boiling and oxygen reactions

The energy contribution by the FA groups was shown in Table VI. Contribution by SFA was: Rs (19.0 %), Rt.s (19.6 %) and Cs (23.4 %); whereas PUFA was: Rs (23.1 %), Rt.s (23.6 %) and Cs (21.8 %). However, linoleic acid contributed 11.5 % (Rs), 11.6 % (Rt.s) and 10.9 % (Cs); alpha-linolenic acid contributed 0.504 % (Rs), 0.60 % (Rt.s) and 1.70 % (Cs). Research evidence indicates that our intake of polyunsaturated should not be much greater than 4 % of the caloric total; in approximate proportions of 1 ½ % omega -3 and 2 ½ % omega-6 [20]. The present results were outside this range.

The calculated total FAs as shown in Table I was shown in Table VII as they would be if the sample FAs was taken as dietary fat. The calculation accounted for all the calculated total fatty acid in each of the samples.

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. The various phospholipids level in the samples was shown in Table VIII. Lecithin (phosphatidylcholine) had the highest level of 725-1168 mg/100 g (36.0-57.2 %). Roasting had a negative effect on the sample (725 mg/100 g, 36.0 %) whereas cooking had a positive effect (1168 mg/100 g, 57.2 %) with raw having a value of 1025 mg/100 g (47.9 %). 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 in the Rs and Cs. These results agreed with the results of Adeyeye *et al*., [21] where lecithin formed 66.8 % in the muscle and 46.7 % in the skin of Tongue sole fish; it also formed 68.7 % in the skin and 69.5 % in the muscle of tilapia (*Oreochromis niloticus*) fish [22]. 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. The US Food and Drug Administration (USFDA had stated that consumption of PS may reduce the risk of dementia and cognitive dysfunction in elder persons [22]. PS range in the samples was 136-275 mg/100 g (6.35-13.5 %); being enhanced by both roasting and cooking. The PS levels in present report were greater than in beef (69 mg/100 g), pork (57 mg/100 g) and European pilchard (sardine) of 16.0 mg/100 g [23]. Phosphatidylinositol (PtdIns or PI) occupied the least positin in Rs, Rt.s and Cs (72.4-110 mg/100 g or 3.38-5.39 %); it showed that PI was a minor component in the samples. PI can be phosphorylated to form phosphatidylinositol phosphate (PIP), phosphatidylinositol (4, 5) – bisphosphate (PIP 2), splits into inositol trisphosphate (IP 3) and diacylglycerol (DAG) and functions as second messenger in signal transduction. PIP, PIP 2 and PIP 3 are collectively called phosphoinositides. Partial hydrolysis of lecithin with removal of only one FA yields a lysophosphatidylcholine [24]. Lysophosphatidylcholine occupied the second position in Rs (596 mg/100 g, 27.8 %) and Rt.s (511 mg/100 g, 25.4 %) but fourth position in Cs (235 mg/100 g, 11.5 %) depicting the effect of cooking on the stability of the phospholipid. Phenylalanine hydroxylase, attached to the endosplamic reticulum, which catalyses the conversion of phenylalanine to tyrosine has its activity enhanced fifty fold in the presence of lysophosphatidylcholine, with which it is probably complexed in the hepatic cell [24].

In Table IX, the differences as shown by Rs-Rt.s, Rs-Cs were shown. Processing method of cooking reduced PE and lysophosphatidylcholine whereas roasting reduced lecithin and lysophosphatidylcholine. PS was best enhanced by cooking by -139 mg/100 g (-102 %) from Rs-Cs.

Levels of phytosterols were shown in Table X. Roasting had negative effect on campesterol, stigmasterol and sitosterol whereas cooking had negative effect on ergosterol, campesterol, stigmasterol and slightly on sitosterol. Generally the phytosterols were low at 129-145 mg/100 g. Sitosterol occupied the first position in concentration among all phytosterols and in all the samples. 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 [25]. β – sitosterol was also the major sterol in the three seed oils of *Collocynthis citrullus* (CLCT), *Cucurbita moschata* (CCBT) and *Cyperus esculentus* (CYP) with levels of (%) 34.6 (CLCT), 53.9 (CCBT) and 55.9 (CYP); [26] these levels were close to the present results. While β – sitosterol occupied the second position in *Plukenetia conophora* (PKCP) with a level of 31.5 %, it occupied the first position in *Adenopus breviflorus* (ADB) seeds oils with a level of 53.3 % [27]. The present results also contained some amounts of cholesterol, ergosterol, campesterol and stigmasterol just like we have in CLCT, CCBT and CYP [26] but excluding cholesterol. Plant sterols have been suggested to have dietary significance and to protect vegetable oils from oxidative polymerisation during heating at frying temperatures [28]. This assertion might be true for cholesterol, ergosterol (in roasting not in cooking), stigmasterol and sitosterol. Cholesterol, reported to be present in small amounts in vegetable oil [29], was detected in all the samples (6.16 – 7.19 %); ADB had 1.1 % cholesterol [27]. The levels of differences in the phytosterols between Rs-Rt.s and Rs-Cs were shown in Table XI. The highest change was in campesterol where Rs-Rt.s was + 7.85 (+ 100 %) whereas ergosterol was -21.7 (-257 %) in Rs-Rt.s.

In Table XII, where statistical summary of the data in Tables III, VI, VIII and X was shown, the details of the implication of the statistical information had been explained under the Results column.

Table XIII showed the uncertainty interval percent (UIP) for the fatty acids. Most of the literature Table UIP levels were correspondingly higher than the present results in all the samples. Also the correlation determined for all the standards: fatty acids, phospholipids and phytosterols, all had values ranging as follows: 0.99833-0.99997 (fatty acids), 0.99909-0.99999 (phospholipids) and 0.99920-0.99994 (phytosterols), all correlation values were greater than 0.95 which is the critical correlation for acceptance of these types of analytical results. Both the correlation values and the UIP values attested to the quality of the determinations.

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 and phytosterols level but not in phospholipids. All the samples were good sources of lecithin but much lower in phytosterols. Quality assurances of the determinations were highly satisfactory. In the pairwise comparison among the samples for the fatty acids level, it was found that roasting enhanced 17 parameters (17/21 or 81.0 %). Since cooking involved moist heating at high temperature in the presence of oxygen, many of the parameters: fatty acids, phospholipids and phytosterols might have been oxidised leading to their lower values; dry heating (roasting) also lowered some parameters as well. On the whole: cooking and roasting enhanced SFA, both reduced TUFA, phospholipids and phytosterols but only cooking reduced PUFA.

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Table I. Crude fat and total fatty acid levels of raw, roasted and cooked groundnut seeds (g/100 g dry weight)

Parameter	Raw seeds	Roasted seeds	Cooked seeds	Mean	SD	CV %
Crude fat	48.6	49.6	47.6	48.6	0.98	2.01
Total fatty acid*	46.4	47.4	45.5	46.4	0.93	2.01

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

Table II. Fatty acid composition of the raw, roasted and cooked seeds of groundnut (% total fatty acid)

Fatty acid	Raw seeds	Roasted seeds	Cooked seeds	Mean	SD	CV %
Acetic acid	-	-	-	-	-	-
Propionic acid	-	-	-	-	-	-
Butyric acid	-	0.19	-	-	-	-
Pentanoic acid	0.00	0.00	0.00	-	-	-
Caproic acid	-	-	-	-	-	-
Caprylic acid	0.16	0.18	0.93	0.42	0.44	104
Capric acid	0.08	0.09	0.44	0.20	0.21	101
Lauric acid	1.33	1.39	1.28	1.33	0.06	4.13
Myristic acid	0.85	0.95	1.48	1.09	0.34	31.0
Palmitic acid	10.1	13.0	12.6	11.9	1.57	13.2
Stearic acid	3.04	1.37	2.34	2.25	0.84	37.3
Arachidic acid	0.61	0.39	0.65	0.55	0.14	25.5
Behenic acid	2.88	2.48	3.73	3.03	0.64	21.1
Lignoceric acid	-	-	-	-	-	-
Myristoleic acid	0.31	0.41	1.07	0.60	0.41	69.2
Palmitoleic acid	0.05	0.05	0.26	0.12	0.12	101
Trans-Petroselinic acid	9.80	10.3	15.1	11.7	2.93	24.9
Petroselinic acid	13.5	14.8	10.7	13.0	2.10	16.1
Trans- 9 Elaidic acid	12.7	13.3	13.3	13.1	0.35	2.64
Oleic acid	10.9	12.0	8.28	10.4	1.91	18.4
Trans- 11 Vaccenic acid	10.6	4.87	5.58	7.02	3.12	44.5
Cis- 11 Gondoic acid	0.08	0.09	0.44	0.20	0.21	101
Linoleic acid	11.2	11.6	9.90	10.9	0.89	8.15
Conjugated linoleic acid	11.2	11.7	9.19	10.7	1.33	12.4
Eicosadienoic acid	0.18	0.24	1.03	0.48	0.47	98.1
Gamma-linolenic acid	0.24	0.29	0.98	0.50	0.41	82.2
Alpha-linolenic acid	0.26	0.32	0.72	0.43	0.25	57.7

Table III. Summary of Table II into SFA, MUFA, DUFA and TUFA values (% total fatty acid)

Fatty acid	Raw Seeds	Roasted seeds	Cooked seeds	Mean	SD	CV %
SFA	19.0	20.0	23.4	20.8	2.31	11.1
MUFA –*cis*	24.8	27.3	20.8	24.3	3.27	13.5
-*trans*	33.2	28.5	34.0	31.9	2.93	9.19
Total	57.9	55.8	54.8	56.2	1.61	2.87
DUFA –*cis*	11.4	11.8	10.9	11.4	0.45	3.97
-*t*rans	11.2	11.7	9.19	10.7	1.33	12.4
Total	22.6	23.5	20.1	22.1	1.73	7.84
TUFA –*cis*	0.50	0.61	1.70	0.94	0.66	70.8
-*trans*	-	-	-	-	-	-
Total	0.50	0.61	1.70	0.94	0.66	70.8
Grand total	100	99.9	100	99.97	0.06	0.06
Ratio	-	1:1	1:1	-	-	-
Total MUFA +DUFA + TUFA81.0	79.9	76.6	79.1	2.30	2.90	
Total DUFA+ TUFA = PUFA23.1	24.1	21.8	23.0	1.12	4.89	
MUFA/SFA	3.05:1	2.79:1	2.34:1	2.72	0.36	13.2
PUFA/SFA	1.21:1	1.20:1	0.93:1	1.12	0.16	14.3
2*n*-6/3*n*-3	43.6:1	36.0:1	13.7:1	31.1	15.5	50.0

Table IV. Differences in fatty acid profiles between raw and roasted, between raw and cooked samples of groundnut seeds

Fatty acid seeds	Raw-roasted seeds	Raw-cooked	Mean	SD	CV %	
Caprylic acid	-0.024(-15.0 %)	-0.77(-93.3 %)		0.40	0.53	133
Capric acid	-0.011(-15.1 %)	-0.36 (-483 %)		0.19	0.25	133
Lauric acid	-0.068(-5.12 %)	+0.48(+3.60 %)		0.27	0.29	106
Myristic acid	-0.098(-11.5 %)	-0.63(-74.0 %)		0.36	0.38	103
Palmitic acid	-2.92(-29.0 %)	-2.50(-24.9 %)		2.71	0.30	11.0
Stearic acid	+1.67(+54.9 %)	+0.70(+22.9 %)		1.19	0.69	57.9
Arachidic acid	+0.22(+35.5 %)	-0.04(-7.23 %)		0.13	0.13	97.9
Behenic acid	+0.401(+13.9 %)	-0.85(-29.4 %)		0.63	0.32	50.8
Myristoleic acid	-0.093(-30.3 %)	-0.76(-249 %)		0.43	0.47	111
Palmitoleic acid	-0.007(-14.9 %)	-0.22(-479 %)		0.11	0.15	133
Trans-Petroselinic acid	-0.54(-5.52 %)	-5.29(-54.0 %)		2.92	3.36	115
Petroselinic acid	-1.38(-10.3 %)	+2.71(+20.2 %)		2.05	0.94	46.0
Trans-9 Elaidic acid	-0.58(-4.53 %)	-0.55(-4.30 %)		0.57	0.02	3.75
Oleic acid	-1.12(-10.3 %)	+2.59(+23.8 %)		1.86	1.04	56.0
Trans-11 Vaccenic acid	- 5.74(+54.1 %)	+5.04(+47.5 %)		5.39	0.49	9.18
Cis-11 Gondoic acid	-0.011(-15.0 %)	-0.36(-482 %)		0.19	0.25	133
Linoleic acid	-0.33(-2.92 %)	+1.32(+11.8 %)		0.83	0.70	84.9
Conjugated linoleic acid	-0.503(-4.51 %)	+1.97(+17.7 %)		1.24	1.04	83.9
Eicosadienoic acid	-0.055(-30.2 %)	-0.85(-463 %)		0.45	0.56	124
Gamma-linolenic acid	-0.039(-15.8 %)	-0.73(-297 %)		0.38	0.49	127
Alpha-linolenic acid	-0.064(-24.7 %)	-0.47(-181 %)		0.27	0.29	108

Table V. Summary of Table IV into SFA, MUFA, DUFA and TUFA values (% total fatty acid)

Fatty acid	**Raw-roasted seeds**	**Raw-cooked seeds**		**Mean**	**SD**	**CV %**	
SFA	-1.03(-5.37%)	-4.42(-23.2 %)		2.73	2.40	88.0	
MUFA –*cis*	-2.53(-10.2 %)	+3.96(+16.0 %)	3.25	1.01	31.2		
-trans	+4.63(+14.0 %)	-0.80(-2.41 %)		2.72	2.71	99.8	
Total	+2.10(+3.62 %)	+3.16(+5.46 %)	2.63	0.75	28.5		
DUFA –*cis*	-0.38(-3.36 %)	+0.48(+4.18 %)	0.43	0.07	16.4		
-trans	-0.505(-4.52 %)	+1.97(+17.7 %)	1.24	1.04	83.7		
Total	-0.89(-3.93 %)	+2.45(10.9 %)	1.67	1.10	66.1		
TUFA –*cis*	-0.102(-20.3 %)	-1.20(-238 %)		0.65	0.78	119	
-trans	-	-		-	-	-	

Table VI. Energy contribution by the various fatty acid fractions

Fatty acid		**Raw seeds**	**Roasted seeds**	**Cooked seeds**		**MeanSD**	**CV %**
SFA							
	kcal	171	180	211	187	21.0	11.2
	kJ	722	761	890	791	87.9	11.1
MUFA							
-cis							
	kcal	223	246	187	219	29.7	13.6
	kJ	941	1037	790	923	125	13.5
-trans							
	kcal	298	257	306	287	26.3	9.16
	kJ	1260	1084	1290	1211	111	9.19
DUFA							
-cis							
	kcal	103	106	98.4	102	3.83	3.74
	kJ	434	448	415	432	16.6	3.83
-trans							
	kcal	100	105	82.7	95.9	11.7	12.2
	kJ	424	443	349	405	49.7	12.3
TUFA							
-cis							
	kcal	4.54	5.46	15.3	8.43	5.96	70.7
	kJ	19.1	23.0	64.6	35.6	25.2	70.9
-trans		-	-	-	-	-	-

Table VII. Fatty acids level in groundnut seeds per 100 g raw, roasted and cooked samples as food

Fatty acid	Raw seeds	Roasted seeds	Cooked seeds	Mean	SD	CV %
Butyric acid	-	0.088	-	-	-	-
Caprylic acid	0.074	0.087	0.425	0.20	0.20	102
Capric	0.035	0.041	0.20	0.092	0.094	102
Lauric acid	0.62	0.66	0.58	0.62	0.04	6.45
Myristic acid	0.39	0.45	0.67	0.50	0.15	29.3
Palmitic acid	4.68	6.15	5.72	5.52	0.76	13.7
Stearic acid	1.41	0.65	1.07	1.04	0.38	36.5
Arachidic acid	0.28	0.19	0.30	0.26	0.06	22.8
Behenic acid	1.34	1.17	1.70	1.40	0.27	19.3
Myristoleic acid	0.14	0.19	0.49	0.27	0.19	69.3
Palmitoleic acid	0.021	0.025	0.12	0.06	0.06	102
Trans-Petroselinic acid	4.55	4.90	6.87	5.44	1.25	23.0
Petroselinic acid	6.25	7.03	4.89	6.06	1.08	17.9
Elaidic acid	5.92	6.31	6.05	6.09	0.20	3.26
Oleic acid	5.15	5.68	3.77	4.87	0.99	20.3
Trans- 11 Vaccenic acid	4.93	2.31	2.54	3.26	1.45	44.5
Cis-11 Gondoic acid	0.035	0.041	0.20	0.092	0.094	102
Linoleic acid	5.21	5.47	4.51	5.06	0.50	9.81
Conjugated linoleic acid	5.18	5.53	4.18	4.96	0.70	14.1
Eicosadienoic acid	0.085	0.11	0.47	0.22	0.22	97.2
Gamma-linolenic acid	0.11	0.15	0.44	0.23	0.18	77.2
Alpha-linolenic acid	0.12	0.15	0.33	0.20	0.11	56.8

Table VIII. Phospholipids level (mg/100 g) of raw, roasted and cooked groundnut seeds

Phospholipids	Raw seeds	Roasted seeds	Cooked seeds	Mean	SD	CV %
Cephalin (PE)	312(14.6 %)	438(21.8 %)	252(12.3 %)	334	94.9	28.4
Lecithin	1025(47.9 %)	725(36.0 %)	1168(57.2 %)	973	226	23.2
Ptd-L-Ser (PS)	136(6.35 %)	262(13.0 %)	275(13.5 %)	224	76.8	34.2
Lysophosphatidycholine	596(27.8 %)	511(25.4 %)	235(11.5 %)	447	189	42.2
PtdIns (PI)	72.4(3.38 %)	75.7(3.76 %)	110(5.39 %)	86.0	20.8	24.2
Totals	2141	2012	2041	2065	67.7	3.28
Ratio (raw to other samples)	-	1.06:1	1:05:1	1.06	0.007	0.67

PE = phosphatidylethanolamine; Lecithin = phosphatidylcholine; PS = phosphatidylserine; PI = phosphatidylinositol.

Table IX. Summary of Table VIII showing the differences in phospholipids level between the raw and roasted as well as between the raw and the cooked samples

Phospholipids	Raw-roasted seeds	Raw-cooked seeds	Mean	SD	CV %
Cephalin (PE)	-126(-40.4 %)	+60.0 (+19.2 %)	93.0	46.7	50.2
Lecithin	+300(+29.3 %)	-143(-14.0 %)	222	111	50.1
Ptd-L-Ser (PS)	-126(-92.6 %)	-139(-102 %)	133	9.19	6.93
Lysophosphatidylcholine	+85 (+14.3 %)	+361(+60.6 %)	223	195	87.5
PtdIns	-3.30(-4.56 %)	-37.6 (-51.9 %)	20.5	24.3	119
Totals	+129(+6.03 %)	+100(+4.67 %)	115	20.5	17.9

Table X. Phytosterols level (mg/100 g) of raw, roasted and cooked groundnut seeds

Phytosterols	Raw seeds	Roasted seeds	Cooked seeds	Mean	SD	CV %
Cholesterol	8.93(6.16 %)	9.28(7.19 %)	9.08(6.78 %)	9.10	0.18	1.93
Cholestanol	0.00	0.00	0.00	-	-	-
Ergosterol	8.47(5.84 %)	30.2(23.4 %)	2.49(1.86 %)	13.7	14.6	106
Campesterol	7.85(5.41 %)	0.00(-)	2.93(2.19 %)	3.59	3.97	110
Stigmasterol	9.05(6.24 %)	7.90(6.12 %)	8.95(6.68 %)	8.63	0.64	7.38
5-Avenasterol	0.00	0.00	0.00	-	-	-
Sitosterol	111(76.6 %)	81.1(62.9 %)	110 (82.1 %)	101	17.0	16.9
Totals	145	129	134	136	8.19	6.02

Table X1. Summary of Table 10 showing the differences in phytosterols level between the raw and the roasted as well as between the raw and the cooked samples

Phytosterols	Raw-roasted seeds	Raw-cooked seeds	Mean	SD	CV %
Cholesterol	-0.35(-3.92 %)	-0.15(-1.68 %)	0.25	0.14	56.6
Cholestanol	-	-	-	-	-
Ergosterol	-21.7(-257 %)	+5.98(+70.6 %)	13.8	11.1	80.3
Campesterol	+7.85(+100 %)	+4.92(+62.7 %)	6.39	2.07	32.4
Stigmastetol	+1.15(+12.7 %)	+0.10(+1.10 %)	0.63	0.74	119
5-Avenasterol	-	-	-	-	-
Sitosterol	+29.9(+26.9 %)	+1.0(+0.901 %)	15.5	20.4	132
Totals	+16(+11.0 %)	+11(+7.59 %)	13.5	3.54	26.2

Table XII. Statistical summary of the data in Tables III, VI, VIII and X

Table	Parameter	r_{xy}	r_{xy}^2	R_{xy}	$\overline{X}$	$\overline{Y}$	C_A	IFE	Remark
3	Rs/Rt.s	0.9992	0.998	1.13	25.0	25.0	4.00	96.0	*
	Rs/Cs	0.9920	0.984	2.23	25.0	25.0	12.6	87.4	*
	Rt.s/Cs	0.9925	0.985	1.15	25.0	25.0	12.2	87.8	*
6	Rs/Rt.s	0.9994	0.999	8.00	450	450	3.47	96.53	*
	Rs/Cs	0.9966	0.993	13.6	450	450	8.22	91.78	*
	Rt.s/Cs	0.9979	0.996	5.38	450	450	6.54	93.46	*
8	Rs/Rt.s	0.9442	0.891	147	428	402	33.0	67.0	NS
	Rs/Cs	0.6569	0.432	-44.4	559	408	75.4	24.6	NS
	Rt.s/Cs	0.3779	0.143	-16.4	539	408	92.6	7.42	NS
10	Rs/Rt.s	0.9475	0.898	3.77	22.8	18.4	32.0	68.0	*
	Rs/Cs	0.9979	0.996	-1.79	20.8	19.1	6.47	93.53	*
	Rt.s/Cs	0.9349	0.874	-4.23	18.4	19.1	35.5	64.5	*

Rs = raw sample, Rt.s = roasted sample, Cs = cooked sample, r_{xy} = linear correlation coefficient, r_{xy}^2 = coefficient of determination, R_{xy} = linear regression coefficient, C_A = coefficient of alienation, IFE = index of forecasting efficient, * = significant $r_{=0.01}$ at n-2 degrees of freedoms, NS = not significant at $r_{=0.01}$.

Table XIII. Uncertainty intervals as percent of analytical results

Fatty acid	UIP(table)	UIP(Rs)	UIP(Rt.s)	UIP(Cs)
C14:0	8.30	2.35	2.11	0.135
C16:0	3.00	1.49	1.16	1.19
C18:0	3.80	2.63	5.84	3.42
C20:0	4.10	4.78	7.41	4.45
C22:0	4.40	2.78	3.23	2.15
SFA	1.90	1.05	1.00	0.855
C18:2*n*-6	3.10	3.65	3.55	4.14
C18:3*n*-6	3.30	0.388	0.312	0.138
C20:2	43.8	3.83	2.94	0.68
C20:4*n*-6	62.5	-	-	-
PUFA	3.0	1.73	1.66	1.84

UIP (table) adapted from peanut butter.