Fatty Acid Composition Of Two Nigerian Masticatories Cum Traditional Snacks: African Walnut (Plukenetia Conophora) Kernel And African Elemi (Canarium Schweinfurthii) Pulp.

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ABSTRACT: Fatty acid composition of plant food (oil) is important for its economic and nutritional value. Assessment of fatty acid contents of two Nigerian masticatories cum traditional snacks: African walnut kernel (AW) and African elemi pulp (AE) were carried out. Samples were subjected to graded wet heat contact time based on their traditional methods of processing and their oil extract evaluated for fatty acid (FA) contents using chromatographic method. The processing methods had no statistically significant effect on both the oil and FA contents of the samples. Both samples contain nutritionally relevant levels of fat ranging respectively from 49.8±1.08 to 52.8±2.70g/100g sample and 41.93±6.03 to 42.8±4.61g/100g sample in AW and AE. A total of six fatty acids including two essential ones namely omega-6 (C18:2) and omega-3 (C18:3), were identified and quantified in the two plant foods. The predominant FAs in the plant foods were oleic acid (16.12±1.86 - 17.11±1.31g/100g fat), linoleic acid (16.88±1.66 - 18.80±1.52g/100g fat) and linolenic acid (55.95±5.68 - 57.08±6.57g/100g fat) in AW and palmitic acid (48.59±4.35 - 50.51±3.29g/100g fat), oleic acid (32.02±3.27 - 35.74±1.46g/100g fat) and linoleic acid (15.15±3.57 - 15.40±3.82g/100g fat) in AE. The study shows that on the average, one serving of AW could supply about 41.52% and 647.09% of the Recommended Daily Intakes (RDIs) for the essential FAs Linoleic and Linolenic acids respectively, while that of AE will supply about 29.13% of the RDI for Lineleic acid. Based on their essential FAs contents the plant foods apparently have potentials for applications as nutraceuticals.

Key word: functional foods, nutraceuticals, masticatories, linoleic acid, linolenic acid.

Introduction:

"Masticatories" are substances (mainly of plants origin) chewed to increase the volume of saliva [1]. Traditionally, a wide range of masticatories are consumed not just to stimulate the flow of saliva but in keeping with custom or personal habit [2]. Adebayo and Oladele [3] reported that the masticatories including African walnut and African elemi are widely consumed as snacks in West and Central Africa. According to Longman Dictionary of Contemporary English definition, snack is a small amount of food that is eaten between main meals or instead of a meal [4]. African walnut an Euphorbiaceae, is a thick and woody perennial shrub, over 30m long, that twines itself (liane) round tall trees in search of sunlight, and ultimately reaches their tops and produces a canopy of foliage. The plant is known internationally as: African walnut, Owusa nut (English), Musyabassa, Awusa (Krio Sierra lone), Owusanot (Sweden) [5] and locally in Nigeria as Ụkpà, Ọ̀kpa (Igbo), Asala, Awùsá (Yoruba), Ókhuẹ, Okwe (Edo). The fruit is a 1-5 chambered capsule containing sub-globular seeds with a thin brown testa enclosing a large mass of cream white endosperm (kernel) that resemble the temperate walnut. African elemi on the other hand is a deciduous large forest tree sometimes exceeding 50m in height and 4m in girth [6].

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The plant is a Burseraceae known internationally as Elemier d'Afrique (French), Elimi (Nigeria), Abel (Cameroon), Aiele (Ivory Coast), Muwafu (Uganda), Bediwunua, Eyere (Ghana), Mpafu, Mbani (Swahili) [7]. And locally in Nigeria as Ube-mgba, Ube-osa, Ube okpoko (Igbo), Atili (Hausa), Agbabuba, Origbo (Yoruba), Eben etridon (Efik) [8]. The fruit (a small drupe) contains a hard spindle – shape, trigonous stone surrounded by a delicious purplish green pulp [9]. The fact that these masticatories are traditional snacking items ascribes possible food functions to them [4]. Mammals lack D-15 desaturase enzyme and therefore cannot introduce double bonds in fatty acids beyond carbon 9 and 10. Consequently, they neither synthesize linoleic acid (LA, ω-6 fatty acid) nor desaturate it to alpha-linolenic acid (ALA, ω-3 fatty acid). This makes the fatty acids and their metabolites classically essential (EFAs) and must be ingested as dietary components [10], [11]. In addition, Yerlikaya et al. [12], Adel et al. [13] and Moulodi et al. [14] stated that fatty acid composition of plant food (oil) is important for its economic and nutritional value. Avalanche of supporting evidences of the significant roles of EFAs in many biochemical pathways identifies the nutrients as functional foods and nutraceuticals [15]. Rohland [16] reported that the healthiest sources of essential fatty acids are found in a variety of plant foods. This study therefore evaluates the fatty acid composition of African walnut kernel and African elemi pulp; two plant foods commonly used as masticatories as well as traditional snacks in Nigeria with the aim of elucidating their potentials as functional foods and nutraceuticals relative to their EFAs contents.

Materials and Methods

Samples collection and processing:

Fresh seeds of African walnut from Ojoto community, Idemili South Local Government Area of Anambra State, and fruits of African elemi from Ngwa Road market in Aba, Aba South Local Government Area of Abia State were washed severally in deionized water and divided into four. Each of the plant samples was processed as masticatory based on the quality achieved by following the traditional method of cooking to eating tenderness as described by Anyalogbu et al. [16], [17]. The first lots were used raw and therefore labeled AW_{raw} and AE_{raw} for African walnut and African elemi respectively. The other lots were given different wet-heat treatments. The 2^{nd}, 3^{rd} and 4^{th} lots of African walnut were boiled in water (99 ± 1^0C) for 45, 90, and 135 min and labeled AW_{45}, AW_{90}, and AW_{135} respectively[16]. While the 2^{nd}, 3^{rd} and 4^{th} lots of African elemi were macerated in hot water (55^0C) for 15, 30 and 45 min and labeled AE_{15}, AE_{30}, and AE_{45} respectively[17]. The pulps and kernels were collected, appropriately labeled, dried in an air-circulatory oven preset at 50^oC for 48hr, milled into powder, passed through a 60-mesh size screen and used as stock samples in the analyses.

Determination of fatty acid concentrations of the samples.

The fatty acids concentration of the samples were determined by the combined separation and analytical technique of Gas Chromatography – Mass Spectrophotometry (GC–MS) as described by Schultz and Pugh [18]. Gas chromatographic analysis requires that compounds be easily vapourized into the gas phase. The fatty acids of fats and oils have high boiling points and hence, low volatility as they are esterified to glycerol at the 3–OH group positions. Their volatility is enhanced by quantitatively converting them to their corresponding more volatile esters of short chain aliphatic alcohol derivatives (e.g. fatty acid methyl esters - FAMEs). The process therefore involves: total lipid extraction, fatty acid derivatization and Gas Chromatography – Mass Spectrophotometry.

Total Lipid extraction

Total lipid contents of the samples were extracted with hexane using semi-continuous exhaustive Soxhlet extraction method [19]. The sample was dried at 105^oC in an air-circulatory oven (Gallenkamp, OVE.100.130M) for 2hr and 5g weighed into a cellulose extraction thimble. The top of the thimble was covered with glass wool to prevent floating and then secured in the Soxhlet extractor. Pre-dried 100ml round-bottomed extraction flask with few anti bumping (boiling) chips was weighed and 150ml hexane measured into it. The Soxhlet extractor and condenser were mounted on the round-bottomed flask and the lipid extracted on a heating mantle pre-set at 70^0C for 8hr at the rate of 150 drops per min. The extract was allowed to cool and the solvent removed in a rotary evaporator (Buchi Rotavapour, Switzerland) at 40^0C under reduced pressure. The flask with the oil was reweighed. The amount of lipid recovered was calculated as follows:

Weight of lipid = (weight of flask + boiling chips + extracted oil) – (weight of flask + boiling chips)

$$\textbf{Lipid content}\ (\%) = \frac{\text{weight of lipid extracted(g)}}{\text{sample weight(g)}} \text{x} \frac{100}{1}$$

Fatty acid derivatization:

The IUPAC [20] standard method for preparation of the fatty acid methyl esters was used. The oil extract (0.8g) was weighed into a 200ml round-bottomed flask and 10ml of 0.5mol/L KOH/CH_3OH added. A condenser was fitted to the flask and refluxed on a heating mantle for 30 min to saponify the fat. Then, 2.0ml of 4:1 HCl/CH_3OH reagent was added through the top of the condenser and the refluxing continued for a further 15min to methylate the fatty acids. The set-up was allowed to cool, and through the top of the condenser, 4.0ml of heptane was added to extract the fatty acid methyl esters. Then, 20ml of 26% NaCl solution (saturated at 20°C) was added and left to salt out. The condenser was then removed and the process continued in a fume cupboard. The aliquot was transferred to a glass separating funnel and the bottom layer drained off while the upper heptane layer containing the FAMEs was collected in a small test tube. A 0.36g of anhydrous sodium sulphate was added to dry the esters and the solution filtered into another test tube using Whatman Number 52 filter paper. The filtrate (heptane layer) was then concentrated in a water bath at 50^oC for 30min and the fatty acid (FAME) contents analyzed chromatographically.

Gas Chromatography - Mass spectrophotometry analysis:

The methyl esters in the concentrated heptane layer were separated, quantified and identified by gas chromatography using Hewlett - Packard GC system (Model HP6890) interfaced with Hewlett Packard Mass spectrophotometer (Hewlett-Packard, Model HP5973, California, USA) as described by Schultz and Pugh [18]. Three microlitre of the concentrated heptane layer filtrate was injected with the aid of a clean microsyringe injector (World Precision Instruments^R,UK) into the split injection port (Split ratio 1:50) of the Hewlett Packard GC with H_2 as carrier gas at a flow rate of $43ms^{-1}$. The GC was equipped with a flame-ionization detector and a 60m x 0.25mm i.d. column coated with a 0.25µm film of Hp.23. The injection port and detector temperatures were 250^0C and 270^0C respectively. The column temperature was maintained at 105^oC for 1min after injection then programmed at 3.5^oC min^{-1} till 185^oC and held for 2min. The peaks were identified with the HP Mass Spectrophotometer (Mass selective detector). The Mass Spectrometer parameters used were electron impact energy 70eV, transfer line 270^0C, source temperature 250^0C, emission current 0.5Ma, cycle time 0.6 sec/scan from 45 to 400 a.m.u., electron multiplier voltage 1.7kv and pre-amp sensitivity 10^{-7} AMP/v. Results are presented as percentage of total fatty acids.

Table 1: *Fatty acid composition of raw and cooked African walnut kernel powders.*

Fatty acid	Samples (g/100g fat)				
	AW_{raw}	AW_{45}	AW_{90}	AW_{135}	Mean of means
Caprylic acid ($C_{8:0}$)	0.50±0.08[a]	0.44±0.08[a]	0.41±0.10[a]	0.30±0.16[a]	0.41±0.12
Palmitic acid ($C_{16:0}$)	4.68±1.16[a]	3.72±1.79[a]	3.54±1.06[a]	3.13±0.68[a]	3.77±1.21
Stearic acid ($C_{18:0}$)	5.86±0.84[ab]	5.55±1.74[abc]	4.37±0.84[abc]	3.49±1.26[c]	4.82±1.44
Total saturated fatty acids	11.04±2.07[ab]	9.71±3.58[abc]	8.32±1.06[abc]	6.92±0.78[c]	9.0±2.45
Palmitioleic acid ($C_{16:1}$)	ND	ND	ND	ND	ND
Oleic acid ($C_{18:1}$)	16.12±1.86[a]	16.26±1.27[a]	16.64±1.60[a]	17.11±1.31[a]	16.53±1.36
Monounsaturated fatty acids	16.12±1.86[a]	16.26±1.27[a]	16.64±1.60[a]	17.11±1.31[a]	16.53±1.36
Linoleic acid ($C_{18:2}$)	16.88±1.66[a]	17.94±0.90[a]	18.13±1.19[a]	18.80±1.52[a]	17.94±1.36
Linolenic acid ($C_{18:3}$)	55.95±5.68[a]	56.07±3.05[a]	54.60±5.07[a]	57.08±6.57[a]	55.92±4.57
Polyunsaturated fatty acids	72.84±4.69[a]	74.01±2.29[a]	72.73±4.37[a]	75.88±7.74[a]	73.86±4.59
Total unsaturated fatty acids	88.96±6.54[a]	90.27±1.54[a]	89.37±3.60[a]	92.99±8.62[a]	90.40±5.17
Unknown	ND	ND	0.11±0.03	0.08±0.04	0.05±0.05
Fat content (g/100g sample)	49.8±1.08[a]	52.8±2.70[a]	51.7±1.61[a]	51.4±4.82[a]	51.43

Values are means of triplicate determinations on dry matter basis. ND = Not detected. Values on the same row with different superscripts are statistically different at 0.05 levels.

Statistical Analysis

Data generated from the analyses were tested for statistical significance using one-way analysis of variance (ANOVA). Treatment means were compared by the Duncan's [21] multiple range test using statistical package for social sciences (SPSS) version-20 and values expressed as Mean ± SD. Differences in the means were considered significant at $p < 0.05$ in all cases.

Results

The result of fatty acid analyses of the plant foods are presented in Tables 1 and 2. A total of six fatty acids (FAs) including two essential ones namely omega-6 ($C_{18:2}$) and omega-3 ($C_{18:3}$), were identified and quantified. The samples were found to be rich in the unsaturated fatty acids linoleic acid and oleic acid, and linolenic acid in AW. The fatty acids identified in AW, ranked in order of abundance, were Caprylic acid ($C_{8:0}$) < Palmitic acid ($C_{16:0}$) < Stearic acid ($C_{18:0}$) < Oleic acid ($C_{18:1}$) < Linoleic acid ($C_{18:2}$) < Linolenic acid ($C_{18:3}$) (Table 1); while in AE the order was, Caprylic acid < stearic acid < Palmitioleic acid < linoleic acid < oleic acid < palmitic acid (Table 2). The effect of thermal heat contact time on the fatty acids concentration expressed as the percentage difference in fatty acid contents of raw and processed samples are shown in Figs. 1and 2. For AW except for linolenic acid, saturated fatty acids decreased while unsaturated fatty acids increased as cooking time increased from 45min to 135min (Fig. 1). While for AE, Oleic acid and linoleic acid (at AE_{15}) were increased and the rest reduced as maceration time was extended (Fig. 2).

Table 2: *Fatty acid composition of raw and heat macerated African elemi seed pulp.*

Fatty acid	Samples (g/100g fat)				
	AE_{raw}	AE_{15}	AE_{30}	AE_{45}	Mean of means
Caprylic acid ($C_{8:0}$)	0.21±0.05[a]	0.13±0.04[b]	ND	ND	0.09±0.10
Palmitic acid ($C_{16:0}$)	50.51±3.29[a]	49.72±6.54[a]	48.96±2.97[a]	48.59±4.35[a]	49.36±3.88
Stearic acid ($C_{18:0}$)	0.76±0.26[a]	0.61±0.17[a]	0.53±0.08[a]	0.52±0.05[a]	0.61±0.17
Total saturated fatty acids	51.48±3.57[a]	50.46±6.53[a]	49.49±2.90[a]	49.11±4.40[a]	50.05±4.0
Palmitioleic acid ($C_{16:1}$)	1.32±0.27[a]	0.99±0.24[a]	ND	ND	0.58±0.63
Oleic acid ($C_{18:1}$)	32.02±3.27[a]	33.15±5.44[a]	33.40±2.89[a]	35.74±1.46[a]	33.78±3.35
Monounsaturated fatty acids	33.34±3.42[a]	34.14±5.55[a]	33.40±2.89[a]	35.74±1.46[a]	34.16±3.27
Linoleic acid ($C_{18:2}$)	15.18±1.92[a]	15.40±3.82[a]	15.17±3.28[a]	15.15±3.57[a]	15.23±2.76
Linolenic acid ($C_{18:3}$)	ND	ND	ND	ND	ND
Polyunsaturated fatty acids	15.18±1.92[a]	15.40±3.82[a]	15.17±3.28[a]	15.15±3.57[a]	15.23±2.76
Total unsaturated fatty acids	48.52±3.66[a]	49.54±8.04[a]	48.57±2.60[a]	50.89±4.79[a]	49.38±4.54
Unknown	ND	ND	ND	0.19±0.08	0.05±0.09
Fat content (g/100g sample)	41.93±6.03[a]	42.61±1.20[a]	42.7±1.22[a]	42.8±4.61[a]	42.51

Values are means of triplicate determinations on dry matter basis. ND = Not detected. Values on the same row with different superscripts are statistically different at 0.05 levels.

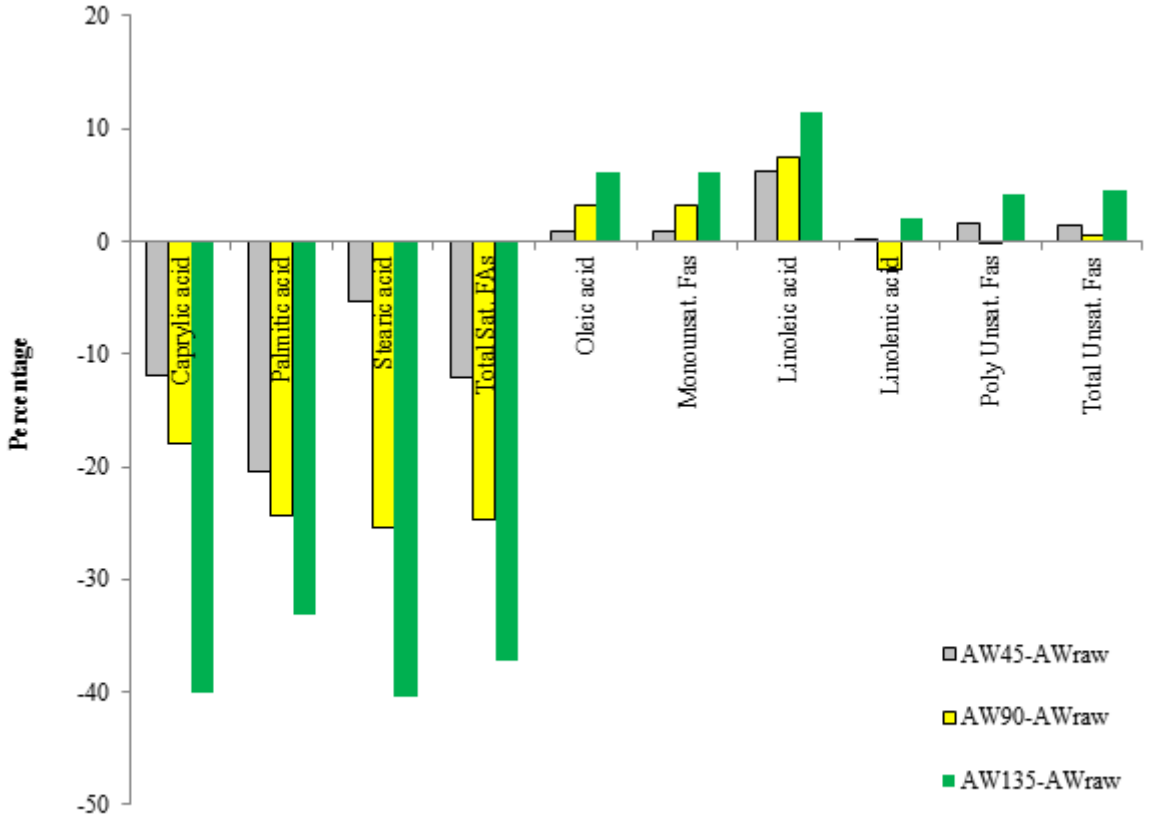

Fig. 1: Percentage difference in fatty acid contents of raw and cooked African walnut seed kernel

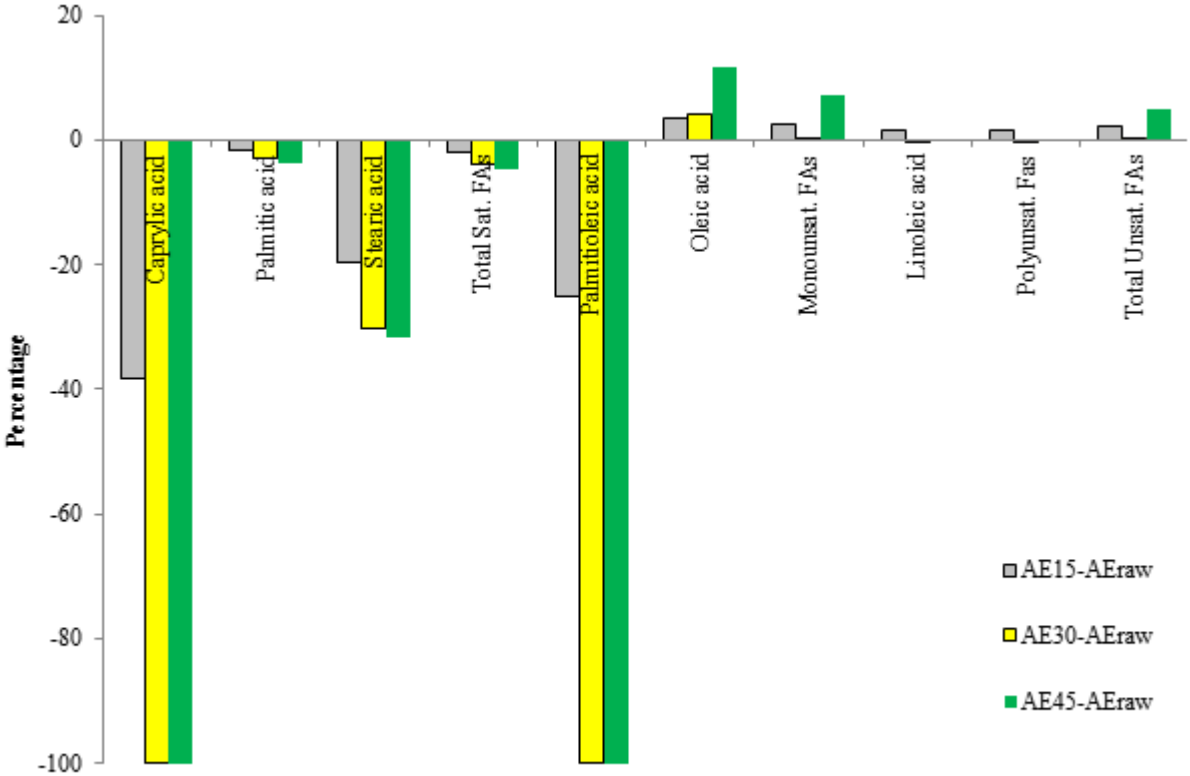

Fig. 2: Percentage difference in fatty acid contents of raw and macerated African elemi seed pulp

Discussion:

The nutritive value of seeds is determined not only by the quantity but also the quality of lipids they contain [12], [22]. Thus, fatty acids present in lipids are playing important role in shelf life, nutrition and flavor of food products. The fat yield of the samples are 49.8±1.08 - 52.8±2.70g/100g sample for AW and 41.93±6.03 - 42.8±4.61g/100g sample for AE. The results show that the predominant fatty acids in the plant foods were palmitic ($C_{16:0}$), oleic ($C_{18:1}$) and linoleic ($C_{18:2}$) and linolenic acids ($C_{18:3}$) in AW (Tables 1 and 2). Like in palm oil and coconut oil [23] and C. odontophyllum Miq [24] linolenic acid was not detected in AE in this work. The palmitic acid value of AW (3.13±0.68 - 4.68±1.16g/100g fat) was comparable to the values (5.61, 4.40, 5.41, 6.52, 4.51, 6.76 and 8.62g/100g fat) for the fatty acid in pumpkin seeds, sesame, watermelon, sunflower, mustard, chia seeds and coconut oils respectively [25], [23], [26], [27]. The observed value for the fatty acid (48.59±4.35 - 50.51±3.29g/100g fat) in AE was lower than 60.88g/100g fat recorded by Leudeu et al. [28] for the sample but compared favourably with 40.31g/100g fat and 50.0g/100g fat obtained for C. odontophyllum and palm oil respectively [24], [29]. The oleic acid ($C_{18:1}$) contents of the samples were 16.12±1.86 - 17.11±1.31g/100g fat and 32.02±3.27 - 35.74±1.46g/100g fat for AW and AE respectively. Earlier, Nzikou et al. [30], Compaoré et al. [31], Shakirin et al. [24], Cordain [26], Olonisakin [32] and Koushki et al. [29], obtained the values (g/100g fat) of 14.15 (pumpkin seeds), 18.52 (sesame), 7.32 (watermelon), 24.39 (Chrysophyllum albidum), 17.13 (Telfairia occidentalis), 45.39 (sunflower), 23.27 (soybean), 38.21 (mustard seed), 50.0 (palm oil), 5.84m (coconut), 41.90 (C. odontophyllum) and 72.40-74.68 (M. oleifera seed). The high percentage of oleic acid (a MUFA) in the samples makes their oil desirable in terms of nutrition and high stability cooking and frying oil [33]. A higher intake of oleic acid is associated with decreased risk of coronary heart disease caused by high cholesterol level in blood [31]. The linoleic acid ($C_{18:2}$; an Ω-6 FA) contents of AW and AE were close (16.88±1.66 - 18.80±1.52 and 15.15±3.57 - 15.40±3.82g/100g fat respectively). These were higher than the values; 0.95, 11.03, 7.03±2.06, 12.14 ± 0.22 and 1.28g/100g fat obtained for M. oleifera, palm oil, extra virgin olive oil, chia seeds and coconut oil respectively but lower than the values 46.02, 52.18, 20.70, 21.38, 28.10 and 25.31g/100g fat reported for sunflower, soybean, pumpkin seeds, sesame, watermelon and mustard seed respectively [14], [23], [26], [27], [31]. Linolenic acid ($C_{18:3}$) (an omega-3 fatty acid) content of AW obtained in this work (55.95±5.68 - 57.08±6.57g/100g fat) was far higher than the values of 0.53±0.1, 0.45, 0.12, 5.63-7.0, 11.30, 17.56, 18.12 and 28.30g/100g fat reported for extra virgin olive oil, M. oleifera, sunflower, soybean, mustard seed, flaxseed and Chrysophyllum albidum seed respectively [14], [23], [26], [31], [32], [25], but compares closely with the value 60.56 ± 1.22g/100g fat recorded by Imran et al. [27] for chia seed oil. Linoleic and α-linolenic acids are the most important essential fatty acids. Alph-linolenic acids are components of the phospholipids of cell membranes and together with linoleic acids provide energy for the body and serve as precursors for eicosanoids. Eicosanoids, signaling molecules, are implicated in the body's cardiovascular, pulmonary, immune and endocrine systems [11], [33], [34]. The high content of these FAs in the samples is an indication that they would be invaluable in supporting growth, physiological functions and body maintenance. For instance, studies have correlated higher dietary/plasma level of linolenic acid with a lower risk of heart failure, coronary disease, and fatal coronary heart disease and, a decreased risk of certain cancers [35], [36], [37]. African walnut at every stage of processing contained more unsaturated FAs (UFAs) than saturated FAs (SFAs) with more polyUFAs (PUFAs) than monoUFAs (MUFAs) while African elemi pulp except for sample macerated for more than 45min contained more SFAs than UFAs (Tables 1 & 2). The SFAs in AW (6.92-11.04g/100g fat) compared favourably with the values 8.51, 15.94 and 18.26g/100g fat obtained for sunflower, mustard and soybean oils respectively [23] while that of AE (49.11±4.40 - 51.48±3.57g/100g fat) was higher than 36.22, 22.27, 26.6±0.01, 20.59, 16.05, 13.42 and 3.2g/100g fat obtained for Chrysophyllum albidum seeds, Telfairia occidentalis seeds, M. oleifera seed oil, tiger nut oil, soybean oil, olive oil and chia seeds respectively [13], [26], [31], [32], [39], but could be compared with the value of 43.42g/100g fat and 50.0g/100g fat obtained for Canarium odontophyllum and palm oil respectively [24], [29]. The observed level of UFAs of AW (88.96±6.54 - 92.99±8.62g/100g fat) compared with 78.72, 77.92, 81.14, 86.18, 79.41 and 91.49g/100g fat of Telfairia occidentalis seeds, M. oleifera seed, soybean, mustard, tiger nut and sunflower oils respectively [13], [23], [31], [32], while that of AE (48.52±3.66 - 50.89±4.79g/100g fat) compared closely with 50.0g/100g fat and 56.58g/100g fat of palm oil and C. odontophyllum respectively [24], [29]. The MUFA value for AW (16.12±1.86 - 17.11±1.31g/100g fat) was lower than those of palm, sunflower and mustard oils. On the average, AW contained high monounsaturated to saturated fatty acids ratio (1.84) and may be an acceptable substitute for highly monounsaturated oils such as olive oil in diets [30]. Epidemiologic studies have found that hyperlipidemia, especially hypercholesterolemia (increased serum cholesterol), is a major risk factor for coronary heart disease (CHD) [24], [40], [41]. Therefore, dietary strategies known to decrease cholesterol levels, such as a decrease in total and saturated fat intake as well as increased intake of dietary MUFAs are associated with a decreased risk of coronary heart disease [41], [42]. A diet high in MUFA may help to reduce elevated levels of total plasma cholesterol (hypercholesterolemia) without reducing the high density lipoprotein (HDL) cholesterol level [38], [43]. The MUFAs content of AE (33.34±3.42 - 35.74±1.46g/100g fat) was higher than 5.84, 2.9 and 23.28g/100g fat obtained for coconut, chia seeds and soybean oils respectively, but lower than 41.46, 42.53, 45.50 and 49.57g/100g fat for palm, C. odontophyllum, sunflower and mustard oils respectively [23], [24], [26]. In contrast, the average monounsaturated to saturated fatty acids ratio for AE (0.68) was very low. The PUFA level of AW from this work (72.84±4.69 - 75.88±7.74g/100g fat) was higher than the corresponding values in sunflower, soybean, mustard, coconut and palm oils [23], [24], [31]. On the other hand, compared to earlier results by Lanna [44], Chowdhury et al. [23] and Cordain [26], the PUFA value from this work for AE (15.15±3.57 - 15.40±3.82g/100g fat) was higher than those of palm oil (11.84g/100g fat) and coconut oil (1.28g/100g fat); lower (in g/100g fat) than those of chia seeds (23.3), sunflower (46.10), soybean oil (57.86)

and mustard seed (36.62). It compared favourably with that of C. odontophyllum (14.05). PUFAs have a hypocholesterolaemic effect in human [45]. The fatty acid contents of the samples where differently affected though non-significantly ($p>0.05$) by the hydrothermal processing methods. Imran et al. [27] suggested that the alteration in fatty acids composition of raw materials during thermal treatment may be due to lipolytic activity and interactions between lipids. The UFA contents of raw samples were generally increased while SFAs were decreased by the thermal processing (Figs. 1 & 2). The observed increase in FA contents could be attributed to the 'releasing effect' of heat. According to Bernhardt and Schlich [46], and Hotz and Gibson [47] heat can increase the bioavailability of nutrients by disruption of the plant cell wall and releasing them from complexes. The 'releasing effect' could be enhanced by the fact that fats melt (increase in fluidity) when subjected to heat. Previous work has shown that the melting and crystallization behaviour of fatty acids and esters depend strongly on structural features such as chain length, position and configuration of double or triple bonds or functional groups [48]. The researchers stated that the melting point of a saturated fatty acid with an odd number of carbon atoms is slightly lower than that of the even-numbered fatty acid with one less carbon atom. The decrease could be as a result of oxidation of FAs which change to primary and secondary oxidation products during the heating process [42]. At ordinary room-temperature the process of oxidation proceeds; but in the presence of heat oxidation is very greatly increased. As stated by Shelton [49], the longer foods are cooked and the higher the temperature to which they are subjected, the more oxidation takes place and the greater is the destruction of the food. The decrease may also have resulted from leaching into the processing water. The solubility of the fatty acids increased with increasing temperature [50]. This study shows that on the average, based on the World's healthiest foods rating (ranking) [51], [52], the plant foods studied are excellent sources of omega-3 and omega-6 fatty acids as one serving (45g DW) of AW could supply about 41.52% and 647.09% of the European Food Safety Authority [53] Recommended Daily Intakes (RDIs) for the essential FAs Linoleic acid (10g/day) and Linolenic acid (2 g/day) respectively, while that of AE will supply about 29.13% of the RDI for Lineleic acid.

Conclusion

The hydrothermal processing methods did not significantly affect the fats and fatty acid contents of the plant foods. Considering the essential fatty acid contents and their metabolic and physiological functions, it could be concluded that African walnut (Plukenetia conophora) kernel and African elemi (Canarium schwenfurthii) pulp: two plant foods commonly used as masticatories as well as traditional snacks in Nigeria apparently have potentials for application as functional foods and nutraceuticals.

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