**Research article**

**Journal of Human, Health and Halal Metrics; 2022, 3(2): 14-22**
https://doi.org/10.30502/JHHHM.2022.364887.1061

# Lipid profile and health attributes of mango (*Mangifera indica* L.) seed kernel and cashew (*Anacardium occidentale* L.) nut kernel: A comparative study

Mathew Olaleke Aremu[1*], Musa Suleiman Awagulu[1], Edward Bebe Ayakeme[1], Caleb Zando[1,2], Mohammad Etsuyankpa Bini[1], Mary Omolola Omosebi[3], Dorcas Oluwakemi Aremu[4,5]

1- *Department of Chemistry, Federal University of Lafia, P.M.B. 146, Nasarawa State, Nigeria.*
2- *Department of Chemical Sciences, Federal University Wukari, P.M.B. 1020, Taraba State, Nigeria.*
3- *Department of Food Science and Technology, Mountain Top University, Magoki, Ogun State, Nigeria.*
4- *Department of Microbiology, Federal University Wukari, P.M.B. 1020, Taraba State, Nigeria.*
5- *Department of Obstetrics and Gynecology, Dalhatu Araf Specialist Hospital, Lafia, Nigeria.*



***Submission***: 8 October 2022 ***Revision***: 10 October 2022 ***Acceptance***: 29 October 2022

**Abstract**

**Background and objective:** Mango (*Mangifera indica* L.) and cashew (*Anacardium occidentale* L.) are tropical trees widely cultivated in Nigeria. They are rich in lipid but their functionality has not been studied well. In this study, we investigated lipid composition of both mango seed and cashew nut kernels.

**Materials and methods:** Fresh mature and disease-free mango seed and cashew nut were collected from farms of Agyaragu in Nasarawa state (Nigeria) in April 2020. Kernel of the samples was separated and their oil were extracted by Soxhlet method for analysis. Profile of fatty acids, phospholipids, and sterols were determined by gas chromatography in the laboratory. To evaluate the health attributes, amounts of saturated fats, unsaturated fats, essential fatty acids, and ratio of saturated to unsaturated fats were calculated.

**Results and conclusion:** In mango seed kernel, palmitic (23.83%), linoleic (23.18%), and oleic (19.85%) acids had the most concentration. In comparison, linoleic (57.21%), oleic (25.30%), and palmitic (5.73%) acids were the abundant fatty acids in cashew nut kernel. Caprylic, capric, and lauric acids were determined in mango seed kernel, but they were not detected in cashew nut kernel. Margaric, arachidic, behenic, palmitoleic, arachidonic, and erucic were present in small quantities in both samples (less than 1%). Total amount of essential fatty acids in cashew nut kernel (62.42%) was much higher than that of mango seed kernel (31.9%). In addition, a higher ratio of polyunsaturated/saturated fatty acids, that is strongly associated with human health, was determined in cashew nut kernel (6.11 vs. 0.74). However, mango seed kernel was rich in phospholipids especially phosphatidylethanolamine, phosphatidylcholine, and phosphatidylinositol, which have significant role in cellular vital processes such as membrane fusion, cell circles, autophagy, and apoptosis. High concentration of phytosterol in cashew nut kernel (295.69 mg/100 g) compared to mango seed kernel (51.18 mg/100 g) was also of importance. Accordingly, we concluded that both oils have a potential for consumption in foods and cosmetics, and animal feeding.

*Keywords*: Cashew, Fatty acid, kernel, mango, phospholipid, phytosterol

[*]Correspondence to: Mathew Olaleke Aremu; E-mail: moaremu@science.fulafia.edu.ng

## 1. Introduction

Oilseeds are commonly cultivated in commercial scale for oil production. However, there are some tropical sources including cashew nut and mango seed that their byproducts such as kernel can be used as a healthful source of lipid [1]. Such byproducts are not used industrially but they may be found in diet of rural populations in tropical regions, especially in places where they are cultivated locally or grown in wildtype [2]. The increasing demand for edible fats and oils with high nutritional value has led to development of nutritional and toxicological studies on the oils obtained from unconventional sources and agricultural waste products including rice-bran, cleome viscose, mahua, kapok, neem oil, cashew nut kernel, and mango seed kernel [3].

The word lipid refers to fat-soluble molecules including fats, oils, waxes, sterols, fat-soluble vitamins, monoglycerides, diglycerides, triglycerides, fatty acids, and phospholipids. They pose vital biological functions in human body. For example, their metabolism toward energy production, acting as structural component of cell membranes, and participation in cell signaling are of main roles of lipids in the body [4]. Incorrectly, lipid is sometimes used as a synonym for fat, that is a subgroup of triglyceride, diglyceride, and monoglyceride [5]. Lipids are classified into three groups of simple, compound, and complex molecules [6]. Phospholipids are of complex lipids containing a chemical group of phosphate. Phospho-glycerides are glycerol-based phospholipids, which have a backbone of glycerol [7]. Specific function of a phospho-glyceride depends on the molecule that is attached to the phosphate group [8]. Fatty acid end of phospho-glycerides is soluble in fat, and the phosphate end is water soluble. It makes phospho-glycerides water- and fat-soluble, by which they show many functions in biological systems [9]. Lipids are of macronutrients in human diet and produce high energy after metabolism. Nevertheless, their high consumption is detrimental to health.

Mango (*Mangifera indica* L.) seed kernel contains 8.15-13.16% lipid. It is a good lipid source because of its health beneficial properties. It has edible components known as structural and functional constituent of the cells in biological systems [10].

Cashew (*Anaccardium occidentale* L.) nut belongs to *Anacardiaceae* family. It is an evergreen tree, native to the northeast region of Brazil, which further transferred to the south American countries. Then, it was cultivated in India, Africa, and Portuguese in the 16$^{th}$ century. Cashew tree spread from India to all-over southeast Asia. Cashew nut is a nutritious food containing 44% lipid. Cashew nut kernel is mainly composed of lipid accounted as 40-47% [11].

Organoleptic attributes of foods are mainly contributed to the lipid content. It has been shown that lipid changes are of main causes of quality loss in foods [12]. Therefore, several researchers have focused on lipid composition and health attributes of unknown sources in the world. To this contribution, we assessed the lipid content of mango seed kernel and cashew nut kernel. Indeed, we analyzed and compared the composition and the amounts of phospholipids and sterols in the both kernels other than their fatty acid profile and nutritional health benefits for the first time.

## 2. Materials and methods

### 2.1. Sample collection

Fresh mature and disease-free mango fruit (2 kg) and cashew nut (3 kg) were collected directly from farms of Agyaragu town located in Nasarawa state of Nigeria in April 2020. The samples were further transferred to the chemistry laboratory of Federal University of Lafia for analysis.

### 2.2. Chemicals

Cholesterol and α-cholestane were purchased from Sigma Aldrich (USA). Standards of stigmasterol and β-sitosterol were supplied by Chroma DEX (USA). Campesterol, ergosterol, avenasterol, phosphatidylethanolamine, phosphatidyl-

choline, phosphatidylserine, lysophosphatidylcholine, phosphatidylinositol, phosphatidic acid, petroleum ether, boron trifluoride, chloroform, and benzene were purchased from Sigma Aldrich (Germany). n-Hexane were provided by Merck (USA). Potassium hydroxide and hydrochloric acid were prepared from Macron (Mexico), and deionized water was obtained using a Millipore purification system (Billerica, MA, USA). All chemicals were of analytical grade.

### 2.3. Sample preparation

Kernel of mango seed and cashew nut was removed by using a kitchen knife. The kernels were separately sundried for 5 days and then oven dried at 65 ºC for 30 h. In the next, the dried samples were ground into powder by electrical grinder. The ground samples were stored in airtight container at -5 ºC until analysis.

### 2.4. Oil extraction

About 50 g of the ground kernel was added to extraction chamber of Soxhlet extractor (Bionics Scientific Technologies Ltd., India). Then, 200 ml of petroleum ether was added. The mixture was heated for 24 h to help lipid extraction. Then, the solvent was evaporated and the extract was rinsed twice with additional petroleum ether. At the end, pure extract was transferred to pre-weighed flask [13].

### 2.5. Analysis of fatty acid profile

At first, methyl esters of fatty acids were prepared in accordance to the method described by Aremu et al. [14]. Accordingly, 50 mg of the extracted oil was saponified with 3.4 ml of KOH solution in methanol (0.5 M) at 95 ºC for 5 min. The mixture was neutralized by HCl (0.7 M), followed by addition of 3 ml of boron trifluoride solution in methanol (14%). The final mixture was heated at 90 ºC for 5 min to complete methylation. Fatty acid methyl esters were analyzed by HP 6890 gas chromatograph (Bionics Scientific Technologies Ltd., India) equipped with flame ionization detector. Nitrogen was used as carrier gas. A polar (HP INNO Wax) capillary column (30 m × 0.53 mm × 0.25 µm) was used for separation of fatty acids. Initial temperature of the column was set at 250 ºC and then increased at rate of 5 ºC/min to reach a final temperature of 310 ºC. Injector and detector temperatures were 310 ºC and 350 ºC, respectively. Quantitative evaluation was carried out by calculation of peak areas. Recovery of 0.96 was achieved by using heptadecanoic ester.

### 2.6. Analysis of phospholipids

Phospholipid content of the samples was determined by gas chromatograph (HP 5890, Bionics Scientific Technologies Ltd., India). At first, 0.01 g of the extracted oil was added to a test tube and was exposed to stream of nitrogen gas to ensure complete solvent removal. Then, 0.04 ml of chloroform and 0.1 ml of chromogenic solution were added to the tube. The mixture was heated at 100 ºC for 1 min in water bath. After cooling, 5 ml of n-hexane was added and the tube was shaken vigorously. In the next, the content was left until the solvent and the aqueous phases were separated. The solvent layer was removed and used for analysis by gas chromatograph equipped with pulsed flame photometric detector. The analysis was carried out by split ratio of 20:1, inlet temperature of 250 ºC, detector temperature of 300 ºC, by using HP5 column (30 m × 0.25 mm × 0.25 µm), and nitrogen as carrier gas. Initial temperature of oven was set at 50 ºC, which increased at rate of 10 ºC/min for 20 min, and maintained at final temperature for 4 min. Then, temperature was increased at rate of 15 ºC/min for 4 min, and maintained at final temperature for 5 min [15].

### 2.7. Analysis of sterols

Analysis of sterols was done as described by AOAC method [16]. At first, the extracted oil was saponified in a capped test tube by addition of 3 ml of KOH solution in ethanol (10%) and 0.2 ml of benzene (to ensure miscibility) followed by heating at 90 °C for 30 min. Then, 2 ml of n-hexane (nonpolar solvent) and 3 ml of deionized

water (polar solvent) were added to separate unsaponifiable materials and polar materials, respectively. After vertexing, polar and nonpolar phases were separated. To maximize the yield of analysis, extraction of the remained sterols in the polar phase was done by 2 ml of n-hexane during three steps for 1 h, 30 min, and 30 min, respectively. All the nonpolar extracts containing unsaponifiable materials were combined and exposed to stream of nitrogen gas to remove the solvent. Determination of sterols was carried out by gas chromatograph under similar condition described for fatty acids methyl esters analysis [14].

### 2.8. Statistical analysis

Data were analyzed by Microsoft Excel 2010. The results are presented as mean ±standard deviation (SD). In addition, data variation is expressed as coefficient of variation (CV) in the tables. The experiments were done in three replications.

## 3. Results and discussion

### 3.1. Fatty acid profile of mango seed kernel and cashew nut kernel

As seen in Table 1, the highest concentration was related to palmitic acid (23.83%) in mango seed kernel and linoleic acid (57.21%) in cashew nut kernel. Palmitic acid was the predominant saturated fatty acid in both samples (23.83% and 5.73% in mango seed and cashew nut kernel, respectively). Cashew nut kernel was free of caprylic, capric, and lauric acids, possibly due to the different environmental condition in which the plant was grown. The fatty acid profile detected in our study was similar to those reported for apple and pear seed oils in study of Yukui et al. [17]. In their study, oleic acid was the main fatty acid in both samples (43.03% in apple seed oil and 56.80% in pearl seed oil). Similarly, oleic acid was detected in relatively high concentration in our samples. In agreement, high concentrations of palmitic (3-18%) and linoleic (1-24%) acids were reported by Nadeem et al. in analysis of *Mangifera indica* L. kernel [18]. Kim et al. detected 44% palmitic acid and 28.6% linoleic acid in chufa (*Cyperus esculentus* L.) tuber oil [19]. Similarly, high amount of oleic acid (56.78%) and linoleic (42.64%) acid was reported by Aremu et al. in analysis of breadfruit (*Artocarpus altilis*) seed and wonderful kola (*Buchholzia aoriacea*) seed, respectively [20]. Furthermore, 35.65% and 33.56% linoleic acid in kernel and pulp of *Balanites aegyptiaca* was reported by Aremu et al. [21]. Linoleic acid was also the main ingredient in citrus seed oil (36.1-39.8%) followed by palmitic (25.8-32.2%), oleic acid (21.9-24.1%), linolenic (3.4-4.4%), and stearic acid (2.8-4.4%) in study of Anwar et al. [22].

Table 1– Fatty acids profile of mango seed kernel and cashew nut kernel

| Fatty Acid | Mango seed kernel (%) | Cashew nut kernel (%) | Mean ±SD (%) | CV (%) |
|---|---|---|---|---|
| Caprylic Acid (C8:0) | 1.61 | 0.00 | 0.81 ±0.80 | 99 |
| Capric Acid (C10:0) | 3.40 | 0.00 | 1.70 ±1.70 | 100 |
| Lauric Acid (C12:0) | 7.80 | 0.00 | 3.90 ±3.90 | 100 |
| Myristic Acid (C14:0) | 4.96 | 0.22 | 2.59 ±3.35 | 129.34 |
| Palmitic Acid (C16:0) | 23.83 | 5.73 | 14.78 ±12.80 | 86.60 |
| Margaric acid (C17:0) | 0.03 | 0.04 | 0.04 ±0.01 | 25.00 |
| Stearic acid (C18:0) | 3.38 | 3.53 | 3.46 ±0.02 | 0.58 |
| Palmitoleic acid (C16:1) | 0.57 | 0.82 | 0.61 ±0.18 | 29.51 |
| Oleic acid (C18:1) | 19.85 | 25.30 | 22.62 ±3.90 | 17.24 |
| Linoleic acid (C18:2) | 23.18 | 57.21 | 40.20 ±17.02 | 42.34 |
| Linolenic acid (C18:3) | 8.72 | 5.21 | 6.97 ±2.48 | 35.58 |
| Arachidic acid (C20:0) | 0.40 | 0.50 | 0.45 ±0.07 | 15.56 |
| Arachidonic acid (C20:4) | 0.05 | 0.06 | 0.06 ±0.01 | 16.67 |
| Behenic acid (C22:0) | 0.31 | 0.33 | 0.32 ±0.01 | 3.12 |
| Erucic acid (C22:1) | 0.22 | 0.24 | 0.23 ± 0.02 | 8.70 |
| Lignoceric (C22:4) | 1.69 | 0.81 | 1.25 ± 0.62 | 49.6 |
| Total | 100 | 100 | | |

### 3.2. Fatty acids distribution and health index of mango seed and cashew nut kernels

Distribution of fatty acids in terms of mono-unsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), saturated fatty acid (SFA), di-unsaturated fatty acid (DUFA), unsaturated fatty acid (UFA), essential fatty acid (EFA), oleic/ linoleic acid ratio (O/L), and polyunsaturated/ saturated fatty acid ratio (PUFA/SFA) is presented in Table 2. We observed that concentrations of both unsaturated and essential fatty acids in cashew nut kernel were higher than those of mango seed kernel, while concentrations of saturated and non-essential fatty acids in mango seed kernel were higher than cashew nut kernel (45.72% vs. 10.35% for SFA; 68.1% vs. 37.58% for non-essential fatty acids, respectively). Amount of SFA in mango seed kernel was much higher than those reported for processed pinto bean (9-12.9%) [23], *Brachystegia eurycoma* (17.06%) [24], *Daucus carota* (23.36%), and *Cucumis sativus* (20.15%) [13], and processed black variety of tigernut (20.5-24.8%) [15].

High dietary intake of SFA is a risk factor of obesity and cardiovascular diseases [25]. Interestingly, high amount of UFA (89.65%) makes cashew nut kernel a healthful candidate for nutritional applications. However, it has been approved that highly unsaturated fats/oils are susceptible to oxidation, and high intake of foods containing the oxidized lipids may put the body at risk of oxidative stress and the associated diseases [15]. On the other hand, linoleic and α-linolenic acids, known as omega-6 and omega-3 fatty acids respectively, are of the most important EFAs required for body maintenance, growth, and physiological functions [26]. They work together in a competitive balance to regulate blood clotting, immune response, and inflammatory processes. Linoleic acid deficiency may lead to dry hair, hair loss, and poor wound healing. In addition, dietary intake of linolenic acid decreases the risk of cardiovascular diseases and protects the consumers against fatal ischemic heart disease [27,28]. It has been reported that linoleic acid could reduce serum cholesterol and low-density lipoprotein (LDL) levels [29]. According to our result, the higher concentration of EFA in cashew nut kernel (62.42%) than mango seed kernel (31.9%) introduces it as source of omega fatty acids for domestic use or food supplements and also cooking under mild heating. Moreover, O/L ratio is important in technical view. Oleic acid is one of MUFAs, known as omega-9, and its abundance in edible oils makes the matrix resistant to oxidative reactions under deep frying [30]. To this contribution, O/L ratio in mango seed kernel (0.86) was significantly higher than that of cashew nut kernel (0.44).

Table 2- Fatty acids distribution in mango seed kernel and cashew nut kernel

| Quality parameter | Mango seed kernel (%) | Cashew nut kernel (%) | Mean ±SD (%) | CV (%) |
|---|---|---|---|---|
| MUFA | 20.64 | 26.36 | 23.54 ±4.10 | 17.42 |
| PUFA | 33.64 | 63.29 | 48.47 ±20.97 | 43.26 |
| SFA | 45.72 | 10.35 | 28.04 ±25.01 | 89.19 |
| DUFA | 23.18 | 57.21 | 40.20 ±24.06 | 59.85 |
| UFA | 54.28 | 89.65 | 71.97 ±7.91 | 10.99 |
| EFA | 31.90 | 62.42 | 47.16 ±21.58 | 45.76 |
| O/L | 0.86 | 0.44 | 0.65 | |
| PUFA/SFA | 0.74 | 6.11 | 3.42 | |

MUFA: mono-unsaturated fatty acid; PUFA: poly-unsaturated fatty acid; SFA: saturated fatty acid; DUFA: di-unsaturated fatty acid; UFA: unsaturated fatty acid; EFA: essential fatty acid; O/L: oleic/linoleic acid ratio; PUFA/SFA: polyunsaturated/saturated fatty acid ratio

### 3.3. Concentration of phospholipids in mango seed and cashew nut kernel oils

According to the results, there were 701.92 and 90.67 mg phospholipid per 100 g of mango seed and cashew nut kernel oils, respectively.

Phosphatidylcholine (PC) (410.2 mg/100 g) and phosphatidylserine (PS) (53.61 mg/100 g) had the highest concentration in mango seed kernel oil and cashew nut kernel oil, respectively. In comparison, PS showed the least concentration (1.03 mg/100 g) in mango seed kernel oil, and Lysophosphatidylcholine (LPC) was detected at least concentration in cashew nut kernel oil (1.89 mg/100 g). Several beneficial effects have been reported for dietary phospholipids. For example, PC participates in maintenance of cell-membrane integrity, transfer of genetic information from DNA to RNA in protein synthesis, and signal transduction [5]. It has been found that PC concentration is high in infancy but it decreases during aging and may drop to 10% of cell membrane in old age [31]. Therefore, its daily supplementation is recommended to maintain the brain's function and memory capacity in adulthood [32]. The US Food and Drug Administration has stated that consumption of PS may reduce rate of dementia and cognitive dysfunction in elderly people. In addition, it reduces mental stress and improves mental function in young people [33]. Supplementation with PS promotes hormonal balance in athletes and could reduce physiological deterioration occurring under overtraining and/or overstretching [34]. Phosphatidylethanolamine (PE) is of abundant phospholipids in animals and plants with significant role in membrane fusion, cell circles, autophagy, and apoptosis. It is of building blocks in membrane bilayer [35]. According to Table 3, mango seed kernel oil can be considered as a good source of PE.

Table 3- Concentration of phospholipids in mango seed kernel oil and cashew nut kernel oil

| Phospholipid | Mango seed kernel oil (mg/100 g) | Cashew nut kernel oil (mg/100 g) | Mean ±SD (mg/100 g) | CV (%) |
|---|---|---|---|---|
| Phosphatidylethanolamine | 100.13 | 4.29 | 52.21 ±67.8 | 129.86 |
| Phosphatidylcholine | 410.20 | 21.13 | 215.67 ±275.1 | 127.56 |
| Phosphatidylserine | 1.03 | 53.61 | 27.32 ±37.2 | 136.16 |
| Lysophosphatidylcholine | 1.79 | 1.89 | 1.84 ±0.1 | 5.43 |
| Phosphatidylinositol | 108.06 | 9.28 | 58.67 ±69.9 | 119.14 |
| Phosphatidic acid | 80.71 | 4.70 | 42.71 ±53.8 | 125.97 |
| Total | 701.92 | 90.67 | | |

### 3.4. Composition of sterols in mango seed and cashew nut kernel oils

Phytosterols have positive role in treatment of rheumatoid arthritis and prevention of heart diseases. However, excessive intake of dietary phytosterols and stanols may contribute to increased blood pressure [36]. Total concentration of 51.18 and 295.69 mg sterol per 100 g of mango seed and cashew nut kernel oils, respectively, were calculated (Table 4). The least and the highest sterol in cashew nut kernel oil was ergosterol (1.49 mg/100 g) and β-sitosterol (235.49 mg/100 g), respectively. In comparison, cholesterol (1.76 mg/100 g) and β-sitosterol (35.32 mg/100 g) was the least and the highest sterol detected in mango seed kernel oil.

High level of total cholesterol and LDL cholesterol in the blood is of main risk factors for coronary heart diseases. Phytosterols are effective in lowering total cholesterol and LDL cholesterol and inhibit intestinal cholesterol absorption. Indeed, phytosterols compete with cholesterol in the small intestine, thereby reduce intestinal absorption of cholesterol and its concentration in the blood. Therefore, dietary intake of phytosterols in favor of reduced cholesterol absorption will reduce the risk of atherosclerosis [15].

Table 4- Concentration of sterols in mango seed kernel oil and cashew nut kernel oil

| Phytosterol | Mango seed kernel oil (mg/100 g) | Cashew nut kernel oil (mg/100 g) | Mean ±SD (mg/100 g) | CV (%) |
|---|---|---|---|---|
| Cholesterol | 1.76 | 4.02 | 2.89 ±1.6 | 55.36 |
| Cholestanol | 2.29 | 9.17 | 5.73 ±4.9 | 85.51 |
| Ergosterol | 2.23 | 1.49 | 1.86 ±0.9 | 48.39 |
| Campesterol | 5.90 | 44.55 | 25.23 ±0.5 | 1.98 |
| Stigmasterol | 6.03 | 9.63 | 7.83 ±27.3 | 348.66 |
| Avenasterol | 3.93 | 6.06 | 5.00 ±2.6 | 52.00 |
| β-sitosterol | 35.32 | 235.49 | 135.41 ±141.5 | 104.50 |
| Total | 51.18 | 295.69 | | |

## 4. Conclusion

Lipid profile and health benefits of mango seed and cashew nut kernels were investigated in the current work. Sixteen and thirteen fatty acids were identified in mango seed and cashew nut kernels, respectively, of which unsaturated fatty acids were predominant in both the samples. Cashew nut kernel contained high level of PUFA, EFA, and phytosterols compared to mango seed kernel, making it a healthy choice for food preparation and supplementation. Although, high PUFA concentration in cashew nut kernel oil makes it inappropriate for deep frying. However, mango seed kernel was rich in phospholipids with higher contents of PE, PC, and phosphatidyl-inositol. We concluded that both the kernel oils have potential for domestic and industrial uses, through which lower wastes are produced which results in reduced environmental pollution and improved financial benefits.

## 5. Conflict of Interest

The authors declare that there is no conflict of interest with respect to this work.

## References

1. Bloom DE, Cafiero ET, Jane-Llopis E, Abraham-Gessel S, Bloom LR, Fathima S, et al. The global economic burden of non-communicable diseases. Geneva, Switzerland: World Economic Forum. 2011.

2. Tabas I, Williams KJ, Boren J. Subendothelial lipoprotein retention as the initiating process in atherosclerosis: Update and therapeutic implications. 2007; 116: 1832-1844. https://doi.org/10.1161/CIRCULATIONAHA.106.676890

3. Schoeman ME. Mango (Magnifera indica L.) kernel fat: fatty acid profile, oxidative stability and development of Fourier Transform Near Infrared (FT-NIR) spectroscopy calibration models. MSc. Thesis. Stellenbosch University, South Africa. 2002.

4. Piironen V, Lindsay DG, Miettinen T, Toivo J, Lampi A. Plant sterols: biosynthesis, biological function and their importance to human nutrition. Journal of the Science of Food and Agriculture. 2000; 80*:* 939-966. https://doi.org/10.1002/%28SICI%291097-0010%2820000515%2980%3A7%3C939%3A%3AAID-JSFA644%3E3.0.CO%3B2-C

5. Aremu MO, Ibrahim H. Dietary phospholipids and phytosterols: A review of some Nigerian vegetable oil. International Journal of Sciences. 2017; 6(9): 94-102. https://doi.org/10.18483/ijSci.1436.

6. Fielding CJ, Fielding PE. Molecular physiology of reverse cholesterol transport. Journal of Lipid Research. 2005; 36: 211-228.

7. Singh IM, Shishehbor MH, Ansell BJ. High density lipoprotein as a therapeutic target: A systematic review. JAMA. 2007; 298: 786-798. https://doi.org/10.1001/jama.298.7.786

8. Fernandez CJ, Calle M. Revisiting dietary cholesterol recommendations: Does the evidence support limit of 300 mg/d? Current Atherosclerosis Representative. 2010; 12: 377-383. https://doi.org/10.1007/s11883-010-0130-7

9. Jing L, Xuling W, Ting Z, Chunling W, Zhenjun H, Xiang L, et al. A review on phospholipids and their main applications in drug delivery systems. Asian Journal Pharmaceutical Science. 2015; 10: 81-98. https://doi.org/10.1016/j.ajps.2014.09.004

10. Lebaka VR, Wee YJ, Ye W, Korivi M. Nutritional composition and bioactive compounds in three different parts of mango fruit. International Journal of

Environmental Research in Public Health. 2021; 18: 741.
https://doi.org/10.3390/ijerph18020741

11. Ling WH, Jones PJ. Dietary phytosterols: A review of metabolism, benefits and side effects. Life Sciences. 2005; 57: 195-206.
https://doi.org/10.1016/0024-3205(95)00263-6

12. Montesano D, Albrizio S, Lucini L, Barba FJ, Gallo M. Lipids and food quality. Journal of Food Quality. 2018; 1-2.
https://doi.org/10.1155/2018/4046381

13. Aremu MO, Ajine PL, Omosebi MO, Baba NM, Onwuka JC, Audu SS, et al. Lipid profiles and health promoting uses of carrot (*Daucus carota*) and cucumber (*Cucumis sativus*). International Journal of Sciences. 2021; 10(7): 22-29.
https://doi.org/10.18483/ijSci.2485

14. Aremu MO, Achuri EI, Ibrahim H, Omosebi MO, Usman A, Oko OJ, et al. Lipid composition of germinated and non-germinated sorghum (*Sorghum bicolor*) found in Nasarawa State, Nigeria. International Journal of Sciences. 2022; 11(1): 22-27.
https://doi.org/10.18483/ijSci.2541

15. Aremu MO, Ibrahim H, Aremu SO. Lipid composition of black variety of raw and boiled tigernut (*Cyperus esculentus* L.) grown in North-East Nigeria. Pakistan Journal of Nutrition. 2016; 15(5): 427-438.
https://doi.org/10.3923/pjn.2016.427.438

16. Association of Official Analytical Chemists. Official methods of analysis. Method validation programs. 19th edition. Washington DC, USA. 2006. Available at: http://www.aoac.org/vmeth.page1.htm

17. Yukui R, Wenya W, Rashid F, Qing L. Fatty acid composition of apple and pear seed oils. International Journal of Food Properties. 2009; 12(4): 774-779.
https://doi.org/10.1080/10942910802054320

18. Nadeem M, Imran M, Khalique A. Promising features of *Mangifera indica L*. kernel oil: a review. Journal of Food Science Technology. 2016; 53(5): 2185-2195.
https://doi.org/10.1007/s13197-015-2166-8

19. Kim M, No S, Yoon SH. Stereospecific analysis of fatty acid composition of chufa (*Cyperus esculentus* L) tuber oil. Journal of American Oil Chemical Society. 2007; 84: 1079-1080.
https://doi.org/10.1007/s11746-007-1131-8

20. Aremu MO, Haruna A, Oko JO, Ortutu SC. Fatty acid, phospholipid and sterol composition of breadfruit (*Artocarpus altilis*) and wonderful kola (*Buchholzia aoriacea*) seeds. International Journal of Sciences. 2017; 6(4): 116-123.
https://doi.org/10.18483/ijSci.1260.

21. Aremu MO, Andrew C, Oko OJ, Odoh R, Zando C, Usman A, et al. Comparative studies on the physicochemical characteristics and lipid contents of desert date (*Balanites aegyptiaca* (L.) Del) kernel and pulp oils. European Journal of Nutrition & Food Safety. 2022; 14(1): 20-30.
https://doi.org/10.9734/EJNFS/2022/v14i130473

22. Anwar F, Naseer R, Bhanger MI, Ashraf S, Talpur FN, Aladedunye FA. Physio-chemical characteristics of citrus seeds and seed oils from Pakistan. Journal of the American Oil Chemists' Society. 2008; 85(4): 321-330.
https://doi.org/10.1155/2014/174954

23. Audu SS, Aremu MO, Lajide, L. Effect of processing on fatty acid composition of pinto bean (*Phaseolus vulgaris* L.) seeds. International Journal of Chemical Sciences. 2011; 4(1): 114-119.

24. Ajayi FA, Aremu MO, Mohammed Y, Madu PC, Atolaiye BO, Audu SS, et al. Effect of processing on fatty acid and phospholipid compositions of harms (*Brachystegia eurycoma*) seed grown in Nigeria. Chemical and Process Engineering Research. 2014; 22: 18-25.

25. Aremu MO, Ibrahim H, Andrew C. Comparative studies on the lipid composition of blood plum (*Haematostaphis barteri* L.) pulp and seed oils. The Open Biochemistry Journal. 2017; 11: 94-104.
https://doi.org/10.2174/1874091X01711010094

26. Salunkhe DK. Postharvest biotechnology of food legumes. CRC Press. 1985.

27. Connor WE, Neuringer M, Reisbick S. Essential fatty acids: The importance of n-3 fatty acids in the retina and brain. Nutrition Reviews. 1992; 50(4): 21-29.
https://doi.org/10.1111/j.1753-4887.1992.tb01286.x

28. Hu FB, Stampfer MJ, Manson JE. Dietary intake of linolenic acid and risk of fatal ischemic heart disease among women. American Journal of Clinical Nutrition. 1999; 69: 890-897.
https://doi.org/10.1093/ajcn/69.5.890

29. WHO/FAO. Fats and oils in human nutrition: report of a joint expert consultation. Rome. 1993. Available at: http://apps.who.int/iris/handle/10665/37862?show=full

30. Branch WD, Nakayama T, Chinnan MS. Fatty acids variation among US Runner-type peanut cultivars. Journal of the American Oil Chemists' Society. 1990; 67: 591–593. https://doi.org/10.1007/BF02540772

31. Adeyeye EI, Olaleye AA, Aremu MO, Ayodele O, Olatoye RA, Gbolagade AY. Lipid composition of the jerky meat (Kilishi) consumed in Nigeria. FUW Trends in Science & Technology Journal. 2020; 5(2): 602-612.

32. Chung S, Tomoe M, Eiko U, Kayoko U, Rieko H, Noviko Y, et al. Administration of phosphatidyl-choline increases brain acetylcholine concentration and improves memory in mice with dementia. Journal of Nutrition. 1985; 125: 1484-1489. https://doi.org/10.1093/jn/125.6.1484

33. Alter T. More than you wanted to know about fats and oils. Sundance National Food Online retrieved. 2006.

34. Starks MA, Starks SL, Kingsley M, Purpura M, Jager R. The effects of phosphatidylserine endocrine response to moderate intensity exercise. Journal of the International Society of Sports Nutrition. 2008; 5(1): 11-16. https://doi.org/10.1186/1550-2783-5-11

35. Wirtz KWA. Phospholipid transfer proteins. Annal Review of Biochemistry. 1991; 60: 73-99. https://doi.org/10.1146/annurev.bi.60.070191.000445

36. Chen Q, Guber H, Swist E, Coville K, Pakenham C, Ratnayake WMN, et al. Dietary phytosterols and phytostanols decrease cholesterol levels but increase blood pressure in WKY *inbred* rats in the absence of salt-loading. Nutrition and Metabolism. 2010; 7: 11-20. https://doi.org/10.1186/1743-7075-7-11