*Original Research Article*

# Comparative Studies on the Physicochemical Characteristics and Lipid Contents of Desert Date (*Balanites aegyptiaca* (L.) Del) Kernel and Pulp Oils


## ABSTRACT

**Aims:** This work is aimed at investigating fatty acid, phospholipid and sterol compositions of desert date (*Balanites aegyptiaca*) kernel and pulp.

**Study Design:** *Balanites aegyptiaca* fruit is one of the oldest feed-stocks in Africa which little or no attention has been given to it. It has a medicinal effect in human body system. The plant plays a diverse cultural and traditional role in different societies. Therefore, it is very important to explore more about the chemical composition of the kernel and pulp oils of *Balanites aegyptiaca;* since it is currently attracting considerable interest as a result of their diverse beneficial properties.

**Methodology:** The physicochemical parameters, fatty acids, phospholipids and phytosterols of *B. aegyptiaca* seed and pulp oils have been analyzed and compared with the standards and that of conventional oil for easy assessment of their suitability for nutritional and industrial applications. **Results:** The results of some physicochemical parameters of kernel and pulp oils were acid value (26.35 and 15.60 mg KOH/g), peroxide value (3.82 and 5.90 meq/kg), saponification value (162.40 and 198.60 mg KOH/g), iodine value (55.20 and 142.50 mg of I/100 g), specific gravity (0.93 and 0.92), kinematic viscosity (2.12 and 1.65 St) and refractive index (1.41 and 1.39), respectively. The most concentrated fatty acids were palmitic acid (14.53%) < linoleic acid (35.65%) < oleic acid (38.27%) for the kernel oil while that of pulp oil were linolenic acid (8.21%) < oleic acid (16.80%) < palmitic acid (32.70%) < linoleic acid (33.56%). Arachidic, behenic, lignoceric and myristic acids were all present in small quantities with none of them recording up to 1.0% in either of the samples. Caprylic, capric acid and lauric acids were determined but not detected in both oils. The fatty acid composition of kernel and pulp oils contained a healthy mixture of all the types of saturated and unsaturated fatty acids. The value of polyunsaturated/saturated index (P/S) which is associated to the impact on human health was


**Comment [AF1]:** Under 'Abstract', the stipulated maximum number of words (300) is exceeded by more than 100.

**Comment [AF2]:** What about the physical characteristics as stated in the title?

**Comment [AF3]:** 1. What is discussed here is not study design.
2. Study design is not one of the subheadings under 'Abstract' as stated in Author's Guideline

**Comment [AF4]:** Analytical methods are expected under Methodology. Fatty acids, phospholipids and sterols are components, not physicochemical parameters, which are, FFA, IV, PV, SV, USM, Pour point, melting point, viscosity etc

higher in the pulp oil (2.47). Phosphatidylcholine had the highest content in both oils that is 75.99 mg/100 g and 25.88 mg/100 g, respectively. The total phytosterols for kernel and pulp oils were 85.00 and 9.87 mg/100 g, respectively.

**Conclusion:** *Balanites aegytiaca* kernel and pulp oils have the potential to substitute several materials used in manufacturing oil in the chemical and pharmaceutical industries. However, in order to extend usage, these oils should be refined to improve the taste and colour.

**Keywords:** *Balanites aegyptiaca*, physicochemical parameters, fatty acids, phospholipids, phytosterols

## 1. INTRODUCTION

Plant seeds are important sources of oils of nutritional and pharmaceutical importance. Seeds have nutritive and calorific values which make them necessary in diet. Fats make a meal more satisfying, enrich its flavor and delay the onset of hunger. This is simply because they contain essential nutrients that play important role in human nutrition. Also plants oil has non-edible applications such as: lubricants, soap production, cosmetics, insulating materials and biodiesel (Akakuru *et al*., 2017).

**Comment [AF5]:** Important and importance amount to tautology in this short statement.

**Comment [AF6]:** wrong reference style

In 1813, Alire Delile derived the word *Balanites* from the Greek word *acorn* which means fruit. *Balanites aegyptiaca* (L.) Del. belongs to the family of *Balanitaceea (*Zygophyllaceae*)*. *Balanites aegyptiaca* is perennial plant and mainly grown in the arid regions of Africa, the Middle East, and South Asia. Israel is considered the Northern-most hemisphere where balanites trees grow naturally. In Israel, balanites is found growing naturally in the Ein-Gedi Oasis, the Arava rift valley, and Bet-Shean valley. Its English name is Desert date, "Aduwa" in Hausa, "Tanni" in Fulani, '*Utazi'* in Igbo, and '*Teji'* in Yoruba [1, 2]. Balanites has multiple uses such as food (sucked as a confectionary), shade, oil and traditional medicine (as purgatives and for treating parasites, sore throat, constipation, liver disease and eye irritation) and potential shelterbelts and agroforestry species. Its multi-use potential varies from ethnomedicine to fire wood. Balanites oil is considered to be a good source for cosmetics and it was found to be used by ancient Egyptian royalty. However, the most important part of the tree is its fruits. Its edible

fruit and seed have 40-87% of edible oil. In many countries, *Balanites aegyptiaca* seed oil has been used as ingredient and as a substitute to groundnut oil in the preparation of local food. The fruit (desert date) is a drupe, pubescent when green, becoming yellowish and glabrous after ripening. It contains four layers, the epicarp (reddish and thin), mesocarp (fleshy), endocarp (thick) and the kernel. All of the four layers can be utilized for different industrial and pharmaceutical products [3, 4]. In spite of the multi-use potential and ecological significance, *Balanites* is the most neglected tree species in the arid regions and the plant has not yet been domesticated. The availability of *Balanites aegyptiaca* fruit in the northern part of Nigeria has made its seed a nuisance along markets and settlement in communities [5]. This is because the potential of the seed kernel remains underutilized in most developing countries. However, the seed kernel oil of *Balanites aeyptiaca* is a good source of raw material for food, cosmetic and pharmaceutical industries [5, 6]. The quality of *Balanites aegyptiaca* oil is similar to sesame and groundnut oils and can be used as a biodiesel [3]. Also, *Balanites aegyptiaca* plant fruit is one of the sources of oil rich fruit product that must be used in order to increase the oil yield to fulfill the demand of the people, and to upgrade the oil quality in order to protect people from health risk. The plant grows in tropical and desert areas. It can be found in many kinds of habitats, tolerating a wide variety of soil types from sand to heavy clay and climatic moisture. It is allowing land species, growing up to 1000 m altitude [4]. *Balanites aegyptiaca* plant has superior protein content than in guava, mango, banana and papaya. The fleshy fruit contains high carbohydrates and steroidal saponins, vitamin A, vitamin C and other essential minerals for human.

The increasing diet related diseases today has called for a critical study with a view to providing information regarding effective utilization of the plant's kernel and pulp in various foods and with the possibility of industrial applications. Thus, the study is aimed at analyzing the physicochemical parameters of kernel and pulp of *Balanites aegyptiaca* as well as the fatty acid, phospholipid and phytosterol contents of both samples*;* so as to provide useful information on the potentiality of the above parameters to serving as components of a healthy lifestyle, to reduce plasma low-density lipoprotein cholesterol (LDL-C) levels, and thereby lower cardiovascular risk.

**Comment [AF7]:** 1. The potential of the kernel and the pulp for use in nutrition and other applications can be deduced from the parameters. The parameters have no potential.
2. The concluding part of the aim introduced bias into thestudy. Physiological effects of the oils should be revealed by experimental data.

## 2. MATERIALS AND METHODS

### 2.1 Collection of samples

The fruits of Desert date (*Balanites aegyptiaca*) were purchased from a local market in Zing local government area, Taraba State, Nigeria in June 2019. The fruits were thoroughly sorted to remove the stones, and the bad ones before washing with tap water. The clean fruits were then transported to the laboratory and proper identification was made by a Taxonomist in the Department of Biological Sciences, Federal University Wukari, Taraba State, Nigeria.

### 2.2 Preparation of samples

Fifty number clean fruits of *B. aegyptiaca* were dried in an oven at 40 °C for 5 days in order to separate the pulp from the seed because the pulp is thin and juicy. The pulp was separated from the seed, and freely ground with Kenwood food blender. The seed was also carefully de-shelled using kitchen knife, and the kernel was dried in an oven at 45 °C for 36 h and ground into powder. Flours of the two samples were separately kept in the refrigerator at -4 °C prior to use.

**Comment [AF8]:** Did the author obtain flours or pastes here? The products of the procedures reported here should be pastes, not flours.

### 2.3 Extraction of oils

Each oven dried sample of kernel and pulp (5 g each) of *B. aegyptiaca* was extracted for 5 h in Soxhlet apparatus with 200 ml of petroleum ether (40-60 $^{o}$C boiling range) of Analar grade (British Drug Houses, London). 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 used for further analysis [7].

### 2.4 Determination of physicochemical parameters of the oils

The acid value, peroxide value, iodine value, saponification value, specific gravity, kinematic viscosity and refractive index of the extracted oils of kernel and pulp of *B. aegyptiaca* were determined according to AOAC [7].

**Comment [AF9]:** The Author should indicate the code of the method for each of the analysis.

### 2.5 Fatty acid analysis

The oil extracted from each sample was converted to the methyl ester using the method described by some workers [8]. A 50 mg aliquot of the dried oil was saponified for 5 min at 95 °C with 3.4 ml of 0.5 M KOH in dry methanol. The mixture was neutralized by 0.7 M HCl and 3 ml of 14% boron trifloride in methanol was added. The mixture was heated for 5 min at 90 °C to achieve complete methylation. The fatty acid methyl esters were analyzed using an HP 6890 gas

chromatograph powered with HP Chemistation Rev. a 09.01 (1206) software fitted with a flame ionization detector and a computing integrator. Nitrogen was used as the carrier gas. The column initial temperature was 250 °C rising at 5 °C/min to a final temperature of 310 °C, while the injection port and the detector were maintained at 310 °C and 350 °C, respectively. A polar (HP INNO Wax) capillary column (30 m × 0.53 mm × 0.25 µm) was used to separate the esters. The peaks were identified by comparison with standard fatty acid methyl esters obtained from Sigma Chemical Co. (St. Louis MO, USA) [8]. However, the quantitative evaluation was carried out on the basis of gas chromatography peak areas of the different methyl esters. The heptadecanoic ester was used to calculate the response factor for fatty acids which was found to be 0.96. Three determinations were made for each sample.

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### 2.6 Phospholipids analysis

The phospholipids content of the kernel and pulp oils of *B. aegyptiaca* were determined by gas chromatography (GC). 0.01 g of the extracted fats was added to the test tube. To ensure complete dryness of the oil for phospholipids analysis, the solvent was completely removed by passing the stream of the nitrogen gas on the oil. 0.04 mL of chloroform was added to the content of the tube and it was followed by the addition of 0.10 mL of chromogenic solution. The content of the tube was heated at a temperature of 100 °C in a water bath for about 1 min. The content was allowed to cool, 5 mL of the hexane was added and the tube with its content shook gently several times. The solvent and the aqueous layers were recovered and allowed to be separated. The hexane layer was recovered and allowed to be concentrated to 1.0 mL for gas chromatography using flame photometric detector. The conditions for phospholipid analysis include: H.P 5890 powered with HP ChemStation REV. A 09.01 (1206) and split injection ratio of 20:1, nitrogen as carrier gas, inlet temperature 250 °C, column type HP5, column dimension: 30 m × 0.25 mm × 0.25 µm, oven program: initial temperature at 50 °C, first ramping at 10 °C/min for 20 min, maintained for 4 min while second ramping at 15 °C/min for 4 min, maintained for 5 min. Detector: PFPD Detector temperature was 300 °C, hydrogen pressure being 20 psi, compressor air being 35 psi [9].

**Comment [AF11]:** This reference is not acceptable. it referred to another work which quoted Raheja et. al.(1973). These researchers used a colormetric method and UV analysis. For gas chromatography to be accepted as a method for phospholipids and sterols analysis, a standard method must be referenced. Liquid chromatography is the method for such analysis.

### 2.7 Phytosterols analysis

The phytosterol analysis was done as described by AOAC [7]. The aliquots of the extracted fat were added to the screw - capped test tubes. The samples were saponified at 90 °C for 30 min,

**Comment [AF12]:** Quote the exact method.

using 3 mL of 10% KOH in ethanol, to which 0.20 mL of benzene was added to ensure miscibility. Deionized water (3 mL) was added and 2 mL of hexane was added in extracting the non – saponifiable materials. Three different extractions, each with 2 mL of hexane were carried out for 1 h, 30 min and 30 min, respectively. The hexane was concentrated to 1 mL in the vial for gas chromatography analysis and 1 μL was injected into the injection pot of GC. The GC conditions of analyses were similar to the GC conditions for methyl esters analyses [9].

### 2.8 Statistical Analysis

Errors of three determinations were computed as standard deviation (SD) for the physicochemical parameters by using MS Excel Spread Sheet. The mean, standard deviation and coefficient of variation (%) for variability test on the kernel and pulp samples were also analyzed.

## 3. RESULTS AND DISCUSSION

### 3.1 Physicochemical properties

The result of physicochemical parameters of oils extracted from kernel and pulp of *B. aegyptiaca* is shown in Table 1. Acid value is a measure of the free fatty acids in oil. The higher the acid value found, the higher the level of free fatty acids which translates into decreased oil quality. Acceptable levels for all oil samples should be below 0.6 mg KOH/g [10]. Acid value is also used as an indicator for edibility of an oil and suitability for use in the paint and soap industries [11]. Acid value of the oil suitable for edible purpose should not exceed 4 mg KOH/g [12]. The acid values obtained from *B. aegyptiaca* kernel and pulp oils were 26.35 and 15.60 mg KOH/g, respectively. This is a bit higher than 22.3 mg KOH/g reported by [13]. However, the relative increase in the amounts of free fatty acid can be attributed to the method adopted in the seed processing, duration of storage or drying of the seeds. Acid value can also be increased due to relative rise in temperature during extraction, processing or storage. From the above study, the kernel oil (26.35 mg KOH/g) has high tendency of going rancid than the pulp oil (15.60 mg KOH/g). Also, none of the oil is suitable for food products but can be used for non-food products like paint, liquid soap, shampoos, etc. [12].

Peroxide value is used to quantify the extent to which rancidity reactions have occurred during storage. It could also be used as an indication of the quality and stability of fats and oils [14]. It

depends on factors such as state of oxidation, method of extraction and type of fatty acid present in the oil. *B. aegyptiaca* kernel and pulp oils have a peroxide value of 3.82 and 5.90 meq/kg. Both values fall within the FAO/WHO standard for vegetable oil which is <10 meq/kg. Zang [14] further confirmed in their work the value of 2.95 meq/kg for its kernel oil. The peroxide values are also very low, indicating that both oils would be stable to oxidative degradation. Rancidity begins to be noticeable when the peroxide value reaches 20 - 40 meq/kg. This value is higher than the values recorded for *Citrullus lanatus* (8.34 meq/kg) and *L. siceraria* (4.83 meq/kg) as reported by [4].

**Table 1: Physicochemical parameters of oils extracted from *Balanites aegyptiaca* kernel and pulp**

| Parameter | *Balanite aegyptiaca* | | Mean | SD | RSD |
|---|---|---|---|---|---|
| | Kernel | Pulp | | | |
| Acid value (mg KOH/g) | 26.35±0.05 | 15.60±0.12 | 20.98 | 5.38 | 25.64 |
| Peroxide value (Meq/Kg) | 3.82±0.17 | 5.90±0.08 | 4.86 | 1.04 | 21.40 |
| Iodine value (mg $I_2$/g) | 55.20±0.46 | 142.50±0.09 | 98.85 | 43.65 | 44.16 |
| Saponification value (mg KOH/g) | 162.40±0.07 | 198.60±0.15 | 180.50 | 18.1 | 10.03 |
| Specific gravity @ 25 $^oC$ | 0.93±0.16 | 0.92±0.35 | 0.93 | 0.0071 | 0.77 |
| Kinematic viscosity @ 30 $^oC$ (St) | 2.12±0.21 | 1.65±0.28 | 1.89 | 0.24 | 12.70 |
| Refractive index @ 40 $^oC$ | 1.41±0.31 | 1.39±0.16 | 1.40 | 0.01 | 0.71 |

SD = Standard deviation; RSD = Relative standard deviation

Saponification value (SV) indicates the average molecular weight and hence, chain length. It is inversely proportional to the molecular weight of the lipid [15]. Saponification value obtained in this work was 162.40 mg KOH/g for kernel and 198.60 mg KOH/g for pulp. This value for seed is lower than that reported by [16]. High saponification values indicate high proportion of lower fatty acid. This high value indicates that the oil could be used in the manufacture of soap [17]. However, the saponification value was much lower than 242 mg KOH/g in *B. aegyptiaca* reported by [13]. The result for the kernel oil is below Codex standard for cotton oil (189 - 198 mg KOH/g), soybean oil (189 - 195 mg KOH/g), corn oil (187 - 195 mg KOH/g) and peanut oil (187 - 196 mg KOH/g) while that of corresponding pulp oil is slightly above the standard [18], but lower than the 246.60 for African pear seed oil, 227.49 for groundnut seed oil and 224.40 for

shea butter tree seed oil [19, 20]. Oil fractions with saponification values of 200 mg KOH/g and above, had been reported to possess low molecular weight fatty acids [11]. The result for the kernel oil of *Balanites aegyptiaca* obtained in this work is less than that of [14] kernel oil which was 200.02 mgKOH/g. Both values are within the range of 195–205 mg KOH/g for edible palm oils [21]. The saponification value of oil is used to determine the suitability of the oil for soap making.

Iodine value is the number of milligrams of iodine absorbed by one-gram fat and it gives an indication of the number of double bonds in any particular oil or fat. Lipids with poly unsaturated fatty acids are easily assimilated and broken down to produce calorific energy than saturated fatty acids. Also, lipids with high iodine value have low stability because it can easily undergo oxidation. However, the iodine values for the seed and pulp of *B. aegyptica* were 55.20 and 142.50 mg $I_2$/g respectively. Oils with iodine value above 125 mg of I/100 g are classified as drying oils; those with iodine value 110 – 125 mg of I/100 g are classified as semidrying oils. Those with iodine value less than 110 are considered as nondrying oil [11]. Thus, the kernel oil of *B. aegyptiaca* has a partial level of unsaturation and it is classified as nondrying oil, while the pulp oil of *B. aegyptiaca* has high iodine value, it is classified as drying oil and can easily undergo oxidation when compared with that of the kernel oil. Hence, the pulp oil of *B. aegyptiaca* is of great interest to paint and coating industry since it is a drying oil. The differences in iodine values between pulp and seed oil samples may be due to the different fatty acid compositions [9].

Density or specific gravity of oil is related to its fatty acid composition and minor components. An oil with low density value means it contains low molecular weight fatty acids; likewise, it will have high saponification value, making it suitable for use in soap production [12, 15]. The values of specific gravity of the extracted kernel and pulp oils were 0.93 and 0.92 $gcm^{-3}$ respectively. The result indicates that the studied oils are less dense than water (1 $gcm^{-3}$) and therefore would be useful in cream production as it will make the oils flow and spread easily on the skin. The low specific gravity of *B aegyptiaca* oils implies good shelf-life characteristics [9].

The viscosities of the investigated oils were 2.12 and 1.65 in kernel and pulp oils, respectively. Oils with low viscosity value indicate that they are light and so probably highly unsaturated.

Kinematic viscosity increases with fatty acid chain length and with increasing degree of saturation of either the fatty acid or alcohol moiety in a fatty ester [22].

The refractive index of oil is a function of molecular structure and impurity. Refractive index provides a quick and easy method to identify oil and determine its purity [1]. The refractive index values of kernel and pulp oils of *B. aegyptiaca* were 1.41 and 1.39, respectively (Table 1). Both are slightly lower than the value obtained for *B. sapida* (1.46) [23] and 1.45 obtained for *C. lanatus* [24]. This shows that the oil is not as thick as most drying oils whose refractive index are between 1.48 and 1.49 [25]. Also, the above result agrees with the refractive indices of many vegetable oils. Hence both oils cannot be easily adulterated [26].

**3.2 Fatty Acid Composition**

The results of fatty acids composition of *Balanites aegyptiaca* indicate that the seed oil has the highest content of oleic acid (C18:1) of 38.27% while linoleic acid has the highest content in the pulp (33.56%). This was confirmed by [14] that the kernel oil of *B. aegyptiaca* is good and edible quality with highest percentage of fatty acids. The oil contains mainly palmitic, stearic, oleic and linoleic acids which were the main fatty acids. It was also observed that the oils contained significant amount of unsaturated fatty acids of 76.17% and 62.72% for the kernel and pulp oils of *B. aegyptiaca*. Elhardallou [27] reported that omega-3 and omega-6 essential fatty acids are present in the kernel and pulp oil. The mono and polyunsaturated fatty acids together account for 75.29% and 62.31% of the total fatty acids composition in the kernel and pulp oils of *B. aegyptiaca.* Palmitic acid (C16:0) was found to be predominant saturated fatty acid (SFA) in the oil samples with values of 14.53% (kernel) and 32.70% (pulp). The observed values of palmitic acid are in agreement with the reported data of some leguminious plant seeds such as *C. lanatus* (17.71%) and 19.15% for *T. cucumerina* seed oils, 20.87% for *G. jasminoide* and 25.37% for *H. barteri*, respectively [11, 28, 29]. It is one of the most common saturated fatty acids found in cheese, milk, butter, animals and plants and it is an antioxidant, a nematicide used in making soups. Some studies have indicated the various impacts of SFAs on the human health. It has been concluded that lauric acid (C12:0) as well as myristic acid (C14:0) raise plasma total cholesterol concentrations, due to an increase in low-density lipoprotein (LDL) cholesterol and the rise of both LDL and high-density lipoprotein (HDL) cholesterol concentrations, respectively [30]. Conclusively, Saed and Isam [31] asserted that the oil exhibited anticancer activity against

lung, liver, and brain human carcinoma cell lines. It also had antimutagenic, antiviral and antimicrobial activities against the selected microorganisms.

**Table 2: Fatty acids composition (%) of oils extracted from *B. aegyptiaca* kernel and pulp**

| | ***B. aegyptiaca*** | | | | |
|---|---|---|---|---|---|
| **Fatty Acid** | **Kernel (%)** | **Pulp (%)** | **Mean** | **SD** | **RSD** |
| C14:0 | 0.5584 | 0.2760 | 0.4172 | 0.14 | 33.56 |
| C16:0 | 14.5298 | 32.6959 | 23.6129 | 9.08 | 38.45 |
| C16:1 | 0.2232 | 3.3708 | 1.797 | 1.57 | 87.37 |
| C17:0 | 0.0946 | 0.0479 | 0.07125 | 0.02 | 28.07 |
| C18:0 | 2.5414 | 2.4475 | 2.4945 | 0.05 | 2.01 |
| C18:1 | 38.2664 | 16.7998 | 27.5331 | 7.73 | 28.08 |
| C18:2 | 35.6483 | 33.5614 | 34.6049 | 1.04 | 3.01 |
| C18:3 | 0.3535 | 8.2075 | 4.2805 | 3.93 | 91.81 |
| C20:0 | 3.7237 | 0.6708 | 2.1973 | 1.53 | 69.63 |
| C20:4 | 0.1528 | 0.0728 | 0.1128 | 0.04 | 35.46 |
| C22:0 | 0.8809 | 0.4190 | 0.6500 | 0.23 | 35.39 |
| C22:1 | 0.6414 | 0.3035 | 0.4725 | 0.17 | 35.98 |
| C24:0 | 2.3856 | 1.1269 | 1.7563 | 0.63 | 35.87 |
| **Total** | **100** | **100** | | | |
| TSFA | 24.71 | 37.69 | | | |
| TSFA% | 24.71 | 37.69 | | | |
| TMUFA | 39.13 | 20.47 | | | |
| TPUFA | 36.16 | 41.84 | | | |
| TUFA | 75.29 | 62.31 | | | |
| TUFA% | 75.29 | 62.31 | | | |
| TEFA | 36.00 | 41.77 | | | |
| TNEFA | 64 | 58.23 | | | |
| O/L ratio | 1.07 | 0.50 | | | |
| P/S ratio | 1.46 | 1.11 | | | |
| n-6/n-3 ratio | 100.84 | 4.10 | | | |

SD = Standard deviation; RSD = Relative standard deviation; TSFA = Total saturated fatty acid; TMUFA = Total monounsaturated fatty acid; TUFA = Total unsaturated fatty acid; TEFA = Total essential fatty acid; TNEFA = Total non-essential fatty acid; O/L = Oleic/linoleic ratio;

TPUFA = Total polyunsaturated fatty acid; n-6/n-3 = linoleic (n-6)/α–linolenic (n-3) ratio, P/S = Polyunsaturated fatty acid/saturated fatty acid.

**Table 3: Phospholipid levels (mg/100 g) of oils extracted from *B. aegyptiaca* kernel and pulp**

| Phospholipid | *B. aegyptiaca* | | | | |
|---|---|---|---|---|---|
| | **Kernel(%)** | **Pulp (%)** | **Mean** | **SD** | **RSD** |
| Phosphatidylethanolamine | 60.7143 | 14.8041 | 37.7592 | 22.96 | 60.81 |
| Phosphatidylcholine | 75.9861 | 25.8781 | 50.9321 | 25.05 | 49.18 |
| Phosphatidylserine | 1.6674 | 3.4593 | 2.5634 | 0.90 | 35.11 |
| Lysophosphatidylcholine | 0.1254 | 1.6324 | 0.8789 | 0.75 | 85.33 |
| Sphingomyelin | 0.2232 | 2.1897 | 1.2065 | 0.98 | 81.23 |
| Phosphatidylinositol | 61.3159 | 5.6803 | 33.4981 | 27.82 | 83.05 |
| Phosphatidic Acid | 58.7798 | 0.0695 | 29.4247 | 29.36 | 99.78 |
| **Total** | **258.8121** | **53.7134** | | | |

SD = Standard deviation; RSD = Relative standard deviation

### 3.3 Phospholipids Composition

The result of phospholipids is displayed in Table 3. Phosphatidylcholine (PC) which is also known as lecithin has the highest abundance in both the kernel and pulp of *B. aegyptiaca* that is 75.99% and 25.88% respectively. This abundance is in line with the assertion of [32] that PC is the most abundant phospholipid of cell membranes therefore it is the most important building block for making replacement membrane mass. PC is highly effective nutraceutical for recovery of the liver following toxic or chronic viral damage. Phosphatidylinositol (PL) having the second most abundance of 61.32% for kernel oil and 5.65% for pulp oil as the third most abundant. Aremu and Ibrahim [33] stated that PL plays a key role in the membrane recruitment and/or activation of proteins. Also, from the above result phosphatidylethanolamine (PE) has the third most abundance of 60.71% for the kernel oil and second most abundance of 14.80% for its pulp oil. PE is a major phospholipid in nervous tissue such as the white matter of brain, neural tissue, nerves and in spinal cord. It is also the most abundant lipid on the cytoplasmic layer of cellular

membranes, with significant roles in cellular processes such as membrane fusion, cell cycle, autophagy and apoptosis [33].

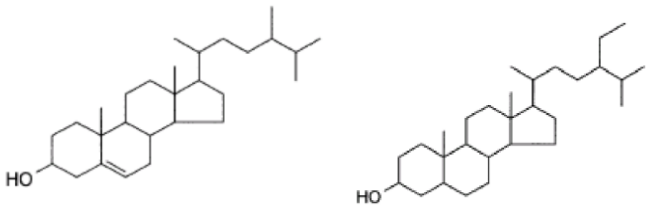
**Table 4. Phytosterol levels (mg/100 g) of oils extracted from *B. aegyptiaca* kernel and pulp**

| Sterol | *B. aegyptiaca* | | | | |
|---|---|---|---|---|---|
| | **Kernel(%)** | **Pulp (%)** | **Mean** | **SD** | **RSD** |
| Cholesterol | 0.05797 | 0.02174 | 0.03986 | 0.02 | 50.17 |
| Cholestanol | 0.05193 | 0.02926 | 0.0406 | 0.01 | 24.63 |
| Ergosterol | 0.02420 | 0.003822 | 0.01401 | 0.01 | 71.38 |
| Campesterol | 16.1088 | 1.6207 | 8.8648 | 7.24 | 81.67 |
| Stigmesterol | 8.6904 | 1.0692 | 4.8798 | 3.81 | 78.08 |
| 5-Avenasterol | 0.3091 | 0.1821 | 0.2456 | 0.06 | 24.23 |
| Sitosterol | 84.9972 | 9.8660 | 47.4316 | 37.57 | 79.21 |
| **Total** | **110.2396** | **12.79285** | | | |

SD = Standard deviation; RSD = Relative standard deviation

### 3.4 Phytosterols Composition

As shown in Table 4, the total phytosterol concentrations of the studied samples were 110.24 and 12.79 mg/100 g for kernel and pulp oils, respectively. The most abundant plant phytosterols for both the kernel and pulp oils were sitosterol, campesterol and stigmasterol with concentrations of 85.00, 8.70 and 16.1 g/100 g for the seed oil; 9.87, 1.62 and 1.07 respectively for the pulp oil. The above result was further confirmed by [34]. Despite the fact the concentrations of sitosterol, campesterol and stigmasterol are the highest in both the kernel and pulp oil, the concentration of the kernel oil is by far higher than that of the pulp oil. The RSD varied from 24.23 in 5–avenasterol to 81.67 in campesterol.



Sitosterol Campesterol

According to Aremu *et al.* [34] who cited Piironen [35] in his work, stated that the daily dietary intake of plant sterols among populations varies, that is between 160 - 400 mg for an average person eating vegetables, and 750 mg per day for a person eating a vegetarian diet. This would provide a significant lowering of cholesterol in the body. Besides their cholesterol lowering effect, phytosterols also have antifungal activity, protect ulcers, and act as anti-inflammatory agent, antioxidative agent and anti-atherosclerosis agent. The intake of phytosterols is beneficial to prevent or treat many different types of cancer including breast, prostate, lung, esophagus, stomach, endometrial, and ovary [33]. Therefore, oil extracted from the kernel of *B. aegytiaca* sample will be a very good source of dietary phytosterols. Thus, plant sterols are readily recommended as adjustments to diet and as dietary agents that can lower risk of cardiovascular disease, render anti-atherogenic effect, preserve oxidative stress, and adjust or normalize endogenous cholesterol uptake.

## 4. CONCLUSION

Vegetable oils are sources of important fatty acids (SFAs, MUFAs, and PUFAs), phospholipids and phytosterols. The study was focused on analyzing the physicochemical parameters of kernel and pulp of *Balanitess aegytiaca* as well as *the* fatty acid composition, phospholipid and phytosterol contents of *Balanites aegyptiaca;* so as to provide useful information on the potentiality of the above parameters to serving as components of a healthy lifestyle, to reduce plasma low-density lipoprotein cholesterol (LDL-C) levels, and thereby lower cardiovascular risk. From these results, it could be concluded that the kernel and pulp oils of *B. aegytiaca* analyzed is good for food and industrial purposes. Since it contains a high level of PUFAs and that of phospholipids (PLs) and phytosterols (PS) are important components of the cell membranes of all living species which contribute to the physicochemical properties of the membrane and thus influence the conformation and function of membrane-bound proteins. *Balanites aegytiaca* kernel and pulp oils have the potential to substitute several materials used to manufacture oil in the chemical industry. However, in order to extend usage, these oils should be refined to improve the taste and colour.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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