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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This work is aimed at investigating physicochemical parameters and compositions of fatty acid, phospholipid and sterol of desert date (*Balanites aegyptiaca*) kernel and pulp.
Study Design: *Balanites aegyptiaca* fruit is one of the oldest feed-stocks in Africa of which little or no attention has been given to it. 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 research interest as a result of its 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

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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 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 higher in the pulp oil (2.47). Phosphatidylcholine had the highest content in both oils that is 75.99 and 25.88 mg/100 g, respectively. The total values of 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 in order to improve the colour and taste.

Keywords: Balanites aegyptiaca; fatty acids; phospholipids; physicochemical parameters; phytosterols.

1. INTRODUCTION

"Plant seeds have caloric and nutritive values which make them necessary in diet and their oils are important sources of oils of industrial and nutritional importance. Fats make a meal more satisfying, enrich its flavour and delay the onset of hunger. This is simply because they contain essential nutrients that play important role in human nutrition. Also there are non–edible applications of plants oil and some of them are biodiesel, cosmetics, soap production, lubricants and insulating materials" [1].

"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" [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]. "*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".

2. MATERIALS AND METHODS

2.1 Collection of Samples

The fruits of desert date (*Balanites aegyptiaca*) were collected directly from a farmer in Bantaje village under Wukari local government area, Taraba State, Nigeria in June 2019. The good fruits were separated from the bad ones before washing with tap water. The clean fruits were taken to the Biology laboratory of Federal University Wukari for proper identification by a Botanist.

2.2 Preparation of Samples

Sixty number clean fruits of *B. aegyptiaca* were dried in an oven at 50 °C for 4 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 40 °C for 42 h and ground into powder. Flours of the two samples were separately kept in the refrigerator at -4 °C prior to use.

2.3 Extraction of Oils

The reagents and apparatus used for the extraction were: Condenser Soxhlet extraction unit, oven, desicator, weighing balance, thimble, heating mantle, glass wool, no 4 filter paper, 250 ml capacity boiling flask and petroleum ether (40 – 60 ^{o}C). 250 ml capacity extracting flask was dried in the oven at 105 ^{o}C, transferred to the desicator to cool to the laboratory temperature and the weight of the flask was measured. Each oven dried sample of kernel and pulp (2.5 g each) of *B. aegyptiaca* was weighed into the labeled porous thimble. 200 ml of the petroleum ether was measured and then added to the dried 250 ml capacity flask. The covered porous thimble with the sample was placed in the condenser of the Soxhlet extractor arrangement that has been assembled. The sample was extracted for 5 h. The porous thimble was removed with care and the petroleum ether in the top container (tube) was collected for the recycling for reuse. The extraction flask was removed from the heating mantle arrangement when it was almost free of petroleum ether. The extraction flask with the oil was cooled in the desicator and the weight of the cooled flask with the dried oil was measured. AOAC Official Method 920.39 (A) [7]. All chemicals are of Analar grade (British Drug Houses, London).

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]. Three determinations were carried out on each sample.

2.5 Fatty Acid Analysis

"The 50 mg of oil extracted from each sample of *B. aegyptiaca* was esterified (saponified) for 5 min at 95 °C using the method described by some workers" [8]. This was done 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 which was then heated for 5 min at 90 °C to achieve complete methylation process. The fatty acid methyl esters (FAME) were extracted thrice from the mixture with redistilled n–hexane. The content was concentrated to 1 ml for GC analysis and 1 µm was injected into the injection port of GC. The GC conditions were:

(i) GC: HP 6890 gas chromatograph powered with HP Chemistation Rev. a 09.01 (1206) software fitted with a flame ionization detector and a computing integrator.
(ii) Injection temperature: 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.
(iii) Split injection ratio: 20:1.
(iv) Carrier gas: Nitrogen.
(v) Column type: A polar HP INNOWax.
(vi) Column dimensions: 30 m × 0.53 mm × 0.25 µm) was used to separate the esters.
(vii) Detector: FID.
(viii) Detector temperature: 320 °C.
(ix) Hydrogen pressure: 22 psi.
(x) Compressed air: 35 psi.

"The peaks were identified by comparison with standard FAME obtained from Sigma Chemical Co. (St. Louis MO, USA)" [8]. However, the quantitative evaluation was carried out on the basis of GC peak areas of the different methyl esters. The heptadecanoic ester was used to calculate the response factor for fatty acid which was found to be 0.96.

2.6 Phospholipids Analysis

The phospholipids content of the kernel and pulp oils of *B. aegyptiaca* were analyzed using GC. 0.01 g of the extracted oil 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 chromo–genic solution. The content of the tube was heated at a temperature of 100 °C in a water bath for about 1 min 20 s. The content was allowed to cool to the laboratory temperature and 5 mL of the hexane was added. The tube with its content was shaken gently several times. The solvent and the aqueous layers were allowed to be separated. The hexane layer was recovered and allowed to be concentrated to 1.0 ml for GC analysis using pulp flame photometric detector. The GC conditions were:

(i) GC: HP 5890 gas chromatograph powered with HP Chemistation Rev. a 09.01 (1206) software fitted with a flame ionization detector and a computing integrator.
(ii) Injection temperature: 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.
(iii) Split injection ratio: 20:1.
(iv) Carrier gas: Nitrogen.
(v) Column type: A polar HP5 INNOWax.
(vi) Column dimensions: 30 m × 0.25 mm × 0.25 µm) was used to separate the esters.
(vii) Oven programme: Initial temperature at 60^{o}C; First ramping at 10^{o}C/min for 20 min and maintained for 4 min; Second ramping at 15^{o}C/min for 4 min and maintained for 5 min.
(viii) Detector: PFPD.
(ix) Detector temperature: 300 °C.
(x) Hydrogen pressure: 20 psi.
(xi) Compressed air: 35 psi. [9].

2.7 Phytosterols Analysis

"The phytosterol extraction and analysis were carried out by following Official Methods AOAC 994.10 and AOAC 970.51" [7]. Each of oven dried sample of *B. aegyptiaca* (5.00 g) was weighed and transferred to Stoppard flask and treated with petroleum ether until the powdered sample was fully soaked. The flask was shaken every 1 h for the first 6 h and then it was kept aside and shook after 24 h. This process was repeated for 3 days and then the extract was filtered. The extract was collected and evaporated to dryness by using nitrogen stream. 0.5 g of the extract from the sample was added to the screw–capped test tube. The sample was saponified at 95 °C for 30 min by using 3 ml of 10% KOH in ethanol to which 0.20 ml of benzene had been added to ensure miscibility. 3 ml of de–ionized water was added and 2 ml of hexane was used in extracting the non–saponifiable materials e,g sterols. Three extractions, each with 2 ml of hexane were carried out for 1 h, 30 min and 39 min, respectively to achieve complete extraction of the sterols. The hexane was concentrated to 2 ml in Agilent vial for GC analysis [9]. The GC conditions were:

(i) GC: HP 6890 gas chromatograph powered with HP Chemistation Rev. a 09.01 (1206) software fitted with a flame ionization detector and a computing integrator.
(ii) Injection temperature: 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.
(iii) Split injection ratio: 20:1.
(iv) Carrier gas: Nitrogen.
(v) Column type: A polar HP INNOWax.
(vi) Column dimensions: 30 m × 0.25 mm × 0.25 µm) was used to separate the esters.
(vii) Oven programme: Initial temperature at 60^{o}C; First ramping at 10^{o}C/min for 20 min and maintained for 4 min; Second ramping at 15^{o}C/min for 4 min and maintained for 10 min.
(viii) Detector: FID.
(ix) Detector temperature: 320 °C.
(x) Hydrogen pressure: 22 psi.
(xi) Compressed air: 35 psi.

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 relative standard deviation 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].

"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].

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

Parameter	[a]*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

[a]*Values are means ± standard deviations of three determinations; SD = Standard deviation; RSD = Relative standard deviation*

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

Fatty Acid	*B. aegyptiaca*		Mean	SD	RSD
	Kernel (%)	Pulp (%)			
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			

Fatty Acid	*B. aegyptiaca*		Mean	SD	RSD
	Kernel (%)	Pulp (%)			
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			

FA = Fatty acids; US = Unsaturated; MU = Mono–unsaturated; PU = Poly–unsaturated; E = Essential; NE = Non–essential; O = Oleic; L = Linoleic; T = Total.

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

Phospholipid	*B. aegyptiaca*		Mean	SD	RSD
	Kernel(%)	Pulp (%)			
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**			

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

Sterol	*B. aegyptiaca*		Mean	SD	RSD
	Kernel(%)	Pulp (%)			
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**			

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

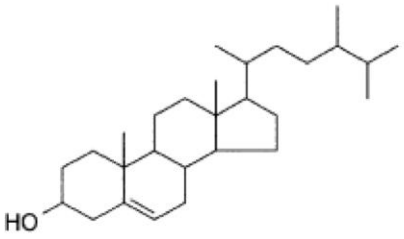
health. It has been concluded that lauric acid (C12:0) as well as myristic acid (C14:0) raise plasma total cholesterol concentrations, due to an increase in low-density lipoprotein (LDL) cholesterol and the rise of both LDL and high-density lipoprotein (HDL) cholesterol concentrations, respectively" [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".

3.3 Phospholipids Composition

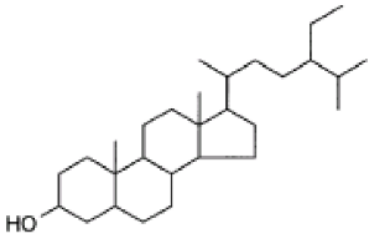
"The result of phospholipids is displayed in Table 3. Phosphatidylcholine (PC) which is also known as lecithin has the highest abundance in both the kernel and pulp of *B. aegyptiaca* that is 75.99% and 25.88% respectively. This abundance is in line with the assertion of" [32] "that PC is the most abundant 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].

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

The study was focused on analyzing the physicochemical parameters of kernel and pulp of *Balanitess aegytiaca* as well as the fatty acid,

phospholipid and phytosterol contents of the two different 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. It was revealed that the kernel and pulp oils of *B. aegytiaca* analyzed were good for food and industrial purposes because it contained a high level of MUFA and PUFAs. The high levels of PLs and PSs especially in the kernel of *B. aegytiaca* are as good as 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.

DISCLAIMER

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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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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