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Physicochemical Properties And Fatty Acids Composition Of Sudanese Baobab (*Adansonia Digitata* L.) Seed Oil

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Abstract: Baobab (*Adansonia digitata*) is a widespread tree species of the genus Adansonia, native to the African continent. The tree has multi-purpose uses, as it produces food and non-food products such as medicines and fuel. The global demand for baobab raw material for industrial applications has increased dramatically in recent years, thereby increasing their commercial value and importance. The aim of this study was to characterize the physicochemical properties and fatty acid composition of *A. digitata* seed oil. The oil is extracted by Soxhlet using n-hexane. The physicochemical properties of the seed oil were assessed by standard and established methods. The fatty acid composition of the seed oil was determined by GC-MS. The reddish yellow with characteristic odor oil obtained from the seeds had the following physicochemical properties: yield, 33.83%; melting point, 8 °C; boiling point, 227 °C; refractive index (25 °C), 1.436; iodine value, 98.3 g/100 g of oil; peroxide value, 4.3 meq. O_2/kg of oil; free fatty acids, 0.34%; acid value, 6.8 mg of KOH/g of oil; saponification value, 180.7 mg KOH/g of oil; unsaponifiable matter, 1.7; moisture and volatile value, 14.79 (wt%); density, 0.867 g/cm^3; viscosity, 35.03 mm^2/s; specific gravity, 0.874. The fatty acids composition showed that linoleic acid (30.63%) was the major fatty acid and followed by oleic- (23.34%), palmitic- (22.87%), stearic- (5.89%), malvalic- (5.52%), cis-10-nonadecenoic- (2.67%), sterculic- (1.61%) and arachidic acid (1.43%). Therefore, more and advanced research should be undertaken for this abundant source of natural oil for possible industrial applications.

Keywords: *Adansonia digitata*, seed oil, extraction, oil yield, physicochemical, fatty acids composition

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1. INTRODUCTION

Baobab (*Adansonia digitata* L.) is a large iconic tree indigenous to Africa and found in many countries.[1]The trees are tolerance to high temperatures and long spans of drought and are grown for their sour fruit and leaves. The fruit consists of pulp and large seeds embedded in the dry acidic pulp and shell. [2] Baobab (*A. digitata* L.) in Sudan called "Tebeldi" and found on sandy soils and seasonal streams in low grassland Savannas. It forms belts in different regions such as Kordofan, Darfur, Blue Nile and Central Sudan.[3] Baobab products such as fruits, seeds, leaves, bark contribute to the livelihood of many populations in Africa as it is a source of food, fiber and medicine.[1] Seed oils (fixed oils) have been used by various societies as nutrition; medicine, cosmetics, and fuel.[3] They are a form of triglycerides that are non-polar and preferred to be extracted by non-polar solvent such as hexane or ether. Various fatty acids were reported to be present in seed oils with correlation of numerous biological activities as well as raw materials and feed stocks in industries.[4,5] However, other parameters on the physicochemical properties of the oil were also testified and proven to be influencing the choice of industry, for example, in the production of skin protector and biodiesel.[6] The geographical variation, environmental conditions and the storage being one of the key factors that impact the physicochemical properties of the plant oil.[5,7] In recent years, due to industry seeks natural alternatives; demand for seed oils as ingredients for food, cosmetics and biofuel has been greatly increased.[2] The utilization of oil for various applications are largely determined by the yield, composition, physical and chemical properties of the oil.[8] So far, the Sudanese baobab seed oils are not been sufficiently investigated to determine their properties and subsequently classified into classes in order to suit world market requirements, especially if it is to be commercially produced in Sudan as potential sources for export. Therefore, this study aimed to determine the physicochemical properties and fatty acid composition of Sudanese *A. digitata* seed oil to increase the economic feasibility of future commercial cultivation and products of this tree.

2. MATERIALS AND METHODS

2.1 Plant Material

A. digitata seeds were obtained on 15 October 2017 from College of Forestry and Range Science, Sudan University of Science and Technology, Khartoum, Sudan. The seeds were dried and grinded into coarse powder by using electrical blender (Panasonic, Japan). Prior to grinding, the percentage moisture content of the plant materials were analyzed via moisture content analyzer. The samples were sealed and kept in a desiccator to avoid any fungal activities.

2.2 Solvent Semi-Continuous (Soxhlet) Extraction Method

The fixed oil (seed oil) was extracted via Soxhlet by using n-hexane and mild extraction temperature was chosen to avoid thermal degradation.[9] The crushed seeds were placed in the drying oven at 40 °C for 30 min prior extraction. The seeds were loaded in the thimble of Soxhlet apparatus and the bottom part was fitted to 500 mL round bottom flask. Sufficient amount of absolute n-hexane was added into the flask and the top part of the Soxhlet was fitted with a condenser. Constant heat was applied through the heating mantle and the extraction was conducted for a minimum extraction of 6 h to make sure the maximum oil was extracted. After complete extraction and cooling, the obtained oil was filtered through filter paper. The solvent was evaporated via rotary evaporator, further dried under open air in a dark area. The yield of the oil was calculated and stored in hermetically closed dark bottles and kept in a refrigerator for further physicochemical study.

2.3 Physicochemical Characteristics of A. digitata Seed Oil

2.3.1 Lipid Content Determination

The lipid content of the oil was calculated based on dry seed weight (50 g) that were used in the extraction and expressed in percentage. The mass (g) of the obtained oil was recorded using experimental balance (Mettler Toledo, Switzerland) with an accuracy of ± 0.001 g and the lipid content was calculated according to the following equation.

$$\% \text{ Lipid} = \frac{\text{Weight of oil (g)}}{\text{Weight of sample (g)}} \times 100\%$$

2.4 Physical Properties of Seed Oil

The physical characters were studied according to eight different aspects as physical state, color, odor, density, freezing-, melting-, boiling points and refractive Index (RI). The methods of the analysis are explained in detail accordingly in the following subtopics.

2.5 Physical State, Color, Odor, Freezing-, Melting- and Boiling Points Determination

Physical state at room temperature of 25 °C and color of the oil were determined visually whereby odor was determined by means of sensation through volatilized smell. For freezing point, the oil was filled in a clear glass vial, a thermometer was immersed into the oil and the oil was solidified through the usage of ice blocks. The solidification temperature was recorded as freezing point. The solidified oil was melted over a water bath at a temperature of 29 °C and the melting point was recorded. Again, around 10 mL of oil was filled in a clear glass vial and a thermometer was inserted. The vial was exposed to heat on a heating mantle and the oil was observed, whereby it starts circulating leading to boiling. The temperature at this point was recorded at the boiling point.[10]

2.6 Density and Refractive Index (RI) Determination

The weight of a small empty vial was weighed and was filled with known amount of oil up to the brim. The vial was weighed again and the density was calculated as

$$\text{Density, } \rho = \frac{[\text{Weight of vial + oil (g)}] - [\text{Weight of empty vial (g)}]}{\text{Volume of oil}}$$

While the RI of the oil was determined by using standard method described by Jessinta[11] with slight modification. This index was measured at 25 °C via pen Refractometer (Atago, Japan) with resolution and accuracy value of 0.1% and ± 0.2% in 10-60 °C. The pen tip was dipped into the sample and the start key was pressed to obtain the reading. The measurement was repeated in triplicate and the average value was reported.

2.7 *Chemical Properties of Seed Oil*

Various chemical properties such as Acid Value (AV), Free Fatty Acid (FFA), Iodine Value (IV), Peroxide Value (PV), fatty acids composition and volatile matter were evaluated as follows

2.7.1 *Acid Value (AV) Analysis*

The AV was determined through direct titration method of oil in an alcoholic medium against standard potassium hydroxide via method described by Jessinta[11] with some modifications. A mass of 0.5 g of oil was weighed into a 250 mL conical flask and 50 mL of freshly neutralized hot ethyl alcohol and 1 mL of phenolphthalein indicator solution were added. The mixtures were boiled around 5 min and were titrated against standardized potassium hydroxide (0.24 M). The AV was then calculated according to the following equation.

$$\text{AV} = \frac{[56.1]\,[\text{Titration of standard (mL)}]\,[\text{Molarity of standard (M)}]}{\text{Weight of sample (g)}}$$

2.7.2 *Fatty Acids Composition, Percentage of Saturated and Unsaturated Fatty Acid Analysis*

The crude oil was analyzed as methyl ester to determine the fatty acid composition. The oil was converted into fatty acid methyl ester through transesterification reaction. A solution of KOH (Methanolic potassium hydroxide) (2 M) was prepared. An amount of 2 mL of oil sample was dissolved in 10 mL of hexane in a test tube. An amount of 1 mL of KOH was added into the same test tube and vortexed. The hexane phase was collected and washed twice with 4 mL of water after 15 min and further dried over anhydrous sodium sulphate. The fatty acids composition analysis was performed on Agilent Technologies 7890A GC Systems coupled with MS detector.[11] The details of chromatography equipment and settings are tabulated in Table 1. The individual fatty acids composition was expressed as a percentage. The percentages of saturated and unsaturated fatty acids were calculated by totaling the percentage of fatty acids detected via the analysis of fatty acid composition. The sum percentage of saturated fatty acids was represented as total saturated fatty acids, whereas the sum of all unsaturated (mono- and polyunsaturated) was represented as total unsaturated fatty acids.[11]

Table 1. Chromatographic settings for the analysis of *A. digitata* oil methyl ester

Parameters	Settings
Chromatograph	Agilent Technologies 7890A GC Systems coupled with MS detector
Auto-sampler	GC autosampler
Column	Nonpolar capillary DB-1 of 100% dimethyl-polysiloxane (30 m, 0.25 mm i.d, film thickness 0.25 µm)
Carrier gas	Helium
Gas flow rate	1 mL/min
Injector mode	Splitless mode
Injector temp.	250 °C
Injection volume	1µL/L
Temp. program	60 °C for 3 min, 240 °C at the rate of 3 °C/min and held for 10 min
Runtime	93 min
Lab data system	NIST Library Chem Station software

2.7.3 *Free Fatty Acid (FFA) Analysis*

Method described by Ouilly[12] with some modifications was adapted to determine the free fatty AV. An amount of 0.2 g of sample was weighted in 250 mL Erlenmeyer flask with the addition of 50 mL of hot neutralized alcohol and 2 mL of phenolphthalein indicator. The solution was swirled to dissolve and titrated with standard sodium hydroxide (0.24 M) until the first permanent pink color that persists for 30 s. The volume of titration required for the changes was recorded and the FFA percentage was calculated as follows:

$$\text{FFA as Oleic (\%)} = \frac{[\text{Titration volume of standard (mL)}]\,[28.2]}{\text{Weight of sample (g)}}$$

2.8 *Iodine Value (IV) Analysis*

The Iodine Value (IV) was determined through method described by Jessinta[11] with slight modification via Wijs reagent. An amount sample was filtered through a dry filter paper and 0.35 g of sample was transferred into a clean, dry, 500 mL glass-stoppered flask containing 20 mL of carbon tetrachloride, and 25 mL of Wijs solution was pipetted into

the flask. The mixture was swirled and allowed to stand in the dark for 30 min. Potassium iodide, 20 mL and recently boiled and cooled water, 100 mL was added and the mixture was titrated with sodium thiosulfate (0.11 M) until the yellow color almost disappears. Starch was added and the titration was continued until the blue color disappears entirely. Toward the end of the titration, the stoppered container was shaken violently so that any iodine remaining in solution in the carbon tetrachloride may be taken up by the potassium iodide. Blank determination was conducted in the same manner and condition and the IV was calculated by following equation.

$$IV = \frac{[\text{Titration of blank} - \text{sample (mL)}]\ [\text{Molarity of standard (M)}]\ (12.69)}{\text{Weight of sample (g)}}$$

2.9 Peroxide Value (PV) Analysis

Method described by Jessinta[11] with some modification was applied to determine the Peroxide Value (PV). An amount of 0.50 g of sample was weight into 250 mL of stoppered conical flask together with 30 mL of acetic acid-chloroform mixture and swirled to dissolve. The mixture was then added to 0.5 mL saturated potassium iodide and allowed to stand in dark with occasional shaking for 1 min and 30 mL of water were added. The liberated iodine in the mixture was titrated with sodium thiosulphate (0.11 M) with vigorous shaking until yellow color is almost gone. Then, 0.5 mL of starch indicator was added and titration was continued until the blue color disappears. The PV was expressed as milliequivalent of peroxide oxygen per kg sample (meq/kg) via the following equation.

$$PV = \frac{[\text{Titration of standard (mL)}]\ [\text{Molarity of standard (M)}]\ [100]}{\text{Weight of sample (g)}}$$

2.10 Moisture and Volatile Matter Analysis

Moisture and volatile matter were analyzed according to air-oven method of AOCS and method described by Jessinta[11]. About 5 g of oil was weighed on a previously dried and tarred dish. The dish was covered with loose lid and was heated in the oven at 105±1 °C for 1 h. The dish was removed from the oven, cooled in a desiccator and weighed. The plate was re-heated for the period of 1 h and the cooling and weighing process was repeated. The process was repeated until weight change between two observations does not exceed 1 mg. The following equation used to calculate the observations.

$$\%\ \text{Moisture and volatile matter} = \frac{[\text{Loss of material on drying (g)}]\ [100]}{\text{Weight of material taken for test (g)}}$$

2.11 Saponification Value Analysis

The saponification value of the oil sample was estimated using Official Method AOCS.[11] Accurately, 2 g of the oil sample was weighed into a 250 mL conical flask. An amount of 25 mL of potassium hydroxide KOH (N) added, then the flask and content was refluxed for one hour. Simultaneously, another conical flask containing only 25 mL of potassium hydroxide KOH (N) was prepared which served as a blank. The condenser connected and the content heated gently, but steadily for one hr. After the condenser and the flask has cooled, but not sufficiently to forming gel, the content washed with a small amount of water and the condenser was removed. Then a few drops of phenolphthalein solution added to the flask and the sample titrated with hydrogen chloride, HCl (0.5N) until the pink color disappeared. The volume of the hydrogen chloride was recorded and the saponification value expressed as following:

$$\text{Saponification value (SV)} = \frac{56.1(B\text{-}S) \times C \times N \text{ of HCl}}{\text{Weight of sample}}$$

Where, B and S are the volume of hydrogen chloride required by blank and sample, respectively, and N is the concentration of hydrogen chloride.

2.12 Unsaponifiable Matter Analysis

The unsaponifiable matter analysis was performed according to method described by Jessinta[11] with some modification. An amount of 50 mL of alcoholic potassium hydroxide was added into a conical flask containing 5 g of oil sample and were boiled under reflux conditions for one hr until a transparent medium is formed. The medium was then transferred into a separating funnel and were washed with petroleum ether allowing the layer to separate. The lower layer was collected and the top layer was continued washing for another 3 times with around 50 mL of solvent per wash. The ether extracts were combined and further washed with alcohol and water, 25 mL each. The ether solution was concentrated to 5 mL; then 2 mL of acetone was added with some heat under the water bath to remove the solvent and further dried at 100 °C for 30 min until a constant weight is obtained. Then the residue was dissolved in 50 mL of warm neutralized ethanol with phenolphthalein indicator and titrated with sodium hydroxide (0.02M). The weight of FFA and unsaponifiable matter values were calculated according to the following equations.

$$\text{Weight of FFA in the extract} = [0.282\ \text{Titration of standard (mL)}]\ [\text{Molarity of standard (M)}]$$

$$\text{Unsaponifiable matter} = \frac{100\ [(\text{Weight of the residue}) - (\text{Weight of free fatty acids in the extract})]}{\text{Weight of sample}}$$

3. STATISTICAL ANALYSIS

The Statistical analysis of the results was done using MS Excel (2007) - version 12.0.4518.1014. The results performed in three repetitions and expressed as mean ± standard deviation.

4. RESULTS AND DISCUSSION

4.1 Lipid Content, Physical State, Color and Odor of A. digitata Seed Oil

Table 2 shows various physicochemical properties of the *A. digitata* seed oil. In general, the results showed that *A. digitata* seed was found to be rich in oil with an average yield of 33.83% (w/w); and this value is represented in terms of lipid content, and the oil was highly unsaturated with a high FFA. The obtained oil is liquid at room temperature of 25 °C, reddish yellow in color with characteristic odor. The freezing, melting, boiling points, specific gravity and viscosity were -14 °C, 8 °C, 227 °C, 0.8741 and 35.03 mm^2/s, respectively. The obtained yield is agreeable with a literature stating that this plant's seed contains 22-45% oil on dry matter basis.[13-19] Previously, reported a golden yellow color for *A. digitata* seed oil and researchers revealed that the difference in the color intensity of oil from the same plant species, but from different location might be attributed due to the presence of various pigments such as the chlorophyll content.[20] The green color of the immature seeds disappears upon maturation resulting in chlorophyll retention. Besides, there is also a report stated that the presence of moisture contents at greater levels impacts the color of the oil, whereby the moisture rises the chlorophyll content and thus contribute in increment of color intensity.[21] The normal and thermal oxidation process of oil can also contribute towards the deterioration of lipids, and thus it might also influence the color changes of the oil.[20,22] From the Table 2 it can be seen that the viscosity of *A. digitata* seed oil is 35.03 mm^2/s which is consider high viscosity oil and it slightly lower than crude rubber seed oil (40.86 mm^2/s) and crude palm oil (38.1 mm^2/s). Therefore it is not advisable to use *A. digitata* seed oil directly as a fuel, because viscosity is an essential property that has to be monitor in a vegetable oil in order to meet the gasoline standard. Generally, vegetable oil is highly viscous. Even though there are suggestions made by some authors reporting the viability of running raw vegetable oil as an alternative fuel in a compression-ignition engines with slight modification and maintenance, but this will create problems related to long-term durability test due to high viscosity and low volatility of such oils. Especially at low temperatures, viscosity increases affecting the fuel fluidity, causing a disturbance in the injection of the fuel operation equipment. Furthermore high viscosity also promotes soot formation and deposition on the engines due to poor fuel atomization. In contrast high viscous oil has its own advantages also. They provide extra lubrication of the injector and also avoid leakage and exhaustion generated by fuel injection pumps that fits imprecisely resulted by low viscous oil.[23]

Table 2. Physicochemical properties of *A. digitata* seed oil

Parameters		Units	Experimental Values*
Lipid Content		%	33.83
Physical State at 25 °C		-	Liquid
Freezing point		°C	-14
Melting point		°C	8
Boiling point		°C	227
Color		-	reddish yellow
Odor		-	Characteristic
Specific gravity			0.8741
viscosity		mm^2/s	35.03
Density at 25 °C		g/cm^3	0.867
RI at 25 °C		-	1.436
AV (% FFA as oleic)		mg KOH/g	6.8
FFA	Linoleic	%	30.63
	Oleic	%	23.34
	Palmitic	%	22.87
	Stearic	%	5.89
	Malvalic	%	5.52
	cis-10-nonadecenoic	%	2.67
	Sterculic	%	1.61
	Arachidic	%	1.43
PV		meq O_2/kg	4.3
Moisture and volatile matter		wt %	14.79
Saponification value		mg KOH/g oil	180.7
Unsaponifiable matter		wt %	1.7
Total Saturated Fatty Acids		wt %	32.34
Total Unsaturated Fatty Acids		wt %	66.57

Values were recorded as mean average

4.2 Density of A. digitata Seed Oil

The density recorded for the oil of this study is 0.867 g/cm^3. Whereas, the literature had reported values ranged from 0.195 to 1.024 g/cm^3, that is, agree to the obtained result.[24] The density differs as the concentration of the wall material varies at which more heavy material fits into spaces between the particles and causes an increase in mass and thus contribute towards high density.[25]

4.3 Refractive Index (RI) of A. digitata Seed Oil

The RI value is acceptable according to the amount of unsaturated fatty acids and long chain hydrocarbon. The RI of the *A. digitata* seed oil is 1.436 and this is attributed by the amount of unsaturated fatty acid, length of the hydrocarbon chain, molecular weight and degree of unsaturation as well as conjugation.[26] Previously, reported that the RI for *A. digitata* seeds oil as 1.459.[19]

4.4 Acid Value (AV) of A. digitata Seed Oil

In addition, the AV is the relative measure of rancidity as FFAs that are formed during decomposition or hydrolysis of oil glycerides due to the action of moisture, temperature and/or lipolytic enzyme lipase. The AV obtained in this study is 6.8 mg KOH/g and this is high when compared to the studies recorded by Erwa[27] and Nkafamiya[19].Their reported values were 0.33 and 2.5 mg KOH/g, respectively. The oxidation and hydrolysis processes are also a factor that led towards increment in AV as the percentage of unsaturated fatty acids increase.[21]

4.5 Iodine Value (IV) of A. digitata Seed Oil

Among various factors of oil classification, the drying quality of the oil is also being considered, whereby it could be drying, semi-drying or non-drying oil through the analysis of the IV.[28] The IV for current study was 98.3 gI_2/100g; and it suggests that it is non-drying oil and it is comparable to the standard IV of less than 100 gI_2/100g in accordance with its physical state of being liquid at room temperature of 25 °C under expose air condition.[29] The low IV represents the fewer amounts of unsaturated bonds and thus the oil has fewer tendencies to go through oxidative rancidity.[21] Researchers reported IV for *A. digitata* ranged from 56 to 96 gI_2/100g which is almost closed to the result obtained in this study.[19]

4.6 Peroxide Value (PV) of A. digitata Seed Oil

On the other hand, the oil had also undergone some chemical decomposition process whereby the obtained PV is 4.3 meq O_2/kg, and this value is lower than that reported by Erwa *et al.*[3] which is 6.6 meq O_2/kg. The PV indicates the rancidity process whereby the higher the PV is the higher the oxidation level and the deterioration of lipids. Theoretically, oil that shows a high amount of PV is more prone to undergo rancidity that affects the total quality of the oil.[26]

4.7 Moisture and Volatile Matter of A. digitata Seed Oil

Besides that, the moisture and volatile matter analysis prove that the oil contains a high amount of moisture and volatile matter, whereby the value recorded is 14.79 wt%. The presence of water or moisture contributes towards hydrolysis in breaking up of triglycerides into glycerol and FFA. This process might be accelerated due to the presence of the action of lipase enzyme. Therefore, both oxidation and hydrolysis reduce the amount of unsaturated FFA and thus contributing towards the reducing of IV and average molecular weight and increasing in the AV.[21]

4.8 Saponification value and Unsaponifiable Matter of A. digitata Seed Oil

The saponification value (SV) using to know the amount of free fatty acids present in the oil, and amount of free fatty acids will estimate by determining the quantity of alkali that must be added to the fat to render it neutral. The SV for studied oil was 180.7 mg KOH/g of oil and it is agreeable to that reported in literature, which is 133 to 200 mg KOH/g of oil.[19,30] Unsaponifiable matter consists of constituents such as sterols, higher molecular weight alcohols, pigments, waxes, and hydrocarbon which do not react with bases during formation of soap. The value for unsaponifiable matter for the present seed oil was 1.7 wt % and it is closed to previously reported values of 2-3.8 wt%.[30] From the current results, it could be said that the oil had undergone some oxidation and hydrolysis process as indicated by the value of unsaturated fatty acids. This oxidation process might be influenced by storage of the oil, whereby the presence of air in the bottle is in contact with the oil surface. Thus, the oxidation process converts the triglycerides into peroxides and hydroperoxides. Moreover, researchers reported that the low value of unsaponifiable matter (< 2 wt%), for *A. digitata* seed oil could be suitable in the application of biodiesel production.[31]

4.9 Free Fatty Acids (FFA), Fatty Acid Composition, Percentage of Saturated and Unsaturated Fatty Acid of A. digitata Seed Oil

Table 3 shows the fatty acid composition of the *A. digitata* seed oil. Generally, fatty acid is a compound that contains carboxylic acids with long hydrocarbon chains,whichis a main constituent of seed oil and known to be a major parameter that differentiates the physicochemical properties of the seed oils. In this study, an amount of twenty three different fatty acids were detected and includes both saturated and unsaturated. The sequence arrangement according to the increasing percentage (>1%) of fatty acid is linoleic- (30.63%), oleic- (23.34%), palmitic- (22.87%), stearic- (5.89%), malvalic- (5.52%), cis-10-nonadecenoic- (2.67%), sterculic- (1.61%), arachidic acid (1.43%). The total percentage of fatty acid chains were 98.76 wt%. All the values are represented as the relative percentage area from the sum of all identified peaks. The overall results of this analysis show that the unsaturated fatty acid makes 66.42% of the compositions, whereby the monounsaturated fatty acids (MUFA) are 35.29 wt% and polyunsaturated fatty acids (PUFA) are 31.13 wt%; and the saturated fatty acids (SFA) were recorded to be the balance at the level of 32.34 wt%. The fatty acid balance of *A. digitata* seeds was 1.04:1.13:1.00 for saturated fatty acid (SFA):MUFA:PUFA which is close to the fat dietary guideline of the current National Cholesterol Education Program (NCEP) and American Heart Association (AHA) compared with other dietary vegetable oils such as palm, soybean oil, sesame, olive, and coconut oils.[32] The preponderance chain detected in the oil was the polyunsaturated linoleic acid with the weight percentage of

30.63%. Several studies have reported oleic acid (35.8%) as the dominance of *A. digitata* seed oil followed by linoleic acid (30.7%) and palmitic acid (24.2%). It was reported that *A. digitata* seed oil contained 17-22% saturated fatty acids (SFA), 32-38% monounsaturated fatty acids (MUFA) and 22-26% polyunsaturated fatty acids (PUFA). Palmitic acid (C16:0) was the most abundant SFA, while oleic (C18:1) and linoleic acid (C18:2) were the dominant MUFA and PUFA, respectively.[33] However, the obtained results were supported by other studies, that the major content was linoleic and followed by oleic acid. Komane[34] reported that the major fatty acids were linoleic- (36.0%), oleic- (25.1%) and palmitic acid (28.8%). Apraku[35] reported that the high content of the essential PUFA is noted to meet the requirements in human nutrition. Fatty acids that are needed for a better growth and nutrition and cannot be biosynthesize by the body and are necessary to be incorporated in diets are the essential FAs. The essential FAs are necessary for the skin regeneration, boosting the immune system and membrane cells functioning. It helps in the synthesis of eicosanoids which aids in renal, cardiovascular, reproductive process and also gastrointestinal functions and disease resistance. Overall, an author had stated that the various fatty acid composition of a same plant from different areas is varied due to its genetic make-up. The fatty acid profile could significantly change due to the storage and climatic conditions whether it could increase with period of storage, air, heat, traces of metal, peroxides, light, or double bonds present in the oil and thus leads towards the deterioration of the quality. *A. digitata* seed oil has reported to be one of the most suitable feedstocks for biodiesel production, according to the fatty acid methyl ester profile that becomes one of the key factors.[6] Therefore, most of the obtained results in this study were acceptable and similar to previous studies. In terms of the overall quality of oil, it is said that the quality decreases as the storage lifetime is longer and the factors that influences are the decrease in IV and RI; and also increase in acid number. As comparison with the past studies, there might be a slight difference in the physicochemical properties as few factors might have influenced such as the geographical origin and environmental condition of the plant, climate cultivation, soil composition, time of fruit harvesting and maturity and the drying process.[7]

Table 3. Fatty acid composition of *A. digitata* seed oil

Fatty Acid*	Formula	Systematic name	Structure	Composition (%)
Saturated				
Palmitic acid	$C_{16}H_{32}O_2$	Hexadecanoic acid	C16:0	22.87
Stearic acid	$C_{16}H_{36}O_2$	Octadecanoic acid	C18:0	5.89
Arachidic acid	$C_{20}H_{40}O_2$	Eicosanoic acid	C20:0	1.43
Myristic	$C_{14}H_{28}O_2$	Methyl tetradecanoate	C14:0	0.28
Behenic	$C_{22}H_{44}O_2$	Docosanoic acid	C22:0	0.64
Lignoceric	$C_{24}H_{48}O_2$	Tetracosanoic acid	C24:0	0.42
Margaric	$C_{17}H_{34}O_2$	Heptadecanoic acid	C17:0	0.28
Tricosylic	$C_{23}H_{46}O_2$	Tricosanoic acid	C23:0	0.12
Cyclopropaneoctanoic	$C_{21}H_{36}O_2$	Cyclopropane octanoic,	C21:0	0.23
Cerotic	$C_{26}H_{52}O_2$	Hexacosanoic acid	C26:0	0.10
Pentadecylic	$C_{15}H_{30}O_2$	Pentadecanoic acid	C15:0	0.08
Unsaturated				
Linoleic acid	$C_{18}H_{32}O_2$	9,12-octadecadienoic acid	C18:2	30.63
Oleic acid	$C_{16}H_{34}O_2$	9-octadecenoic acid	C18:1	23.34
Malvalic	$C_{18}H_{32}O_2$	Methyl2-propene-1-butyl-cyclo heptanoic acid	C18:1	5.52
Cis10- nonadecenoic	$C_{19}H_{36}O_2$	Cis-10-Nonadecenoic acid	C19:1	2.67
Sterculic acid	$C_{19}H_{34}O_2$	Methyl2-butyl cyclopropane-1-octanoic acid	C19:1	1.61
Elaidic	$C_{18}H_{34}O_2$	9-Octadecenoic acid(E)	C18:1	0.94
Cis-10-Heptadecenoic	$C_{17}H_{32}O_2$	Cis-10-Heptadecenoic acid	C17:1	0.48
8,11-Octadecadienoic	$C_{18}H_{32}O_2$	8,11-Octadecadienoic acid	C18:2	0.38
Gondoic	$C_{20}H_{38}O_2$	Cis-11-Eicosenoic acid	C20:1	0.37
Palmitoleic	$C_{16}H_{30}O_2$	9-Hexadecenoic acid	C16:1	0.36
Terephthalic	$C_9H_8O_4$	1,4-Benzenedicarboxylic acid	C9:3	0.10
7,10-Hexadecadienoic	$C_{16}H_{28}O_2$	7,10-Hexadecadienoic acid	C16:2	0.02

*The obtained results in terms of fatty acid methyl esters from GC-MS library data system was reviewed and the final results were listed out in the form of fatty acid chains.

5. CONCLUSION

In this study, the physicochemical properties and fatty acid composition of the Sudanese baobab (*A. digitata*) seed oil were assessed by standard and established methods. Based on the results of the study, the oil properties are interesting and promising for several applications. The overall results of this analysis show that the oil content was 33.83%; major fatty acid compositions were linoleic acid (30.63%) and followed by oleic acid (23.34%), palmitic acid (22.87%), and stearic acid (5.89%). The unsaturated fatty acid makes 66.42% of the compositions, whereby the MUFA, PUFA and SFA were 35.29, 31.13 and 32.34 wt%. Most of the obtained results in this study were acceptable and similar to previous studies. The worldwide demand for baobab has increased dramatically as raw material for many industrial products. Thus, the Sudanese baobab seed oil which does not contain of linolenic acid could not be suitable for several applications such as paint, varnish and ink industries, but it might suitable for others industrial aspects such as pharmaceutical, cosmetic and food industries, due to its fatty acid content. Therefore, further studies on Sudanese baobabs are needed to investigate their potential as raw materials for new industrial products and applications to increase the economic feasibility of future commercial cultivation of the tree.

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7. AUTHORS CONTRIBUTION STATEMENT

Dr. Abeer A. and Dr. Azhari H. conceptualized and gathered the data with regard to this work. Dr. Mahmoud M., Dr. Ibrahim Y. and Dr. Omer A. analyzed these data and necessary inputs were given towards the designing of the manuscript. All authors discussed the methodology and results and contributed to the final manuscript.

8. CONFLICT OF INTEREST

Conflict of interest declared none.

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