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EXTRACTION, FTIR AND GC-MS CHARACTERIZATION OF PALM KERNEL OIL FOR LAUNDRY SOAP PRODUCTION

[1]*Jacob, A. G., [2] Musa, I., and [1]Ogbesejana, A. B.
[1]Department of Industrial Chemistry, Federal University Dutsin-Ma, Katsina State, Nigeria
[2]Department of Chemistry, Federal University Dutsin-Ma, Katsina State, Nigeria
Email: gjacob@fudutsinma.edu.ng; imusa1@fudutsinma.edu.ng; abiodunogbesejana@fudutsinma.edu.ng
Tel.: +2348064871012; +2348037873752; +2348030688729

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ABSTRACT

This study aimed at extracting and characterizing palm kernel oil from oil palm seed for laundry soap production. Palm kernel oil was obtained by Soxhlet extraction with n-hexane. Standard methods were used to determine the physicochemical properties of the kernel oil and laundry soap. Fourier Transform Infrared Spectroscopy (FTIR) and Gas Chromatography-Mass Spectrometry (GC-MS) analyses were used to characterize the oil. Results revealed that the palm kernel seed yielded 45.51±1.10% oil. Relative density, saponification value, acid value, and iodine value of the oil were 0.87±0,034 g/mL, 224.40±3.13 mg KOH/g, 3.25±0.11 mgKOH/g, and 14.72±0.25 gI_2/100g, respectively. FTIR spectrum showed absorption peaks of methylene groups (723, 2855, 2922 cm^{-1}), carbonyl group (1744 cm^{-1}), and olefin group (1632 cm^{-1}) which are characteristics of fatty acids. GC-MS analysis showed oleic acid, trans-13-octadecenoic acid, elaidic acid, petroselinic acid and vaccenic acid. Quality parameters of the white and hard palm kernel oil soap were found to be 9.55±0.43, 5.20±0.48 cm, 9.65±0.97% and 72.50±2.34% for the pH, foam height, moisture content, and total fatty matter, respectively. These findings suggest that FTIR and GC-MS can substantially be used to effectively verify the suitability of a vegetable oil for soap production. Finally, the moderately high oil yield of the kernel seed indicates its potential for large-scale soap production in Nigeria considering the country's position as the world's 4th largest producer of palm kernel oil.

Keywords: Palm kernel oil; Laundry soap; Characterization; FTIR/GC-MS; Quality parameters

INTRODUCTION

Oil palm (*Elaeis guineensis*) fruit is formed in a cluster in a spiky tight bunch, and the main objective of palm industries is to generate oil. The fruit pericarp contains three layers including the exocarp, mesocarp and endocarp. The fruit produces two distinct types of oils namely crude palm oil from the mesocarp and palm kernel oil from the endosperm of the endocarp (Sharmila *et al.*, 2014). Each of the two oils exhibits differences in composition, properties and applications (Ibrahim, 2013; Bahadi *et al.*, 2020). Palm kernel oil is mostly used in various non-edible products, such as detergents, cosmetics, plastics, surfactants, herbicides, and a broad range of other industrial and agricultural chemicals (Hassim & Dian, 2017).

Since palm kernel oil contains a high amount of pure fatty acids, an important primary raw material, it can be used to produce soap, washing powder and other personal care products (Liu *et al.,* 2019). Palm kernel oil is similar to coconut oil in composition, and both are the only source of lauric oil available in the world market. Besides the industrial applications, this oil is used locally as body creams, cooking oil and medicinally, as antidotes for poisoning as well as surface protectants for minor wounds (Muhammad *et al*., 2022).

Palm kernel oil is a valuable ingredient in soap production due to its high saturated fat content, which provides excellent lathering and cleansing properties (Mahlia *et al*., 2019; Bahadi *et al.,* 2020). Similar to coconut oil, palm kernel oil can be a rich source of saturated fats than palm oil but also contain trans-fatty acids. The lauric acid present in palm kernel oil has been associated with high levels of blood low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) (Temme *et al.*, 1996). Thus, the oil is not frequently used for cooking purpose, and accordingly, it can be best suitable for soap production.

Soap is one of the most important cosmetics used daily by humans for cleansing and skin care purposes. Palm kernel oil has many advantages for making soap (Febrina & Noviani, 2022), shampoo, and other skin care products. Its medicinal properties help to remove toxins from the body (Adebisi & Sosanya, 2020). Thus, palm kernel oil alongside aqueous solution of both sodium hydroxide and potassium hydroxide (lye) with other additives are used to prepare soap (Adane *et al.,* 2021). Soap can be made from various types of fats or oils, including palm kernel oil, coconut oil, olive oil, and many others. Fats and oils are chemically composed of triglycerides, which are organic esters made up of glycerol and fatty acids. Generally, alkaline solution such as a solution of sodium hydroxide (NaOH) or potassium hydroxide (KOH), is used in the saponification process. The alkaline solution acts as a catalyst to facilitate the reaction between the fats or oils and the hydroxide ions (Nisar *et al.,* 2021).

Traditionally, saponification is a chemical reaction between a fat or oil and an alkaline solution, typically sodium hydroxide or potassium hydroxide (Iyasele *et al.,* 2022). This reaction results in the formation of soap and glycerin. Saponification is an important process in soap making, as it enables the conversion of oils or fats into soap, which possesses cleansing properties. During the saponification reaction, in the presence of the alkaline solution, the ester bonds in the fats or oils are hydrolyzed, breaking them down into glycerol and fatty acids. The hydroxide ions from the alkaline solution react with the fatty acids, producing soap molecules (carboxylate ions) and water, during the saponification process (Marius *et al.,* 2021).

FTIR analysis has been used to identify and quantify fatty acids present in vegetable oils (He & Lei, 2020), which is crucial for soap production. FTIR analysis of palm kernel oil for soap production can provide a better understanding of molecular composition and functional groups present, stability, and impurities in the oil (Panhwar *et al.,* 2019). This study focused on analyzing the absorption bands associated with different functional groups, such as carbonyl (C=O) stretching and methylene (CH_2) scissoring vibrations, to determine the fatty acid composition. This knowledge will help in optimizing soap formulations, assessing the quality and shelf life of palm kernel oil-based soaps, and ensuring the production of high-quality soaps with desired properties (Marius *et al.*, 2021).

GC-MS analysis of palm kernel oil for soap production could give valuable insights into the fatty acid composition (Nainggolan & Sinaga, 2021), triglyceride profile, impurities, and volatile organic compounds present in the oil. However, in this aspect of the study, the GC-MS analysis of palm kernel oil focused on understanding the fatty acid composition in the oil. This information is very instrumental in

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optimizing soap formulations, ensuring soap quality, and developing soap products with desired characteristics and fragrances.

Studies reveal that current research publications on palm kernel oil are primarily focused on sustainability, environmental impact and health effects with limited articles on alternative uses (Silalertruksa & Gheewala, 2012; Dey *et al*., 2021). Thus, it is necessary to extend research on palm kernel oil to soap making for an overall development of this industry. The present study therefore focuses on the application of Fourier-transform infrared spectroscopy and gas chromatography coupled with mass spectrometry, to study the chemical functional group and fatty acids composition in palm kernel oil, and evaluate the quality of soap produced from it.

MATERIALS AND METHODS

Palm kernel seeds were bought from the Wednesday Market, Dutsin−Ma, Katsina State. Sodium hydroxide pellet (NaOH), hydrochloric acid (HCL), potassium hydroxide (KOH), potassium iodide (KI) was obtained from QReC Chemicals (Auckland, New Zealand). Ethanol, *n*-Hexane, sodium thiosulphate ($Na_2S_2O_3$) was bought from Merck (Darmstadt, Germany). All the chemicals were of analytical grade and used as received.

The kernel seeds were sorted to remove all contaminants and washed with deionized water. The seeds were sun-dried for 7 days and oven-dried at 80 ℃ for 3 days before pulverizing into fine powder using a grinding machine. The pulverized sample was stored in a plastic polythene vessel and kept at room temperature until further use.

Extraction of palm kernel oil (PKO) was carried out in a Soxhlet apparatus adopting the method described by Ahmed *et al*. (2019), with slight modification. Briefly, 70.0 g of palm kernel seed powder was measured into a porous thimble that was placed in a Soxhlet apparatus, and 250 mL of *n*-hexane was added for extraction. The extraction was performed at 80 °C for 9 h. The oil was then recovered using a rotatory evaporator (RE300/MS, Bibby Scientific Limited, Staffordshire, UK) under vacuum and the *n*-hexane solvent was removed. The extracted palm kernel oil was preserved in a refrigerator at a low temperature for physicochemical characterization and soap production (Ahmed *et al*., 2019).

The palm kernel oil obtained from the Soxhlet extraction was transferred into a beaker and placed in water bath at 70 ℃ for 30 min to ensure the *n*-hexane was completely evaporated. The residual palm kernel oil was calculated and expressed as percentage oil yield according to equation 1.

$$\text{Oil yield (\%)} = \frac{\text{weight of oil}}{\text{weight of sample}} \times 100 \quad (1)$$

Palm kernel oil (10 mL) was added into a pre-weighed measuring cylinder and weighed. Using the difference between the weight of the palm kernel oil, and the weight of oil and cylinder, the specific gravity of palm kernel oil was calculated from equation 2 (Jimoh & Jimoh, 2021).

$$\text{Specific density (g/mL)} = \frac{W_1 - W_O}{V_O} \quad (2)$$

Where W_0 is the weight of empty measuring cylinder, W_1 is the weight of empty measuring cylinder + palm kernel oil, and V_0 is the volume of palm kernel oil used.

Palm kernel oil, 2.0 g was transferred into a round bottomed flask containing 30.0 mL of 0.5 M ethanolic KOH and the flask was mounted on a condenser for 30 min to ensure the oil was completely dissolved. A blank was also set up using the same reagent but without palm kernel oil. Both samples were refluxed for 1 h and allowed to cool. Phenolphthalein (1 mL) was added and the sample was titrated with 0.2 M HCl until the pink color of phenolphthalein disappeared indicating an end point (Paulin & Irene, 2019). The saponification value (SV) was calculated from equation 3.

$$\text{Saponification value (mgKOH/g)} = \frac{(B - S) \text{ x M x } 56.1}{W} \quad (3)$$

Where B is the titre value of the blank, S is the titre value of the palm kernel oil, M is the molarity of the HCl, W is sample weight while the molecular weight of KOH = 56.1 g/mol.

To determine the acid value, the method reported by Adane (2021) was modified. In this study, palm kernel oil (10.0 g) was added to 100 mL of ethanol in a 250 mL beaker and the mixture was brought to boiling. After removing the heat, the mixture was titrated with 0.1 M KOH using phenolphthalein indicator until a permanent pink color was noted at the end point (Adane, 2021). The acid value (AV) was calculated from equation 4.

$$\text{Acid value (mgKOH/g)} = \frac{M \times C \times T}{W} \quad (4)$$

Where M is the molar mass of KOH, C is the concentration of KOH, T is the titre value and W is the weight of palm kernel oil.

The method reported by Mechqoq *et al*. (2021) was adopted and modified to determine the iodine value. Palm kernel oil (0.50 g) was dissolved in 15 mL of carbon tetrachloride in conical flask (100 mL) and 5.0 mL of Wij's iodine solution was added. The solution was allowed to stand in a dark at 25 ℃ for 2 h and a solution of KI (5.0 mL) was added. The mixture was titrated with 0.1 M $Na_2S_2O_3$ starch indicator. A blank titration without PKO was also carried out (Mechqoq *et al*. 2021), and the iodine Value (IV) was calculated from equation 5.

$$\text{Iodine value } \left(\frac{g}{100}g\right) = \frac{12.69 \times M(V_1 - V_2)}{W} \quad (5)$$

Where M is the Molarity of sodium thiosulphate solution, V_1 = Volume of sodium thiosulphate used in blank, V_2 is the volume of sodium thiosulphate used with palm kernel oil and W is the weight of the palm kernel oil.

FTIR spectra of palm kernel seed and palm kernel oil were acquired using a Cary 630 FTIR spectrometer (Agilent Technologies Inc., Santa Clara, CA, USA) in a single-bounce attenuated total reflectance **(**ATR) mode coupled to a deuterated triglycine sulfate (DTGS) detector. Roughly 1.0 mg of each sample was placed on a diamond ZnSe crystal plate, and examined at an average of 16 scans and 4 cm^{-1} resolution, while the spectrum was obtained in a transmission mode for a wavenumbers range of 400 cm^{-1} - 4000 cm^{-1} (Jacob *et al*., 2021).

GC–MS analysis of palm kernel oil was carried out using a gas chromatography instrument (GC–7890B model) coupled to a mass spectrometer detector (MSD–5977A series) from Agilent Technologies (Santa Clara, CA, USA). The injector and detector temperatures of the ultra-inert capillary column: 190915–433UI HP–5MS (30 m x 0.25 mm x 0.25 μm) were set to 250 °C and 260 °C, respectively. A 0.5 μL sample (split ratio of 1/20) aliquot was injected and analyzed at 60 °C, held for 2 min and then elevated to 260 °C at a rate of 3 °C/min. The helium carrier gas was set at 1.6 mL/min. Each component was expressed as a proportion of the total peak area. An electron ionization mode with a 70 eV energy was used for the mass-spectral detection. The resultant fragmentation pattern was compared with the National Institute of Standards and Technology (NIST) spectral library (Jacob *et al*., 2022).

A method described by Jimoh and Jimoh (2021) was adopted to produce the soap with slight modification. The PKO (70.0 mL) was gently warmed and transferred into a beaker, and 70.0 mL of NaOH solution (170 g/L) was added to form an intimate mix. The mixture was frequently stirred with a stirring rod at room temperature for 20 min to form a slurry. The slurry was poured into a mold, and allowed to set and harden, to form a solid bar soap (Jimoh & Jimoh, 2021).

The soap, 10.0 g was dissolved in 100 mL of distilled water to form a 10% soap solution.

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The electrode of a pH meter was immersed in the soap solution, and the pH value of the soap was measured using a pH meter (JENWAY 3505, UK) (Zauro *et al*., 2016). The soap, 0.3 g was placed in a measuring cylinder (100 mL) and 10 mL of distilled water was added. The content was shaken vigorously for 3 min to produce a soap solution, and was left to stand for 10 min. The height of the foam was measured and recorded with a meter rule in centimeter (Mohammed *et. al*., 2022). To determine the moisture content, 10.0 g of the soap was weighed and heated at 105 ºC for 30 min in a crucible. The content was cooled to room temperature and reweighed. The moisture content was estimated from the difference according to equation 6 (Zauro *et al*., 2016).

$$\text{Moisture content (\%)} = \frac{B - C}{B - A} \times 100 \quad (6)$$

Where A is the weight of the crucible, B is the weight of crucible + sample and C is the weight of crucible + sample after heating.

The soap (5.0 g) was placed in a beaker (250 mL) and 100 mL of hot distilled water was added to completely dissolve it. A solution of HNO_3 (0.5 mol/L, 40 mL) was added until the mixture turned slightly acidic. The content was heated in water a bath till fatty acids was observed floating above the solution. The mixture was rapidly cooled in ice water to harden the fatty acids which were separated, and chloroform (50 mL) was added to the residual solution and the resultant solution was transferred into a separatory funnel. After shaking, the solution formed two layers and the lower layer was separated. Extraction of the fatty acids with chloroform was repeated in the separating funnel. The fatty acid content was transferred into a weighed porcelain dish. The content was evaporated while the residue was weighed (Atolani *et al*., 2016). The total fatty matter in the soap was calculated from the difference in weight using Equation 7.

$$\text{Total fatty matter (\%)} = \frac{X - Y}{Z} \times 100 \quad (7)$$

Where Y is the weight of the porcelain dish (g), X is the weight of the porcelain dish + soap after drying (g) and Z is the weight of the initial sample of soap (g).

RESULTS AND DISCUSSION

The physicochemical properties of oil extracted from palm kernel seeds by the Soxhlet method are presented in Table 1. The palm kernel oil revealed various physicochemical properties which are basic characteristics of palm kernel oil. As shown, 45.51±1.10% of oil was recovered from the palm kernel seeds (Table 1).

The 45.51% oil yield obtained here was higher than 39.64% reported in literature (Marius *et al.*, 2021). For an oil seed, this result is moderately significant, suggesting that palm kernel seed is a good source of oil. The fairly high oil content from palm kernel revealed in this study indicates the oil source is a suitable and sustainable resource for saponifiable oil. The relative density of palm kernel oil as displayed in Table 1, was found to be 0.87±0.03 g/mL which is comparatively lower than the 0.91 g/mL published previously Amira *et al*. (2014), but similar to 0.87±0.03 g/mL recreantly reported Iyasele *et al.* (2022), for palm kernel oil.

However, the value obtained here is marginally close to the range of 0.899-0.914 g/mL recommended for palm kernel oil at 40 ℃ (Alimentarius, 1999). The low relative density of palm kernel oil indicates present of fatty acids with high saponification potential for soap production (Iyasele *et al.*, 2022).

Table 1: Physicochemical properties of palm kernel oil

Physicochemical parameter	Value obtained
Oil yield (%)	45.51±1.10
Relative density (g/mL)	0.87±0.03
Saponification value (mgKOH/g)	224.40±3.13
Acid value (mgKOH/g)	3.25±0.11
Iodine value (g I_2/100g)	14.72±0.25

The saponification value is a parameter expressed as the number of mg of potassium hydroxide or sodium hydroxide needed to saponify 1.0 g of an oil. The saponification value of palm kernel oil is shown in Table 1, and was found to be 224.40±3.13 mgKOH/g which is higher compared to 216.20 mgKOH/g reported by Marius *et al.* (2021). This value is also higher than 177 mgNaOH/g reported from castor bean seed oil (Abdulrasheed *et al*., 2015). Saponification value gives information about the nature of fatty acids present in an oil. A high saponification value of 224.40±3.13 mg KOH per g for the palm kernel oil indicates a high proportion of triacylglycerol corroborating the suitability of the oil for soap production (Iyasele *et al*., 2022). Overall, the saponification value obtained in this study falls within the range (218.6-230 mgKOH/g) for palm kernel oil.

Acid value denotes the amount in milligrams of potassium hydroxide needed to neutralize free fatty acid existing in 1.0 g of an oil sample. The acid value observed for the palm kernel oil in this study is presented in Table 1. The acid value was 3.25±0.11 mgKOH/g which is greater than 1.14 and 2.70 mgNaOH/g reported by Abdulrasheed *et al.* (2015) for castor bean seed oil, and for palm kernel oil (Amira *et al.,* 2014). Conversely, this value is lower compared with 6.37 mgKOH/g reported by Marius *et al.,* (2021). Literature reports reveal that the higher the acid value of an oil, the greater the fatty acids it contains. This finding suggests that palm kernel oil has high potential for production of quality soaps.

Iodine value is the amount of iodine in gram that is consumed by 100 g of an oil sample. Table 1 shows the iodine value of palm kernel oil obtained in this study was 14.72±0.25 g I_2/100 g. This value is lower than the range of 7.5-10.0 g I_2/100 g (Jose, 2020), and 17.52 g I_2/100 g (Marius *et al*., 2021) published in literature for coconut oil and palm kernel oil, respectively. Nondrying oils including olive oils used for producing soap usually have relatively low iodine values. Iodine value of an oil measures its degree of unsaturation. The iodine value of 14.72±0.25 g I_2/100 can be attributed to the low amount of unsaturation of palm kernel oil, therefore making it suitable, and facilitating the production of hard soaps (Zauro *et al.,* 2016).

FTIR spectra of palm kernel seed and palm kernel oil are presented in Figure 1, whereas the adsorption data are shown in Table 2. Generally, the spectra depicted several prominent absorption peaks representing different functional groups present in the samples.

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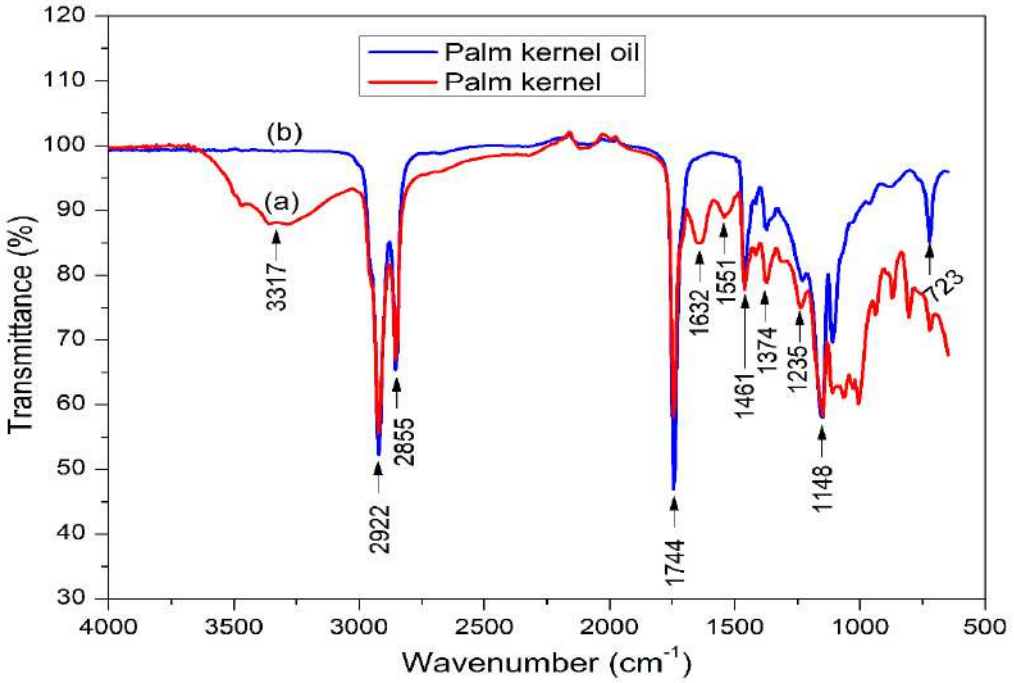

Figure 1: FTIR spectra of (a) Palm kernel seed, and (b) Palm kernel oil

FTIR can be used to pinpoint the molecular composition and structure of a sample. As seen in Figure1a, the broad absorption peak centered at 3317 cm^{-1} is assigned to the O–H stretching of free-bonded water. Interestingly, the peak for the O–H bond completely disappeared in Figure1b, indicating that pure palm kernel oil was obtained from the Soxhlet extraction. In other words, the seed of palm kernel initially contained water which was removed in the process of extraction.

The two strong absorption peaks at 2922 and 2855 cm^{-1} found in both spectra are the corresponding asymmetric and symmetric stretching vibrations of C–H bonds of saturated hydrocarbon (Jacob *et al*., 2021). The sharp peak located at 1744 cm^{-1} is assigned to the stretching vibration of C═O bonds of the carboxyl or carbonyl groups, while the peak at 1632 cm^{-1} corresponds to stretching vibration of C═C bonds which originate primarily from cis- or trans- olefins (Jacob *et al*., 2021). Remarkably, the weak absorption peaks at 1632 cm^{-1} and 1551 cm^{-1} in the spectrum of palm kernel seed (Figure 1a) have completely vanished in the spectrum of palm kernel oil (Figure 1b). This could be due to the fact that some of the saturated compounds in palm kernel seed were converted to unsaturated compounds.

Table 2: FTIR data of palm kernel oil

Peak (cm^{-1})	Functional group	Compound
723	C─H rocking vibration	Methylene (─CH_2) of triglycerides
1200–1400	C─H bending vibration	Methylene (─CH_2) of triglycerides
1461	C─H bending vibration	Methylene (─CH_2) of aliphatic
1632	C═C stretching vibration	cis– and trans–olefins
1744	C═O stretching vibration	Carbonyl or carboxyl groups
2855	C─H symmetric stretch	Methylene of saturated hydrocarbons
2922	C─H asymmetric stretch	Methylene of saturated hydrocarbons
3317	O─H stretching vibration	Loosely bonded water molecules

Other FTIR absorption peaks at 1461 cm^{-1}, 1200-1400 cm^{-1}, and 723 cm^{-1} (Table 2) correspond to bending and rocking molecular vibrations of methylene groups of the aliphatic and triglycerides, respectively. Overall, the results of the FTIR analysis reveals that a pure palm kernel oil was extracted from palm kernel seeds.

The chromatogram and data of fatty acids composition of palm kernel oil are presented in Table 3 and Figure 2, respectively, while Figure 3 shows the MS spectra of the identified fatty acids in the palm kernel oil. Generally, the extracted palm kernel oil contained different compounds including fatty acids with varying retention times (RT) (Table 3). Figure 2 shows that the palm kernel oil comprised many chemical compounds of which five fatty acids were detected using their retention times (RT) (Table 3). The primary fatty acid present in the oil was octadecenoic acid with various isomers comprising of oleic acid (18.06 min), trans-13-octadecenoic acid (24.89 min), elaidic acid (29.36 min), petroselinic acid (31.81 min) and vaccenic acid (37.05 min).

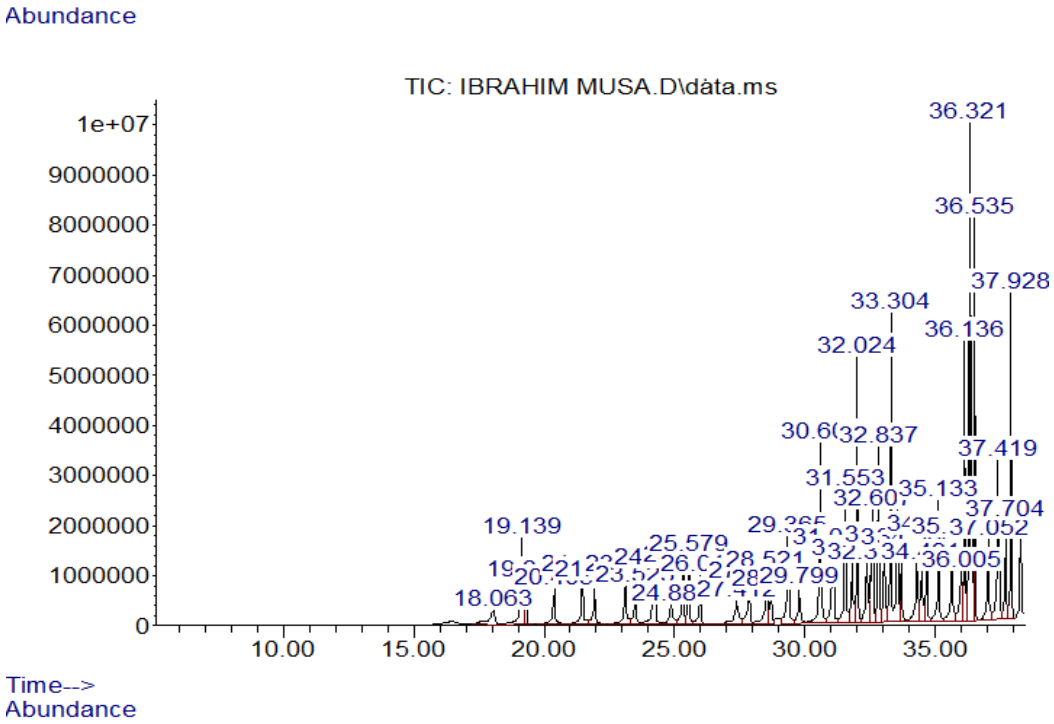

Figure 2: GC chromatogram of compounds present in palm kernel oil

The fatty acid with the highest percentage similarity to the target compound was oleic acid (78%), and all the five fatty acids excited as isomers. Hence, the spectrum of oleic acid depicting the fragmentation pattern is presented in Figure 3.

Table 3: GC data of fatty acids composition of palm kernel oil

Common Name	IUPAC Nomenclature	RT (min)	Peak Area	SI%
Oleic acid	Cis-9-octadecenioc acid	18.06	1.1543	79
13-Octadecenoic acid	Cis-13-octadecenioc acid	27.41	1.3074	45
Elaidic acid	Trans-9-octadecenioc acid	29.36	2.6154	43
Petroselinic acid	Cis-6-octadecenioc acid	35.66	1.9752	49
Vaccenic acid	Trans-11-octadecenioc acid	37.05	1.8205	58

Note: RT = Retention time, IUPAC = International Union of Pure and Applied Chemistry, SI = similarity index, T.C. = Target compound.

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A close observation indicates that the spectrum of palm kernel oil (Figure 3b) fairly matched well with that of the NIST Library (Figure 3a) with little variations. In a nutshell, only 5 non-essential fatty acids were found in palm kernel oil extracted from palm kernel seeds by the Soxhlet method.

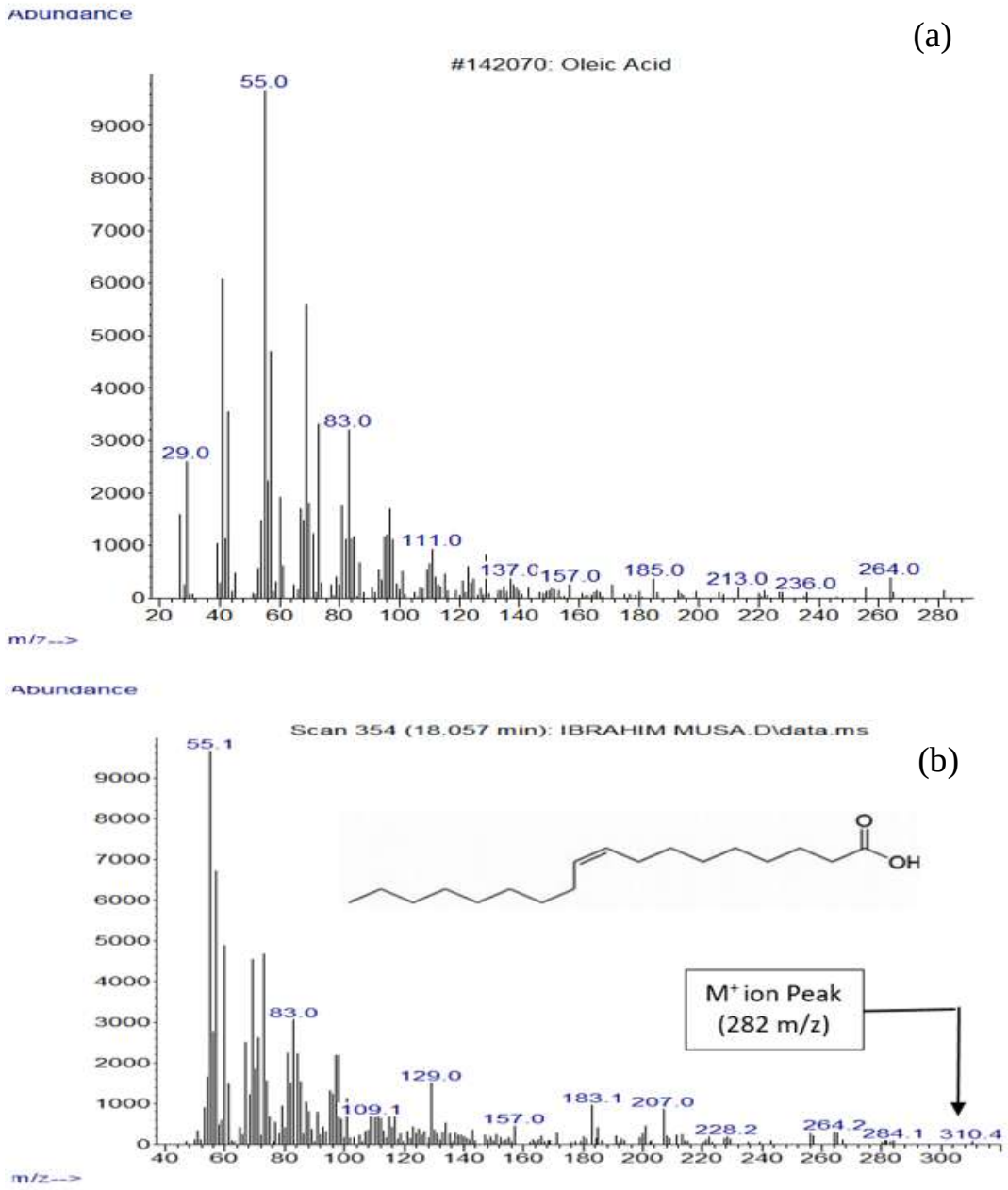

Figure 3: MS spectra of (a) Oleic acid from National Institute of Standard Technology and (b) Oleic acid identified in palm kernel oil.

Chemical characteristics of lipophilic portion of soaps play major roles in defining the performance quality of the soap. Physicochemical properties of the palm kernel oil soap are shown in Table 4. These properties are standard parameters used in evaluating the quality of soaps. The soap's quality parameters: colour, pH, foam height, moisture content and total fatty matter were investigated. Fatty acids with higher carbons 14-18 are the favorites for soaps production. High amount of long chain unsaturated C-18 fatty acids in the kernel oil resulted to the production of quality soap (Table 4).

A white soap was produced from the palm kernel oil. A pH that measures the basicity is imperative for determining the suitability of soaps to be used by humans. From Table 4, the soap was alkaline showing a pH value of 9.55±0.43. For effective use in public laundry, the pH of a soap must range from 9-11 (Adane *et al.*, 2021). Soaps with pH higher than 11 can irritate the skin (Zauro *et al*., 2016). This finding shows that palm kernel oil soap has the acceptable alkalinity for use in laundry.

Table 4: Physicochemical properties of palm kernel oil soap

Physicochemical parameter	Value obtained
Color	White
pH	9.55±0.43
Foam height (cm)	5.20±0.48
Moisture content (%)	9.65±0.97
Total fatty matter (%)	72.50±2.34

Foam height measures the ability of a soap to form lather (Mohammed *et. al*., 2022). The foam height was 5.20±0.48 cm (Table 4). Moisture content determine the shelf-life of a soap (Zauro *et al*., 2016). The moisture content was found to be 9.65±0.97% (Table 4). This outcome is nearly similar to a literature-based standard range (10.5–12.5%).

Total fatty matter (TFM) assesses the total amount of fatty matter which is mostly fatty acids separated from a sample's mineral acid. It is typically related to the hardness and quality of soaps. Higher values of TFM guarantee soaps with least harmful effects on the skin and less dryness. TMF value of the soap was 72.50±2.34% (Table 4). According to literature, TFM values of laundry soaps should range between 34% and 75%, while values <50% are associated with low quality and hardness (Adane *et al.*, 2021). A minimum and maximum TFM values of soaps were established at 75% for grade-1 and 65% for grade-2 soaps (Popescu *et al.*, 2011). This finding suggests that a grade-2 soap was produced from palm kernel oil.

CONCLUSION

The study revealed that the presence of fatty acids in palm kernel oil is beneficial for producing high quality soap. The palm kernel oil soap correspondingly showed acceptable quality parameters for laundry purpose. Findings suggest that palm kernel seeds are renewable source of copious oil for sustainable production of laundry soap. Besides, FTIR and GC-MS are proven tools for characterizing vegetable oils intended for soap production. The study recommends the used of other methods to extract the kernel oil for comparative study.

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