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GC–MS, ^{1}H and ^{13}C NMR, and physiochemical properties of oils of *Dacryodes Edulis* and *Persea Americana*

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Abstract
A comparative investigation was carried out on the seed oils of *P. americana* and *D. edulis* for their physiochemical properties and spectroscopic properties. Oils were extracted from the respective powdered seeds using Soxhlet extraction technique giving 18.63% and 45.49% yields for *P. americana* and *D. edulis*, respectively. The seed oils were subjected to physiochemical analysis using standard protocols as prescribed by the American Oil Chemist Society (AOCS) and the American Society for Testing and Materials (ASTM). The fatty acid content was determined using Gas Chromatography, Proton (^{1}H) and Carbon-13 (^{13}C) Nuclear Magnetic Resonance spectroscopy. The results indicates that linoleic acid is the most unsaturated fatty acid, while stearic acid is the most saturated fatty acid in both oils. Unsaturated fatty acid peaks for olefinic H were observed at 5.34 and 5.31 ppm for *P. americana* and at 5.43 and 5.32 ppm for *D. edulis* oils in ^{1}H-NMR. For ^{13}C-NMR, the presence of C with triple bond attached to an alkyl group was observed at 85 ppm for the *P. americana,* while similar peak was observed for *D. edulis* at 128.21 to 130.1 ppm. The chemical characterization of the oils gave iodine values of 51.86 mgI_2/g for *P. americana* oil and 48.72 mgI_2/g for *D. edulis* oil. Similarly, acid values of 3.45 mg KOH/kg and 5.76 mg KOH/kg were obtained for *P. americana* and *D. edulis* seed oils respectively. The physiochemical and spectroscopic results obtained showed that *P. americana* and *D. edulis* seed oils have the potential for use in a number of industrial applications.

Keywords Avocado · Seed oil · GC–MS analysis · ^{1}H-NMR · ^{13}C-NMR · Fatty acids

1 Introduction

It has been estimated that Nigeria's product consumption margin has increased by a thousand tons [1]. This is natural because the population of the country is increasing rapidly, thereby increasing the rate of demand for edible seed oils like coconut oil, etc. for several purposes including cosmetics production, soap making, and other industrial purposes. This situation calls for serious consideration for effective future planning of reducing edible seed oil utilization and maximizing non-edible seed oils production in the country. Seeds that cannot be eaten, such as *P. americana* and *D. edulis*, have been found to contain a substantial quantity of oil that can be used for many purposes.

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Internationally, customers are increasingly prioritizing health and the prevention of aging. Consumers are interested in food products that are abundant in nutrients and bioactive chemicals, which are known to provide numerous health advantages. According to Chafaa et al. [2], pear seed oils provide a significant amount of these health benefits.

P. americana is cultivated on an avocado tree, which is a perennial tree belonging to the Lauraceae family. It is harvested prematurely and thereafter undergoes a gradual ripening process before being sold on the market. *P. americana* is referred to as climacteric fruits since they undergo full ripening after being harvested, similar to bananas [3]. The *P. americana* species evolved in the region of south-central Mexico, specifically within the time period between 7000 and 5000 B.C according to the History of California Avocado [4]. *D. edulis* is a perennial tree that is always green and belongs to the Buseraseae safau family. This family is known for having an ovary with 2 to 5 cells that can be easily seen in the tree's bark, wood, and intra-terminal disk [5]. It is prevalent in numerous sub-Saharan nations in Africa, such as Nigeria and Liberia.

Vegetable oils can be obtained from seeds of *P. americana* and *D. edulis* using different means such as expression, solvent extraction, or a combination of both. They can be of different colours depending on the means of extraction and the quality of the seed. Currently, the seeds are an under-utilized resource and a waste for *P. americana* and *D. edulis* pear oil processors [6]. The significant anti-nutritional components found in *P. americana* seeds could provide a potential risk to their utilization in animal and human diets. Although the raw seeds contain anti-nutrients, their levels can be significantly reduced with effective processing techniques such as soaking and boiling [7]. The primary anti-nutrients found in *D. edulis* are trypsin inhibitors (7.33%), followed by saponins (1.14%) and tannins (1.05%). The polyphenols, oxalates, and phytates were present in smaller quantities, with concentrations of 0.35%, 0.64%, and 0.77% respectively. Saponins are known for their bitter taste and their ability to hinder nutrient delivery and impede growth [8]. The existence of these anti-nutrients has hindered the consumption of the *D. edulis* seed by humans.

The seed oils of *D. edulis* and *P. americana* have significant potential in cosmeceuticals designed for everyday facial and body care. Additionally, they can function as a cosmetic foundation that inhibits the loss of water through the skin. This is achieved by creating a protective barrier on the outer layer of the skin, which can also have the effect of minimizing the appearance of fine wrinkles and functioning as an anti-aging treatment [9]. The major advantage with respect to skin care of *P. americana* oil is its softening, soothing, and notable absorptive. The present work is therefore aimed at fully investigating the characteristics of the oils with a view to establishing their potential uses.

2 Materials and methods

2.1 Sample collection and preparation

The fruits (Figs. 1 and 2), comprising the pulp and seed, were gathered from Ogige Market in Nsukka, Enugu State, Nigeria. The fruits were grown in Ovoko area of Nsukka local government council and harvested on the day of purchase (22nd July, 2022). The process of dehulling was performed, wherein the fruit was meticulously sliced in half, facilitating the extraction of the stone seeds. Subsequently, the sample was divided into several dimensions. The sample was air-dried for 48 h prior to pulverization using a hammer mill in order to decrease the moisture content, hence improving the efficiency of the extraction and distillation procedure. While grinding, caution was used to avoid grinding the particles too



Fig. 1 *P. americana* Fruit and Seed

Fig. 2 *D. edulis* Fruit and Seed



finely, since this would impede the solvent's ability to flow freely during extraction, potentially resulting in a decrease in the yield of the extracted oil.

2.2 Extraction of seed oil

Precisely 70 g of the ground seed sample was measured and placed in a 500 cubic centimeter beaker. It was then immersed in 300 cubic centimeters of hexane for a duration of 24 h. The resulting solution was successively and meticulously filtered using Whatman No 2 filter papers (8 µm particle size range and slightly slower filtration speed), until all remnants of oil were completely removed from the sample. The oil-hexane mixture, often known as miscella, was separated using the Soxhlet equipment. To ensure the complete evaporation of any remaining hexane in the oil, the oil was heated at 78 °C for 2 h using a Gallen Kamp hot air oven model OV160. The aforementioned technique was employed to extract oil from the milled seeds of both *D. edulis* and *P. americana*.

2.3 Physiochemical characterization of the seed oils

The iodine value, acid value, peroxide value, viscosity, refractive index, smoke point, and melting point were measured using the established protocols outlined by the American Oil Chemist Society (AOCS) and the American Society for Testing and Materials (ASTM).

The iodine value is a measure of the unsaturation of a substance, specifically the number of double bonds it contains. Precisely 0.1 g of each oil sample were measured and placed into a conical flask. Then, 2.0 mL of tetrachloromethane were added to the oil sample, followed by 4.0 ml of Wij's solution. The mixture was stirred to mix, covered, and left undisturbed for 30 min in a dark environment. 3.0 mL of a 10% KI solution and 20 mL of distilled water were added to the mixture, which was then titrated with 0.1 N Sodium thiosulfate until a clear solution was obtained. The blank titration was done using all the reagents involved without any sample. Average of triplicate determinations was reported for both sample and blank titrations.

2.4 Calculation

2.4.1 Iodine value

$$\left(\frac{g}{100g}oil\right) = (B - S \times W \times 12.69)$$

where; **B** is the blank titer, value **S** is the sample titre value and the weight of the sample is **W.**

2.4.2 Peroxide value

Precisely 0.1 g of the oil sample was weighed, and dissolved in a 30 mL acetic acid/chloroform mixture (3:2) and 0.5 mL of 10% KI was added to the mixture. It was agitated and kept for 2 min before adding 30 mL of distilled water and 0.5 mL of 1% starch solution and titrated with 0.1 N sodium thiosulfate till a milky solution was obtained and the titre obtained. The blank titre was obtained by using all the reagents without any oil sample.

Calculation: Peroxide value

$$\left(\frac{Meq}{Kg}\right) = \frac{S - B \times 0.1 \times 1000}{W}$$

where; **B** is the blank titer value, **S** is the sample titer value and **W** is the weight of the sample.

2.4.3 Acid value

Each oil sample (1.0 mL) was weighed into conical flasks and 20 mL of ethanol/petroleum ether (1:1) was added to the samples. Two drops of phenolphthalein indicator were added to the mixture and titrated with 0.1 M KOH solution to a pink colouration which persists for 30 s. The titre value was obtained blank using all the reagents without any oil sample. Average of triplicate determinations was reported for both sample and blank titrations.

Calculation: Acid value

$$\left(\frac{mgKOH}{gOil}\right) = \frac{V \times N \times 5.61}{W}$$

where **V** is the volume of KOH, **W** is the weight of the sample examined (g), and **N** is the normality or molarity of KOH.

2.4.4 Saponification value

Precisely, each oil sample was measured and placed into conical flasks, followed by the addition of 12.5 mL of a 0.5 M KOH solution. The combination was heated for a duration of 15 min, then let to cool. Following this, 2 drops of phenolphthalein indicator were introduced to the mixture. The substance was subjected to titration using a 0.1 M HCl solution until a transparent solution was obtained. The blank was prepared with all reagents except any oil sample. Average of triplicate determinations was reported for both sample and blank titrations.

Calculation: Saponification value

$$\left(mg\frac{KOH}{gOil}\right) = \frac{[28.05 \times (A - B) \times F]}{S}$$

where; **S** is sample weight, **A** is the titre value of blank (ml), **B** is the titre value of sample (mL), and F is the molarity of the HCl standard solution.

2.5 Spectroscopic characterization of the oils

Gas Chromatography-Mass Spectrometry (Thermo Scientific ISQ 7610 single quadrupole GC–MS): The temperature of the injector was adjusted to 250 °C, whilst the temperature of the detector was set to 310 °C. The samples were subjected to a heating ramp of 10 °C/min, starting at an initial temperature of 40 °C and reaching a final temperature of 310 °C. This heating process lasted for a total of 16 min. The NIST, 2008 library was utilized to ascertain the peaks of the chromatogram.

2.6 Nuclear magnetic resonance spectroscopy

Agilant Model 400-MR—NMR Spectrometer, from USA was used. The instrument was turned on and allowed to warm up for at least 30 min. The oil sample was placed in the sample holder making sure the sample is dry and free from

Table 1 Physical Properties of Oils from *P. americana* and *D. edulis* seeds (n = 3 ± SD)

Test	P.A seed	D.A seed
Yield (%)	18.6±0.13	45.5±0.9
Refractive.index (cp)	1.5±0.01	1.5±0.0
Viscosity (mPas)	972±2.32	967.9±3.7
Smoke point (˚F)	79.4±1.95	100±1.5
Flashpoint (˚F)	36.1±0.78	155±1.3
Melting point(˚C)	52.5±0.99	42 .4±0.5
Colour	Reddish brown	Yellowish green
Odor	*P. americana*	*D. edulis*

Table 2 Chemical properties of oils from *Persea americana* and *Dacryodes edulis* seeds (n = 3 ± SD)

Test	P. A seed	D.E seed
Acid value (mgKOH/g oil)	3.5 ± 0.0	5.8 ± 0.6
Iodine value (mglodine/100g oil)	51.9 ± 1.5	48.7 ± 1.1
Peroxide value (Meq/kg)	35.0 ± 1.2	23.0 ± 1.0
Saponification value (Meq/kg)	175.4 ± 2.7	184.3 ± 2.0

any contaminants. Then the sample holder was closed and secured into the instrument. The measurement was carried out by pressing the measurement button on the instrument. After the measurement was done, the instrument displayed the results on its LCD screen, which showed the seed oil content as a percentage. The results were recorded as needed and exported to a computer using the instrument's USB interface. The sample holder was removed from the instrument and cleaned thoroughly before using it again.

3 Results and discussion

The physiochemical properties of the oils obtained in this study are shown in Tables 1 and 2, respectively. Comparative studies of the characteristics of *D. edulis* and *P. americana* seed oils were carried out to ascertain their possible applications and the difference in their components. The percentage yield of the *P. americana* seed oil was 18.47 ± 0.13% while that of the *D. edulis* seed oil was 45.49 ± 0.87%. The percentage yield of the *D. edulis* seed oil was more than that of the *P. americana* seed, the reason for the low yield of oil by the *P. americana* seed is due to the moisture content and the genetic factors. *D. edulis* seeds yielded more oil which means that it can be more available for use industrial purposes.

3.1 Refractive index

According to Codex Standard [10], the refractive index for fats and oil from vegetable/ plant source should be around 1.4707 for virgin, refined and refined-pomace oils. From Table 1, for *P. americana* oil, the refractive index was 1.481 ± 0.01 and that of *D. edulis* seed oil was 1.468 ± 0.02.

3.2 Viscosity

The *P. americana* seed oil has a viscosity value of 972.0 ± 2.32 mPas and that of *P. edulis* seed oil was found to be 967.95 ± 3.65 mPas. *D. edulis* seed oil has a lower viscosity than *P. americana* seed oil indicating that it is lighter in weight. Normally viscosity increases with increase in molecular weight and decreases with an increase in unsaturation level and high temperature [11]. The standard range for viscosity is 0.43 to 1,302.39 mPas.

3.3 Smoke point

The smoke points of *D. edulis* and *P. americana* are 100 ± 1.45 °C and 79.4 ± 1.95 °C respectively. According to Iniobong et al. [9], the smoke point of an oil rises as the amount of free fatty acids drops. According to Mishra and Manchanda [12],

heating oil results in the production of free fatty acids. As the heating period increases, more free fatty acids are generated, leading to a decrease in the smoke point. An oil's smoke point is the temperature at which it transitions from being healthy to becoming unhealthy. When an oil hits its smoke point, it undergoes structural degradation, resulting in the loss of nutrients, altered flavor, darker color, and the formation of potentially harmful chemicals that can negatively impact health [9]. These findings suggest that these oils are OK for frying, as long as they are not heated beyond their specific smoke thresholds. This is important to avoid the formation of excessive free radicals, which can be harmful to health [9].

3.4 Acid value

According to Table 2, the acid value is a measure of the amount of free fatty acids in the oils. It serves as an indicator of the presence and degree of hydrolysis caused by lipolytic enzymes and oxidation [13]. Acid value has the range of 0.34 to 68.88 mgKOH/g oil. The *P. americana* oil has an acid value of 3.45 ± 0.03 mgKOH/g which is higher than the 2.06 mgKOH/g reported by Pushkar et al. [14] and 3.01 mgKOH/g reported by Otaigbe et al. [15]. The *D. edulis* seed has an acid value of 5.76 ± 0.64 mgKOH/g oil; this is close to 5.61 mgKOH/g obtained by Ajaye and Adesanwo [16]. This result portrayed *P. americana* seed oil as having low levels of hydrolytic and lipolytic activities [15]. The same applies to the *D. edulis* seed oil even though it is a bit higher than the *P. americana* seed oil, it can be useful in the production of liquid soap, paints and shampoo [17].

3.5 Saponification value

In Table 2, we saw that the *P. americana* seed oil has a saponification value of 175.43 ± 2.67 Meq/kg meanwhile *D. edulis* seed oil has a saponification value of 184.32 ± 1.98 Meq/kg. Both oils possess a high saponification value, indicating their suitability for soap manufacturing and oil-based body cream. The saponification value of oils varies between 5.58 milliequivalents per kilogram (Meq/kg) to 249.90 Meq/kg. It quantifies the level of oxidation that occurs throughout the storage process. Additionally, it signifies the degradation of oils and the existence of fatty acids. A high saponification value indicates a lower concentration of fatty acids in the oil, whereas a low saponification value suggests a higher proportion of fatty acids, rendering the oil inedible.

3.6 Iodine value

The iodine value is a quantitative measure of the level of unsaturation in seed oils, and it serves as an important criterion for identifying and characterizing these oils in the cosmetic industry [18]. The iodine value ranged from 2.65 to 153 g/100 g oil. It can be seen in Table 2 that the *P. americana* seed oil has an iodine value of 51.86 ± 1.53 g/100 g oil while the Iodine value of 48.72 ± 1.11 g/100 g showed that the *P. americana* seed oil had a high degree of unsaturation [19]. The iodine value is a measure of the oil's double bond content, indicating its vulnerability to oxidation. A lower iodine value indicates a reduced amount of unsaturated bonds, resulting in decreased susceptibility to oxidative rancidity in the oil. Both oils are classified as non-drying oils due to their iodine contents being below 100 g/100 g oil. They have the potential to serve as emollients, which can effectively moisturize and soften the skin. The low iodine values of both oils indicate minimal oxygen absorption reactivity, classifying them as non-drying oils. Therefore, both oils can be used effectively as plasticizers or lubricants [15]. The values are also an indication that the *P. americana* seed oil may have more unsaturated bonds than the *D. edulis* seed oil. Due to their non-drying properties, non-drying oils are not ideal for the manufacturing of ink and paint, but they may be beneficial in the production of soap and can be viewed as liquid oil [20]. Non-drying oils don't oxidize quickly, therefore they stay liquid for a very long time. They are very helpful as lubricants and lamp fuel because of this property. These findings indicate that the oils derived from P. americana and D. edulis seeds can be used topically to safeguard the skin's protective barrier. This is achieved by creating a barrier that prevents moisture loss and promotes moisture retention in the skin, therefore lowering the loss of water through the skin. According to [9], the skin will become moisturized, resulting in increased flexibility and reduced appearance of fine wrinkles.

3.7 Peroxide value

The *P. americana* seed oil has a peroxide value of 35 ± 1.22 Meq/kg, this accounts for the decreased unsaturated fatty acids of the oil and increased colour and viscosity. The peroxide value of the D. edulis oil is 23 ± 0.95 Meq/kg, which is lower than the peroxide value of the *P. americana* seed oil, as indicated in Table 2. The peroxide value is a quantitative indicator

of the degree to which an oil sample has experienced primary oxidation [21]. Unrefined oil has a greater peroxide value compared to refined oil. It has a range of 0.45 to 290.

3.8 Proton (^{1}H) nuclear magnetic resonance spectroscopy

The H^1-NMR along with other characterization results help in accounting for the presence of triglycerides in characterized oils [22]. Tryglycerides are nonpolar lipid molecules composed of a glycerol molecule associated with three fatty acids molecules and they represent the main form of lipid storage and energy in the human organism [23]. Triglycerides exhibits distinct chemical shifts in the ^{1}H-NMR due to the presence of the following functional groups: Fig. 3 is a ^{1}H-NMR spectrum for the *P. americana* seed oil. The presence of olefinic hydrogen (-CH_2=CH-), protons was represented by the double bond that appeared downfield at 5.34 to 5.31 ppm. This signal is typically a multiplet due to cis/trans configurations in natural fatty acids [24]. Hydrogen bonded to the α-methylene carboxylic acid (-OCO=CH_2-) has a peak at 2.50 to 1.85 ppm, this signal is critical for identifying ester linkages characteristic of triglycerides. The peak at 1.43 to 1.35 ppm indicates the presence of hydrogen of linolenic acyl chains (-CH_3). This signal usually appears as a triplet due to coupling with the adjacent -CH_2- group. These peaks are indicative of the fatty acid chain length and are prominent in triglycerides. The signal for linoleic acid, a polyunsaturated fatty acid [22] was detected at a peak of 0.92 to 0.81 ppm. The absence of signals around 3.6 ppm, typical of the -OH protons in free fatty acids, further confirms the esterified nature of the glycerol backbone and the presence of triglycerides in the *P. americana* seed oil.

The *D. edulis* seed oil has the following significant peaks as seen in Fig. 4; vinyl hydrogen (olefinic) (-CH=CH-) signals at 5.43 to 5.32 ppm, a diallyl methylene hydrogen signals (=CH-CH_2-CH=) at 2.75 to 2.74 ppm, and protons on the methylene groups (-OCO-CH_3-) directly adjacent to the ester carbonyl groups resonate around 2.5 to 2.73 ppm. This signal is highly specific to esterified fatty acids and is key to identifying triglycerides in *P. americana* seed oil

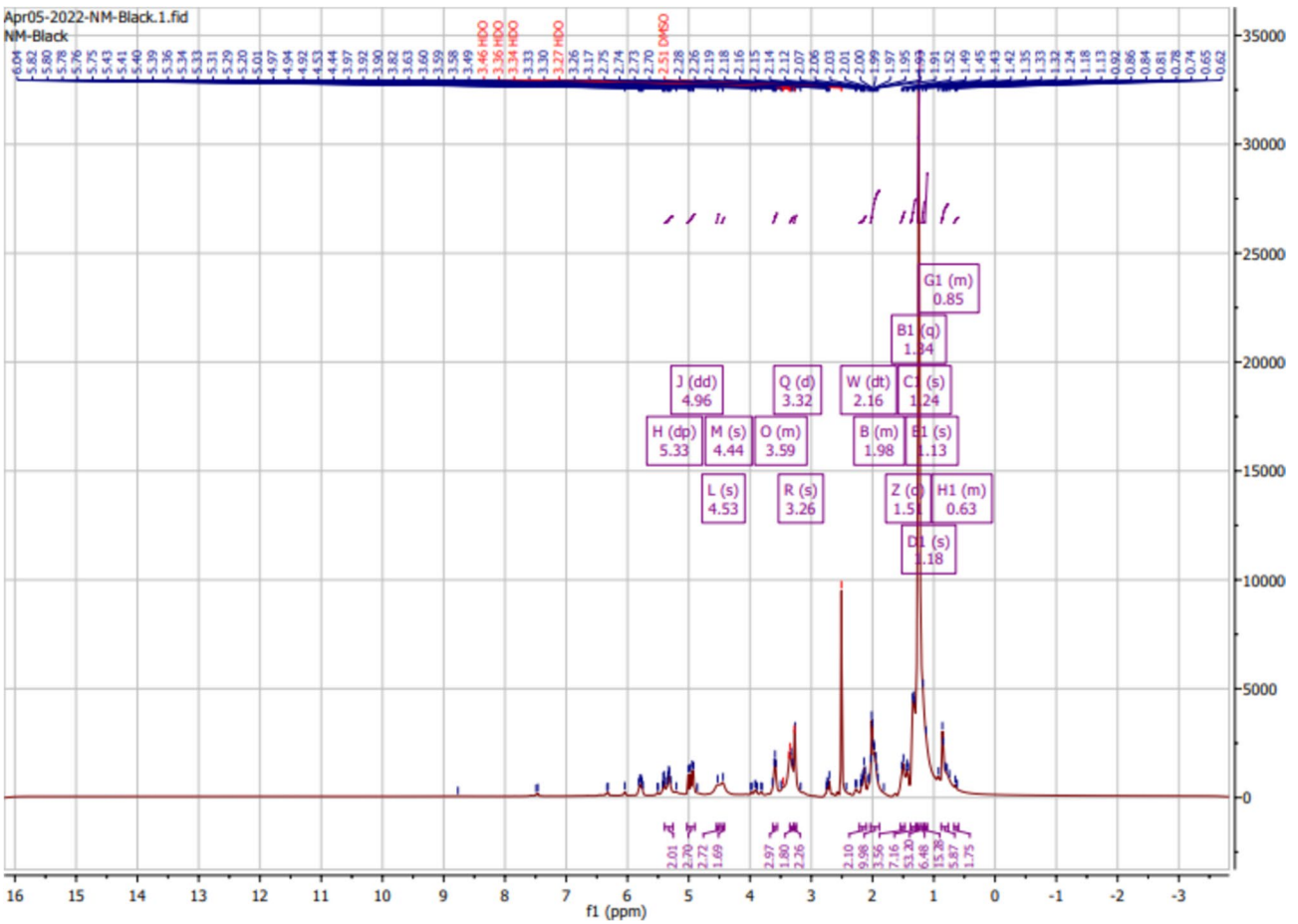


Fig. 3 ^{1}H Nuclear Magnetic Resonance for *P. americana* seed oil

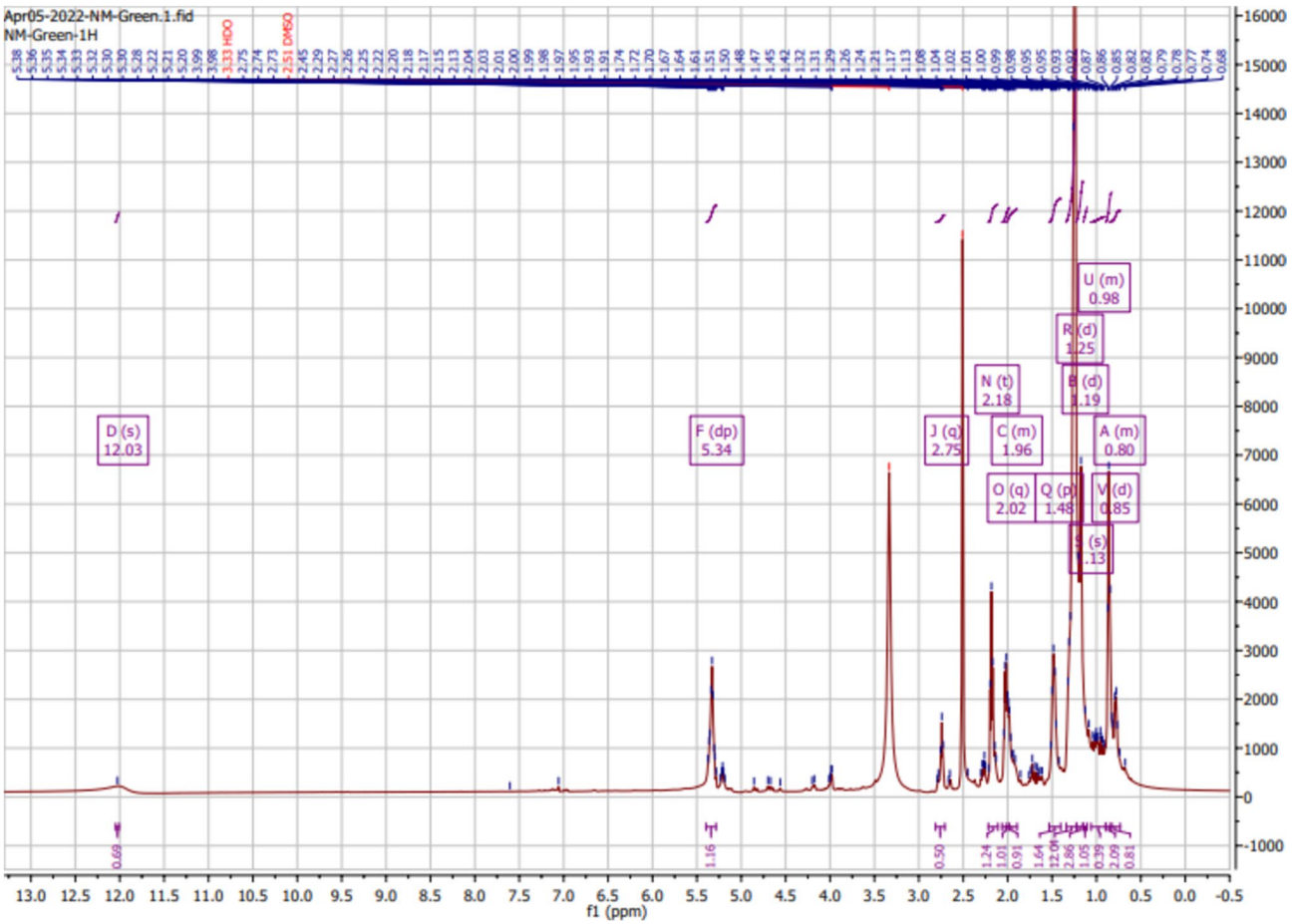


Fig. 4 ^{1}H Nuclear Magnetic Resonance for *D. edulis* seed oil

[25]. The signal at 5.56 to 5.48 ppm indicates the presence of (-CHOCOR) hydrogen, which is ester hydrogen. The allylic methylene hydrogen signal (-CH_2-CH = CH =) is at 1.98 to 2.00 ppm and a high integration of methylene (-CH_2 -) peaks in the aliphatic region around 1.2–1.5 ppm indicates long hydrocarbon chains, confirming the presence of fatty acids. The linoelic acyl chain hydrogen signal (-CH_3) at 1.51 to 1.48 ppm and the saturated, oleic, linoelic and acyl chain hydrogen (-CH_3). These significant peaks also confirm the presence of triglycerides in the seed oil.

3.9 Carbon-13 (^{13}C) nuclear magnetic resonance spectroscopy

The ^{13}C-NMR spectroscopy was employed to specifically differentiate between mono-, di-, and triglycerides in the oils due to its highly effective ability to identify the individual components and free fatty acids [26]. The characteristic signals for the functional groups in the *P. americana* seed oil as shown in Fig. 5 are: The central carbon in the glycerol backbone (CH-O), bonded to the two (-CH_2-O) groups, resonates around 68–70 ppm. This chemical shift is specific to the glycerol backbone and does not typically appear in other types of lipids like phospholipids or free fatty acids. The broad peaks around 29–34 ppm for the methylene carbons provide a relative measure of chain length, while the peaks at 128–130 ppm indicate unsaturation. High integration of these vinyl carbons would suggest a higher degree of unsaturation, which is typical for oils rich in unsaturated fatty acids like *P. americana* seed oil. Indicating the presence of a monoglyceride; at 85 ppm the signal indicates the presence of carbon with triple bond attached to an alkyl group. The signal at 15 to 30 ppm indicates the presence of R-CH_3, R-CH_2-R and R-CH-R. The chemical shifts, especially around 61–70 ppm (glycerol backbone), provide definitive evidence of triglycerides. The additional presence of unsaturated signals (128–130 ppm) confirms the typical fatty acid profile of *P. americana* seed oil.

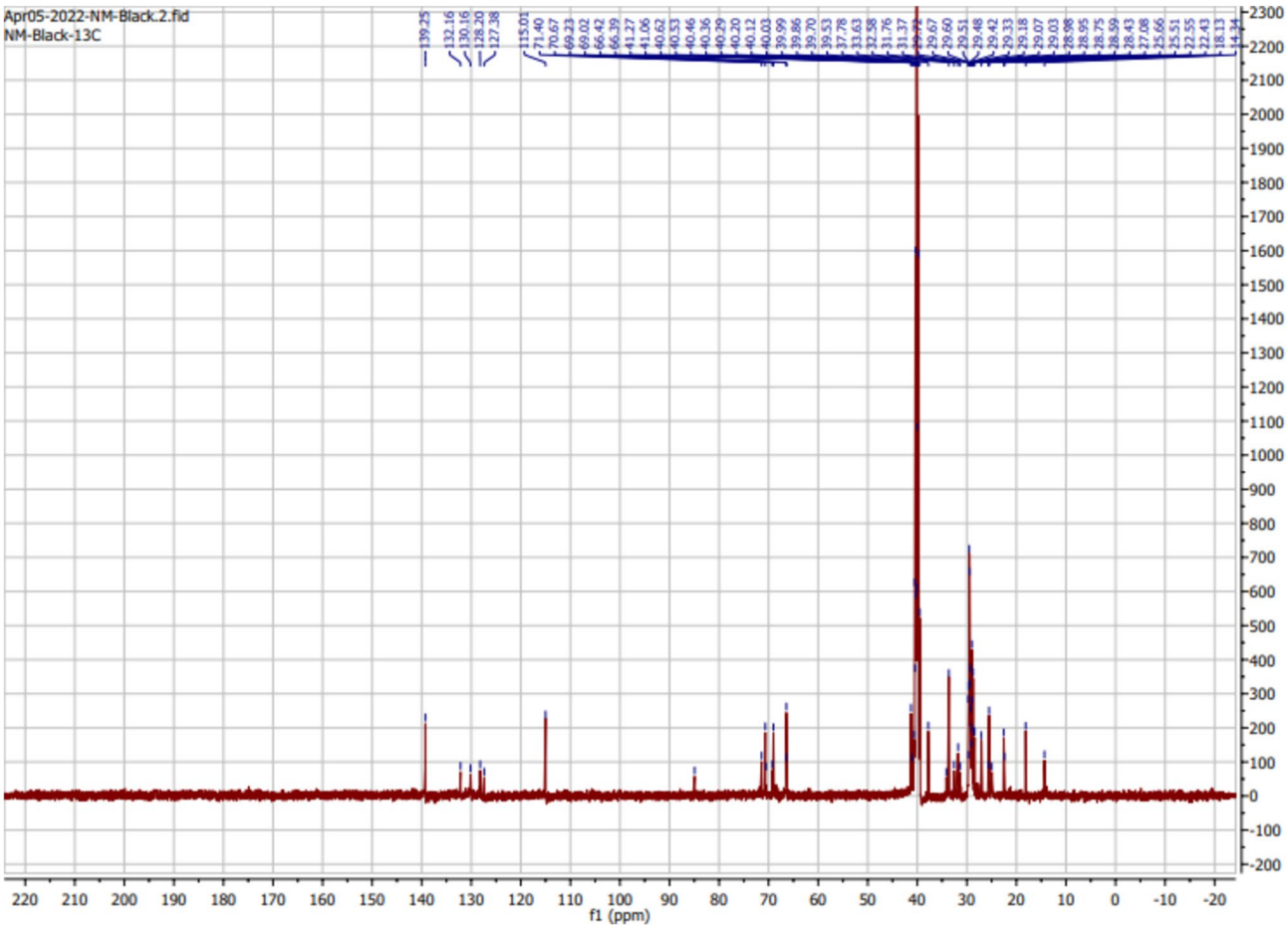


Fig. 5 ^{13}C Nuclear Magnetic Resonance Spectra for *P. americana* seed oil

The following observations were drawn from the ^{13}C-NMR of the *D. edulis* seed oil in Fig. 6, The ester carbonyl carbon resonates around 172–174 ppm, characteristic of a single ester linkage in monoglycerides. This signal is typically more intense than in mono- or diglycerides due to the higher number of ester bonds.

The absence of the 62–63 ppm (CH_2-OH) signal can help confirm the presence of triglycerides which lack this signal entirely. The alkyl carbon bonded to two alkyl group gave a peak at 128 to 130 ppm and the peaks between 27.07 to 29.03 ppm indicates the presence of methyl carbon.

3.10 Gas chromatography-mass spectrometry

These techniques are appropriate for the analysis of vegetable oils. Due to the ease with which the semi-volatile and volatile analytes that make up vegetable oils may be separated, recognized, and quantified. From the Total Ion Chromatogram (TIC) chromatogram in Fig. 7, the following compounds in Tables 3 and 4 and Figures S1, S2, S3 and S4, were found to be dominant in the *Persea americana* seed oil.

Tables 5 and 6 shows the significant compounds present in the *D. edulis* seed oil (Figure S5, S6, S7) identified using GC–MS (Fig. 8). It also shows the retention time and the percentage area of the observed fatty acids in the oils. The GC–MS analysis of *D. edulis* seed oil showed high content of saturated fatty acids.

Calculating the Ratio

$$Xa = \frac{PUSFA}{SFA}$$

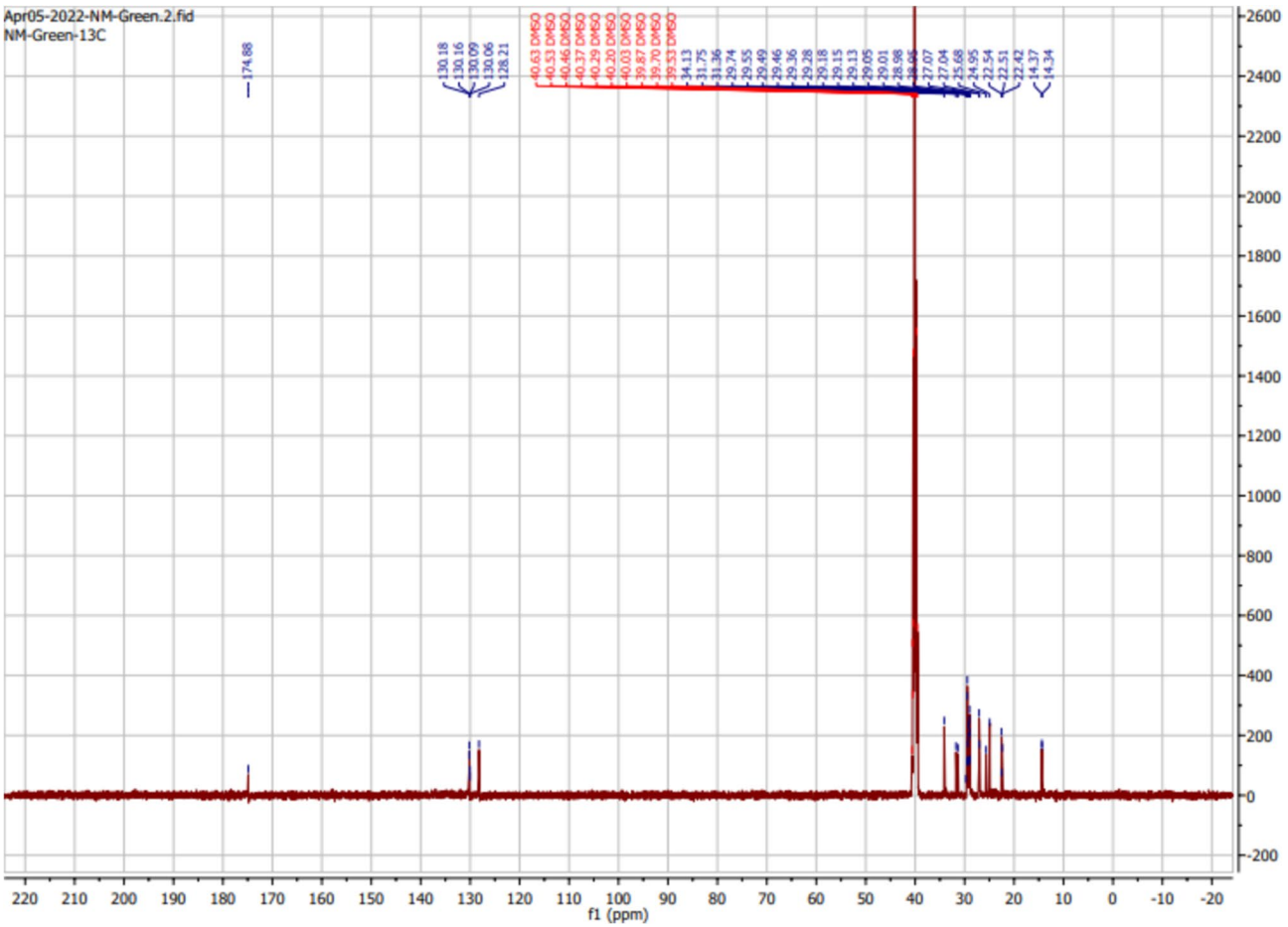


Fig. 6 ^{13}C Nuclear Magnetic Resonance Spectra for *D. edulis* Seed Oil

$$Xb = \frac{MUSFA}{SFA}$$

Table 7 shows the fatty acid profile of both *P. americana* and *D. edulis* seed oils. The seed oil of P. americana was discovered to have 11.70% saturated fatty acid, primarily stearic acid, 3.35% monounsaturated fatty acid, primarily palmitic acid, and 12.82% polyunsaturated fatty acid, primarily linoleic acid. Flores et al. [27] analyzed the fatty acid content of avocado seed oil from two types (Negra de la Cruz and Hass) harvested in Chile. They found that linoleic and oleic acid were the predominant fatty acids in the oil [27]. The *D. edulis* seed oil consists of 36.58% saturated fatty acid, primarily stearic acid, 72.21% monounsaturated fatty acid, primarily oleic acid, and 8.77% polyunsaturated fatty acid, primarily linoleic acid. Sonntag [28] reported that the oil belonged to the oleic acid group because oleic, which made up 76% of the total fatty acid content, was the predominant monounsaturated fatty acid in it [28]. The amount of oleic acid in Dacryodes is higher than the 15–20% recorded for cottonseed oil, whereas the amount of palmitic acid is lower than the 25–26% reported for cottonseed [29]. The analysis of *P. Americana* seed oil has identified the presence of many fatty acids, including lignoceric acid, arachidic acid, margaric acid, behenic acid, gadolenic acid, and erucic acid, albeit in minor amounts [30]. The same thing applies to *D. edulis seed* oil, except for arachidic acid which has the percentage content of 11.59%.

4 Conclusion

This study demonstrates that *D. edulis* and *P. americana* can both be used as substitute resource bases for fats and oils. The physio-chemical properties and fatty acid makeup of these oils, point to their potential industrial applications. 18.63% and 45.49% yields for *P. americana* and *D. edulis* were respectively obtained. The chemical characterization of

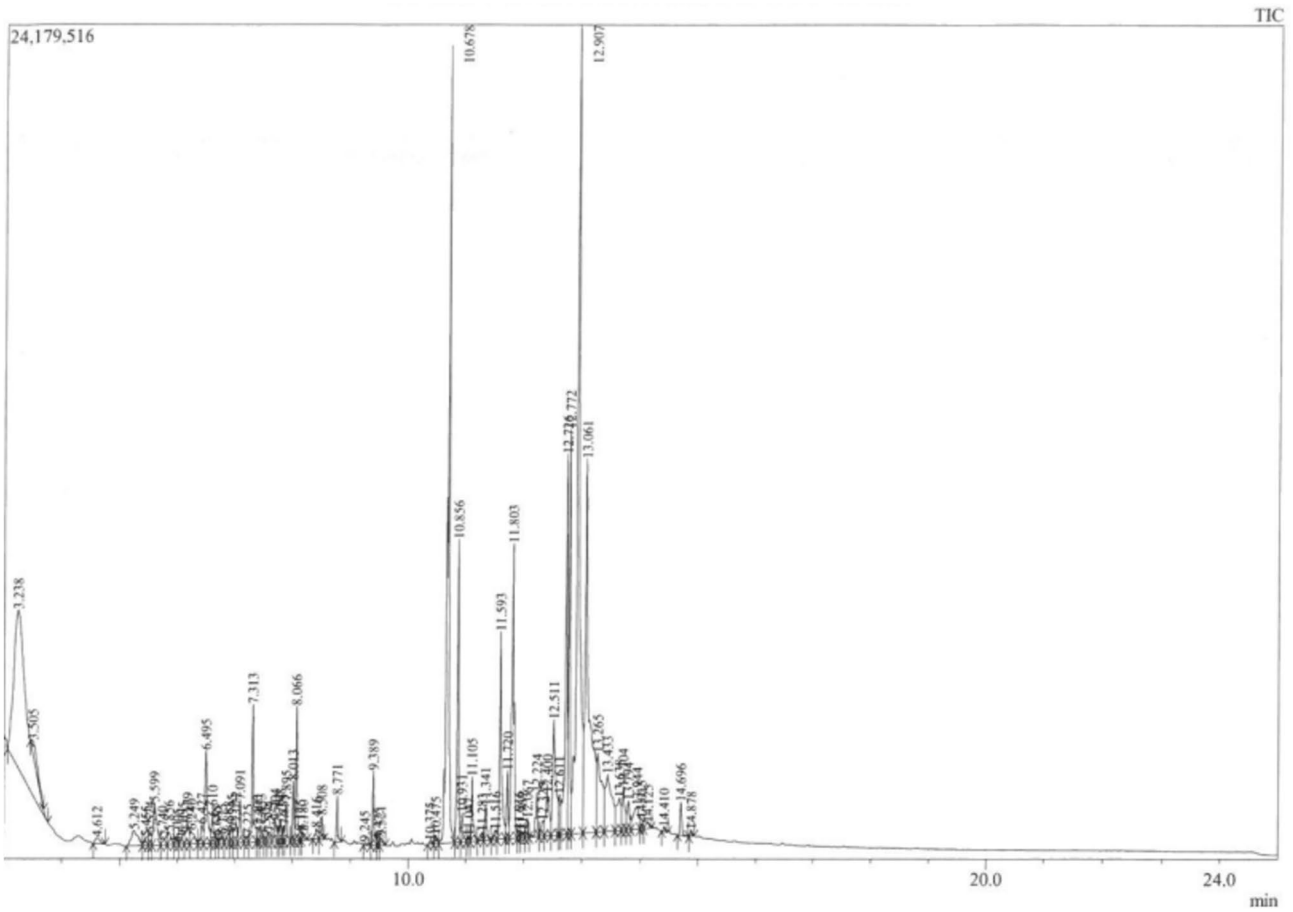


Fig. 7 TIC Chromatogram of *Persea americana* seed oil

Table 3 Identified Compounds in *Persea americana* Oil by GC–MS

No.	Compound	Retention Time/Area	Molecular Formula	Molecular weight (g/mol)	Concentration (%)
1.	1-Octadecene	9.389	$C_{16}H_{36}$	252.5	0.72
2.	2-Cyclohexene-1-carboxaldehyde	11.803	$C_{10}H_{16}O$	152.2	4.31
3.	Hexadecanoic acid	11.642	$C_{16}H_{32}O_2$	256.4	2.69
4.	Cyclopropanecarboxyllic acid tridec-2-ynyl ester	12.772	$C_{17}H_{28}O_2$	278.4	4.04
5.	Cyclopropanecarboxyllic acid undec-2-enyl ester	12.907	$C_{15}H_{26}O_2$	281.2	14.66

the oils gave iodine values of 51.86 mgI_2/g for *P. americana* oil and 48.72 mgI_2/g for *D. edulis* oil. Similarly, acid values of 3.45 mg KOH/kg and 5.76 mg KOH/kg were obtained for *P. americana* and *D. edulis* seed oils respectively. The *D. edulis* and *P. americana* seed oils are both considered non-drying oils, making them suitable for use in the cosmetics industry. The seed oil derived from *P. americana* contains a greater proportion of monounsaturated fats. When refined, these fats have the potential to reduce levels of harmful cholesterol and decrease the likelihood of developing heart disease and stroke. The high fatty acid concentration of the two oils makes them effective emollient and antiaging agents that can be used in body cream manufacturing.

Table 4 Identified Compounds in *Persea americana* Oil by GC–MS

No.	Compound	Applications
1.	1-Octadecene	1. Polyethylene and other polymers. 2. used as a solvent for oil-based active ingredients. 3. Surface treatment agent.
2.	2-Cyclohexene-1- carboxaldehyde	1. Fragrance Component in Perfumery. 2. Pesticide and Fungicide Synthesis. 3. Modifier in Resin Production.
3.	Hexadecanoic acid	1. Helps thicken formulations. 2. Food Additive and Flavoring Agent. 3. Has shown some antimicrobial activity.
4.	Cyclopropanecarboxyllic acid, tridec-2-ynyl ester	1. Insecticide Active Ingredient. 2. Surfactant or Additive in Specialized Formulations. 3. Research on Bioactive Compounds.
5.	Cyclopropanecarboxyllic acid, undec-2-enyl ester	1. Pest Management in Stored Grains. 2. Insecticides for Household Use. 3. Precursor in Chemical Synthesis.

Table 5 Identified compounds in *Dacryodes edulis* Oil by GC–MS

No.	Compound	Retention time/area	Molecular formula	Molecular weight (g/mol)	
1.	Tridecane	7.315	C13H28	184.367	1.62
2.	Tetradecane	8.067	$C_{14}H_{30}$	198.39	1.62
3.	Hexadecanoic acid	11.642	$C_{16}H_{32}O_2$	256.42	24.85
4.	Ethyl ester	11.726	$C_{20}H_{40}O_2$	312.5	3.23
5.	9,12-Octadecadienoic acid	12.550	$C_{18}H_{32}O_2$	280.445	6.30
6.	Dodecane, 2,6,11-trimethyl	12.772	$C_{15}H_{32}$	212	9.779
7.	Linoleic acid, Butyl ester	13.340	$C_{22}H_{42}O_2$	338.5677	0.09

Table 6 Identified compounds in *Dacryodes edulis* Oil by GC–MS

No.	Compound	Applications
1.	Tridecane	1. Emollient and Skin Conditioner In cosmetics. 2. Component in Jet and Diesel Fuels. 3. Solvent in Chemical Synthesis
2.	Tetradecane	1. Solvent and Carrier for Fragrance Compounds. 2. Non-reactive base in topical pharmaceutical creams. 3. As a feedstock in creating surfactants and detergents.
3.	Hexadecanoic acid	1. Helps thicken formulations. 2. Food Additive and Flavoring Agent. 3. Has shown some antimicrobial activity.
4.	Ethyl ester	1. Widely used in fish oil supplements. 2. Used as solvents in formulations. 3. Excipients in Formulations as inert carriers.
5.	9,12-Octadecadienoic acid	1. A building block that supports immune function. 2. Anti-Acne and Anti-Inflammatory Agent. 3. Used in making of Paints, Coatings, and Varnishes.
6.	Dodecane, 2,6,11-trimethyl	1. Induction of autoimmune diseases in animal models. 2. Tracer in Environmental Studies. 3. Found in small amounts in fragrances.
7.	Linoleic acid, Butyl ester	1. Conditioning agent in hair products. 2. Anti-Inflammatory support. 3. Serves as an environmentally friendly solvent.

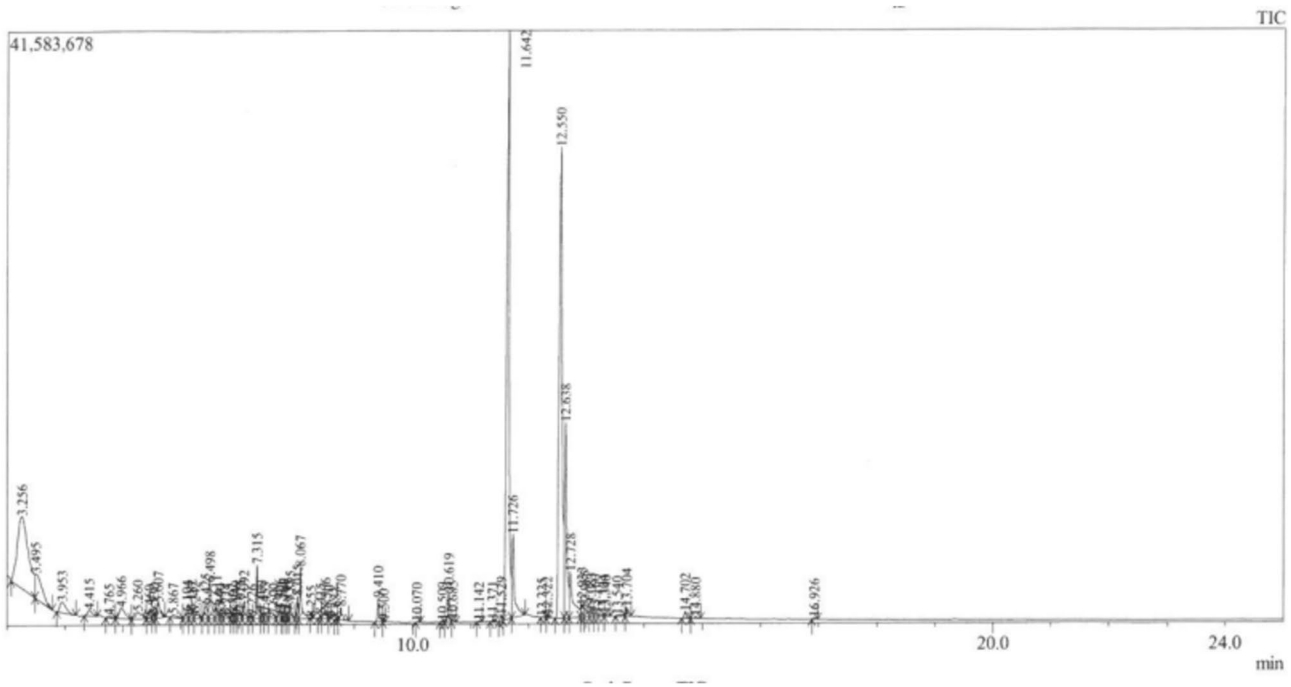


Fig. 8 TIC Chromatogram of *Dacryodes edulis* seed oil

Table 7 Fatty acid profile of *P. Americana* and *D. edulis*

Class	Saturated fatty acids (SFA) (%)			Monounsaturated fatty acids (MUSFA)					Polyunsaturated fatty acids (PUSFA)		Total			Ratios	
Fatty Acids	Stearic 18:00	Arach 20:00	Beh 22:00	Lig 24:01	Pal 16:01	Gad 20:01	Ole 18:01	Eru 22:10	Lin 18:2n6	Alp 18:3n3	SFA	MUSFA	PUSFA	Xa	Xb
P. americana	9.54	0.07	2.09	0.07	2.69	0.12	0.16	0.31	12.10	0.72	11.70	3.35	12.82	1.09	0.28
D. edulis	24.66	11.59	0.33	0.06	24.85	0.37	46.83	0.37	6.30	2.47	36.58	72.21	8.77	0.23	1.97

N.B Arch Arachidic, *Beh* Behenic, *Lig* Lignoceric, *Pal* Palmitic, *Ole* Oleic, *Gad* Gadoleic, *Eru* Erucic, *Lin* Linoleic, *Alp* Alpha linoleic, *FA* Fatty acid

Author contributions Ejikeme P.M.: conceptualization, data analysis, proofreading, Eze J.C.: experiments, Abugu H.O. and Nwadibia P.C.: manuscript writing, data analysis, Anyaogu D.I.: Literature Writing, proofreading and FTIR Interpretation.

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Data availability All data generated or analyzed are available within the manuscript.

Declarations

Plant ethics statement *Dacryodes edulis and Persea americana* were collected in Ogige Market in Nsukka, Enugu State, Nigeria. The cultivated plants' fruits were grown in Ovoko area of Nsukka local government council and harvested on the day of purchase (22nd July, 2022). The plant material were identified by Dr. N. Abu of the Department of Plant science of the university of Nigeria and a voucher specimen was deposited at University of Nigeria herbarium. The collection of the plants used in the study complies with local or national guidelines with no need for further affirmation.

Competing interests The authors declare no competing interests.

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