Phytochemical Profiling and Therapeutic Potentials of Monoterpenes and Aromatic Hydrocarbons from Avocado Seed Extract

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ABSTRACT

The present study focuses on the phytochemical profiling and therapeutic potentials of monoterpenes and aromatic hydrocarbons isolated from the avocado (Persea americana) seed extract. Gas Chromatography-Mass Spectrometry (GC-MS) analysis of the active fraction (ADAE3) revealed the presence of diverse bioactive compounds, including β-myrcene, 1-methyl-4-(1-methylethyl)-1,3-cyclohexadiene, (1R)-2,6,6-trimethylbicyclo [3.1.1] hept-2-ene, p-cymene, and pseudocumene. These compounds exhibit a wide range of pharmacological activities such as anti-inflammatory, analgesic, antioxidant, antimicrobial, and neuroprotective effects. β-Myrcene was particularly noted for its superior ability to reduce inflammatory markers and alleviate neuropathic pain compared to standard analgesics, while p-cymene demonstrated synergistic effects with other bioactive agents, enhancing antimicrobial and anti-inflammatory responses. Additionally, aromatic hydrocarbons such as pseudocumene were found to contribute antioxidant activity, underscoring their therapeutic relevance. Supporting compounds identified, including halogenated epoxides, saturated and unsaturated hydrocarbons, and carboxylic acid esters, provide further evidence of the chemical diversity and industrial significance of the extract. Collectively, the findings highlight the potential of avocado seed as a valuable source of natural therapeutic agents, offering opportunities for pharmaceutical, cosmetic, and industrial applications. This study therefore contributes to the growing body of evidence supporting the medicinal and economic relevance of bioactive compounds from plant-derived sources.

Keywords: Avocado seed, Aromatic hydrocarbons, Monoterpenes, Phytochemical profiling, Therapeutic potential

INTRODUCTION

Avocado (Persea americana), a member of the Lauraceae family, is a tropical and subtropical fruit valued for its nutritional and medicinal benefits. While its pulp and oil have been extensively studied, the seed remains largely underutilized despite accumulating evidence that it contains diverse bioactive compounds with significant pharmacological potential. Recent studies have revealed that avocado seed extracts possess antioxidant, antimicrobial, anti-inflammatory, and anticancer properties, which are largely attributed to their complex mixture of secondary metabolites such as terpenes, hydrocarbons, esters, and phenolic compounds [1, 2]. Among these constituents, monoterpenes and aromatic hydrocarbons have gained increasing scientific interest due to their wide range of therapeutic and industrial applications.

Monoterpenes are a class of terpenoids composed of two isoprene units and are widely distributed in essential oils of aromatic plants. They are known for their volatility, pleasant aroma, and bioactivity [3]. Compounds such as β-myrcene, linalool, and limonene have been reported to exhibit analgesic, anti-inflammatory, sedative, and antimicrobial properties [4, 5]. β-Myrcene, in particular, has demonstrated superior efficacy in reducing inflammatory markers and alleviating neuropathic pain compared to conventional analgesics. Similarly, 1-methyl-4-(1-methylethyl)-1,3-cyclohexadiene has been identified for its strong antioxidant and antimicrobial effects, making it a promising compound for therapeutic and cosmetic formulations [2, 6]. The monoterpene (1R)-2,6,6-trimethylbicyclo [3.1.1] hept-2-ene, a key constituent in essential oils and fragrances, also demonstrates broad-spectrum antibacterial and antifungal activities comparable to synthetic drugs [7, 8].

Aromatic hydrocarbons, on the other hand, are organic compounds characterized by their benzene ring structure, which confers chemical stability and diverse biological functionality [9]. In avocado seed extracts, compounds such as pseudocumene and p-cymene have been identified as major constituents. Pseudocumene serves as a precursor for high-performance polymers and exhibits antioxidant activity [10, 11], while p-cymene is known for its anti-inflammatory, antimicrobial, and synergistic interactions with other bioactive agents [12]. These properties suggest that aromatic hydrocarbons from plant sources may contribute significantly to the medicinal value of natural products.

Despite the growing recognition of these compounds, there remains limited information on the chemical composition and therapeutic relevance of monoterpenes and aromatic hydrocarbons derived specifically from avocado seed extract. Given the increasing demand for natural bioactive compounds as alternatives to synthetic pharmaceuticals, exploring these constituents may provide valuable insights into developing plant-based therapeutic agents with broad-spectrum efficacy and reduced side effects. Furthermore, valorizing avocado seed—a byproduct often discarded as waste—aligns with global efforts toward sustainable resource utilization and waste-to-wealth conversion in natural product research. Therefore, this study aims to carry out a phytochemical profiling of monoterpenes and aromatic hydrocarbons present in avocado seed extract and to evaluate their therapeutic potentials, including their anti-inflammatory, antimicrobial, and antioxidant properties. The findings are expected to provide a scientific basis for the medicinal and industrial applications of these compounds, contributing to the growing field of phytopharmacology and green chemistry.

Material and methods

Materials

All reagents and solvents were of analytical grade and obtained from Sigma-Aldrich (USA) and BDH Chemicals (UK). Instruments used included: rotary evaporator (Heidolph, Germany), UV–Vis spectrophotometer (Shimadzu UV-1800), GC–MS (Agilent 7890A/5975C), analytical balance (Mettler Toledo, USA), and incubator (Memmert, Germany).

Collection and Preparation of Plant Material

Fresh avocado (Persea americana) fruits were obtained from Eke Agbani Market in Enugu State, Nigeria. The seeds were removed, washed thoroughly with distilled water to remove adhering pulp, and air-dried at room temperature for 14 days. The dried seeds were then oven-dried at 45 °C to constant weight and ground into fine powder using an electric blender. The powdered sample was stored in an airtight container at room temperature until extraction.

Extraction Procedure

About 200 g of the powdered avocado seed was soaked in 800 mL of analytical grade ethanol (Sigma-Aldrich, ≥99.9% purity) for 72 hours with intermittent shaking to ensure maximum extraction of phytochemicals. The mixture was filtered through Whatman No. 1 filter paper, and the filtrate was concentrated using a rotary evaporator (Heidolph, Germany, Model 4011) at 40 °C under reduced pressure. The concentrated crude extract was weighed and labeled as Avocado Seed Ethanolic Extract (ASEE) and stored at 4 °C for further analysis.

Chromatographic Fractionation of Extract

The separation of phytoconstituents was carried out using column chromatography. A clean, dried glass column was packed with silica gel (mesh size 60–120) that had been activated at 110 °C to serve as the stationary phase. The column was carefully filled with the silica gel and the solvent (mobile phase) to prevent air bubbles, and the stationary phase was allowed to stabilize. The plant extract was mixed thoroughly with portions of the stationary and mobile phases, and the solvent was evaporated to obtain a free-flowing material. This dried material was then introduced into the column and eluted in a gradient manner using a mixture of ethyl acetate and n-hexane. The resulting fractions were collected, and the solvent was recovered by simple distillation. Fractions exhibiting similar separation patterns on TLC plates were pooled together for further analysis.

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The collected fractions were subsequently analyzed using Thin Layer Chromatography (TLC). Pre-coated MERCK F254 silica gel plates were used, and small quantities of each fraction were applied using a capillary tube and allowed to dry. The plates were developed in a TLC chamber containing a solvent mixture of ethyl acetate and hexane (3:7). After the solvent front reached an appropriate distance, the plates were removed, air-dried, and examined under UV light to detect fluorescence and compound activity. To further visualize the separated components, the plates were sprayed with 5% sulfuric acid in anisaldehyde and heated gently in a fume cupboard. The number of visible spots and their migration distances were recorded, and the retention factor (Rf) values were calculated to characterize each compound present in the fractions.

UV-Vis of the Extract

The UV/Vis spectra were recorded with a spectrophotometer (UV-1650PC, Shimadzu, Kyoto, Japan). Quartz cells (1cm) were used for the measurement of all absorbance. The spectra for all sample were scanned from range 200 to 800 nm. Samples were predisposed to plastic cuvettes supplied by Eppendorf (Hamburg, Germany) and covered by cardboard to shield the cuvette from stray light. The spectra were normalized by setting the absorbance at 800 nm equal to zero.

Fourier-Transform Infrared Spectroscopy (FTIR)

An FTIR spectrophotometer (Spectrum BX, PerkinElmer, England) was used to characterize the functional groups of ethyl acetate and hexane (3:7) isolate of Persea americana seed using the KBr pellet method. About 5 mg of the sample was mixed homogeneously with 100 mg of dry KBr powder and compressed into a 13 mm transparent disc using a hydraulic press. The pellet was placed in a demountable cell holder and scanned in the spectrophotometer within the range of 4000–800 cm^{-1} to identify functional groups present in isolate of Persea americana seed

Gas Chromatography–Mass Spectrometry (GC–MS) Analysis

The chemical composition of the active ethyl acetate and hexane (3:7) isolate of Persea americana seed was evaluated by GC-MS (Agilent Technologies 7890A GC paired with 5975C MS detector). The device used an HP-5MS capillary column (30 m × 0.25 mm × 0.25 µm). Helium was employed as the carrier gas, with a constant flow rate of 1.0 mL/min. The oven temperature was programmed to start at 50 °C (held for 2 minutes), then increase to 200 °C at 10 °C/min, and lastly to 280 °C at 5 °C/min (held for 5 minutes). The injector and detector temperatures were kept at 250 degrees Celsius. The injection volume was 1 µL, and ionisation was achieved using electron impact at 70 eV. The overall running time was 40 minutes. Compounds were identified by matching their mass spectra to those found in the NIST and Wiley spectral databases. Monoterpenes, aromatic hydrocarbons, halogenated epoxides, saturated and unsaturated hydrocarbons, and esters were identified based on retention times and fragmentation patterns.

RESULT AND DISCUSSION

Quantitative Phytochemical Screening of Avocado (Persea Americana) seed

The sequential purification of the crude extract using n-hexane, chloroform, and ethyl acetate aimed to remove impurities and isolate target phytochemicals, particularly flavonoids. In this study, flavonoids were classified based on structural differences in the C-ring, and their concentrations are presented in Table 1.

Table 1: Quantitative Phytochemical Screening of Avocado (Persea Americana) seed

	Compounds	Conc.(µg/mL)	Functional groups	Family
1	Daidzin	5.79720	-OH, C=O, Glucoside (-O-glucose)	flavonoid
2	Butein	4.79777	-OH, Ketone (C=O), Phenyl (-C_6H_5	flavonoid
3	Naringenin	0.237282	-OH, C=O, Benzopyran	flavonoid

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4	Luteolin	4.51648	-OH, C=O, Benzopyran	flavonoids
5	Kaempferol	0.305119	-OH,C=O, Benzopyran	flavonoids
6	Epicatechin	0.822314	-OH, Benzopyran	flavonoid
7	Epigallocatechin	0.471428	-OH, Benzopyran	flavonoid
8	Quercetin	0.487359	- OH), Ketone (C=O), Benzopyran	flavonoid
9	Gallocatechin 3 gallate	0.173139	-OH), Ester (-COO- from gallate), Benzopyran	flavonoid
10	Robinetin	0.213070	-OH, C=O	flavonoid,
11	Myricetin	3.35567	-OH, C=O	flavonoids
12	Nobiletin	2.39335	$-OCH_3$, C=O	flavonoids
13	Baicalin	0.474066	-OH), Glucuronide (-COO-glucose), Ketone (C=O)	flavonoids
14	Tangeretin	0.318264	$-OCH_3$), Ketone (C=O	flavonoids
15	Artemetin	2.42077	$-OCH_3$), Hydroxyl (-OH), Ketone (C=O	flavonoids
16	Naringin	0.407388	ydroxyl (-OH), Ketone (C=O), Rhamnoglucoside	Flavanone glycoside
17	Lunamarin	0. 656105	Ketone (C=O),	Flavonoids
18	Cinnamic acid	0. 465011	Hydroxyl (-OH), Benzopyran	Phenolic Acids
19	Vinnillic acid	2.37956	-OH), Carboxyl (-COOH), Methoxy ($-OCH_3$	Phenolic Acids
20	Coumaric acid	0. 85394	-OH), Carboxyl (-COOH), Phenyl ($-C_6H_5$)	Phenolic Acids
21	Ferrulic acid	0.812418	-OH), Carboxyl (-COOH), Methoxy ($-OCH_3$	Phenolic Acids
22	Piperic acid	12.46763	-COOH), Methylenedioxy ($-O-CH_2-O$), Alkene (-C=C	Phenolic Acids
23	Ellagic acid	15.59621	-COO-), Hydroxyl (-OH), Benzophenone	Phenolic Acids
24	Flavone	17.79720	Ketone (C=O), Benzopyran	flavonoids
25	Flavon-3-ol	17.09166	Hydroxyl (-OH), Benzopyran	flavonoids
26	Gentisic acid	11.39680	Hydroxyl (-OH), Carboxyl (-COOH)	Phenolic Acids
27	Cinnamic acid	2.93940		Phenolic Acids

The high amounts of flavone (17.79720 µg/mL) and flavon-3-ol (17.09166 µg/mL) suggest substantial bioactivity with antioxidant and anti-inflammatory properties, supporting therapeutic applications [13, 14]. Flavones are associated with cardiovascular and neuroprotective effects, whereas flavon-3-ols have anti-aging and immune-boosting qualities. Plant flavonoid concentrations (10-20 µg/mL) support previous findings [4, 15].

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Other flavonoids with lower quantities include daidzin (5.79720 µg/mL), butein (4.79777 µg/mL), and luteolin (4.51648 µg/mL).
Persea americana seed extract included lower amounts of kaempferol (0.305119 µg/mL), naringenin (0.237282 µg/mL), and epicatechin (0.822314 µg/mL), supporting their antioxidant and anti-inflammatory activities in metabolic regulation [16]. These findings support the pharmacological relevance and nutritional benefits of flavonoids across plant species, such as better digestion, anti-carcinogenic, and cardioprotective properties [12, 17].

Phenolic acids, denoted by hydroxyl (-OH) and carboxyl (-COOH) groups, aid in antioxidant and anti-inflammatory properties. High quantities of ellagic acid (15.59621 µg/mL), piperic acid (12.46763 µg/mL), and gentisic acid (11.39680 µg/mL) indicate high pharmacological potential. Ellagic acid decreases oxidative stress and promotes neuroprotection [18], whereas piperic acid improves nutrient absorption and cognitive performance [14]. Their presence in seeds increases nutritional and therapeutic value, improving cardiovascular health and lowering the risk of chronic diseases. These findings support prior research on the bioactivity of phenolic acids and their use in functional foods and nutraceutical formulations to promote health outcomes [12, 16].

UV-Vis Analysis of fraction of Avocado (Persea Americana) seed

The fraction of avocado (Persea Americana) seed recovered using column chromatography from an ethyl acetate and n-hexane combination (3:7) has a single spot with an Rf value of 0.78. The UV-Vis spectrum (Figure 2) revealed a significant absorption peak in the UV area between 270-290 nm (Figure 1), indicating the presence of phenolic chemicals or flavonoids [17]. The progressive decrease in absorbance above 300 nm revealed the absence of strongly conjugated systems that absorb in the visible region. A modest peak near 350-400 nm may indicate the presence of flavonoids with prolonged conjugation [16, 18].

The substantial absorption in the lower UV range (below 250 nm) corresponds to the $\pi \rightarrow \pi^*$ transitions typical in aromatic rings, confirming the presence of polyphenols [5, 19]. The presence of a small shoulder around 320 nm may also indicate flavonoid compounds [20]. The spectrum's structure is comparable with prior research on plant extracts high in phenolic and flavonoid chemicals, which are known to have antioxidant effects [21]. The UV-Vis spectrum of the separated fraction of Persea americana seed indicated the presence of bioactive chemicals, specifically polyphenols and flavonoids. These chemicals contributed to the extract's possible biological activity, which included antioxidant properties.

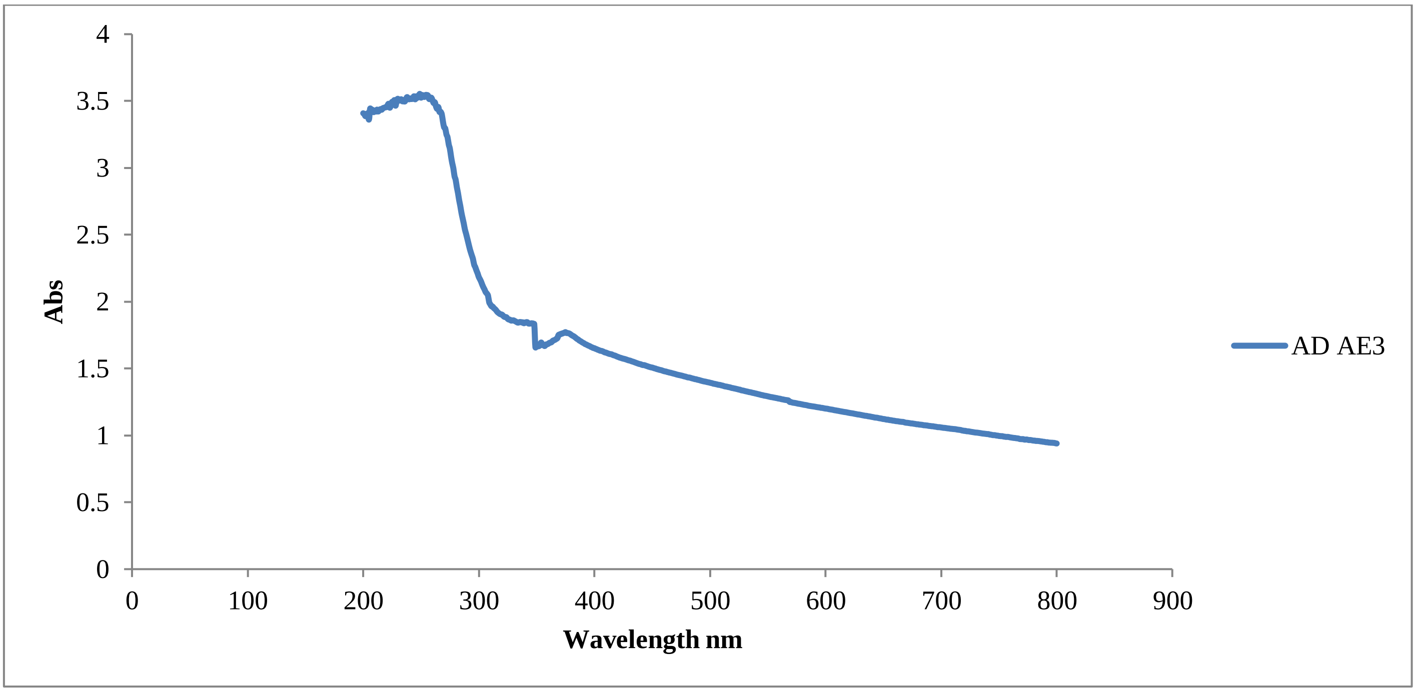

Figure 1: UV-Vis spectrum of ADAE3 Fraction of Persea americana seed

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FTIR Analysis of isolated fraction of Avocado (Persea Americana) seed

The FTIR analysis of the isolated fraction of Avocado (Persea Americana) seed via mixed solvent of ethyl acetate and n-hexane are shown in Table.2

Table 2: FTIR analysis of isolated fraction of Avocado (Persea Americana) seed

Functional Group	Frequency Range (cm^{-1})	Description
O-H/N-H Stretching	3200-3600	Broad absorption indicating hydroxyl (O-H) or amine (N-H) groups, commonly found in alcohols, carboxylic acids, and amines.
C-H Stretching	2800-3000	Peaks in this range correspond to aliphatic C-H stretching, suggesting hydrocarbons.
C=O Stretching	1700-1750	Sharp peak confirming the presence of carbonyl (C=O) groups in aldehydes, ketones, esters, or carboxylic acids.
C=C Stretching	1500-1600	Peaks in this region indicate aromatic rings or alkene groups.
C-O Stretching / Si-O Bonding	1000-1300	Absorption bands related to C-O stretching in esters or ethers and Si-O bonding in silicates.

The broad absorption band in the 3200-3600 cm^{-1} region indicates the presence of hydroxyl (O-H) or amine (N-H) functional groups, which are commonly present in alcohols, carboxylic acids, and amines [6, 21]. Peaks at 2800-3000 cm^{-1} correspond to aliphatic C-H stretching, indicating the presence of hydrocarbons [22]. A high signal around 1700-1750 cm^{-1} revealed the presence of carbonyl (C=O) groups, which are often associated with aldehydes, ketones, esters, or carboxylic acids [17]. Peaks between 1500-1600 cm^{-1} imply C=C stretching, possibly associated with aromatic rings or alkenes [13]. Significant absorption bands were seen between 1000-1300 cm^{-1}, indicating C-O stretching in esters or ethers and Si-O bonding in silicate-based compounds [23].

The FTIR spectrum of the isolated fraction shows a complex molecular structure containing functional groups like hydroxyl, carbonyl, aliphatic C-H, and aromatic C=C bonds. The statistics indicate that the sample may contain a mixture of organic components, such as polymers, biomolecules, or composite materials.

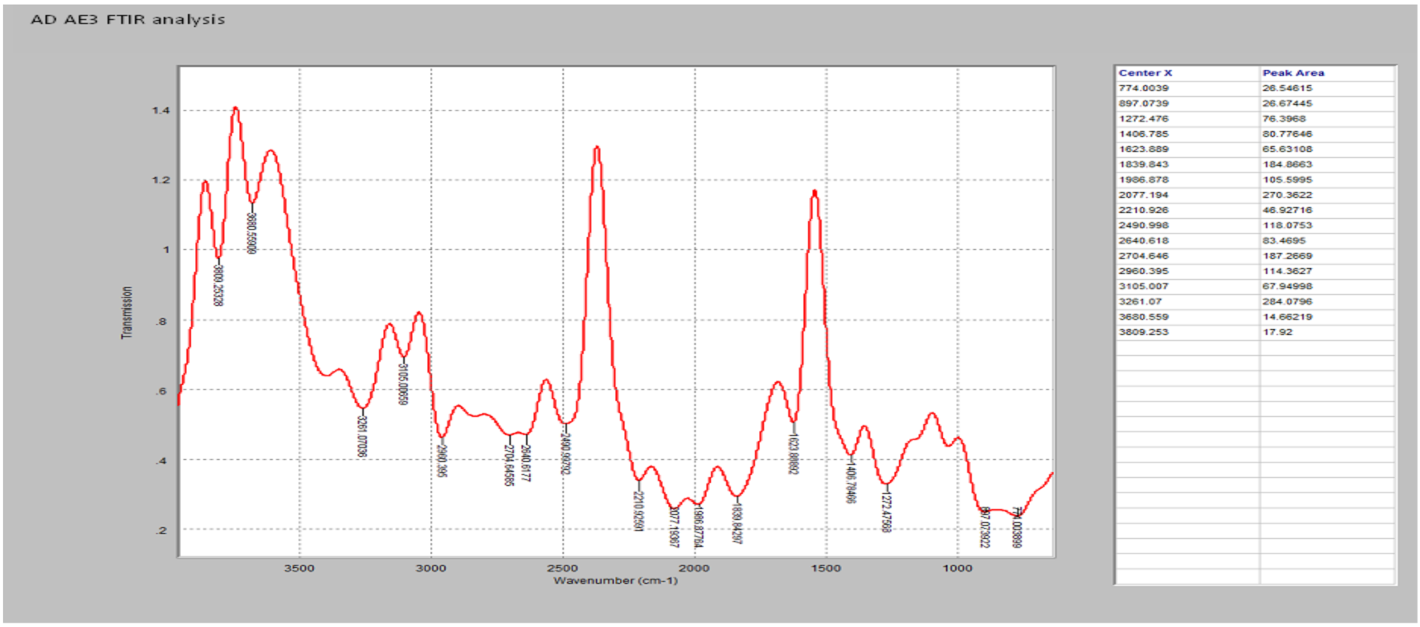

Figure 2: FTIR spectrum of ADAE3 Fraction of Persea americana seed

GCMS Analysis of isolated fraction of Avocado (Persea Americana) seed

The GCMS analysis of the isolate of Avocado (Persea Americana) seed via mixed solvent of ethyl acetate and n-hexane are shown in Table.3

Table 3: GCMS of isolated fraction of Avocado (Persea Americana) seed

	Name of compounds	Formula	Functional group	Rf values	Classification
1	β-Myrcene	$C_{10}H_{16}$	C=C	6.301	Monoterpene
2	Pseudocumene	C_9H_{12}	Benzene ring	6.365	Aromatic Hydrocarbon
3	Epichlorohydrin	C_3H_5ClO	Oxirane, methyl $-CH_2Cl$,	6.496	Halogenated Epoxide
4	**1-methyl-4-(1-methylethyl)-1,3-cyclohexadiene**	C10H16	(-C=C-), isopropyl groups	6.956	Monoterpene
5	p-Cymene	$C_{10}H_{14}$	Benzene ring and Isopropyl	7.201	Monoterpene derivative
6	2,2,5-trimethylHexane,	C_9H_{20}	-	7.949	Saturated Hydrocarbon
7	(1R)-2,6,6-Trimethylbicyclo [3.1.1] hept-2-en	$C_{10}H_{16}$	C=C	8.160	Monoterpene
8	3,6-dimethyldecane,	$C_{12}H_{26}$	-	8.258	Alkane
9	2,6,10,14-Tetramethylheptadecane	$C_{21}H_{44}$	-		Alkane
10	2,6,10,14-tetramethyl Heptadecane	$C_{21}H_{44}$	-	8.958	Isoprenoid
11	prop-1-en-2-yl tridecyl ester	$C_{16}H_{30}O_2$	-COO-	9.339	Carboxylic Acid Ester
12	Carbonic acid, nonyl vinyl este	$\mathbf{C_{12}H_{22}O_3}$	(-O-(C=O)-O-)	9.543	**Carbonate Ester**
13	Bicyclo[7.2.0]undec-4-ene	$C_{11}H_{18}$	(-C=C-)	18.346	Bicyclic Alkene
14	2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	Phenol	20.974	Substituted Aromatic HC
15	4-Heptafluorobutyryloxyhexadecane	$C_{20}H_{37}F_7O_2$	-COO-, Perfluoroalkyl ($-C_4F_7$)	22.690	Fluorinated Ester
16	E-14-Hexadecenal	$C_{16}H_{30}O$	-CHO and (C=C	27.258	**Unsaturated Aldehyde**
17	1,2-Benzenedicarboxylic acid,	$C_8H_6O_4$	-COOH)	30.022	Aromatic Carboxylic Acid

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18	1-Eicosene	$C_{20}H_{40}$	-C=C-	30.257	Unsaturated Hydrocarbon)
19	6-(Trifluoromethoxy)-N-(trimethylsilyl)-1,3-benzothiazol-2-amine	$C_{10}H_{13}F_3N_2OSi$	$-OCF_3$, $-Si(CH_3)_3$,-NH-	30.433	Benzothiazole derivative
20	Oleic Acid	$C_{18}H_{34}O_2$	-COOH) and-C=C-	31.666	Fatty Acid
21	Eicosanol	$C_{20}H_{42}O$	-OH	32.969	Fatty Alcohol
22	Bis(2-ethylhexyl) phthalate	$C_{24}H_{38}O_4$	-COO-	34.008	Phthalate Ester
23	Piperidine-4-carbonitrile	$C_6H_{10}N_2$	-C≡N) and Piperidine	34.216	Heterocyclic Nitrile

Monoterpenes are a type of terpene composed of two isoprene units that are recognised for their volatility, aroma, and therapeutic properties [1]. β-Myrcene has analgesic and anti-inflammatory effects, which can help relieve pain and relax muscles [3]. It exhibits sedative and neuroprotective properties [24], as well as greater anti-inflammatory activity when compared to linalool and limonene [25]. [3] proved its efficiency in treating neuropathic pain in comparison to conventional analgesics. Similarly, 1-Methyl-4-(1-methylethyl)-1,3-cyclohexadiene has antibacterial and antioxidant characteristics, which can help prevent infections and reduce oxidative stress [23]. Its antioxidant activity is comparable to that of thymol [26], and its potential for bacterial inhibition has been confirmed [27]. (1R)-2,6,6-Trimethylbicyclo [3.1.1] hept-2-ene is utilised in essential oils and perfumes for its antibacterial and antifungal properties [28]. [24] further reported that monoterpenes enhance the bioavailability of anticancer drugs.

Aromatic hydrocarbons, characterized by benzene rings, are frequently used in the dye, resin, and pharmaceutical industries [29]. The separated fraction of avocado seed included pseudocumene and p-cymene. Pseudocumene (C_9H_{12}) is an intermediate in trimellitic anhydride production for high-performance polymers [26]. It also shows antioxidant properties in classical formulations [28, 30]. p-Cymene ($C_{10}H_{14}$) is used in perfumes and solvents (Smith & Jones, 2018), and has anti-inflammatory and antibacterial properties [17]. It boosts the effects of other bioactive substances, making them more effective in pain and respiratory therapy [31].

Halogenated epoxides, which combine halogen and epoxide groups, are extremely reactive and industrially valuable. The fraction contains epichlorohydrin (C_3H_5ClO), which is utilised in epoxy resin manufacture for adhesives and coatings [32] as well as medications for hypertension and bacterial infections [33]. Despite its toxicity and carcinogenicity, it remains essential in resin and drug manufacturing.

Saturated hydrocarbons, like 2,2,5-trimethylhexane (C_9H_{20}) and 3,6-dimethyldecane ($C_{12}H_{26}$), serve as solvents, lubricants, and fuel additives [28]. Although they are not medicinally active, they help pharmaceutical formulations by increasing drug solubility and bioavailability [17, 18]. Unsaturated hydrocarbons, such as 1-eicosene ($C_{20}H_{40}$), are reactive and beneficial in coatings and polymers [24]. 2,6,10,14-Tetramethylheptadecane ($C_{21}H_{44}$) provides emollient benefits for skin protection [21] and has potential functions in wound healing and regenerative medicine [33]. Carboxylic acid esters, which are essential in cosmetics and pharmaceuticals, serve as emulsifiers and bioactives. Prop-1-en-2-yl tridecyl ester ($C_{16}H_{30}O_2$) is useful in coatings, lubricants, and dermatological conditioning [28, 31]. Bis(2-ethylhexyl) phthalate ($C_{24}H_{38}O_4$), a plasticiser, causes endocrine hazards (Jones & Brown, 2019), leading to safer alternatives [6]. These esters illustrate the importance of balancing industrial utility with health safety through continual research and innovation.

CONCLUSION

The phytochemical analysis of avocado seed extract revealed the presence of pharmacologically active monoterpenes and aromatic hydrocarbons with diverse therapeutic properties. β-Myrcene, p-cymene, and related compounds demonstrated strong biological potentials, including anti-inflammatory, analgesic, antimicrobial, and antioxidant activities, suggesting their possible use in managing pain, infection, and oxidative stress-related disorders. The detection of additional hydrocarbons, esters, and halogenated epoxides further underscores the multifunctional nature of the extract, linking it to both medicinal and industrial applications. These findings affirm that avocado seed, often regarded as waste, represents a promising natural reservoir of bioactive compounds with significant health and economic benefits. Continued research on isolation, structural elucidation, and pharmacological evaluation of these compounds is essential to fully exploit their therapeutic and formulation potentials in modern medicine and biotechnology.

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