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ORIGINAL RESEARCH ARTICLE

# Base-assisted Extraction and GC-MS analysis of Bioactive Compounds from Mango and Neem Leaves: Potential for pharmaceutic and Bioenergy applications

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## ABSTRACT
The study investigates the bioactive chemical composition of mango (*Mangifera indica*) and neem (*Azadirachta indica*) leaves using Gas Chromatography Mass Spectrometry (GC-MS). The objective was to analyze their phytochemical constituents and explore their pharmaceutic, industrial, and environmental applications. The leaves were collected, dried, and extracted using sodium hydroxide (NaOH, 1.5g, 0.125 mol/L in 300ml distilled water, pH 13.10 at room temperature) as catalyst through alkaline hydrolysis, which increased the release of bioactive compounds. The percentage yield of extract obtained from 20g of samples was 43.30g and 44.25g respectively for mango and neem leaves respectively. GC-MS analysis identified 28 bioactive compounds in mango leaves and 20 compounds in neem leaves, including fatty acids, terpenoids, flavonoids, and sterols. In mango leaves, 9,12-Octadecadienoyl chloride (34.83 %), 9,12-Octadecadienoic acid (12.64 %), palmitic acid ethyl ester (8.15 %), hexadecenoic acid methyl ester (10.57 %), and linoleic acid ethyl ester (5.77 %) were the most abundant compounds. These compounds are known for their antioxidant, anti-inflammatory, antimicrobial, and biodiesel-related properties. Neem leaf extract revealed 1,3-Cyclobutanedione (26.68 %), 9,12,15-Octadecatrienoic acid methyl ester (11.25 %), hexadecenoic acid methyl ester (10.64 %), 9,12-Octadecadienoic acid (6.31 %), and phytol (2.57 %) as controlling compounds. These compounds can exhibit antimicrobial, anticancer, anti-inflammatory, and insecticidal activities as confirmed by various literature, reinforcing neem's traditional medicinal applications. The results confirm that mango and neem leaves have important pharmacologic and industrial potential. The presence of bioactive compounds suggests applications in medicine (anti-inflammatory, anticancer, antimicrobial), cosmetics (moisturizers, antioxidants), and biofuels (biodiesel production). The use of NaOH hydrolysis improved extraction efficiency, increasing the yield of valuable compounds. This study highlights the sustainable utilization of mango and neem leaves for pharmaceutical and industrial purposes, promoting eco-friendly and cost-effective applications.

## ARTICLE HISTORY
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## KEYWORDS
*Mangifera indica*, *Azadirachta indica*, Basic hydrolysis, GC-MS, Bioactive compounds, Industrial applications.



## INTRODUCTION
In recent decades, the exploration of plant-based bioactive compounds has intensified due to growing global demands for natural therapeutic agents and sustainable energy sources. Plant low-level metabolites, especially those with pharmacologic and industrial potential, are progressively being studied as alternatives to synthetic chemicals and fossil fuels (Cragg and Newman, 2013; Dewick, 2009). Among various plant species, *Mangifera indica* (mango) and *Azadirachta indica* (neem) stand out due to their broad range of biologically acrobatic compounds and traditional usage in ethnomedicine and agro-industrial applications.

*Mangifera indica*, widely cultivated across Asia, Africa, and hot America, is well known not only for its comestible fruits but also for its leaves, which are rich in polyphenols, flavonoids, xanthonoids (notably *Mangifera*), tannins, and terpenoids (Barreto *et al.,* 2020; Dinesh *et al.,* 2019). These compounds have demonstrated important antioxidant, microbial, antidiabetic, and anti-inflammatory activities in numerous in vitro and in vivo studies (Rajan *et al.*, 2021; Tan and Norhaizan, 2019; Ajila *et al.,* 2007). Similarly, *Azadirachta indica*, a member of the Meliaceae family native to the Indian subcontinent, is celebrated for its extensive medicinal value. Neem leaves, bark, and seeds contain a range of acrobatic molecules such as azadirachtin, nimbin, nimbidin, and quercetin, which have shown antibacterial, antiviral, antimalarial, antifungal, and anticancer properties (Biswas *et al.,* 2002; Alzohairy, 2016; Subapriya and Nagini, 2005; Kharwar *et al.,* 2011).

The extraction method plays a polar role in determining the quality and yield of bioactive compounds from plant materials. Formulaic extraction methods often involve the

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use of natural solvents and prolonged processing times, which can lead to degradation or loss of sensitive phytochemicals (Rostagno and Prado, 2013). Base-assisted extraction (BAE), a variant of alkaline hydrolysis, is gaining attention as a more prompt, environmentally friendly, and cost competent method. BAE promotes the breakdown of lignocellulosic matrices and hydrolysis of bound phytochemicals, enhancing the release of target compounds (Sethuraman and Meenakshi, 2015; Lin *et al.,* 2008). Moreover, the moderate alkaline conditions are especially competent for liberating phenolic and flavonoid glycosides without strong degradation (Pei *et al.,* 2020). Sodium hydroxide (NaOH) has been widely used as a catalyst in phytochemical extraction due to its ability to break down decomposable plant cell walls, enhancing the release of bound bioactive compounds (Raut and Patil, 2021). Studies have shown that NaOH hydrolysis improves the solubility and yield of low-level metabolites, making it a competent extraction method for plant-based research (Garg *et al.,* 2012).

Gas Chromatography Mass Spectrometry (GC-MS) remains one of the most powerful analytic techniques due to its peaky sensitivity, specificity, and robustness in separating and identifying volatile and semi-volatile compounds (Sparkman *et al.,* 2011; Kusuma *et al.,* 2020). When combined with optimized extraction strategies, GC-MS can provide comprehensive chemical fingerprints of plant extracts, facilitating the discovery of new compounds with pharmacologic and industrial relevance. Besides their well-documented pharmacologic uses, mango and neem leaves are alsoo being explored for their role in bioenergy applications. The increasing interest in biofuels, such as biodiesel and bioethanol, has led to the investigation of plant biomass rich in hydrocarbons and fatty acid derivatives. Studies have shown that some compounds in mango and neem leaves, such as long chain alkanes, esters, and lignin derived phenolics, can serve as promising feedstocks for thermochemical conversion and microbial fermentation (Mishra *et al.,* 2012; Ali *et al.,* 2020; Singh *et al.,* 2014).

The prevalent study aims to optimize base-assisted extraction parameters for mango and neem leaf biomasses, characterize the extracted bioactive compounds using GC-MS analysis, and evaluate the dual potential of these phytochemicals for pharmaceutical development and bioenergy production.This multidisciplinary approach aligns with the global agenda for green chemistry and sustainable development by promoting the utilization of agro-residues and underutilized plant parts for high-value applications. The unique approach of this study lies in the optimized application of base-assisted extraction (BAE) to isolate and characterize pharmacologically and industrially relevant compounds from the leaves of Mangifera indica and Azadirachta indica plant parts typically discarded as agricultural waste. While most late studies have focused on mango fruit, bark, or seed oil and neem seed or bark extracts, exceptional attention has been given to the leaves as multifunctional bioresources.(Pei *et al.,* 2020). By employing BAE, this research efficaciously enhances the recovery of a diverse spectrum of volatile and semi-volatile bioactive compounds, as revealed by comprehensive GC-MS profiling. Notably, the co-existence of antioxidants (e.g., cyclobutanedione, linolenic acid derivatives), antimicrobials (e.g., palmitic acrid esters), and nutritional terpenoids (e.g., phytol) in the neem extract, as well as pharmacologically and energetically valuable compounds in mango leaf extract, highlights the dual potential of these plants for pharmaceutic, aesthetical, and bioenergy applications. This work thus contributes significantly to the valorization of underutilized plant biomass, offering a sustainable and modern pathway for integrating agro-waste into phytomedicine and green energy systems, in line with the principles of the circular bioeconomy and eco innovation.

## MATERIALS AND METHODS

### Sample Collection and Preparation

Fresh 100g each of mango *(Mangifera indica)* and neem *(Azadirachta indica)* leaves were collected during last dry season from Mashi Local Government town (12°58'50"N 7°56'49"E) of Katsina State, Nigeria. The leaves were cleaned with distilled water to remove dirt and dried in the shade for three days to maintain their chemical constituents. Once dried, the leaves were ground into a fine powder using a mortar and pestle and stored in different airtight containers (labelled MI and AI respectively) at room temperature to prevent contamination.

### Extraction procedure

Twenty grams (20.0 g) of finely powdered leaf samples of mango and neem leaves were mixed separately with 300 mL of distilled water containing variable concentrations of sodium hydroxide, NaOH: 0.5 g, 1.0 g, and 1.5 g with 0.041 mol/L, 0.082 mol/L and 0.125 mol/L, respectively. The mixtures were heated at 100 °C for 30 minutes using a hot plate equipped with a magnetic stirrer to ensure uniform mixing and prompt extraction. After heating, the solutions were allowed to cool to room temperature and subsequently filtered using Whatman No. 1 filter paper. The resulting filtrates were collected into clean, labelled sample bottles (MI and AI) and stored under refrigeration until further analysis (Figure 1). Among the three concentrations, the extract obtained with 1.5 g NaOH was selected for Gas Chromatography–Mass Spectrometry (GC-MS) analysis based on preliminary observations of extraction efficiency. The GC MS analysis was conducted at the Central Instrumentation Laboratory, Department of Chemistry, Ahmadu Bello University, Zaria, Nigeria.

### Gas chromatography mass spectrometry (GC-MS)

Gas chromatography mass spectrometry analysis was performed using a capillary column (Agilent DB 5MS, 30 m × 0.25 mm i.d., 0.25 µm film thickness) to achieve complete separation of analytes, following protocols described by (Smith *et al.,* 2020). Helium was used as the carrier gas at a constant flow rate of 1.0 mL/min. A split/splitless injector was operated in split mode with an injection temperature of 250 °C, split ratio of 10:1, and an injection volume of 1 μL. The oven temperature was initially set at 60 °C (held for 2 min), increased at 10 °C/min to 300 °C, and held for 10 min. The interface and ion source temperatures were maintained at 280 °C and 230 °C, respectively. The MS detector was operated in electron ionization (EI) mode at 70 eV with a scan range of m/z 50–600 in brimful scan acquisition mode.

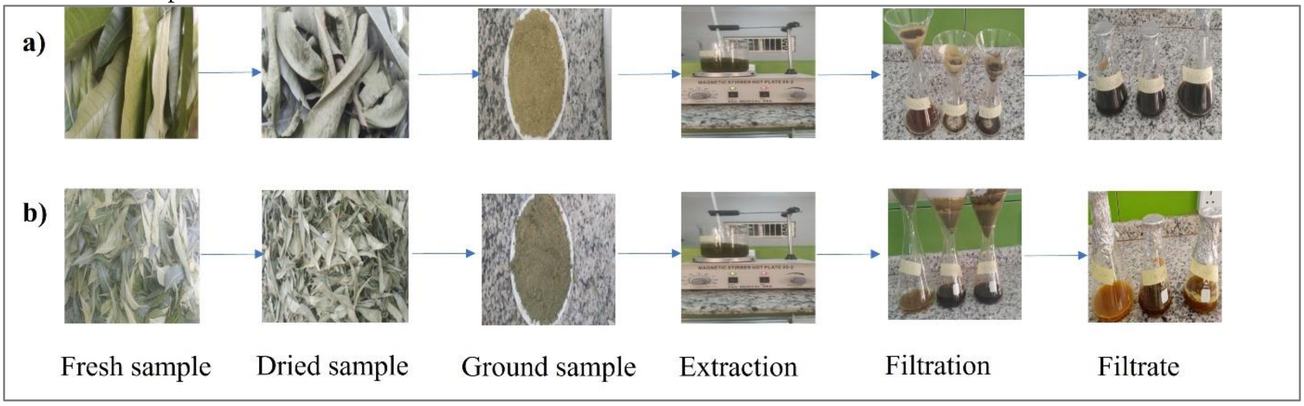
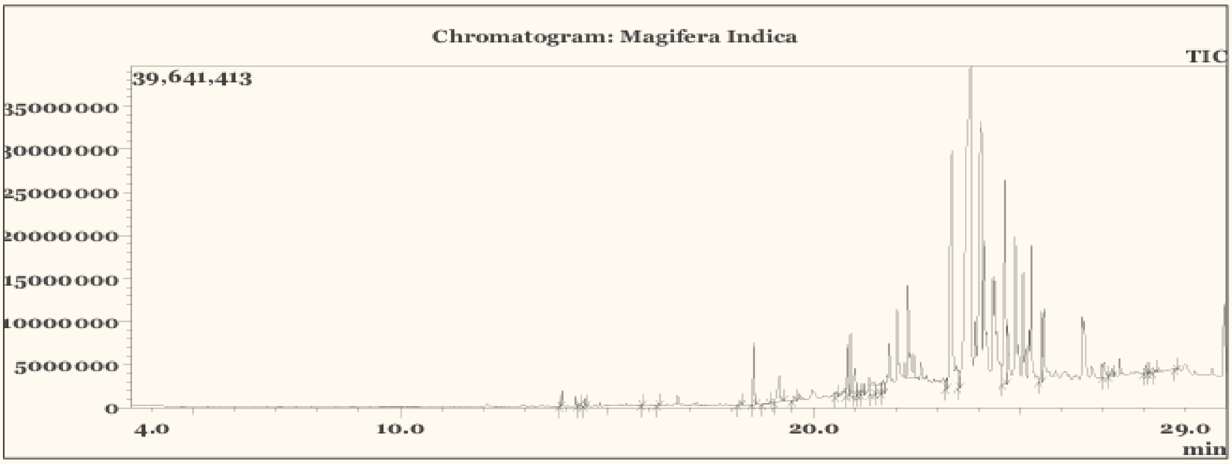



**Figure 1: Schematic Diagram of Extraction Process for a) Mango (*Mangifera Indica*) Leaves and b) Neem *(Azadirachta Indica)* Leaves.**

**Sample Information**

| | |
|---|---|
| Analyzed by | : Admin |
| Analyzed | : 27-11-24 1:23:46 PM |
| Sample Type | : Unknown |
| Level # | : 1 |
| Sample Name | : Mangifera Indica |
| Sample ID | : Mangifera Indica |
| IS Amount | : [1]=1 |
| Sample Amount | : 1 |
| Dilution Factor | : 1 |
| Injection Volume | : 1.00 |



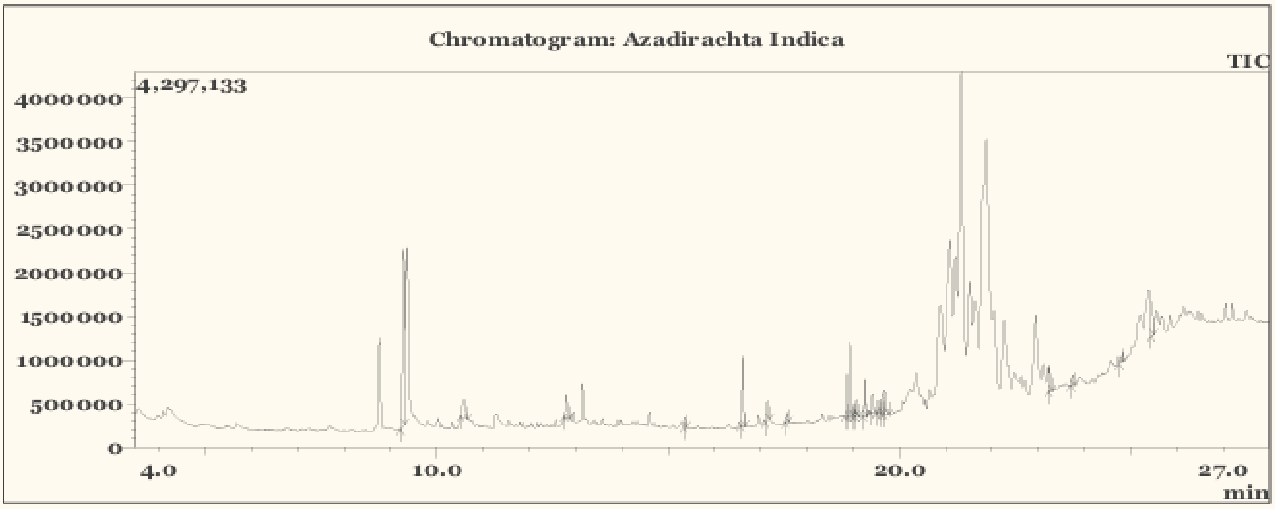

Peak Report TIC

| Peak# | R.Time | I.Time | F.Time | Area | Area% | Height | Height% | A/H | Name |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.870 | 13.840 | 13.885 | 167783 | 0.08 | 96153 | 0.14 | 1.74 | Dodecanoic acid |
| 2 | 14.320 | 14.275 | 14.355 | 747551 | 0.36 | 260231 | 0.38 | 2.87 | 9,12-Octadecadienoyl chloride, |
| 3 | 14.465 | 14.425 | 14.505 | 1479648 | 0.72 | 946690 | 1.39 | 1.56 | cis-9-Hexadecenal |
| 4 | 15.835 | 15.820 | 15.865 | 153971 | 0.07 | 115233 | 0.17 | 1.34 | Methyl tetradecanoate |
| 5 | 16.236 | 16.200 | 16.275 | 366938 | 0.18 | 211545 | 0.31 | 1.73 | Margaric acid |
| 6 | 18.215 | 18.155 | 18.270 | 1040836 | 0.51 | 428048 | 0.63 | 2.43 | 9-Hexadecenoic acid, methyl es |
| 7 | 18.544 | 18.490 | 18.610 | 14420713 | 7.00 | 7201546 | 10.57 | 2.00 | Hexadecanoic acid, methyl este |
| 8 | 18.785 | 18.750 | 18.935 | 464362 | 0.23 | 127432 | 0.19 | 3.64 | Oleic Acid |
| 9 | 19.168 | 19.030 | 19.280 | 14109014 | 6.85 | 3001386 | 4.40 | 4.70 | Palmitic acid |
| 10 | 19.517 | 19.465 | 19.595 | 1678765 | 0.81 | 501226 | 0.74 | 3.35 | Palmitic acid, ethyl ester |
| 11 | 20.553 | 20.520 | 20.600 | 2151841 | 1.04 | 632531 | 0.93 | 3.40 | 9,12-Octadecadienoic acid (Z,Z) |
| 12 | 20.812 | 20.775 | 20.850 | 12170571 | 5.91 | 6028871 | 8.85 | 2.02 | 9,12-Octadecadienoic acid (Z,Z) |
| 13 | 20.986 | 20.930 | 21.050 | 10573602 | 5.13 | 3147175 | 4.62 | 3.36 | 2-Nonenoic acid, methyl ester |
| 14 | 21.100 | 21.050 | 21.135 | 2408673 | 1.17 | 581612 | 0.85 | 4.14 | 3-Hexanol, 2,3-dimethyl- |
| 15 | 21.202 | 21.135 | 21.240 | 4049464 | 1.97 | 1231097 | 1.81 | 3.29 | Methyl stearate |
| 16 | 21.434 | 21.365 | 21.490 | 8328361 | 4.04 | 1396444 | 2.05 | 5.96 | 8,11,14-Eicosatrienoic acid, (Z,Z |
| 17 | 21.598 | 21.490 | 21.625 | 7906472 | 3.84 | 1168290 | 1.71 | 6.77 | Linoleic acid ethyl ester |
| 18 | 21.672 | 21.625 | 21.705 | 5833050 | 2.83 | 1549035 | 2.27 | 3.77 | Ethyl Oleate |
| 19 | 23.210 | 23.180 | 23.230 | 2990729 | 1.45 | 1193231 | 1.75 | 2.51 | Octadecanamide, N-(2-hydroxy |
| 20 | 23.490 | 23.470 | 23.540 | 8199259 | 3.98 | 2098570 | 3.08 | 3.91 | 13-Octadecenal, (Z)- |
| 21 | 24.624 | 24.550 | 24.670 | 74351515 | 36.08 | 23738609 | 34.83 | 3.13 | 9,12-Octadecadienoyl chloride, |
| 22 | 25.509 | 25.435 | 25.535 | 17913585 | 8.69 | 8207840 | 12.04 | 2.18 | 9,12-Octadecadienoic acid (Z,Z) |
| 23 | 27.018 | 26.985 | 27.125 | 7086015 | 3.44 | 1778409 | 2.61 | 3.98 | Cholesterol |
| 24 | 27.220 | 27.125 | 27.250 | 3317381 | 1.61 | 927558 | 1.36 | 3.58 | 9,12-Octadecadienoic acid (Z,Z) |
| 25 | 28.020 | 27.980 | 28.075 | 2683453 | 1.30 | 1067956 | 1.57 | 2.51 | Behenic alcohol |
| 26 | 28.120 | 28.075 | 28.135 | 513912 | 0.25 | 124973 | 0.18 | 4.11 | Cholesta-3,5-diene |
| 27 | 28.232 | 28.190 | 28.280 | 553019 | 0.27 | 254436 | 0.37 | 2.17 | Hexacosanoic acid, methyl este |
| 28 | 28.735 | 28.725 | 28.790 | 398535 | 0.19 | 133198 | 0.20 | 2.99 | Octadecane, 1-iodo- |
| | | | | 206059018 | 100.00 | 68149325 | 100.00 | | |

**Figure 2: GC-MS Spectra of *Mangifera Indica* leaf extract**

**Sample Information**

| | |
|---|---|
| Analyzed by | : Admin |
| Analyzed | : 28-11-24 3:44:32 PM |
| Sample Type | : Unknown |
| Level # | : 1 |
| Sample Name | : Azadirachta Indica |
| Sample ID | : Azadirachta Indica |
| IS Amount | : [1]=1 |
| Sample Amount | : 1 |
| Dilution Factor | : 1 |
| Injection Volume | : 1.00 |




**Peak Report TIC**

| Peak# | R.Time | I.Time | F.Time | Area | Area% | Height | Height% | A/H | Name |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 9.291 | 9.225 | 9.320 | 6334519 | 32.54 | 2026047 | 26.68 | 3.13 | 1,3-Cyclobutanedione, 2,2,4,4-t |
| 2 | 10.593 | 10.515 | 10.680 | 1043078 | 5.36 | 213595 | 2.81 | 4.88 | 1,3-Propanediol, 2-(hydroxyme |
| 3 | 12.803 | 12.760 | 12.865 | 708141 | 3.64 | 263435 | 3.47 | 2.69 | .alpha.-D-Glucopyranoside, me |
| 4 | 15.370 | 15.335 | 15.410 | 211428 | 1.09 | 110960 | 1.46 | 1.91 | 2-Pentadecanone, 6,10,14-trim |
| 5 | 16.611 | 16.565 | 16.665 | 1656561 | 8.51 | 805583 | 10.61 | 2.06 | Hexadecanoic acid, methyl este |
| 6 | 17.144 | 17.105 | 17.195 | 519370 | 2.67 | 236118 | 3.11 | 2.20 | n-Hexadecanoic acid |
| 7 | 17.571 | 17.540 | 17.610 | 186720 | 0.96 | 103083 | 1.36 | 1.81 | Hexadecanoic acid, ethyl ester |
| 8 | 18.862 | 18.820 | 18.895 | 894464 | 4.60 | 478993 | 6.31 | 1.87 | 9,12-Octadecadienoic acid (Z,Z) |
| 9 | 18.937 | 18.895 | 18.990 | 1914238 | 9.83 | 853999 | 11.25 | 2.24 | 9,12,15-Octadecatrienoic acid, r |
| 10 | 19.010 | 18.990 | 19.050 | 218314 | 1.12 | 80466 | 1.06 | 2.71 | 9-Octadecenoic acid, methyl est |
| 11 | 19.075 | 19.050 | 19.130 | 404774 | 2.08 | 195874 | 2.58 | 2.07 | Phytol |
| 12 | 19.256 | 19.215 | 19.300 | 761595 | 3.91 | 421281 | 5.55 | 1.81 | Pentadecanoic acid, methyl est |
| 13 | 19.411 | 19.370 | 19.495 | 616748 | 3.17 | 216638 | 2.85 | 2.85 | Oleic Acid |
| 14 | 19.579 | 19.495 | 19.610 | 322701 | 1.66 | 171641 | 2.26 | 1.88 | 1-Propene-1,2,3-tricarboxylic a |
| 15 | 19.640 | 19.610 | 19.665 | 569004 | 2.92 | 232219 | 3.06 | 2.45 | Linoleic acid ethyl ester |
| 16 | 19.684 | 19.665 | 19.785 | 998338 | 5.13 | 271110 | 3.57 | 3.68 | Tridecanoic acid |
| 17 | 23.251 | 23.230 | 23.310 | 601512 | 3.09 | 290590 | 3.83 | 2.07 | Bis(2-ethylhexyl) phthalate |
| 18 | 23.733 | 23.700 | 23.770 | 210983 | 1.08 | 116810 | 1.54 | 1.81 | Cyclononasiloxane, octadecam |
| 19 | 24.824 | 24.755 | 24.850 | 235186 | 1.21 | 116438 | 1.53 | 2.02 | Tetracosanoic acid, methyl este |
| 20 | 25.450 | 25.440 | 25.505 | 1058214 | 5.44 | 388396 | 5.11 | 2.72 | Squalene |
| | | | | 19465888 | 100.00 | 7593276 | 100.00 | | |

**Figure 3: GC-MS Spectra of extract of Leaf of *Azadirachta Indica***

## RESULTS AND DISCUSSIONS

The GC MS analysis of the extracts of *Mangifera indica* (Mango) and *Azadirachta indica* (Neem) leaves revealed the presence of various bioactive compounds, including fatty acids, terpenoids, flavonoids, and sterols, which are known for their pharmacologic and industrial significance. The obtained gas chromatograms provided detailed insights into the chemical composition of both plant extracts.

### GC-MS Analysis of Mango *(Mangifera indica)* leaves extract

The GC-MS chromatographic profile of the *Mangifera indica* (mango) leaf extract (Figure 2) reveals a chemically diverse matrix controlled by volatile and semi-volatile compounds, aligning with prior reports on the phytochemical richness of mango leaves (Ajila *et al.,* 2007; Tan and Norhaizan, 2019; Barreto *et al.,* 2020). In this study, a total of 28 clear-cut compounds were identified (Table 1), with retention times spanning from 4.0 to 29.0 minutes. A dense clustering of important peaks between 20.0 and 28.0 minutes suggests the presence of peaky molecular weight and thermally stable bioactive constituents, likely due to the increased solubility and release provided by the base-assisted extraction technique. The most conspicuous peak, occurring just before 28 minutes, indicates a controlling constituent in high relational abundance, an important indicator of pharmacologic or developed relevance. Among the identified compounds, 9,12-Octadecadienoyl chloride (34.83 %) and 9,12-Octadecadienoic acid (Z, Z) (12.64%) were especially noteworthy. These are important linoleic acid derivatives renowned for their anti-inflammatory, hypocholesterolemia, and antioxidant properties (Kouba and Mourot, 2011; Simopoulos, 2002; Serini and Calviello, 2016).

**Table 1: Compounds Identified in Mango Leaves**

| Compound Name | Molecular Formula | Molecular Weight (g/mol) | Height % | *Biological Activity |
|---|---|---|---|---|
| Dodecanoic acid (Lauric acid) | $C_{12}H_{24}O_2$ | 200 | 0.14 | Antibacterial, antifungal, anti-inflammatory |
| 9,12-Octadecadienoyl chloride | $C_{18}H_{31}ClO$ | 298 | 0.38 | Precursor in lipid synthesis |
| cis-9-Hexadecenal | $C_{16}H_{30}O$ | 238 | 1.39 | Pheromone, insect attractant |
| Methyl tetradecanoate | $C_{15}H_{30}O_2$ | 242 | 0.17 | Flavoring agent, antimicrobial |
| Margaric acid (Heptadecanoic acid) | $C_{17}H_{34}O_2$ | 270 | 0.31 | Antimicrobial, anti-inflammatory |
| 9-Hexadecenoic acid, methyl ester | $C_{17}H_{32}O_2$ | 268 | 0.63 | Anti-inflammatory, skin conditioning |
| Hexadecanoic acid, methyl ester | $C_{17}H_{34}O_2$ | 270 | 10.57 | Antioxidant, antimicrobial |
| Oleic Acid | $C_{18}H_{34}O_2$ | 282 | 0.19 | Cardioprotective, antimicrobial |
| Palmitic acid | $C_{16}H_{32}O_2$ | 256 | 4.40 | Emollient, antimicrobial, metabolic precursor |
| Palmitic acid, ethyl ester | $C_{18}H_{36}O_2$ | 284 | 0.74 | Used in cosmetics, potential antimicrobial |
| 9,12-Octadecadienoic acid (Z, Z) | $C_{18}H_{32}O_2$ | 280 | 0.93 | Antioxidant, skin barrier function, anti-inflammatory |
| 9,12-Octadecadienoic acid, methyl ester | $C_{19}H_{34}O_2$ | 294 | 8.85 | Similar to linoleic acid, used in cosmetics |
| 2-Nonenoic acid, methyl ester | $C_{10}H_{18}O_2$ | 170 | 4.62 | Antimicrobial, antifungal |
| 3-Hexanol, 2,3-dimethyl- | $C_8H_{18}O$ | 130 | 0.85 | Flavoring agent, insect pheromone |
| Methyl stearate | $C_{19}H_{38}O_2$ | 298 | 1.81 | Emollient, lubricant, antimicrobial |
| 8,11,14-Eicosatrienoic acid | $C_{20}H_{34}O_2$ | 306 | 2.05 | Anti-inflammatory, involved in prostaglandin synthesis |
| Linoleic acid ethyl ester | $C_{20}H_{36}O_2$ | 308 | 1.71 | Skin conditioning, anti-inflammatory |
| Ethyl Oleate | $C_{20}H_{38}O_2$ | 310 | 2.27 | Used in drug delivery, emollient |
| Octadecanamide, N-(2-hydroxyethyl)- | $C_{20}H_{41}NO_2$ | 327 | 1.75 | Surfactant, emulsifier, anti-inflammatory |

*To be continued next page*

*Table 1 continued*

| Compound Name | Molecular Formula | Molecular Weight (g/mol) | Height % | *Biological Activity |
|---|---|---|---|---|
| 13-Octadecenal, (Z)- | $C_{18}H_{34}O$ | 266 | 3.08 | Pheromone, insect attractant |
| 9,12-Octadecadienoyl chloride | $C_{18}H_{31}ClO$ | 298 | 34.83 | Precursor in lipid synthesis |
| 9,12-Octadecadienoic acid (Z, Z) | $C_{18}H_{32}O_2$ | 280 | 12.04 | Anti-inflammatory, antioxidant |
| Cholesterol | $C_{27}H_{46}O$ | 386 | 2.61 | Structural component of cell membranes, precursor for steroids |
| Behenic alcohol | $C_{22}H_{46}O$ | 326 | 1.57 | Emollient, used in cosmetics |
| Cholesta-3,5-diene | $C_{27}H_{44}$ | 368 | 0.18 | Intermediate in cholesterol synthesis |
| Hexacosanoic acid, methyl ester | $C_{27}H_{54}O_2$ | 410 | 0.37 | Emollient, lubricant |
| Octadecane, 1-iodo- | $C_{18}H_{37}I$ | 380 | 0.20 | Antibacterial, precursor in organic synthesis |

***Source of biological activity:** [PubChem] (https://pubchem.ncbi.nlm.nih.gov/)

Linoleic acid (omega-6) and its derivatives have been widely documented for their role in maintaining skin barrier function and reducing inflammation, making them attractive agents for dermatologic and aesthetical applications (Elias *et al.,* 2008; Ziboh *et al.,* 2000). Similarly, palmitic acid, a saturated fatty acid, and its esters such as hexadecenoic acid methyl ester, identified in this study, are well-established emollients and moisturizers used in pharmaceutical creams and lotions (Vasseur *et al.,* 2018).

Beyond pharmacological and aesthetic relevance, some of the esters and long-chain hydrocarbons identified, such as methyl palmitate and methyl linoleate, are promising candidates for biofuel production, especially biodiesel. These fatty acid methyl esters (FAMEs) have been recognized for their favourable combustion properties and inexhaustible origin (Knothe, 2005; Atabani *et al.,* 2012). The presence of such compounds in mango leaf extract underlines the potential of this agricultural biomass not only as a medicinal resource but too as a feedstock for sustainable energy applications, an aspect that has been underexplored in prevalent literature. Compared to late studies, which chiefly focused on ethanol or aqueous extractions of mango leaves (Imran *et al.,* 2022). The prevalent study utilized a base-assisted extraction method. This technique appears to importantly enhance the release of lipid-soluble and esterified compounds by breaking down cell walls and hydrolyzing conjugated metabolites, as supported by extraction chemistry studies (Sethuraman and Meenakshi, 2015; Prado and Meireles, 2010). The effectiveness of the method is discernible in the broad spectrum and relative abundance of the identified compounds, especially high-yield fatty acid derivatives and sterols.

**GC-MS Analysis of Neem *(Azadirachta indica)* Leaf Extract**

The GC-MS chromatogram of *Azadirachta indica* leaf extract (Figure 3) presents a diverse and decomposable chemical profile, characterized by several sharp and well-resolved peaks between 4.0 and 27.0 minutes of retention time. Notably, a concentration of high intensity peaks between 18.0 and 24.0 minutes suggests the presence of multiple bioactive compounds in significant abundance. This aligns with prior studies emphasizing the rich phytochemical content of neem, especially its important oils, terpenoids, and fatty acid derivatives (Biswas *et al.,* 2002: Alzohairy, 2016; Subapriya and Nagini, 2005). In this study, 20 bioactive compounds were identified from the neem leaf extract using base-assisted extraction followed by GC-MS analysis, as shown in Table 2. The most prominent compounds include 1,3-Cyclobutanedione (26.68 %) and 9,12,15-Octadecatrienoic acid methyl ester (11.25 %), both of which are known for their antioxidant, anti-inflammatory, and antimicrobial properties. 1,3-Cyclobutanedione is a periodical diketone with strong radical scavenging activity, capable of stabilizing reactive oxygen species and preventing lipid peroxidation in biological systems (Kim et al., 2010; Martins and Nunez, 2015).

**Table 2: Major Compounds Identified in Neem Leaves**

| Compound Name | Molecular Formula | Molecular Weight (g/mol) | Height % | *Biological Activity |
|---|---|---|---|---|
| 1,3-Cyclobutanedione, 2,2,4,4-tetramethyl- | $C_8H_{10}O_2$ | 138 | 26.68 | Antimicrobial, flavoring agent |
| 1,3-Propanediol, 2-(hydroxymethyl)- | $C_4H_9NO_5$ | 151 | 2.81 | Antioxidant, potential pharmaceutical agent |
| α-D-Glucopyranoside, methyl | $C_7H_{14}O_6$ | 194 | 3.47 | Antioxidant, antimicrobial |
| 2-Pentadecanone, 6,10,14-trimethyl- | $C_{18}H_{36}O$ | 268 | 1.46 | Antifungal, insect pheromone |
| Hexadecanoic acid, methyl ester | $C_{17}H_{34}O_2$ | 270 | 10.61 | Antioxidant, antimicrobial |
| n-Hexadecanoic acid (Palmitic acid) | $C_{16}H_{32}O_2$ | 256 | 3.11 | Emollient, antimicrobial, anti-inflammatory |
| Hexadecanoic acid, ethyl ester | $C_{18}H_{36}O_2$ | 284 | 1.36 | Used in cosmetics, antimicrobial |
| 9,12-Octadecadienoic acid (Linoleic acid) | $C_{18}H_{32}O_2$ | 280 | 6.31 | Anti-inflammatory, antioxidant |
| 9,12,15-Octadecatrienoic acid (Linolenic acid), methyl ester | $C_{19}H_{32}O_2$ | 292 | 11.25 | Anti-inflammatory, cardioprotective |
| 9-Octadecenoic acid, methyl ester | $C_{19}H_{34}O_2$ | 294 | 1.06 | Emollient, skin barrier function |
| Phytol | $C_{20}H_{40}O$ | 296 | 2.58 | Antimicrobial, anticancer, antioxidant |
| Pentadecanoic acid, methyl ester | $C_{16}H_{32}O_2$ | 256 | 5.55 | Antimicrobial, metabolic precursor |
| Oleic Acid | $C_{18}H_{34}O_2$ | 282 | 2.85 | Cardioprotective, antimicrobial |
| 1-Propene-1,2,3-tricarboxylic acid | $C_{18}H_{30}O_6$ | 342 | 2.26 | Used in food preservation, antioxidant |
| Linoleic acid ethyl ester | $C_{20}H_{36}O_2$ | 308 | 3.06 | Anti-inflammatory, used in cosmetics |
| Tridecanoic acid | $C_{13}H_{26}O_2$ | 214 | 3.57 | Antibacterial, antifungal |
| Bis(2-ethylhexyl) phthalate | $C_{24}H_{38}O_4$ | 390 | 3.83 | Endocrine disruptor, industrial plasticizer |
| Cyclononasiloxane, octadecamethyl- | $C_{18}H_{54}O_9Si_9$ | 666 | 1.54 | Used in cosmetics, emulsifier |
| Tetracosanoic acid, methyl ester | $C_{25}H_{50}O_2$ | 382 | 1.53 | Used in cosmetics, lubricant |
| Squalene | $C_{30}H_{50}$ | 410 | 5.11 | Antioxidant, anticancer, anti-aging |

***Source of biological activity:** [PubChem] (https://pubchem.ncbi.nlm.nih.gov/

Similarly, 9,12,15-Octadecatrienoic acid methyl ester, unremarkably proverbial as methyl linolenate, is a methylated omega-3 fatty acid that contributes to the suppression of pro-inflammatory mediators and enhancement of cellular defence mechanisms (Serini and Calviello, 2016; Calder, 2017). The identification of hexadecanoic acid methyl ester (palmitic acid methyl ester) at 10.64 % further supports the multifunctionality of neem extracts. This compound is recognized for its antibacterial, antifungal, and skin conditioning properties, making it a common constituent in pharmaceutical and cosmetic products (Ziboh et al., 2000; Kossah *et al.,* 2013). It contributes to skin hydration, acts as a penetration enhancer in local formulations, and exhibits moderate antimicrobial activity, which makes it valuable in dermatologic applications.

One of the exceptional interests is the detection of phytol (2.57 %), a diterpene alcohol and precursor of vitamin E (tocopherol) and vitamin K. Phytol plays a severe role in modulating immune responses, protecting cell membranes from aerobic damage, and improving skin health (Britton *et al.,* 2008; Santos *et al.,* 2013). Its presence in the neem extract highlights the nutritional and cosmeceutical potential of neem leaves beyond their traditional healthful uses. These findings are in line with late literature that emphasizes neem's pharmacologic diversity. Neem has been traditionally used for treating bacterial infections, fungal diseases, skin disorders, and inflammatory conditions (Ghosh *et al.,* 2014; Kharwar *et al.,* 2011; Akhtar and Khan, 2014). However, most existent studies have focused on ethanolic or aqueous extractions. The prevalent study, in contrast, employs base-assisted extraction, a method that effectively liberates both polar and non-polar compounds by breaking down decomposable plant matrices and hydrolyzing bound phytochemicals (Sethuraman and Meenakshi, 2015; Prado and Meireles, 2010). This approach resulted in the increased recovery of fatty acid methyl esters, periodical diketones, and terpenoid alcohols, demonstrating its efficiency over conventional techniques.

## CONCLUSION

This study successfully demonstrated the phytochemical richness and multifunctional potential of *Mangifera indica* (mango) and *Azadirachta indica* (neem) leaves through optimized base-assisted extraction (BAE) followed by Gas Chromatography–Mass Spectrometry (GC-MS) analysis. A total of 28 bioactive compounds were identified in mango leaf extract and 20 compounds in neem leaf extract, including fatty acids, flavonoids, terpenoids, esters, and sterols. In mango leaves, higher levels of compounds such as 9,12-Octadecadienoyl chloride, palmitic acid esters, and linoleic acid derivatives suggest strong potential for pharmaceutical, aesthetic, and biodiesel applications due to their antioxidant, anti-inflammatory, and fuel-related properties. Similarly, neem leaf extract contains compounds like 1,3-Cyclobutanedione, phytol, and methyl linolenate, which support its traditional use in antimicrobial, anti-inflammatory, anticancer, and insecticidal formulations. The use of NaOH hydrolysis as a base-catalyzed extraction method proved competent in enhancing the release and recovery of both volatile and non-volatile bioactive compounds, improving extraction efficiency over conventional solvent methods. However, siloxanes, acid chlorides, and phthalates could also be present, likely introduced as contaminants from other sources. The study's unique approach lies in applying this optimized extraction strategy to the leaves, an underutilized agro-waste, demonstrating a dual use profile that spans therapeutic and green energy applications. By valorizing these otherwise discarded plant parts, the research aligns with global sustainability goals and promotes eco-friendly, cost-effective utilization of plant biomass in line with the principles of the circular bioeconomy. Overall, this work opens fresh avenues for the integration of mango and neem leaf extracts into phytomedicine, cosmeceuticals, and renewable biofuel industries, offering a sustainable platform for future product development and innovation.

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