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GC–MS ANALYSIS OF *Jatropha Curcas* SEED OIL AND ETHANOL-DERIVED BIODIESEL PRODUCED USING GREEN-SYNTHESIZED MGO NANOCATALYST

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ABSTRACT

This study reports the extraction and GC–MS characterization of *Jatropha curcas* seed oil, as well as the analysis of biodiesel produced via ethanolysis using a green-synthesized magnesium oxide (MgO) nanocatalyst. Seed oil obtained by solvent extraction was evaluated for key physicochemical properties. Biodiesel production was conducted via heterogeneous base-catalyzed transesterification employing plant-mediated MgO nanocatalyst. GC–MS profiling confirmed the formation and compositional distribution of fatty acid ethyl esters (FAEEs). Major ester components identified included ethyl oleic (C18:1), ethyl linoleic (C18:2), ethyl palmitic (C16:0), and ethyl stearate (C18:0). The biodiesel exhibited the same four FAEEs but in different concentrations, consistent with reported *Jatropha* fatty acid distributions. The MgO nanocatalyst delivered high catalytic efficiency, enabling substantial reduction or disappearance of triglyceride peaks and the emergence of the expected ester signals in the chromatograms, confirming effective transesterification. Physicochemical properties of both oil and biodiesel such as density, kinematic viscosity, acid value, and flash point, cloud point, pour point, met ASTM D6751 and EN 14214 specifications. Overall, the findings demonstrate the viability of converting non-edible *Jatropha curcas* oil into high-quality biodiesel using green-synthesized MgO nanoparticles, and reaffirm the reliability of GC–MS for compositional verification and fuel-quality assessment.

Keywords: *Jatropha curcas*, Biodiesel, MgO nanocatalyst, Green synthesis, Transesterification, GC–MS, Fatty acid ethyl esters (FAEEs)

INTRODUCTION

The increasing demand for sustainable energy and the environmental challenges associated with fossil fuels have intensified interest in renewable biofuels such as biodiesel. Biodiesel consists mainly of fatty acid methyl (or ethyl) esters (FAMEs/FAEEs), commonly produced through the transesterification of vegetable oils or animal fats with short-chain alcohols. Compared with petroleum diesel, biodiesel is biodegradable, renewable, and associated with lower emissions of particulate matter and greenhouse gases (Muhammad and Mashi, 2025; Zhang *et al*., 2022).

Non-edible oilseed crops have attracted significant attention as biodiesel feedstocks because they do not compete directly with food resources (Ruatpuia *et al.*, 2024).

Among these, *Jatropha curcas* has emerged as a promising candidate due to its high oil content, ability to grow on marginal land, and adaptability to semi-arid conditions (Mhetras & Gokhale, 2025). Its fatty acid composition, typically dominated by C16 and C18 chains, makes the oil particularly suitable for biodiesel production.

The conversion of *Jatropha curcas* oil into biodiesel traditionally employs homogeneous base catalysts such as sodium or potassium hydroxide. However, these catalysts often lead to problems such as soap formation, excessive wastewater generation, and complex downstream purification steps, which increase both processing costs and environmental burden. (Mahdi *et al.*, 2023).

To overcome these limitations, heterogeneous solid catalysts, particularly nanostructured metal oxides have gained increasing attention. Magnesium oxide (MgO) nanoparticles are of particular interest due to their large surface area, strong basicity, high catalytic efficiency, ease of separation and reusability, all of which contribute to improved process sustainability (Esmaeili *et al.*, 2019). When synthesized via green routes, MgO nanocatalysts further enhance the environmental compatibility of biodiesel production.

Ethanolysis, which produces fatty acid ethyl esters (FAEEs), is increasingly favored over methanol-based transesterification because ethanol is renewable, less toxic and suitable for decentralized biofuel systems. Despite these advantages, reliable verification of triglyceride conversion and accurate assessment of biodiesel composition remain essential for evaluating fuel quality and process efficiency.

Gas chromatography–mass spectrometry (GC–MS) is widely regarded as the most reliable technique for identifying and profiling fatty acids and their alkyl esters in oils and biodiesel. By combining chromatographic separation with mass spectral identification, GC–MS enables confirmation of ester formation and detailed characterization of biodiesel composition (Elissavet Emmanouilidou *et al.*, 2024; Kwakye *et al.*, 2024). In biodiesel studies, GC–MS serves primarily as a compositional verification technique rather than a process-operational tool (Shanthini *et al*., 2025).

Although several studies have reported biodiesel production from *Jatropha curcas* oil using heterogeneous catalysts, limited attention has been given to detail GC–MS compositional verification of ethanol-derived biodiesel produced over green-synthesized MgO nanocatalysts. In particular, systematic confirmation of fatty acid ethyl ester formation and comparative profiling of oil and biodiesel compositions remain insufficiently explored. Therefore, the aim of this study is to apply GC–MS analysis to characterize *Jatropha curcas* seed oil and its ethanol-derived biodiesel produced using a green-synthesized MgO nanocatalyst, with emphasis on validating ester formation and assessing biodiesel compositional quality.

MATERIALS AND METHODS

Materials

Mature *Jatropha curcas* seeds were collected from Orerokpe Town, Okpe Local Government Area, Delta State, Nigeria. Fresh leaves of *Carica papaya* (pawpaw) and *Mangifera indica* (mango) were also collected from the same location. All plants were identified and authenticated by a botanist from the Department of Botany, Delta State University, Abraka. Voucher specimen identification numbers were assigned as DELSUH-287 *for Jatropha curcas L., and* DELSUH-010 *for Mangifera indica L., and* DELSUH-127 *for Carica papaya L. deposited at Delta State University Herbarium (DELSUH)*

Analytical-grade ethanol, n-hexane, and other reagents including magnesium sulpate hexahydrate ($MgSO_4 \cdot 6H_2O$), sodium hydroxide (NaOH), isopropyl alcohol, phenolphthalein, and hydrochloric acid (0.1 M), were used in this study. All chemicals employed were of analytical grade and used without further purification.

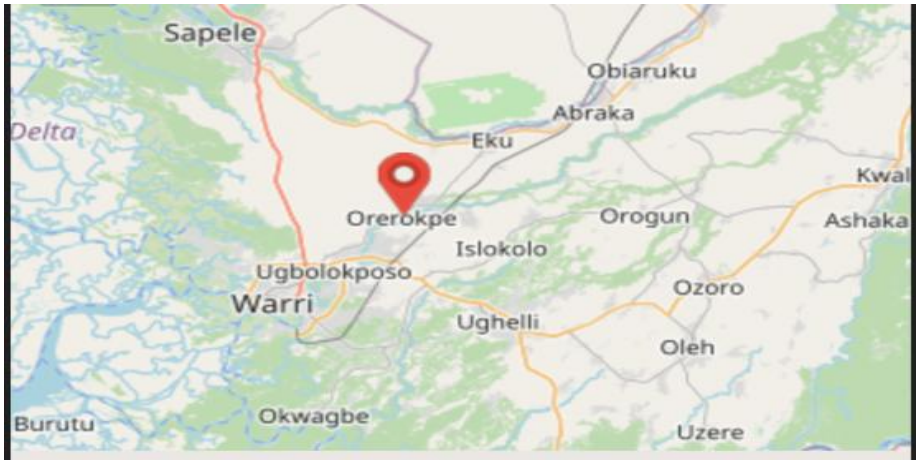

Figure 1: Map Showing the Location of Orerokpe Town, Okpe Local Government Area, Delta State, Nigeria, where Plant Samples (*Jatropha curcas*, *Mangifera indica*, and *Carica papaya*) were Collected

Table 1: Coordinates of the Five Collection Points of Mature *Jatropha curcas* L. Seeds in Orerokpe Town, Okpe Local Government Area, Delta State, Nigeria

Location	Latitude	Longitude
Site 1	5.635424 (N 5°38′7.52388″)	5.875432 (E 5°52′31.55412″)
Site 2	5.633832 (N 5°38′1.79412″)	5.876048 (E 5°52′33.77388″)
Site 3	5.635223 (N 5°38′6.79812″)	5.878697 (E 5°52′43.30812″)
Site 4	5.635526 (N 5°38′7.91412″)	5.879057 (E 5°52′44.60412″)
Site 5	5.6360991 (N 5°38′13.1676″)	5.878842(E 5°52′43.83264″)

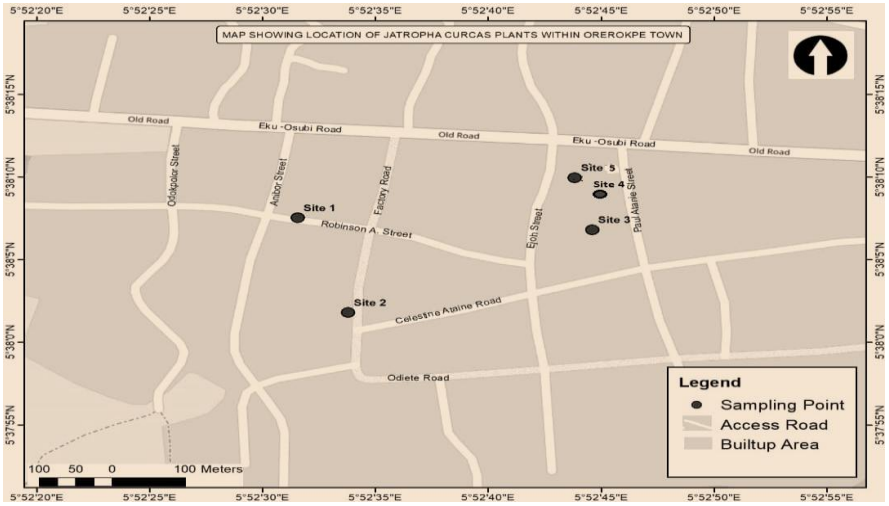

Figure 2: Map of Sample Points Showing Locations of *Jatropha curcas* L. Seed Collections within Orerokpe Town

Instruments and Apparatus

The following instruments were used: soxhlet extractor, rotary evaporator, oven, viscometer, (GC: 6890-MSD: 5977, Agilent, USA). gas chromatograph, condensers, incubator, magnetic stirrers, hot plates, thermometers, glass rods, crushers ,pH meter, separating funnels, filter papers, water baths, beakers, conical flasks, graduated cylinders, aluminum foil, grinding machine, weighing balance, filtration setup (filter paper and funnel).

Drying of Seeds

The seeds were cleaned, air-dried for 7 days in an open shade, de-shelled, and ground into powder using mechanical Grinder a fine powder before the oil extraction process, which was carried out using a Soxhlet apparatus with n-hexane as the solvent at approximately 70 °C for 6 h. After extraction, the solvent was removed under reduced pressure using a rotary evaporator, and the oil was stored in amber bottles prior to GC–MS analysis and biodiesel production

Extraction of *Jatropha curcas* Oil

The oil was extracted from 100 g of pulverized *Jatropha curcas* L. seeds using the Soxhlet extraction method using n-hexane at 70 °C at the extraction time of 6 hrs. The pulverized seed samples was wrapped in a filter cloth and placed inside a thimble. A round-bottom flask containing 250 mL of *n*-hexane served as the extraction solvent. The extraction process was repeated several times to produce sufficient quantities of oil. At the end of extraction, the solvent oil mixture was concentrated using a rotary evaporator to remove excess n-hexane. The oil yield obtained from 100 g of seeds was approximately 37.3 g, corresponding to a percentage yield of 37.3%, calculated using Equation (1)

$$\text{Percentage weight of oil yield} = \frac{\text{Mass of extracted oil}}{Mass\ of\ sample\ before\ extraction} \times 100 \quad (1)$$

Following oil extraction, gas chromatography–mass spectrometry (GC–MS) (GC: 6890-MSD: 5977, Agilent Technologies, USA model). GC–MS analysis was applied to determine the fatty acid components of oil. The oil components are given in Table 1. The components of fatty acids in the *Jatropha curcas* oil are necessary for biodiesel production.

Physicochemical Analysis of Oil and Biodiesel

The physicochemical properties of *Jatropha curcas* seed oil and the produced biodiesel were determined to evaluate fuel quality using standard ASTM methods. Density (25 □C) was measured using ASTM D1298. Kinematic viscosity (40 □C) was determined using ASTM D445. Acid value, representing the free fatty acid content, was measured following ASTM D664. Flash point was determined using ASTM D93. Iodine value, indicating the degree of unsaturation, was measured using ASTM D5768 and Pour point was measured using ASTM D97.

These analyses ensured that both the crude oil and biodiesel were characterized according to internationally recognized standards, providing reliable data for fuel quality assessment.

Free Fatty Acid Content Analysis

The free fatty acid (FFA) content of *Jatropha curcas* L. seeds oil was done using acid–base titration (blank and sample) was used. Blank titration was performed by titrating the blank solution (certain amount of isopropanol and indicator solution, Phenolphthalein) against the burette solution (0.025 M KOH). Whereas, sample titration was done using a known amount of seeds oil along with indicator and was titrated against the basic solution. The FFA content of crude oil was calculated using the following

$$\text{Acid value (mg KOH g}^{-1}) = \frac{(V \times C \times 56.1)}{m} \quad (2)$$

Where:

V = volume of KOH (mL)
C = molarity of KOH
m = mass of oil (g)

Green Synthesis of MgO Nanocatalyst

Leaves of *Mangifera indica* (mango) and *Carica papaya* (pawpaw) were washed with distilled water, shade-dried at room temperature for seven days, and ground into fine powder using a mechanical grinder. For extract preparation, 10 g of each powdered leaf (20 g total) was mixed with 200 mL of distilled water and heated to boiling for 30 min in a 500 mL round-bottom flask with continuous stirring. The mixture was then filtered, and the aqueous filtrate was collected and stored for use in the green synthesis of MgO nanocatalysts.

The MgO nanocatalyst was prepared following a modified procedure of Saman *et al.* (2021). Briefly, magnesium sulphate hexahydrate ($MgSO_4 \cdot 6H_2O$) was dissolved in distilled water, and the plant extract was slowly added under continuous stirring to initiate nanoparticle formation. The mixture was maintained under stirring until a homogeneous suspension was obtained, followed by controlled precipitation induced by the bioactive phytochemicals present in the plant extract under continuous stirring. The resulting solid was washed repeatedly with distilled water, dried, and then calcined at 500 °C in a muffle furnace to obtain MgO nanostructures.

The prepared MgO nanocatalyst was characterized using X-ray diffraction (XRD) and scanning electron microscopy (SEM) to determine its structural and morphological properties and subsequently applied in biodiesel synthesis.

Transesterification Reaction

Transesterification of *Jatropha curcas* oil was carried out following the method reported by V. and Warrier (2019) with slight modifications. The reaction was performed using ethanol at an ethanol-to-oil molar ratio of 6:1 in the presence of a green-synthesized MgO nanocatalyst at a loading of 5 wt% relative to the oil mass. The reaction mixture was maintained at 60–65 °C under continuous stirring for 2 h. Upon completion, the mixture was transferred to a separating funnel to allow phase separation of biodiesel and glycerol. The biodiesel layer was carefully collected and washed repeatedly with warm distilled water (50 °C) until the wash water became clear and neutral in pH, indicating the removal of residual catalyst, glycerol, and other water-soluble impurities. The washed biodiesel was then dried under reduced pressure to remove any remaining moisture. Finally, the dried biodiesel was filtered and stored in airtight containers prior to GC–MS analysis.

The biodiesel yield obtained in this study was 85.0 wt. % (based on oil mass), demonstrating efficient transesterification catalyzed by green-synthesized MgO nanoparticles. The observed yield aligns with previous reports on biodiesel production using MgO nanocatalysts, which show that nanostructured catalysts can enhance conversion efficiency due to high surface area and strong basicity (Rotti *et al.,* 2023).

The percentage yield of biodiesel was calculated using Equation (3):

$$\text{Yield of biodiesel (\%)} = \frac{\text{weight of biodiesel obtained from each experiment}}{\text{weight of } jatopha\ curcas \text{ oil used in each sample}} \times 100 \quad (3)$$

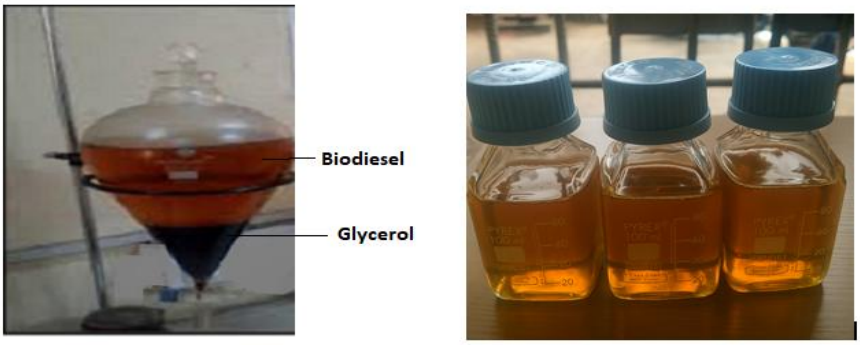

Figure 3: Biodiesel Produced from *Jatropha curcas* Oil using Synthesized MgO Nanocatalyst

Characterization Techniques (GC–MS Analysis)

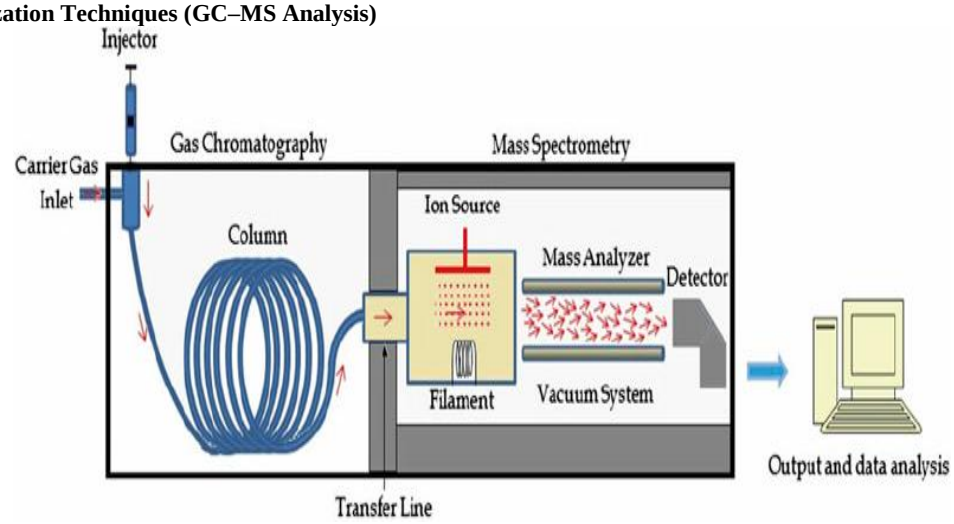

Figure 4: Diagram of the Gas Chromatograph Coupled to a Mass Spectrometer (Emwas *et al.,* 2015)

The general principles of the GC–MS Analysis is that The process begins in the gas chromatograph, where the sample is injected into the injector and carried by an inert carrier gas through a coiled capillary column (30 m 250µmx0.25µm). Inside the column, compounds are separated based on their boiling points and interactions with the column's stationary phase. The separated components then travel through the transfer line into the mass spectrometer. In the ion source, molecules are bombarded by electrons from a filament, causing them to ionize. The resulting ions are sorted according to their mass-to-charge ratio in the mass analyzer under a controlled vacuum system. Finally, the ions reach the detector, which converts their signals into data. This data is processed by a connected computer which has software with an integrated mass spectral library for compound identification (Hesham Kisher *et al.,* 2025)

GC–MS Analysis of Oil Extracted From *Jatropha Curcas* Seeds and Biodiesel

GC–MS characterization of the oil extracted from *Jatropha curcas* seeds and the biodiesel produced via ethanolysis using green-synthesized MgO nanocatalyst was carried out using an Agilent 5977 GC/MSD system. The analysis was performed for qualitative profiling and relative quantification of fatty acids and fatty acid ethyl esters (FAEEs) present in the oil and biodiesel samples. The instrument was equipped with an automated liquid sampler, and chromatographic separation was achieved using an Agilent HP-5MS Ultra Inert fused-silica capillary column (30 m × 250 µm × 0.25 µm film thickness). The gas chromatograph was interfaced to an Agilent 5977 mass selective detector (MSD).

Helium was employed as the carrier gas at a constant flow rate of approximately 1.0 mL min^{-1}, with the injector operated in splitless mode and an injection volume of 1 µL. The injector temperature and MS transfer line were maintained at 250 °C. The oven temperature program commenced at 110 °C (held for 2 min), ramped at 10 °C min^{-1} to 200 °C, followed by a second ramp of 5 °C min^{-1} to 280 °C, where it was held for 9 min, giving a total run time of approximately 36 min. Data acquisition and processing were carried out using Agilent MassHunter Workstation software.

Compound identification was based on comparison of mass spectra with the NIST14 mass spectral library, using a minimum match quality of 80% as the acceptance criterion, together with retention time comparison.

RESULTS AND DISCUSSION

Catalyst Characterization

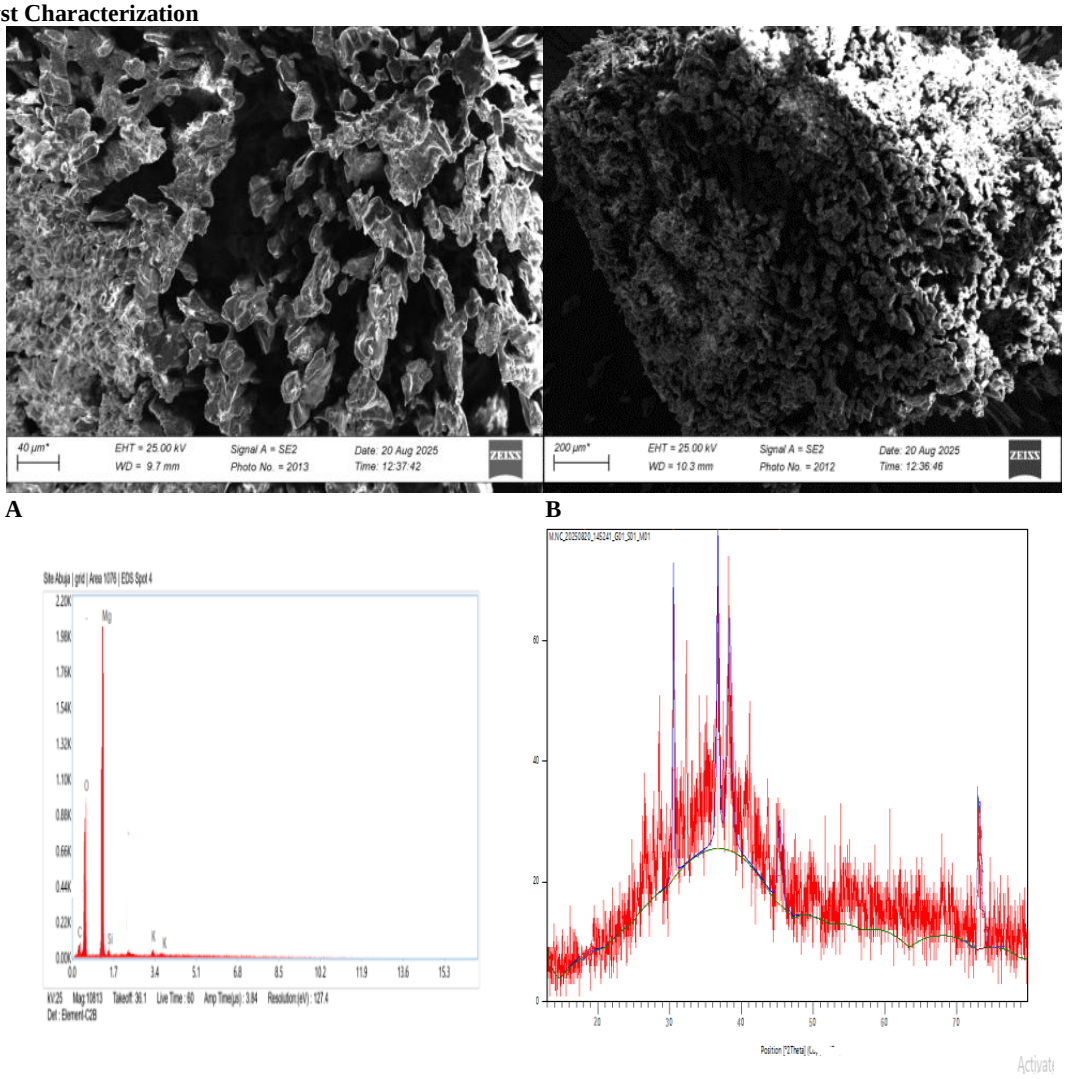

Figure 5: (a) and (b) The Scanning Electron Microscopy (SEM) of Synthesized MgO Nanocatalyst, (c) EDS Spectrum of Elemental Composition of MgO Nanocatalyst, (d) XRD Patterns of Synthesized MgO Nanocatalyst.

Table 2: XRD Peak Angles and their Corresponding Peak Height, Full Width at Half Maximum, d Spacing, and Relative Intensity of Synthesised MgO Nanocatalyst

Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]
31.5263	36.40	0.2362	4.32699	100.00
36.6934	36.03	0.3542	3.33966	99.00
38.3232	25.68	0.7085	3.15109	70.57
45.3343	9.53	0.7085	2.54026	26.20
73.3214	35.00	0.6000	1.29010	27.00

SEM Images (a–b): The SEM micrographs show rough, porous, and irregular surface morphology typical of biosynthesized MgO nanocatalysts, with particles appearing agglomerated and sponge-like, indicative of high surface area beneficial for catalytic activity during transesterification. Such structural features have been observed in MgO nanocatalysts and are associated with increased surface active sites and enhanced catalytic performance in biodiesel synthesis (Ameen *et al.*, 2022: Farouk *et al.*, 2024).

EDS Spectrum (c): The EDS analysis confirms the elemental composition of the material, showing strong magnesium (Mg) and oxygen (O) peaks, which verifies the formation of MgO with minimal impurities, consistent with previous reports (Ammulu *et al.*, 2021; Khan *et al.*, 2025)

XRD Pattern (d): The XRD diffractogram of the MgO nanocatalyst exhibits broad diffraction peaks, characteristic of nanocrystalline materials. Such peak broadening is indicative of small crystallite sizes, which is typical for biosynthesized or green-synthesized metal oxide nanoparticles (Almontasser & Parveen, 2022; Rotti *et al.*, 2023)

The Composition of *jatropha* Seed Oil Fat Fatty Acids

The Compositions of fatty acid in the jatropha seed oil was obtained by gas chromatography (Agilent 5977 GC/MSD,

USA). The detailed result from the gas chromatography is shown in table 3.1 below. Showing the peaks separated by its composition by the gas chromatography. Each peak represents the composition of each Fatty acids component.

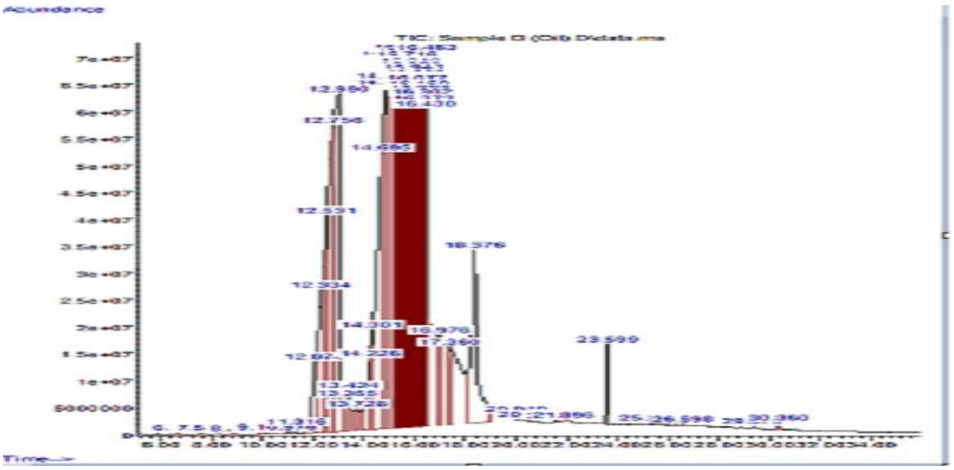

Figure 6: Fatty Acids Composition of Jatropha *Curcas* oil using GC/MS

Table 3: Major Compounds Identified by GC-MS in *Jatropha curcas* Oil

No.	Fatty Acid (Free)	Mol. Wt. (g/mol)	Mol. Formula	Saturation/Type	Retention Time (min)	Peak Intensity (%)	Fraction (%)
1	Myristic acid	228.37	$C_{14}H_{28}O_2$	Saturated	9.95	0.95	1.20
2	Palmitic acid	256.42	$C_{16}H_{32}O_2$	Saturated	11.32	8.10	24.50
3	Stearic acid	284.48	$C_{18}H_{36}O_2$	Saturated	16.46	1.69	3.60
4	Oleic acid	282.47	$C_{18}H_{34}O_2$	Monounsaturated	14.88	5.10	21.10
5	Linoleic acid	280.45	$C_{18}H_{32}O_2$	Polyunsaturated	14.22	6.47	25.70
6	cis-Vaccenic acid	282.47	$C_{18}H_{34}O_2$	Monounsaturated	16.01	2.14	8.80
7	cis-13-Octadecenoic acid	282.47	$C_{18}H_{34}O_2$	Monounsaturated	15.30	1.55	6.10
8	Squalene	410.73	$C_{30}H_50$	Unsaturated Hydrocarbon (Terpenoid)	23.60	0.45	1.60
9	γ-Sitosterol	414.72	$C_{29}H_{50}O$	Unsaturated Sterol	30.36	0.082	0.40

The GC–MS analysis of the oil sample extracted from Jatropha curcas seeds (Orerokpe provenance) yielded a complex chromatographic profile composed predominantly of long-chain fatty acids, along with minor hydrocarbons, esters, and sterol-like components. (See Table 3.1.) When peaks associated with saturated and unsaturated C16–C18 fatty acids are summed, the oil appears to be dominated by palmitic (C16:0), (24.5 %), linoleic (C18:2), (25.7 %), and oleic acids C18:1), (21.1 %), consistent with literature (Alhammad *et al.*, 2023; Ruatpuia *et al.*, 2024; Aseibichin et al., 2024). High C16–C18 content confirms excellent suitability for biodiesel. Overall, the GC–MS results show that the *Jatropha curcas* seed oil extracted from seed collected from Orerokpe exhibits a typical composition suitable for biodiesel production dominated by long-chain fatty acids, particularly palmitic acid (C16:0), oleic acid (C18:1), and linoleic acid (C18:2), which collectively accounted for the majority of the total peak area, which are ideal for transesterification to produce high-quality ethyl esters. Minor constituents such as squalene and γ-sitosterol, which are known for their antioxidant activity, may contribute to oxidative stability due to their reported antioxidant activity Kachel *et al.*, 2023; Li *et al.*, 2024).

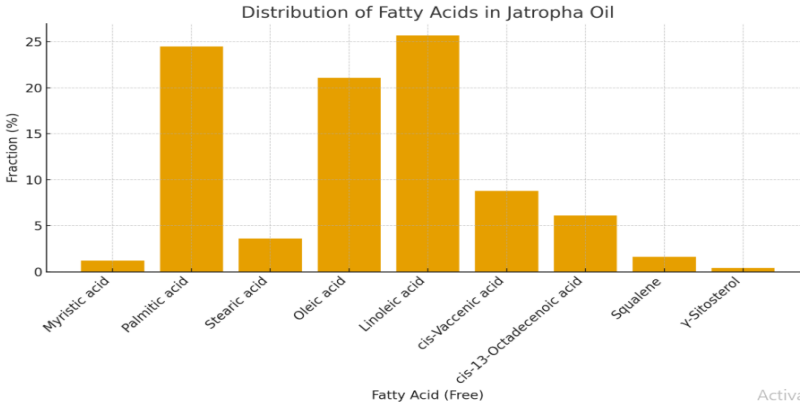

Figure 7: Distribution of the Fatty Acids in *Jatropha curcas* Oil

Gas Chromatography Mass Spectrometer (GC-MS) Analysis of *Jatropha curcas* Biodiesel

The biodiesel produced after transesterification was analyzed also by GC-MS instrument. Many structurally distinct groups of saturated and unsaturated ethyl esters were recognized as shown below.

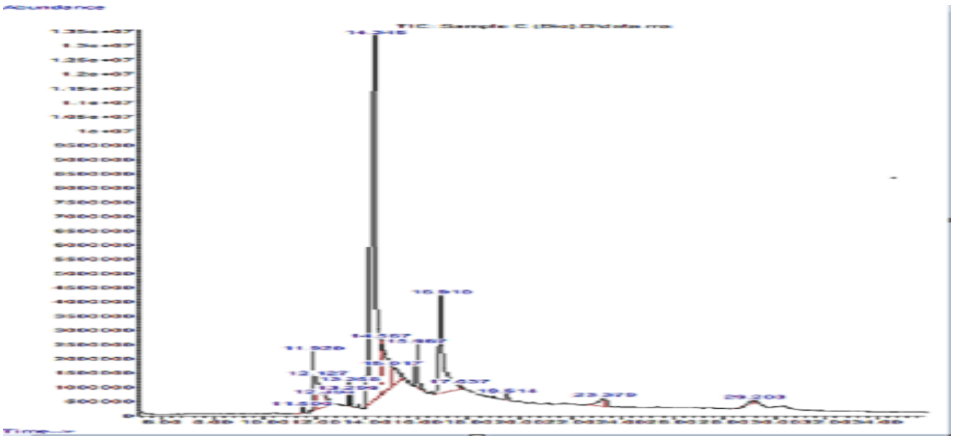

Figure 8: Fatty Acids Ethyl Esters (FAEEs) Composition of Jatropha *curcas* Biodiesel using GC/MS

Table 4: Chemical Classes Identified by GC–MS of *Jatropha curcas* Biodiesel

No	Fatty acid constituent	Corresponding FAEE	Mol. Wt. (g/mol)	Mol. Formula	Saturation /Type	Retention Time (min)	Peak Intensity (%)	Fraction (%)
1	Pentadecanoic acid, 14-ethyl-, ethyl ester	Ethyl 14-ethylpentadecanoate	270.45	$C_{16}H_{32}O_2$	Saturated	11.50	0.26	1.10
2	n-Hexadecanoic acid (Palmitic acid)	Ethyl palmitate	256.42	$C_{16}H_{32}O_2$	Saturated	11.92–12.39	8.75	10.80
3	ethyl 9-cis,11-trans-octadecadienoate	Ethyl linoleate	294.47	$C_{19}H_{34}O_2$	Polyunsaturated	13.30	0.37	1.50
4	8-Octadecenoic acid, ethyl ester	Ethyl oleate	296.49	$C_{19}H_{36}O_2$	Monounsaturated	13.36	0.92	2.10
5	cis-13-Octadecenoic acid	Ethyl oleate	282.47	$C_{18}H_{34}O_2$	Monounsaturated	14.35	57.98	70.21
6	Cycloeicosane		280.55	$C_{20}H_{40}$	Saturated Hydrocarbon	14.56	9.97	9.80
7	Oleic acid	Ethyl oleate	282.47	$C_{18}H_{34}O2$	Monounsaturated	15.02	2.99	3.30
8	Dodecanoic acid, 1,2,3-propanetriyl ester	Glycerol trilaurate	638.99	$C_{39}H_{74}O_6$	Triglyceride	29.14	0.56	1.00

The GC–MS chromatogram of the *Jatropha curcas* biodiesel synthesized using ethanol and green-synthesized MgO nanocatalyst confirmed the formation of fatty acid ethyl esters (FAEEs) as the predominant transesterification products. Several distinct peaks corresponding to saturated and unsaturated FAEEs were observed in the chromatogram (Table 3.2), indicating effective ethanolysis of the parent triglycerides.

The dominant compound identified was ethyl oleate (cis-13-octadecenoic acid ethyl ester), eluting at a retention time of 14.35 min, with a peak intensity of 57.98%, accounting for approximately 70.21% of the total biodiesel composition. This observation is consistent with the naturally high oleic acid content of *Jatropha curcas* oil and agrees with previous reports on *Jatropha*-based biodiesel (Aseibichin *et al*., 2024; Ruatpuia *et al.,* 2024).

The detection of cycloeicosane, a saturated cyclic hydrocarbon, at low relative abundance (≈9.8%) may be attributed to thermal rearrangement or cracking of long-chain hydrocarbons and lipid-derived components during high-temperature calcination of the MgO catalyst or GC injector conditions. Similar cyclic hydrocarbons have been reported as minor constituents in GC–MS profiles of biodiesel derived from non-edible oils and are often associated with natural hydrocarbon fractions of plant oils or secondary transformation products formed during analysis. Importantly, cycloeicosane does not interfere with ester identification and its presence at low concentration does not compromise biodiesel quality (Valdis Kampars et al., 2022).

Other notable FAEEs detected included ethyl palmitate and ethyl linoleate, representing saturated and polyunsaturated ester fractions, respectively. The predominance of monounsaturated ethyl esters is desirable, as it contributes to improved oxidative stability, favorable cold-flow behavior, and efficient combustion performance of biodiesel fuels (Folayan *et al.*, 2019; Sergii *et al.*, 2025).

Minor peaks corresponding to hydrocarbons and trace glyceride-related compounds were detected at very low intensities (<1%), indicating a high degree of transesterification efficiency and minimal residual unreacted species. The substantial reduction or disappearance of triglyceride-associated peaks, alongside the emergence of characteristic fatty acid ethyl ester (FAEE) signals, confirms the effective catalytic performance of the green-synthesized MgO nanocatalyst under the applied reaction conditions. However, the presence of trace triglyceride peaks (<1%) indicates that the transesterification was near-complete but

not absolute, which is typical for heterogeneous catalyst-mediated biodiesel production.

Overall, the GC–MS profile demonstrates the successful production of high-quality ethanol-derived biodiesel dominated by monounsaturated fatty acid ethyl esters, validating both the efficiency of the catalytic system and the reliability of GC–MS for compositional verification (Shanthini *et al*., 2025; Kwakye *et al.,* 2024).

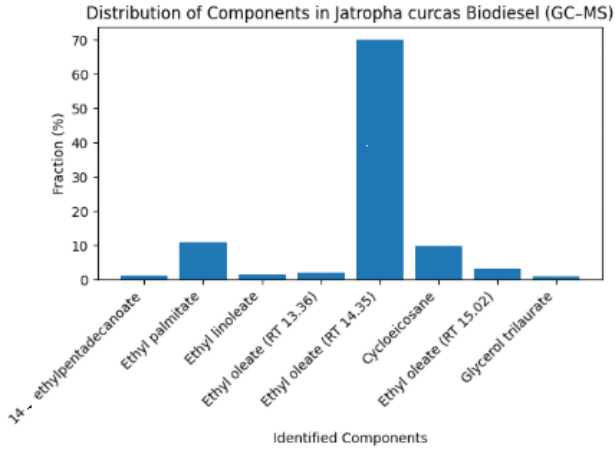

Figure 9: Distribution of Fatty Acid Ethyl Esters (Faees)

The GC–MS chromatogram and bar chart (Figure 3.4) reveal the distribution of major fatty acid ethyl esters (FAEEs) present in the biodiesel produced using green-synthesized MgO nanocatalyst. The presence of long-chain ester compounds confirms that transesterification occurred successfully. The dominant peaks correspond to oleic-type esters cis-13-octadecenoic acid ethyl ester (ethyl oleate), which exhibited the highest intensity (57.98%) at a retention time of 14.35 min. This compound represents the ethyl ester of oleic acid, a monounsaturated C18:1 FAEEs that is known to enhance biodiesel's oxidative stability and combustion efficiency. The predominance of ethyl oleate is consistent with the fatty acid composition of Jatropha oil and has been reported in similar studies by (Folayan *et al.,* 2019; Reza Nageubri Balfas *et al.,* 2024), indicating effective conversion of triglycerides into FAEEs during transesterification.

Other significant compounds include cycloeicosane (9.97 %), a cyclic hydrocarbon, and n-hexadecanoic acid ethyl ester (8.75 %), representing the ethyl ester of palmitic acid. The presence of these compounds indicates a good balance between saturated and unsaturated components, contributing to improved ignition quality, viscosity, and cold flow properties of the produced biodiesel (Pradana *et al.,* 2024; Milano *et al.,* 2025). Minor peaks corresponding to oleic acid (2.99%), ethyl linolelaidate (0.37%), and pentadecanoic acid ethyl ester (0.26 %) were also detected, suggesting trace amounts of unreacted free fatty acids or incomplete esterification, possibly due to steric hindrance or limited ethanol–oil interaction during the reaction.

Overall, the bar chart pattern indicates that unsaturated FAEEs predominate. The GC–MS results thus confirm the successful synthesis of high-quality biodiesel from *Jatropha curcas* oil catalyzed by MgO nanocatalyst derived from pawpaw and mango leaves.

Determination of Fuel Properties

Biodiesel properties were measured according to standard methods: Density (ASTM D1298), Kinematic viscosity (ASTM D445), Acid value (ASTM D664), Flash point (ASTM D93), Iodine value (ASTM D5768), Pour point (ASTM D97). Results were compared with ASTM D6751 and EN 14214 specifications.

Properties of *Jatropha curcas* oil and Biodiesel

The produced biodiesel met ASTM and EN standards:

Table 5: Properties of *Jatropha curcas* oil and Biodiesel

Property	Unit	Oil	Biodiesel	ASTM D6751 Limit	EN 14214 Limit
Density (25 °C)	g/cm³	0.91	0.86	0.86–0.90	0.86–0.90
Viscosity (40 °C)	mm²/s	38.50	3.72	1.9–6.0	3.5-5.0
Acid Value	mg KOH/g	6.52	0.47	≤ 0.80	≤ 0.50
Flash Point	°C	209	140	≥ 130	≥ 120
Iodine Value	g I_2/100 g	100.2	87.5	-	-
Pour Point	°C	8	3	-15 – 10	-
Yield	%	37.3	85.0	-	-

The physicochemical properties of the *Jatropha curcas* biodiesel produced using green-synthesized MgO nanocatalyst were evaluated against ASTM D6751 and EN 14214 standards. The density (0.86 g/cm³) falls within the recommended range (0.86–0.90 g/cm³), ensuring adequate energy content and engine compatibility. The kinematic viscosity (3.72 mm²/s) meets both ASTM (1.9–6.0 mm²/s) and EN (3.5–5.0 mm²/s) limits, supporting proper atomization and combustion. The acid value (0.47 mg KOH/g) is below the maximum allowable limits, minimizing corrosion and deposits in engines. The flash point (140 °C) confirms safe handling and storage, while the iodine value (87.5 g I_2/100 g) indicates moderate unsaturation, favorable for oxidative

stability. The pour point (3 °C) ensures acceptable low-temperature flow characteristics.
These results indicate that the biodiesel exhibits properties consistent with high-quality fuel, suitable for diesel engines. The predominance of monounsaturated ethyl esters, particularly ethyl oleate, contributes to good oxidative stability, improved cold-flow behavior, and efficient combustion, confirming the practical applicability of the produced biodiesel.

CONCLUSION

This study demonstrates the effectiveness of green-synthesized MgO nanocatalysts for biodiesel production from *Jatropha curcas* oil. GC–MS analysis confirmed that the biodiesel consists of high-quality fatty acid ethyl esters (FAEEs) dominated by ethyl oleate. The nanocatalyst enabled high conversion efficiency, producing biodiesel that conforms to international fuel standards. The use of environmentally friendly catalysts further enhances the sustainability and economic feasibility of biodiesel production. GC–MS analysis conclusively verified efficient triglyceride conversion to fatty acid ethyl esters, confirming that green-synthesized MgO nanocatalysts are effective and sustainable catalysts for high-quality biodiesel production from *Jatropha curcas* oil.

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