International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 1084-1099 www.ijaem.net ISSN: 2395-5252

Comparing the Quality of Jatropha Seed Oil Biodiesel Produced Using Mechanical and Solvent Extraction Process

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Date of Submission: 25-08-2025 Date of Acceptance: 05-09-2025

ABSTRACT:
This research investigates the production of biodiesel from Jatropha caucus seeds using two distinct extraction methods: mechanical and solvent-based. The aim is to compare the quality of biodiesel obtained through these processes. The study comprises three main objectives: oil extraction from Jatropha seeds using hexane as a solvent and mechanical extraction, transesterification to produce biodiesel using potassium methoxide as a catalyst, and a comparative analysis of the biofuel properties obtained from each process. The experimental design involved the collection of Jatropha seeds and subsequent drying, washing, and sun-drying processes. Results indicated significant differences between the properties of biodiesel and raw oil obtained through different methods. Biodiesel from mechanical extraction exhibited a higher density and flash point than solvent-extracted biodiesel, which displayed superior low-temperature properties. FTIR and GCMS analyses revealed distinct functional group patterns and fatty acid compositions, emphasizing the impact of extraction methods on molecular structures. In conclusion, the comparative analysis reveals that the choice of extraction method significantly influences the properties of Jatropha seed oil biodiesel. Mechanical extraction yields biodiesel with favourable low-temperature properties, while solvent extraction introduces a more diverse fatty acid composition.

KEYWORDS: Biodiesel production, Solvent-based, Jatropha seeds, Sustainability, Comparative analysis.

I. INTRODUCTION

Bioenergy is a kind of renewable energy that is derived from living organisms, namely plants and animals. The term "biomass" refers to any plant or animal matter that may store energy via the use of sunlight. Bioenergy uses materials classified as "biomass," including but not limited to sugar cane, grasses, straw, soybeans, and maize, among other things [1]. Biofuels are derived from renewable energy sources, such as biological materials derived from living creatures, and they may also be achieved via the use of biodegradable trash. These are waste products from plants and animals that can be utilized as fuels in their natural state or with just minor modifications making them suitable for use. According to Marshall et al. [2], these wastes may also be used to manufacture fibers and chemicals necessary for the survival of every living thing

Biodiesel can fulfill the energy requirements of the whole planet since it is a renewable energy resource that is both energy-competitive and biodegradable. It serves as an alternative to petrol and diesel, as well as a suitable substitute for fossil fuels, which are a major contributor to the depletion of the ozone layer and the overall damage of the environment. During combustion, it produces less pollutants, and it may be used in gasoline-diesel engines that are already in use without requiring any changes [3]. Biodiesel may be used as fuel in any diesel engine; however, diesel engines manufactured before to the early 1990s may need some modifications because they include components produced with natural rubber, which deteriorates when it comes into touch with biodiesel.

According to Fedoroff and Cohen [4], it is anticipated that the demand for food on a worldwide scale will rise in the years to come. Additionally, it is anticipated that the demand for transportation fuels on a global scale will also increase. The use of various energy sources over

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the course of time has led to the rise in global temperature, which is also referred to as global warming. The reason for this is because there is a significant amount of carbon that is emitted as byproducts and exhaust gasses. Therefore, as a result of this tragic circumstance, there has been a quest for other sources of fuel that are less harmful to the environment. These fuels have been responsible for a progressive rise in the quantity of pollution that has been created over the course of many years. They have also been responsible for significant oil spills, which have a tendency to harm the near isolated area where such resources are situated. Their extraction practices have also contributed to these disasters. As a result, there is a significant need for renewable energy sources that do not do a significant amount of damage to the environment and do not compete with the supply of food. It is only possible for food-based biofuels to provide a small percentage of the energy requirements for transportation. Biofuels that can be grown on agriculturally marginal soils with minimal fertilizer or pesticides or that can be obtained from agricultural leftovers have the potential to supply fuel sources that have more environmental advantages than fossil fuels or biofuels derived from food. Biodiesel may be produced from a variety of oils, including those derived from jatropha, melon, palm oil, soybean, sugar cane, and used oil. Because it is a plant that cannot be consumed and does not compete with other plants in the food chain, jatropha is a very significant component in the manufacture of biodiesel. According to Peterson et al. [5], significant advancements in the use of biodiesel as an alternative fuel are targeted at developing a method of producing energy that is not only inexpensive and renewable but also simple to produce and less harmful to the environment

This research compares the quality of jatropha seed oil biodiesel produced using mechanical and solvent extract processes. The objectives included extracting the oil from jatropha seeds using solvent (methanol) and mechanical extraction methods; Producing biodiesel by carrying out the transesterification process with potassium methoxide serving as the accelerator; and comparing the biofuel qualities from various procedures

II. JATROPHA (J. CURCAS) AS A FEEDSTOCK

During the course of this investigation, the seeds of the Jatropha plant, which belongs to the family of plants known as cucurbits, were the non-edible plant sources used for the production of the biodiesel.

When deciding which oilseed to use, it is essential to take into consideration all of the relevant factors, including the climate, the soil, the production, and the quality of the oil. In order to produce biodiesel, non-edible oils such as Jatropha, waste cooking oils, and animal tallow are what are used in the production process. Considering that the manufacturing of these oils does not compete with the production of food, this is an essential component of the process. Because plant oils account for about 70–95 percent of the overall expenses associated with the manufacture of biodiesel [6. 7], the use of non-edible oils and fats, such as Jatropha and waste cooking oils, has the potential to significantly reduce the costs associated with the manufacturing of biodiesel.

Holding true to what Hoekman et al. [8] found, Jatropha is among the most abundant Oil seeds that may be found compared to other types of oil seeds, such as oil palm, coconut, and micro-algae. Due to the high concentration of monounsaturated fatty acids that it contains, jatropha oil has been shown to be an efficient source of biodiesel [9, 10]. Because jatropha includes components that are hazardous to people and animals, neither the oil that is extracted from the seeds of the jatropha plant nor the press cake that is made from those seeds may be consumed by any of these groups.

It is also possible to cultivate jatropha on marginal terrain, which is often not suitable for the cultivation of food crops. According to Rodríguez et al. [11], jatropha does not pose a threat to food production because of this. According to Vaknin et al. [9], the press cake that is left behind after the oil has been extracted has a high protein content. since of this, it is beneficial once the hazardous components have been removed since it may be used as an organic fertilizer or in animal feeds.

The synthesis of conventional biodiesel includes the trans-esterification of triglycerides with the help of a catalyst that is either alkaline or acidic, as well as a short-chained alcohol. Both inappropriate handling and storage of jatropha oil have the potential to have a negative impact on the oil's natural quality. Free fatty acid (FFA) concentrations increase when the substance is handled improperly and when it is exposed to sunshine and air in the surrounding environment. The trans-esterification, which is accomplished by an alkaline reaction, becomes more challenging as a result of this. In point of fact, the FFAs cause the catalyst to become inactive, which in turn leads to

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saponification and the formation of more soap than is ideal, This causes the production of methyl esters and glycerin to drop. Put simply, the catalyst becomes dysfunctional due to the FFAs. The distillation of oil in steam, the extraction of alcohol, and the esterification of oil with the use of acid catalysts are some of the oil pretreatments that have been suggested with the purpose of lowering the adverse effect that FFAs have on the production of biodiesel. Regardless, due to its simplicity of execution, esterifying FFAs with methanol in the presence of acidic catalysts has become the preferred approach. This explains why it has become the method of choice.

An acid catalyst is present throughout the first stage of the process, during which oil fatty acids undergo esterification, which is a chemical transformation. During the second phase, the leftover tri-acylglycerides are trans-esterified with the aid of conventional alkaline catalysis [12, 13]. The goal of this technique is to create the compounds of interest. Because water may cause the hydrolysis of monoesters and alkoxides (catalyst), which in turn lowers reaction yield [14], it is essential that the oil has a low water content. This is another reason the oil is beneficial. This is very important due to the fact that water has the ability to catalyze the hydrolysis of monoesters and alkoxides. Because the alkaline catalyst loses its ability to function when it is exposed to situations that include rising acidity, greater humidity, or gums (phospholipids), the ester yields and the quality of the biodiesel both suffer as a result. Syam et al. [15] and Berchmans and Hirata [12] state that phosphoric acid degumming helps ease difficulties with saponification and moisture, and it also greatly lowers the number of phospholipids that are present in the oil

III. EXPERIMENTATION

Jatropha caucus seed samples used in this study were collected in Warri, Delta state, Nigeria. To facilitate the degradation of the seeds, the cucurbit fruits were cut open, placed in a sac, and allowed for 5 days to decay after collection. First, the seeds were washed and then allowed to dry in the sun for about one week before being transported to the laboratory. That was followed by a period of storage at 25 ^{o}C, or room temperature, until it was needed for the oil extraction procedure.

Jatropha seeds and their coverings were separated beforedrying. The moisture content of the seed samples was reduced to a minimum by oven drying them at 80 ^{o}C for three days. The next step was to physically smash them into very small particles using a mortar and pestle. Using three distinct stainless-steel sieves with apertures of 0.5µm, 500µm, and 1mm, the estimated particle size of the crushed seeds (PSCS) was derived. To carry out the extraction process, particles having a size of 0.5 µm were used, which were then sieved. For better oil-solvent accessibility, a smaller particle size was chosen due to its higher surface area-to-volume ratio. Once the sample had been weighed at 60 g, it was then transferred to separate vials containing the reagents and sealed. Following the procedure shown in Plate 3.3, 300milliliters of hexane, the solvent, was carefully added to the 60 grams of feedstock in the container and left to submerge entirely.

The gear that was used in the process of extracting oil from crushed seeds is shown in Plate 3.2; this apparatus consisted of an extractor column and a 300 ml round-bottom flask designed to collect oil. The extractor's dimensions necessitated using a flask with a spherical bottom for the extraction. The extraction column was filled with the solute (feedstock), and 100 grams of solvent (either hexane or another suitable choice) was measured and added to the round-bottomed flask for collecting oil. In order to chill the process, a condenser was mounted to the Soxhlet and linked to a nearby water supply during setup. In this particular instance, filter paper is used as the filter due to the fact that it is easily accessible and very affordable.

The round-bottom flask used to collect oil was heated to 65 ^{o}C for the hexane solvent and 75 ^{o}C for the other solvent using the heating mantle, which is attached to an electrical source. By use of the Soxhlet, the vapor that is produced by the boiling solvent is sucked into the condenser. In order to collect the sample, the liquid condensate drops onto the filter paper. Through the thimble's pores, the extract seeps into the siphon tube, which carries it back to the circular bottom flask that collects the oil. Up until the feedstock in the extractor became clear and we had a full reflux, this process was going on continuously with many refluxes.

Following the completion of the extraction, the heat source was shut off, and the length of time that the extraction took was noted. The extract was promptly transferred to a reagent bottle and sealed with a cork after being let to cool to 25 ^{o}C.

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Figure 1:Fruits of Jatropha Caucus seed

Figure 2: Illustration of the apparatus for Soxhlet extraction

The extract was cooled before being distilled at 65 ^{o}C to remove the hexane and get the oil. After that, the oil was spun in a centrifuge to spin out the particles that were not oil.

Weighing the oil after solvent removal allowed us to calculate its quantity in terms of oil yield, as shown in Equation (3.1).

$$\%\ \text{of oil yield}\ \left(\frac{w}{w}\right) = \frac{\text{weight of extracted oil } (W_{oil})}{\text{weight of crushed seeds } (W_{cs})} \times 100$$

Equation 1

Equation was also used in order to ascertain the density of the oil (3.2):

$$\text{density} = \frac{\text{mass of oil}}{\text{volume of oil}}$$

Equation 2

To get the total oil % yield, weigh the sample of oil after extracting it with hexane and then weigh it again.

To begin the extraction procedure, the Jatropha caucus seeds had their husks removed from the reverse side. The temperature of the equipment used for mechanical extraction was carefully regulated to 180 ^{o}C. The machine started the oil extraction process after going through a heating step to get to the specified temperature. Mechanical equipment operating at a constant 180 °C successfully extracted oil from seeds.

The oil and the seed remnant (shaft) were effectively separated during the mechanical extraction process by an internal mechanism of the machine. After carefully collecting the oil in a specific container, this separation step guaranteed its isolation. Successful recovery of Jatropha caucus seed oil for further processing in the biodiesel manufacturing method was achieved throughout the mechanical extraction operation by precisely controlling the temperature and separating the oil and shaft.

THE TRANSESTERIFICATION PROCESS

The reaction was mixed at a 4:1 ratio of alcohol to oil. The oil sample, which is 100 ml in volume, is then put to a beaker that is 400 ml in volume and contains methanol. A temperature range of 48 to 54 ^{o}C was reached by heating the mixture while stirring it for 5 minutes. The oil was slowly mixed with the potassium methoxide solution while stirring constantly for one hour at a temperature of 60 ^{o}C. This reaction was seen in both oil samples.

The solution that had been produced by the red reaction was moved to a separate funnel and allowed to cool. The mixture was allowed to settle for around fifteen hours, subjected to the attraction of gravity. The denser glycerol solidified at the base of the separator funnel, resulting in the formation of a gelatinous material. Meanwhile, the methyl ester, also known as biodiesel, floated to the top of the funnel. All of the crude biodiesel was transferred to a new container in a meticulous manner. To maintain the reaction mixture in a semi-liquid state, it was essential to maintain it above 38 ^{o}C, since glycerol solidifies at temperatures below this mark.

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Figure 3: The separation set-up of biodiesel from glycerol in sample A

Figure 4: The separation set-up of biodiesel from glycerol in sample A

To remove any leftover catalyst, glycerol, or other impurities, the biodiesel was washed with lukewarm water after being removed from the glycerol. A cloudy, white liquid dropped to the bottom of the container while the spinning continued for an extended period of time. Careful decantation was used to extract the cleaned biodiesel from this cloudy mixture. By heating the cleaned biodiesel to 100 ^{o}C, any remaining water was evaporated.

DETERMINATION OF BIODESEL PHYSIOCHEMICAL PROPERTIES

To determine the biodiesel value, the Jenweh pH meter, model 3320, was used. The meter was configured to measure temperature at 25 ^{o}C and pH mode at 0.15. Following the meter's calibration, the 30 cm^3 biodiesel sample was transferred to a beaker. There was biodiesel in the beaker, and the meter's electrode was in the other. The pH level of the oil sample was recorded on the screen once it had stabilized.

To determine density, a sterile, temperature-stabilized hydrometer cylinder was used to transfer about 5 milliliters of the biodiesel sample, ensuring that no air bubbles are present. After adding the biodiesel to a cylinder that had been weighed before (M1) (M2), the measurements were taken and recorded. We used this formula to get the density:

$$\text{Density} = \frac{M_2 - M_1}{V}$$

Equation 3.3

Where M_2 = Final mass, M_1 = Initial mass and V = Volume

To compute the cloud point, a sealed test tube was used to hold five milliliters of the biodiesel sample. The test tube holding the sample was placed on top of a little amount of ice that had been put to a beaker. Following the appearance of wax crystals on the sample's surface, the temperature was determined using this process.

Pour 100 cc of the sample into a closed cup of the Seta Hope flash point equipment while the temperature ranges from 60 to 190 ^{o}C. When the sample was heated to 140 ^{o}C, a hot wire was inserted into the cup at 5^{o} intervals and then dropped to 2^{o} intervals as the temperature neared the desired range. Accurate measurements were acquired at the precise moment when the brief flash occurred.

The mass of a dry, clean, dense bottle with a volume of 50 cm^3 was measured (M0). After we had finished filling the bottle with distilled water to the mark and then corked it (M1), we removed it from the bottle and weighed it once again. After the water was extracted from the bottle, it was dried in the oven and allowed to cool as it was removed. After filling the container to the mark with the biodiesel sample, the weight was rechecked (M2). Equations (3.4 and 3.5) provide the formula for the specific gravity.

$$\text{Specific Gravity} = \frac{\text{mass (substance)}}{\text{mass (equal volume of water)}}$$

Equation 3.4

$$\text{specific gravity} = \frac{M_2 - M_0}{M_1 - M_0}$$

Equation 3.5

Ten milliliters of the biodiesel sample should be placed in a beaker. Cover a large section of the viscometer spindle with the sample, then dip it into the biodiesel. Make sure the spindle can withstand the amount of biodiesel being poured. We collected the data after five minutes of spinning at 30 rpm.

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IV. RESULTS FROM TESTS

Physiochemical Properties of Raw oil and Biodiesel

From Figure 4.1, the pH values of all samples are within the neutral range, with the biodiesel (mechanical extraction) and biodiesel (solvent extraction) having pH values of 7.18 and 7.34, respectively. On the other hand, the raw oil (mechanical extraction) and raw oil (solvent extraction) have pH values of 6.92 and 6.84, respectively. pH values are relatively neutral, typical for biodiesel and oil. Literature might show that pH values can be influenced by the extraction method and the presence of impurities.

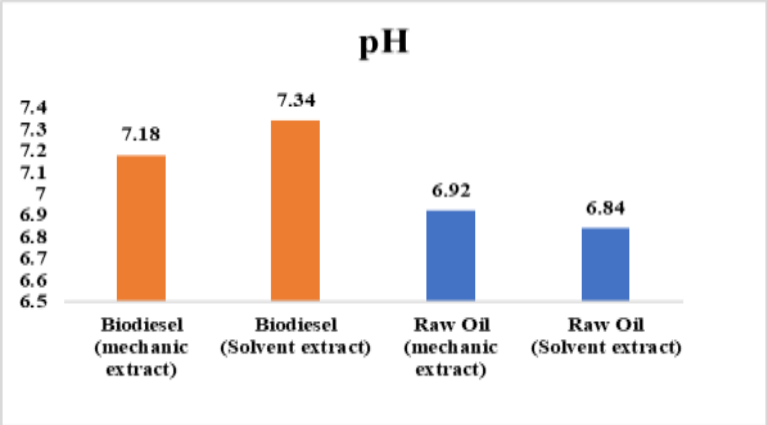

Figure 5: pH of the raw extracted oil and biodiesel

In terms of density, from Figure 4.2, the biodiesel (mechanical extraction) has the highest density value of 0.874 g/ml, while the biodiesel (solvent extraction) has a density value of 0.862 g/ml. Meanwhile, the raw oil (mechanical extraction) and raw oil (solvent extraction) have density values of 0.936 g/ml and 0.918 g/ml, respectively. The values obtained are consistent with typical biodiesel and oil densities. Differences between mechanical and solvent extracts may indicate variations in impurity content.

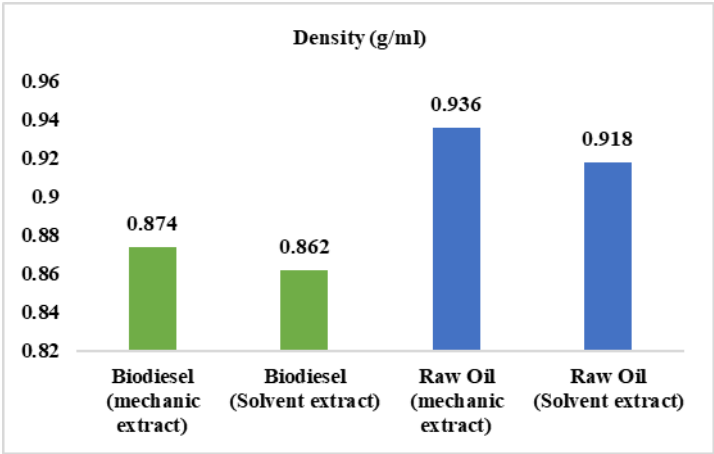

Figure 6: The density of the raw biodiesel and extracted oil

The cloud point, which is the temperature at which the fuel becomes cloudy, is significantly lower for the raw oil extractions compared to the biodiesel extractions see Figure 4.3. The biodiesel (mechanical extraction) has the highest cloud point value of 10.6 °C, while the biodiesel (solvent extraction) has a cloud point of 14.5 °C. On the other hand, the raw oil (mechanical extraction) and raw oil (solvent extraction) have cloud point values of 7.3 °C and 8.7 °C, respectively

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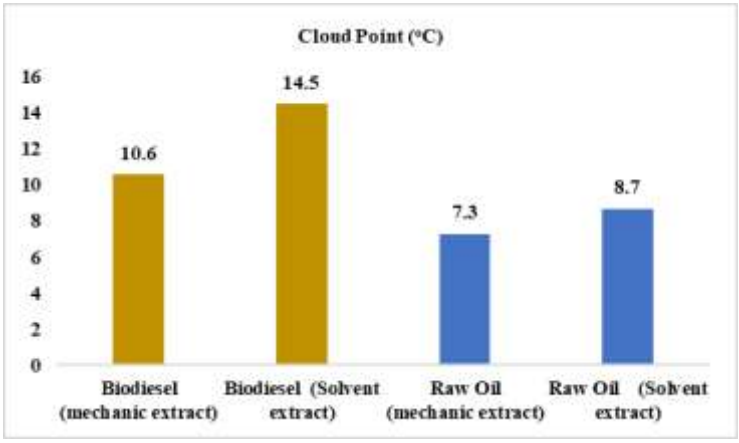

Figure 7: Cloud Point of the raw extracted oil and biodiesel

Compared to the biodiesel extractions, the raw oil extractions had a higher flashpoint, which is defined as the lowest temperature at which fuel vapours can ignite when provided an ignition source. This information can be found in Figure 4.4. The raw oil (mechanical extraction) has the highest flash point value of 284.2 °C, while the raw oil (solvent extraction) has a flash point of 267.8 °C. On the other hand, biodiesel (mechanical extraction) and biodiesel (solvent extraction) have flash point values of 110.3 °C and 98.7 °C, respectively. Flash point is important for safety considerations. The solvent-extracted samples have lower flash points, which might indicate higher volatility and potential safety concerns.

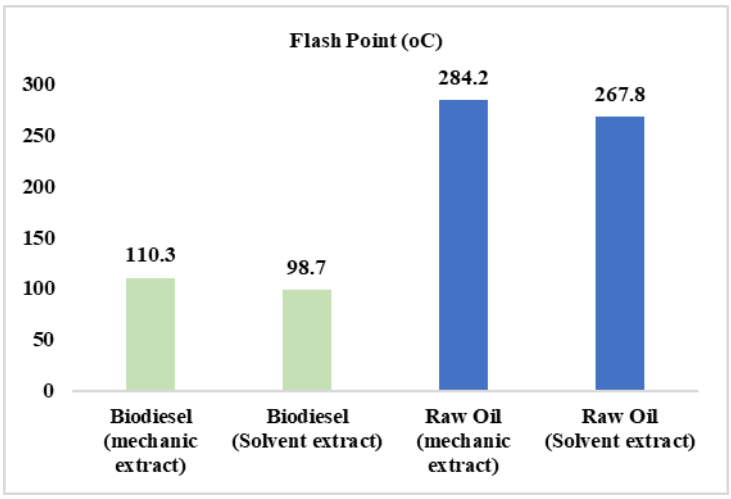

Figure 8: The flash Point of the raw biodiesel and extracted oil

When compared to the density of a reference material, the specific gravity of a substance is a measurement of the density of the individual substance. The ratio of the density of a material to the density of a reference substance is reflected by this dimensionless quantity, which acts as a measure of the ratio. In the Figure 4.5, the specific gravity is different for all the four substances. The specific gravity of Biodiesel (mechanical extraction) is 0.874, Biodiesel (Solvent extract) is 0.862, Raw Oil (mechanical extraction) is 0.936, and Raw Oil (Solvent extract) is 0.918. It is important to note that the specific gravity of a substance can provide valuable information about its properties and behaviour, such as its buoyancy, viscosity, and solubility.

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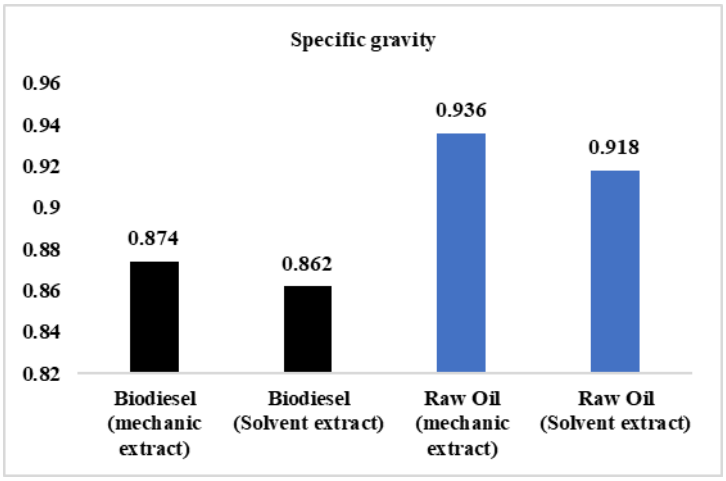

Figure 9: The specific gravity of the raw biodiesel and extracted oil

Finally, kinematic viscosity, a measure of a fluid's resistance to flow, is significantly higher for raw oil extractions than for biodiesel extractions. The raw oil (mechanical extraction) has the highest kinematic viscosity value of 18.34 mm2/s, a kinematic viscosity value of 15.79 mm2/s is recorded for the raw oil that was extracted using solvents. In contrast, biodiesel (mechanical extraction) and biodiesel (solvent extraction) have kinematic viscosity values of 2.86 mm2/s and 3.13 mm2/s, respectively.

These results are consistent with existing literature on the properties of biodiesel and raw oil extractions obtained through different methods. For instance, a study by Knothe et al. [16] showed that the density of biodiesel was affected by the type of feedstock and production method. Similarly, in a study by Demirbas[17], raw oil was found to have a much greater kinematic viscosity than biodiesel, according to the results of an investigation into the qualities of biodiesel and raw oil that was extracted using various techniques.

In summary, the results obtained in this study provide valuable insights into the properties of biodiesel and raw oil extractions obtained through different methods. These results can be used to guide the selection of appropriate extraction methods to produce biodiesel and raw oil with desired properties.

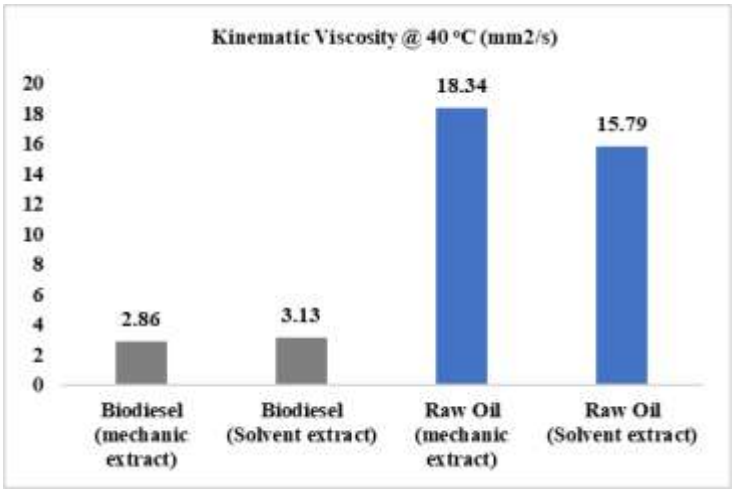

Figure 10: The kinematic viscosity of the raw biodiesel and extracted oil

Biodiesel using Mechanical Extraction

In the examination of biodiesel derived from Jatropha seeds using Fourier Transform Infrared Spectroscopy (FTIR), different peaks that correspond to certain functional groups are discernible. Key peaks include one at 879.57cm^{-1},

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associated with C-H bending in the methylene group, while another at 918.15cm^{-1} indicates C-H bending in the methyl group. A peak at 1211.34cm^{-1}corresponds to C-O stretching in the ester linkage, and 1496.81cm^{-1} represents C-H bending in the methyl group. The peak at 1712.85cm^{-1} signifies C=O stretching in the ester linkage, and 1820.86cm^{1} suggests C-H bending in the methyl group. Another significant peak at 2106.34cm^{-1} is linked to C-H bending in the methyl group, and 2337.8cm^{-1} indicates C-H bending in the methylene group. Peaks at 2476.68cm^{-1} and 2615.56cm^{-1} correspond to C-H bending in the methyl group. Additionally, peaks at 2715.86cm^{-1}, 2777.59cm^{-1}, and 3016.77cm^{-1} represent C-H bending and stretching in various methyl and methylene groups. Peaks at 3248.23cm^{-1}, 3394.83cm^{-1}, and 3564.57cm^{-1} indicate C-H stretching in methyl groups. Finally, a peak in the methylene group that is located at 3811.47cm^{-1} reflects the stretching of the C-H bond.

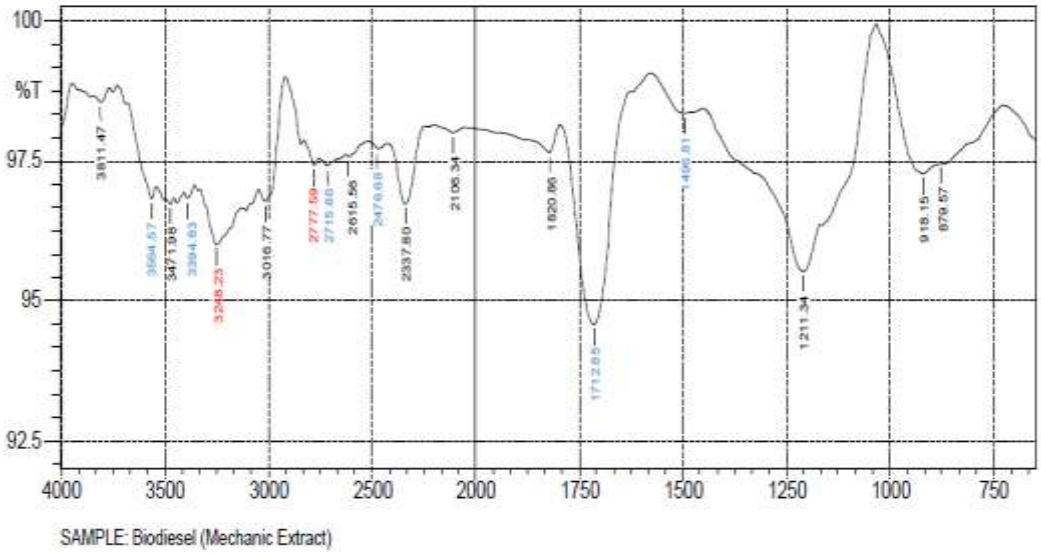

Figure 11: FTIR of Biodiesel using Mechanical Extraction

Biodiesel using Solvent Extraction

The Fourier Transform Infrared Spectroscopy (FTIR) examination of biodiesel that was extracted from Jatropha seeds via the use of solvent extraction revealed unique peaks that are connected with certain functional groups. Notable peaks include one at 794.7cm^{-1}, indicative of C-H bending in the methylene group, and another at 856.42cm^{-1} representing C-H bending in the methyl group. A peak at 1103.32 cm^{-1} corresponds to C-O stretching in the ester linkage, and 1203.62cm^{-1} signifies C-H bending in the methyl group. The C-H bending in the methyl group is responsible for the peak that can be seen at 1373.36 cm^{-1}, while 1512.24cm^{-1} indicates C-H bending in the same functional group. The peak at 1712.85cm^{-1} suggests C=O stretching in the ester linkage, and 1820.86 cm^{-1} is associated with C-H bending in the methyl group. Another noteworthy peak at 2114.05cm^{-1} corresponds to specific C-H bending, and 2337.8cm^{-1} indicates C-H bending in the methylene group. Peaks at 2685cm^{-1}, 2785.3cm^{-1}, and 2847.03cm^{-1} represent various C-H bending and stretching vibrations. Additionally, peaks at 3109.35cm^{-1}, 3232.8cm^{-1}, and 3417.98cm^{-1} are associated with distinct C-H stretching modes. Peaks at 3595.43cm^{-1}, 3726.6cm^{-1}, and 3857.76cm^{-1} further characterize C-H stretching in different functional groups.

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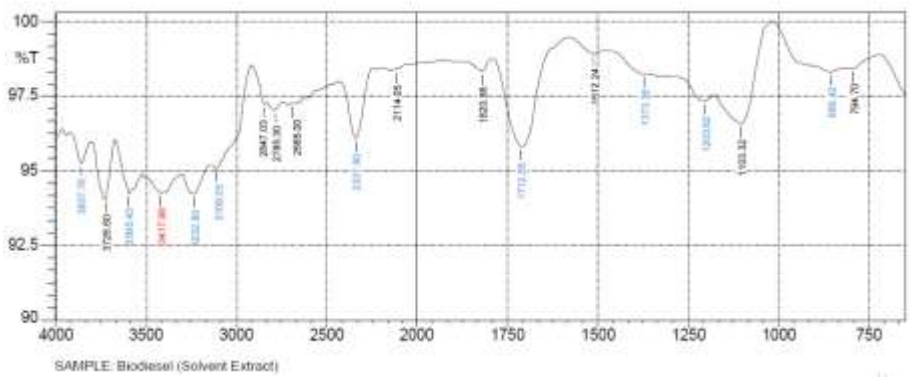

Figure 12: FTIR of Biodiesel using Solvent Extraction

Raw oil using Mechanical Extraction

Through the use of mechanical extraction, the Fourier Transform Infrared Spectroscopy (FTIR) study of raw oil recovered from Jatropha seeds for the manufacturing of biodiesel shows unique peaks that are connected with certain functional groups. Notable peaks include one at 879.57cm^{-1}, indicative of C-H bending in the methylene group. Another peak at 918.15cm^{-1} represents C-H bending in the methyl group, C-O stretching in the ester bond is the cause of a prominent peak measuring 1211.34cm^{-1}, which correlates to the peak. In addition, a peak at 1496.81cm^{-1} suggests that the methyl group is bending its carbon-hydrogen bonds, and a strong peak at 1712.85cm^{-1} indicates that the ester linkage is stretching its carbon-oxygen bonds. Another peak at 1820.86cm^{-1} is associated with C-H bending in the methyl group. The C-H bending that occurs in the methyl and methylene groups is shown by the peaks that occur at 2106.34cm^{-1} and 2337.8cm^{-1}, respectively. The peak at 2476.68cm^{-1} represents C-H bending in the methyl group, and a peak at 2615.56cm^{-1} suggests C-H bending in the methyl group. Peaks at 2715.86cm^{-1}, 2777.59cm^{-1}, and 3016.77cm^{-1} indicate various C-H bending and stretching vibrations in different functional groups. Additionally, peaks at 3248.23cm^{-1}, 3394.83 cm^{-1}, and 3471.98cm^{-1} are associated with distinct C-H stretching modes. A significant peak at 3564.57cm^{-1} further contributes to the characterization of C-H stretching in different functional groups. The last peak at 3811.47 cm^{-1} represents C-H stretching in the methylene group

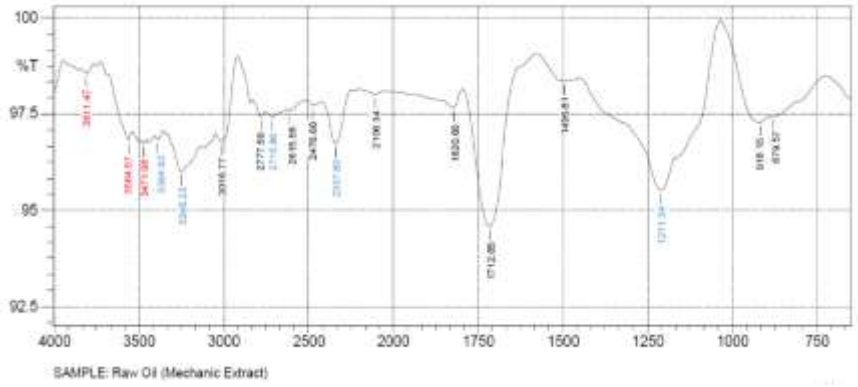

Figure 13: FTIR of Raw oil using Mechanical Extraction

4.1.2D Raw oil using Solvent Extraction

From Figure 4.10, prominent peaks include those at approximately 879.57 cm^{-1}, indicating C-H bending in the methylene group; 918.15 cm^{-1}, reflecting the stretching of the carbon-hydrogen bond in the methyl group; and 1211.34 cm^{-1}, which corresponds to the stretching of the carbon-oxygen bond in the ester linkage. Additionally, a significant peak at 1496.81 cm^{-1} signifies C-H bending in the methyl group,The presence of a peak at 1712.85 cm^{-1} shows that the ester bond is undergoing C=O stretching. Another relevant peak at 1820.86 cm^{-1} is associated with C-H bending in the methyl group.

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Further peaks at 2106.34 cm^{-1} and 2337.8 cm^{-1} correspond to C-H bending in the methyl and methylene groups, respectively. The peak at 2476.68 cm^-1 represents C-H bending in the methyl group, and 2615.56 cm^{-1} suggests C-H bending in the methyl group. Peaks at 2715.86 cm^{-1}, 2777.59 cm^{-1}, and 3016.77 cm^{-1} indicate various C-H bending and stretching vibrations in different functional groups. Additionally, peaks at 3248.23 cm^{-1}, 3394.83 cm^{-1}, and 3471.98 cm^{-1} are associated with distinct C-H stretching modes. The last notable peak at 3564.57 cm^{-1} further contributes to the characterization of C-H stretching in different functional groups.

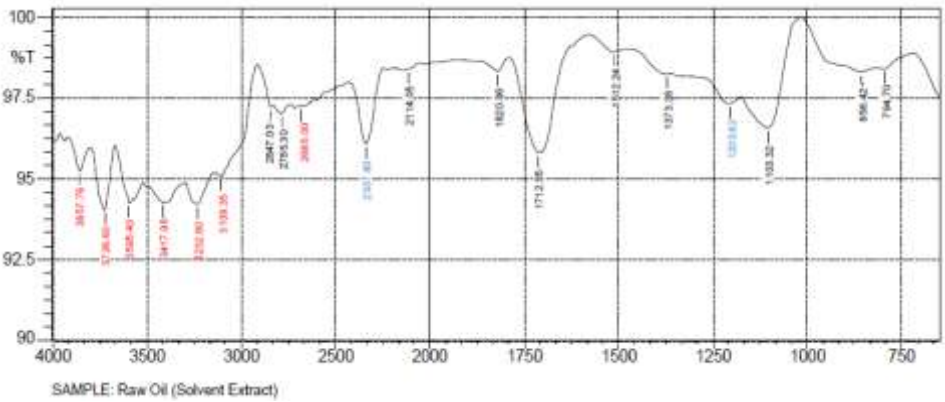

Figure 14: The FTIR of Raw oil extracted using Solvent Extraction

The FTIR analyses of biodiesel and raw oil from Jatropha seeds obtained through mechanical and solvent extraction methods exhibit distinct functional group patterns. In both biodiesel samples, peaks indicating C-H bending in the methylene and methyl groups, C-O stretching in the ester linkage, and C=O stretching in the ester linkage are evident. However, solvent-extracted biodiesel displays additional peaks associated with unique C-H bending and stretching vibrations, emphasizing its diverse functional group composition. Similarly, both mechanical and solvent-extracted raw oil samples exhibit common peaks linked to C-H bending and stretching in various functional groups. Notably, solvent-extracted raw oil presents additional peaks indicative of distinct C-H bending and stretching modes. Overall, the FTIR results emphasize the impact of extraction methods on the molecular composition of biodiesel and raw oil, providing valuable insights into their potential applications and qualities.

Biodiesel using Mechanical Extraction

The composition of biodiesel, as revealed by the GCMS analysis, encompasses a spectrum of fatty acids, each with distinct impacts on the fuel's performance. Increasing the oxidative stability of biodiesel is accomplished by the addition of saturated fatty acids, such as palmitic and stearic acid; nevertheless, an excess may elevate cloud and pour points, impacting low-temperature characteristics. Monounsaturated fatty acids, such as oleic and erucic acid, improve fluidity and performance at low temperatures, which in turn contributes to an increase in oxidative stability. The presence of an excessive amount of unsaturation, on the other hand, may increase the vulnerability to toxicity. Polyunsaturated fatty acids, including eicosapentaenoic and docosahexaenoic acid, contribute to fluidity at low temperatures but necessitate careful control to prevent oxidative degradation, ensuring stability over time.

Additionally, the presence of short-chain fatty acids like caprylic and pelargonic acid may influence the combustion characteristics of biodiesel, potentially affecting ignition quality and combustion efficiency. The total energy content of biodiesel is composed of long-chain fatty acids, such as arachidic and lignoceric acid, which contribute to the overall energy content. However, an excessive abundance of long-chain fatty acids may impact fuel properties and combustion efficiency. The identification of polyunsaturated fatty acids like eicosadienoic and arachidonic acid, though in small amounts, underscores the necessity of monitoring their levels to ensure biodiesel quality. Finally, quality indicators such as monoester, diester, and triester content represent crucial parameters for assessing fuel quality, where higher ester levels generally indicate superior biodiesel quality.

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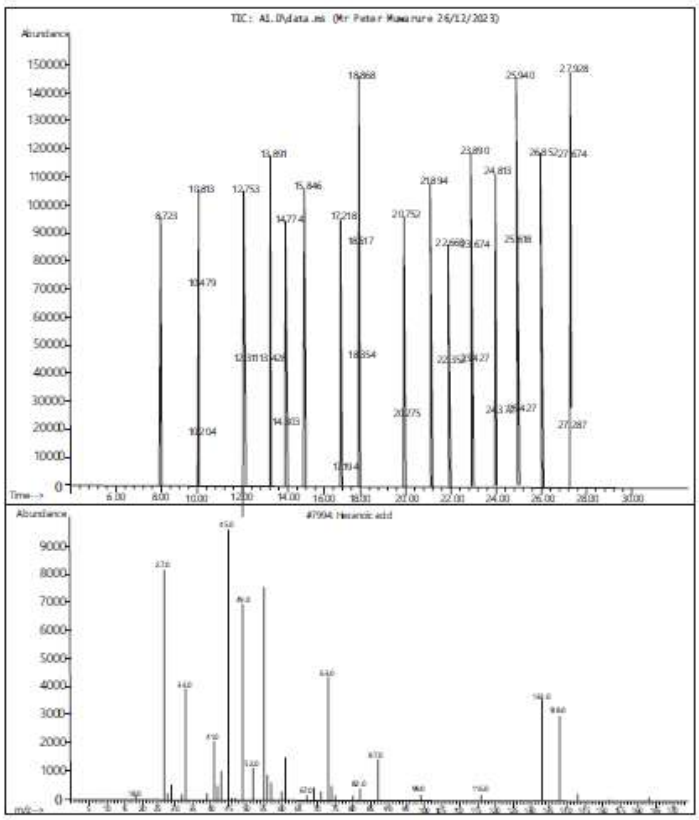

Figure 15: GCMS of Biodiesel using Mechanical Extraction

Biodiesel using Solvent Extraction

The GCMS analysis results for Biodiesel obtained through solvent extraction reveal a diverse composition of fatty acids, each imparting unique characteristics to the fuel. Saturated fatty acids, including Caprylic Acid and Lauric Acid, contribute to the oxidative stability of biodiesel. However, caution is warranted to prevent excessive amounts, which could elevate cloud and pour points, adversely affecting low-temperature properties. Monounsaturated fatty acids such as Oleic Acid and Erucic Acid enhance fluidity and low-temperature performance, contributing to improved oxidative stability. Yet, vigilance is required to avoid an overabundance of unsaturation, which may heighten susceptibility to oxidation. Polyunsaturated fatty acids, exemplified by Eicosadienoic Acid and Docosahexaenoic Acid, contribute to fluidity at low temperatures but necessitate careful control to prevent oxidative degradation, ensuring long-term stability.

Moreover, short-chain fatty acids like Caprylic Acid and Pelargonic Acid may influence combustion characteristics, potentially impacting ignition quality and combustion efficiency. Long-chain fatty acids, including Arachidic Acid and Lignoceric Acid, contribute to the overall energy content of biodiesel, though excessive amounts may impact fuel properties and combustion efficiency. The presence of polyunsaturated fatty acids like Eicosadienoic Acid and Arachidonic Acid, albeit in small amounts, underscores the necessity of monitoring their levels to ensure biodiesel quality. Additionally, quality indicators such as Monoester, Diester, and Triester content serve as crucial parameters for assessing fuel quality, with higher ester levels generally indicating superior biodiesel quality. Understanding the implications of these compounds is vital for optimizing the formulation of biodiesel from solvent extraction, ensuring compliance with standards and the fulfillment of specific application requirements. Adjustments in composition may be necessary to achieve stable and high-quality biodiesel production.

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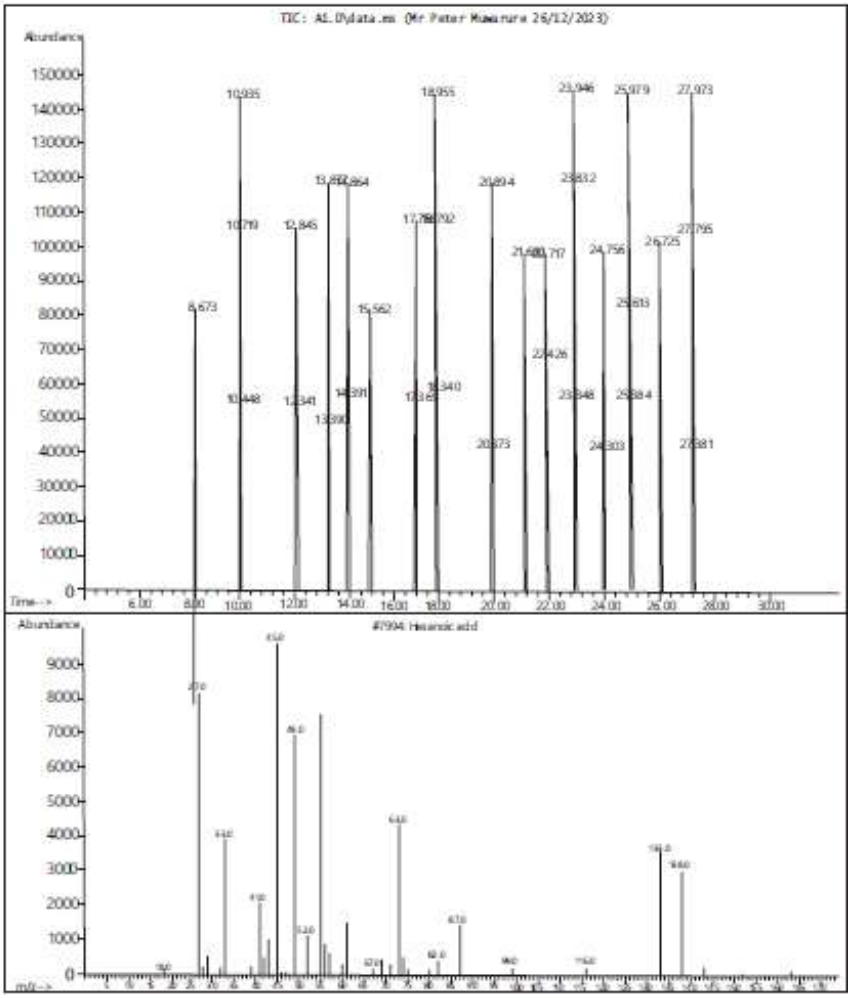

Figure 16: GCMS of Biodiesel using Solvent Extraction

Raw oil using Mechanical Extraction

The GCMS analysis results for raw oil from Jatropha seeds obtained through mechanical extraction present a comprehensive profile of fatty acid compounds. The identified compounds include saturated acids like Caprylic and Lauric acid, as well as monounsaturated acids such as Oleic acid and Erucic acid. Additionally, polyunsaturated acids such as eicosadienoic acid and docosahexaenoic acid are present in abundant amounts. The varying composition of these fatty acids plays a critical role in determining the oil's stability, fluidity, and overall quality. Notably, the identified short-chain and long-chain fatty acids contribute to the energy content of the raw oil, however, in order to maximize their characteristics and shield them from deterioration, their levels need to be constantly controlled. Quality indicators, such as ester content, offer insights into the overall quality of the oil. The information derived from this analysis is pivotal for understanding the suitability of the raw oil for various applications, requiring consideration of extraction methods and potential adjustments to meet specific end-use requirements or industry standards.

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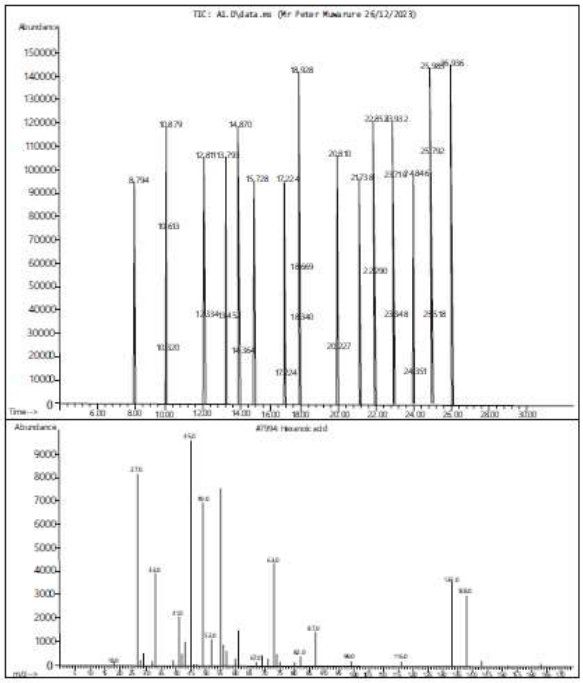

Figure 17: GCMS of Raw Oil using Mechanical Extraction

Raw oil using Solvent Extraction

The GCMS analysis results for raw oil extracted from Jatropha seeds using solvent extraction reveal a diverse composition of fatty acids, encompassing saturated, monounsaturated, and polyunsaturated compounds. These fatty acids contribute to the stability, fluidity, and energy content of the raw oil. However, careful control of unsaturation levels is crucial to prevent oxidative degradation and ensure overall stability. Short-chain and long-chain fatty acids, along with quality indicators, provide insights into specific characteristics and ester content, respectively. The composition of the raw oil is pivotal for potential applications such as biodiesel production or other industrial uses, necessitating consideration of extraction and refining processes to meet desired end-use requirements and adhere to quality standards.

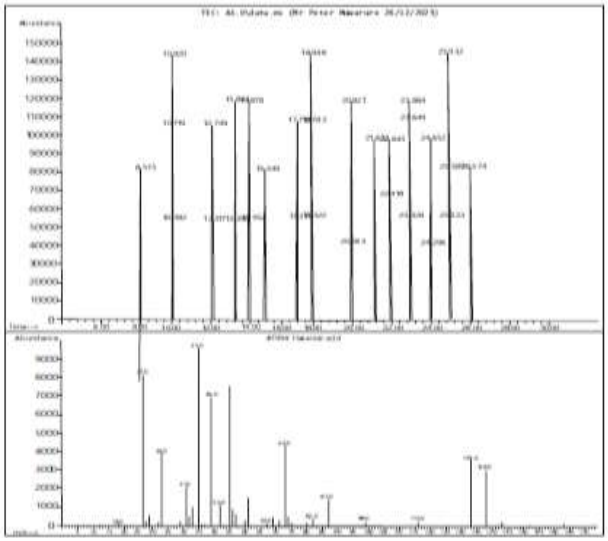

Figure 18: GCMS of Raw Oil using Solvent Extraction

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 1084-1099 www.ijaem.net ISSN: 2395-5252

V. CONCLUSION

This study investigated oil extraction, transesterification, and comparative analysis to determine the influence of different methods on biodiesel quality. Solvent extraction produced biodiesel with higher density but ;lower cloud and flash points, while mechanical extraction yielded biodiesel of lower density with higher cloud and flash points. FTIR analysis confirmed the presence of consistent functional groups in both methods, though solvent extraction revealed additional peaks.during transesterification solvent-derived biodiesel exhibite distinct fatty acid compositions that affect stability, fluidity, and energy content, whereas mechanical extraction maintained more consistent profiles with slight variations. Overall, the comparative analysis showed clear differences in physicochemical properties and molecular composition, emphasizing that extraction techniques significantly shape the performance and quality of biodiesel.

SOME OF THE ADVANTAGES FROM THE ABOVE RESULTS

i. This study contributes to the scientific understanding of how different extraction methods (mechanical and solvent) affect the quality and properties of jatropha seed oil biodiesel. It sheds light on the best way to produce biodiesel that is both efficient and environmentally friendly.
ii. The research's findings help enhance the efficiency and sustainability of biodiesel production, contributing to global efforts to reduce carbon emissions and combat climate change.
iii. By comparing the costs and benefits of mechanical and solvent extraction methods, this study offers insights into the economic viability of jatropha seed oil biodiesel production, companies and industries that produce biofuels stand to gain from this.
iv. Rural areas and farmers will benefit from the effects of biodiesel generation from jatropha crops. Understanding the optimal extraction method would influence land use decisions and promote sustainable practices

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