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Biodiesel Production from Mahua Oil Through Transesterification Process

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Abstract: This research explores the creation of biodiesel fuel from mahua oil, a plant-based source. The process focuses on a chemical reaction called transesterification. The paper examines factors like how much amount of biodiesel is produced. This esterification process transforms mahua oil into methyl esters, the key component of biodiesel. The resulting biodiesel boasts properties similar to diesel fuel, including flashpoint, viscosity, and density. Notably, the viscosity of neem biodiesel is close to regular diesel, while its energy output (calorific value) is about 15.38% lower. Overall, this study strengthens the case for mahua oil, a non-edible resource, as a practical alternative to diesel fuel.

***Keywords* – Mahua oil, Transesterification, Biodiesel, Sodium Hydroxide.**

I. Introduction

The reliance on a handful of oil-exporting countries for petroleum fuels has driven India to explore alternative fuels in recent years. This urgency stems from the ever-increasing demand for diesel and gasoline, particularly diesel. To ensure future fuel security and meet stricter emission standards, the Indian government has taken significant steps. Biodiesel and ethanol are emerging as promising supplementary fuels, offering the potential to not only reduce dependence on petroleum but also generate rural employment through the cultivation of oilseed crops [1].

The high-fat content oils are transesterified into mono-esters using a two-step procedure. The oil's FFA level is lowered to less than 2% in the first phase, known as acid-catalyzed esterification. The products of the first stage are converted to their mono-esters and glycerol in the second step, which is the alkaline-catalyzed transesterification process.

The cottonseed sector may become more viable if cottonseed oil is used as a feedstock for biodiesel manufacturing, which is a potential prospect given the ongoing research on the creation of biodiesel from vegetable oils. [2]. India ranks among the top five nations in the world for cotton seed output [3]. Neem is inexpensive and thrives in practically every kind of soil, including clayey, saline, and alkaline ones. The seeds of the deciduous madhuca indica tree, which can thrive in semi-arid, tropical, and sub-tropical climates, are used to make mahua oil. It thrives in circumstances of water logging and can withstand rocky, sandy, dry shallow soils [4]. Because of their increased viscosity, using vegetable or animal fats directly as fuel can result in several engine issues, including inadequate fuel atomization, incomplete combustion and the production of carbon deposits, engine fouling, and lubricating fluid pollution [2]. Therefore, a variety of techniques, such as oil mixing, micro emulsification, cracking/pyrolysis, and transesterification, can be used to lower the viscosity of vegetable oils [5]. Transesterification is one of these processes that is frequently used to produce industrial biodiesel [6]. Transesterification is a chemical process that yields biodiesel [7, 8]. Methanol was frequently utilized in the transesterification process [9, 10], as it is less expensive than ethanol and can be recovered more easily from unreacted methanol [10].

Potassium hydroxide (KOH) or sodium hydroxide (NaOH) are utilized as base catalysts because they are less costly and easier to handle during storage and transportation. Esterification and transesterification are required in two phases when oil samples have a high free fatty acid (FFA) concentration. This two-step process is also referred to as alkali catalysis first, then acid catalysis [12]. In the current study, the transesterification process was utilized to manufacture biodiesel from vegetable oils. Alcohol was added along with the FFA value, which is used to determine the catalyst amount for each batch of biodiesel synthesis. Transesterification costs are also examined. It also determines properties like as density, viscosity, fire point, flash point, and calorific value.

II. RESEARCH METHODOLOGY

2.1 Materials

- **$FeCl_3$ Nanoparticles**

  Ferric chloride ($FeCl_3$) nanoparticles are tiny particles of ferric chloride, a chemical compound composed of iron and chlorine. These nanoparticles exhibit unique properties compared to their bulk counterparts due to their small size and high surface area to volume ratio. **Fig.1** Displays the $FeCl_3$ nanoparticles. $FeCl_3$ nanoparticles can be synthesized through various methods including chemical precipitation, sol-gel synthesis, hydrothermal methods, and sonochemical methods. Each method offers different control over the size, shape, and properties of the nanoparticles. The size of $FeCl_3$ nanoparticles can vary depending on the synthesis method used. Typically, they range from a few nanometers to tens of nanometers in diameter. The shape of the nanoparticles can also vary, including spherical, rod-like, or irregular shapes. $FeCl_3$ nanoparticles have a high surface area to volume ratio, which can lead to enhanced reactivity and surface interactions. The surface of the nanoparticles can be modified or functionalized to tailor their properties for specific applications. Table 1 shows the properties of $FeCl_3$.

Fig 1: Ferric Chloride ($FeCl_3$) nanoparticles

Table 1 Properties of Ferric Chloride ($FeCl_3$)

Properties	$FeCl_3$
Molar Mass	162.2 g/mol (anhydrous)
Appearance	Green-black by reflected light, purple-red by transmitted light
Density	2.90 g/cm (anhydrous), 1.82 g/cm (hexahydrate)
Melting point	307.6 °C (anhydrous), 37 °C (hexahydrate)
Boiling point	316 °C (anhydrous, decomposes), 280 °C (hexahydrate, decomposes)
Solubility	912 g/L (anhydrous or hexahydrate, 25 °C)

- **Mahua Oil**

  Mahua is the name for a medium to larger tree Madhuca longifolia of the family Sapotaceae. The tree may attain a height of up to 20 meters. Mahua is a slow-growing species, that attains a mean height of 0.9-1.2m at the end of the fourth year. A large deciduous tree, found in Maharashtra, West Bengal, Orissa, in South Indian forests. The orange-brown pipe flesh berry (2.5-5.0 cm long) contains 1- 4 shining seeds. The yield of mahua seeds varies (5-200 kg/tree) depending on the size and age of the tree. Kernel contains 20-50 % oil. The quality of expelled oils depends largely on the storage conditions of the kernels, which are susceptible to fungus and insect attack. Fresh oil from properly stored seeds is yellow, while commercial oils are generally greenish yellow with disagreeable odor and taste. Mahua is the second most widely known tree in India after mango. Besides oil, flowers, and fruit give good economic returns. Almost all parts of the Mahua tree are saleable. **Fig 2** Shows the Mahua Seeds.

2.2 Transesterification process

Through a well-known process called transesterification, crude Mahua oil was converted into biodiesel. Firstly, 500 ml of the mahua oil was collected and heated to 50°C in a glass container. Subsequently, 150 ml of methanol containing 1.6% NaOH catalyst was added and the mixture was heated to 60ºC. A condenser apparatus captured the evaporating methanol throughout the process. A magnetic stirrer maintained the equilibrium throughout the 60-minute process. Subsequent separation of glycerol and methyl ester was achieved using an isolation funnel. The methyl ester was then purified by water washing and subsequent heating to remove residual moisture. The container stored the heated biodiesel that had been produced. **Fig.3** Displays the transesterification process flowchart.

2.3 List of Abbreviations

B100	100% Mahua Biodiesel
B20	20% Mahua Biodiesel
$FeCl_3$	Ferric chloride
D100	Pure diesel
ppm	Parts Per Million
NaOH	Sodium hydroxide
BTE	Brake thermal efficiency (%)
BSFC	Brake specific fuel consumption)
NHRR	Net heat release rate (J/^{O}CA)
CP	Cylinder pressure (bar)
UHC	Hydrocarbons (ppm)
NO_X	Nitrogen oxides (ppm)
IP	Injection pressure
ADC	Analog-to-digital converter

Fig 2 Mahua seeds

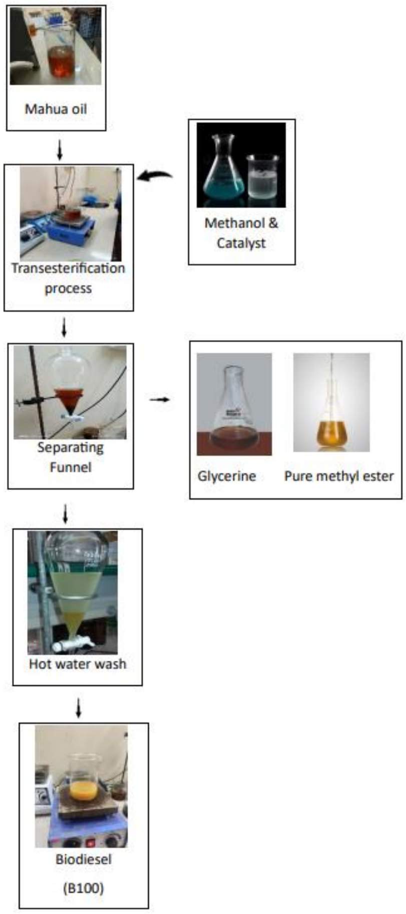

Fig 3 Biodiesel Preparation through Transesterification process

III. RESULTS AND DISCUSSION

Comparisons of Properties of Diesel & Mahua Biodiesel. However, it was discovered that crude Mahua oil had fuel qualities, particularly viscosity, well above any of these regulatory limitations. As a result, its direct usage as a diesel engine fuel was restricted.

Properties	Diesel	Mahua Biodiesel
Flashpoint (^{O}C)	60	174.6
Fire point (^{O}C)	62	185
Density(kg/m3)	820	870.67
Calorific value (MJ/kg-K)	45.5	38.5
Viscosity at 40 °C (mm2 /s)	2.2	3.98

3.1 Flash Point

Flash points of Mahua Biodiesel were determined to be 174.6^{o}C, respectively, and were quite high compared to 60^{o}C for the diesel. Thus, the overall flammability hazard of Mahua biodiesel is much less than that of conventional diesel. **Fig. 4** shows the Flashpoint comparison of diesel and mahua biodiesel.

3.2 Fire Point

Fire points of Mahua Biodiesel were determined to be 185^{o}C, respectively, and were quite high compared to 62^{o}C for the diesel. Thus, the overall flammability hazard of Mahua biodiesel is much less than that of conventional diesel. **Fig. 5** shows the Fire point comparison of diesel and mahua biodiesel.

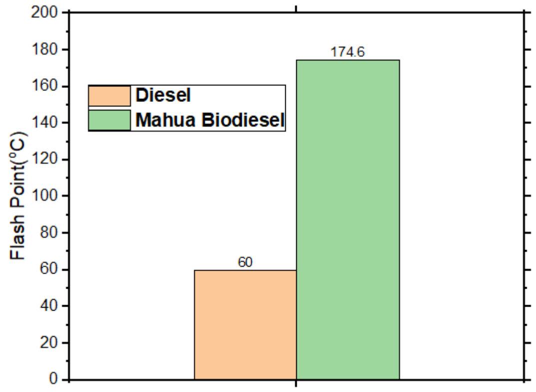

Figure 4 Displays the Flash point comparison of diesel and mahua biodiesel

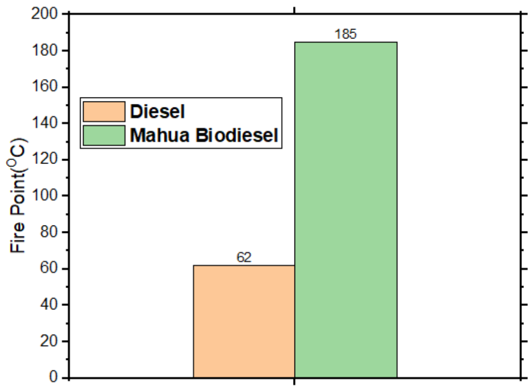

Figure 5 Displays the Fire point comparison of diesel and mahua biodiesel

3.3 Density

It was shown that the density of Mahua biodiesel was, respectively, 5.81% greater than that of diesel. As a result, when crude mahua oil was converted to biodiesel, its density decreased by almost 6.5%. The larger molecular weights of the triglyceride molecules seen in crude Mahua oil and Mahua biodiesel as opposed to diesel may be the cause of their higher densities. **Fig. 6** shows the density comparison of diesel and mahua biodiesel

3.4 Calorific value

The results showed that the gross calorific values of Mahua biodiesel were 38.5 MJ/kg, respectively, which is 15.38% less than the 45.5 MJ/kg for diesel. This may be because the chemical makeup of Mahua oil and biodiesel differs from that of diesel, because the amount of carbon and hydrogen content varies, or because the molecules of oxygen are present in the molecular structures of both. **Fig. 7** shows the Calorific value comparison of diesel and mahua biodiesel.

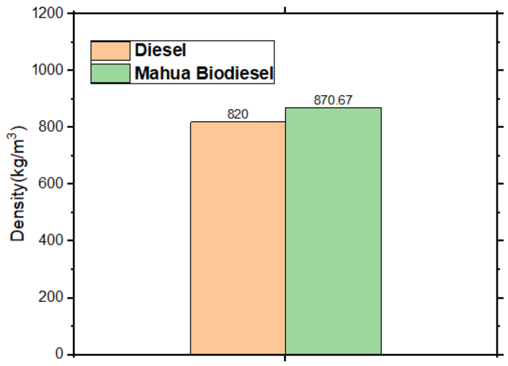

Figure 6 Displays the density comparison of diesel and mahua biodiesel

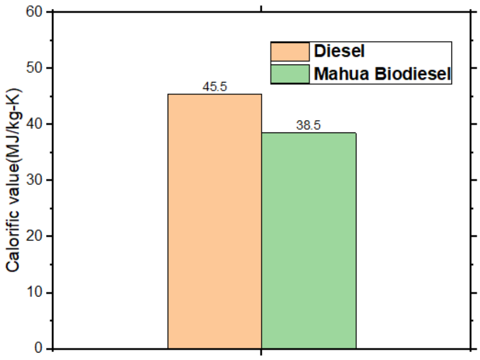

Figure 7 Displays the Calorific value comparison of diesel and mahua biodiesel

Conclusion

Considering particular inferences from the study's findings, the following ones were made:

- Mahua biodiesel's fuel qualities were acceptable and on par with those of regular diesel. Mahua biodiesel was shown to have greater fuel qualities than diesel, except for calorific value.
- The catalyst, reaction temperature, and reaction rate three factors that affect the generation of biodiesel are examined.

However, our research also identified areas for future investigation. Further studies could focus on optimizing alternative catalysts and exploring innovative techniques to enhance biodiesel yield and quality. Additionally, assessing the environmental impact of Mahua biodiesel production through life cycle analysis would provide valuable insights into its sustainability.

In conclusion, the preparation of Mahua biodiesel holds great promise as a sustainable energy solution. By leveraging the abundant and renewable resource of Mahua oil, we can mitigate environmental degradation, foster rural development, and pave the way toward a cleaner and more sustainable energy future. Continued research and development in this field are essential to realize the full potential of Mahua biodiesel and its contribution to global energy security and environmental sustainability.

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