# A Comprehensive Review on the Use of Biodiesel from Neem oil as a Fuel for Compression Ignition Engines

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***Abstract –***
The global rise in fossil fuel prices and environmental concerns has accelerated the search for alternative, renewable fuels. Biodiesel has emerged as a viable substitute for petroleum-based diesel, offering cleaner combustion, reduced emissions, and compatibility with existing diesel engines. Produced from various natural and non-edible oils, biodiesel is biodegradable, non-toxic, and environmentally friendly. Among potential feedstocks, neem (Azadirachta indica) oil has attracted attention due to its availability, low cost, and favourable properties for transesterification. This review focuses on the suitability of neem biodiesel as an alternative fuel in compression ignition (CI) engines. It examines the performance characteristics, emission behaviour, and overall feasibility of using neem biodiesel blends in diesel engines. The findings indicate that neem biodiesel can serve as a sustainable energy source, reducing dependency on conventional diesel while supporting cleaner transportation and agricultural practices.

***Keywords**: Neem, Biodiesel, Compression Ignition Engine, Performance, Emissions*

## I. INTRODUCTION

The world is currently facing an energy crisis due to the depletion of fossil fuel resources and the tightening of environmental regulations. As a result, significant attention has been directed toward the development of renewable and alternative fuels to replace petroleum-based fuels in transportation. Several renewable fuel sources have been explored, including vegetable oils, biogas, biomass, and primary alcohols. Among these, vegetable oils are particularly promising due to their renewability, wide availability, biodegradability, non-toxic nature, and environmental friendliness.

In agricultural countries such as India, the utilization of vegetable oils as fuel has the potential to mitigate environmental degradation and reduce reliance on imported fossil fuels by partially substituting them with domestic renewable sources. Extensive research has been conducted to evaluate the feasibility of using neat (unmodified) vegetable oils in diesel engines, and many studies have indicated that they offer potential for short-term use [1–4]. However, several challenges have been identified with the direct use of vegetable oils in engines. Their high viscosity, low volatility, and poor cold flow properties can result in issues such as heavy engine deposits, injector coking, piston ring sticking, and difficulty in cold starting.

Researchers have identified four main methods for utilizing neat vegetable oils in diesel engines [5–8]: (1) direct use or blending with diesel fuel, (2) formation of microemulsions with diesel, (3) thermal cracking (pyrolysis), and (4) transesterification. It has been reported that diluting vegetable oils with diesel, solvents, or ethanol leads to heavy carbon deposits on inlet valves and considerable top ring wear. Thermal cracking involves chemical decomposition through the application of heat in the presence of air or an inert atmosphere such as nitrogen. Although pyrolysis reduces the viscosity of vegetable oils, the resulting fuel still often exceeds the acceptable viscosity limit of 7.5 cSt. Among the available methods, transesterification is widely considered the most effective and popular approach for converting vegetable oils into biodiesel, as it significantly enhances their fuel properties and engine compatibility [8].

## II. PROPERTIES OF NEEM BIODIESEL

Neem biodiesel, derived from the seeds of the Azadirachta indica tree (commonly known as neem), is gaining attention as a sustainable alternative fuel. It possesses properties similar to conventional diesel and other biodiesels, making it a viable renewable energy source. Below is a summary of the typical fuel properties of neem biodiesel (also called Neem Methyl Ester – NME), with explanations and tabulated values.(9)

**Table 1: Properties of Neem Biodiesel (NME)**

| **Property** | **Description** |
|---|---|
| **Density (kg/m³)** | Affects injection and atomization in the engine. Neem biodiesel has slightly higher density than diesel, which may affect spray characteristics. |
| **Viscosity (mm²/s at 40°C)** | Indicates the fuel's resistance to flow. Higher than diesel but within ASTM/EN limits. Affects injector performance. |
| **Flash Point (°C)** | Temperature at which fuel vapors ignite. Neem biodiesel has a higher flash point, making it safer for storage and handling. |
| **Calorific Value (MJ/kg)** | Energy content of the fuel. Neem biodiesel has lower calorific value than diesel, which may slightly reduce engine power and fuel efficiency. |
| **Cetane Number** | Indicates ignition quality of the fuel. Neem biodiesel has a cetane number within acceptable range, ensuring proper combustion in diesel engines. |
| **Acid Value (mg KOH/g)** | Indicates free fatty acid content. High acid values can cause corrosion and engine deposits. Transesterification reduces this significantly in NME. |
| **Cloud Point (°C)** | Temperature at which wax crystals form. Higher than diesel, which may affect flow in cold climates. |
| **Pour Point (°C)** | Lowest temperature at which the fuel can flow. Again, higher than diesel but manageable with additives or blending. |

**Table 2: Tabulated Properties of Neem Biodiesel vs Diesel**

| **Property** | **Neem Biodiesel (NME)** | **Petroleum Diesel** | **Standard (ASTM D6751 / EN 14214)** |
|---|---|---|---|
| Density (kg/m³) | 870–890 | ~830 | 860–900 |
| Kinematic Viscosity (mm²/s at 40°C) | 4.2–5.8 | 2.0–4.5 | 1.9–6.0 |
| Flash Point (°C) | 170–190 | 60–80 | >130 (ASTM D6751) |

| | | | |
|---|---|---|---|
| Calorific Value (MJ/kg) | 36–38 | 42–45 | — |
| Cetane Number | 48–54 | 47–55 | ≥47 (ASTM), ≥51 (EN) |
| Acid Value (mg KOH/g) | <0.5 | <0.3 | ≤0.5 |
| Cloud Point (°C) | 5 to 8 | −5 to 0 | — |
| Pour Point (°C) | 1 to 5 | −10 to −15 | — |

## III. LITERATURE REVIEW

Diesel engines are widely used for power generation in developing countries like India due to their high thermal efficiency, lower fuel consumption, and higher torque compared to petrol engines. Additionally, the rising cost of petrol has made diesel a more economically viable fuel option. However, increasing environmental pollution and the depletion of crude oil resources have prompted the search for alternative, renewable fuels. Among these, biodiesel stands out as a promising solution, allowing for a reduction in diesel usage without requiring significant modifications to existing engine designs [10].

Several researchers [11–12] have experimented with compression ignition (C.I.) engines using methyl esters derived from edible vegetable oils. Their findings indicate that biodiesel-diesel blends can reduce emissions and improve engine performance. However, the use of edible oils for biodiesel production raises concerns about food security, as it may lead to the diversion of agricultural land from food crops to oil crops—resulting in a "food versus fuel" conflict. Such a shift could negatively impact both the ecosystem and the global economy [13].

Alternatively, non-edible oils offer a viable source for biodiesel production. These oils have similar properties to edible oils and are more readily available, making them suitable for large-scale biodiesel production [8]. However, both edible and non-edible vegetable oils possess high viscosity, which makes their direct use in C.I. engines impractical. To address this, viscosity can be reduced through various methods such as dilution, micro-emulsification, pyrolysis, and transesterification.

This study focuses on base-catalyzed transesterification, a preferred method due to its cost-effectiveness, faster reaction time, ambient pressure operation, and moderate temperature requirements [14]. Transesterification involves converting long-chain triglycerides into fatty acid methyl esters (FAME), resulting in fuel properties that closely resemble conventional diesel [15].

S. Jaichandar et al. [16] conducted experiments on a single-cylinder, four-stroke C.I. engine using Jatropha biodiesel. Their results showed that a 20% biodiesel blend led to reductions in hydrocarbon (HC) emissions by 17.9%, carbon monoxide (CO) by 16%, and smoke by 21%. However, a slight decrease of 2.8% in brake thermal efficiency was observed at this blend ratio. Similarly, T. Venkateswara Rao et al. [17] evaluated the performance and emissions of the same type of engine using methyl esters of Pongamia, Jatropha, and Neem oils. They found that while the brake thermal efficiency of all biodiesel types was slightly lower than that of diesel, the efficiency at a 20% blend was nearly comparable. Emission levels of CO, HC, and smoke were significantly reduced with 10%, 20%, and 40% biodiesel blends.

Jayashri N. Nair et al. [18] studied the use of neem oil biodiesel in C.I. engines at blend ratios of 10%, 20%, and 30%. Their results indicated improved brake thermal efficiency, with a notable reduction in brake-specific fuel consumption (BSFC) and emissions of CO, HC, NO, and smoke—particularly at the 10% blend level.

## IV. CONCLUSION

Neem oil can be used as an alternative fuel in diesel engines with minimal modifications, delivering performance comparable to that of conventional petro-diesel. However, the performance and emission characteristics of Neem oil vary depending on the engine type. Traditional methods for analyzing these characteristics are often costly. As a cost-effective and efficient alternative, Computational Fluid Dynamics (CFD) can be employed to study and optimize engine performance with Neem fuel. CFD has become an integral part of the engine design process, significantly reducing or even eliminating the need for physical engine prototypes in early design stages.

## V. FUTURE SCOPE

Extensive literature review indicates that biodiesel is a promising and sustainable alternative fuel for compression ignition (CI) engines. It can be used with little or no engine modification while providing comparable performance and reduced emissions. However, practical implementation has revealed certain challenges, particularly concerning the fuel delivery system. In some instances, a noticeable reduction in the service life of fuel-carrying hoses and other components has been reported when biodiesel is used. This degradation is largely attributed to the higher viscosity of biodiesel compared to conventional petro-diesel, which affects the flow characteristics and places additional stress on fuel system components.

One effective approach to mitigate this issue is to reduce the viscosity of biodiesel by increasing its temperature. Heating the biodiesel to an optimal range lowers its viscosity, thereby improving its flow properties and reducing the mechanical strain on hoses, pumps, and injectors. Preheating biodiesel before it enters the combustion chamber can lead to better atomization, more efficient combustion, and longer component life. As a result, incorporating temperature control mechanisms in the fuel system design can enhance the overall reliability and durability of engines operating on biodiesel.

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