Production of Mahua Oil Ethyl Ester (MOEE) and its Performance test on four stroke single cylinder VCR engine

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Abstract. Biodiesel is a substitute for gasoline that is produced from vegetable oils and animal fats. It has gained popularity due to depleting fossil fuel resources, its renewable character and comparable combustion properties to diesel fuel. Biodiesel is formed from non-edible oils, edible oils, tallow, animal fats and waste cooked oils. Biodiesels are monoalkyl esters of elongated chain fatty acids. Biodiesel can be a viable choice for satisfying long term energy requirements if they are managed proficiently. The method of the transesterification shows how the reaction occurs and advances. In this study, biodiesel is produced from Madhuca indica seeds commonly known as Mahua by using transesterification process using a low capacity pressure reactor and by-product of transesterification is glycerol, which is used in preparation of soaps. Mahua Oil Ethyl Ester (MOEE) was produced from the Mahua oil and is mixed with diesel to get different ratios of blends. MOEE was tested in a 4-stroke single cylinder VCR diesel engine. The study was extended to understand the effect of biodiesel blend magnitude on the performance of engine parameters like, brake thermal efficiency, brake power and fuel properties like flash point, cloud point, kinematic viscosity, calorific value, cetane number and density were studied.

Index Terms. Biodiesel, Mahua Oil Ethyl Ester (MOEE), Pressure reactor, Transesterification, Engine Performance.

1. Introduction
India is the sixth largest consumer of fossil fuels and the demand is increasing over the approaching years and is also one of the largest pollution emitting countries [1]. Since India is a tropical country, it is covered in million hectares of forest land and the forest resources are abundant. An extensive variety of trees yield a significant quantity of oil rich seeds. The study has been carried out on Mahua (Madhuca Indica). It is a large sized evergreen or semi evergreen tree from the Sapotaceae family [4]. It is a large deciduous tree found in most of the parts of India. Mahua oil contains roughly 41–51% oleic acid. Other Free Fatty Acids (FFA) are also present in the oil, such as stearic (20.0–25.1%), palmitic (16.0–28.2%), and linoleic acids (8.9–18.3%) [8-10]. The Mahua seeds are shown in Figure 1 and Mahua tree with seeds is shown in the Figure 2.
Biodiesel is mono-alkyl esters of long chain fatty acids derived from vegetable oils or animals fats. In layman’s terms, it is a clean-burning alternative fuel made from fat or oil that has been chemically processed to confiscate glycerin. Biodiesel is a second generation fuel which is generally prepared from non edible lignocelluloses biomass. Biodiesel refers to the unadulterated fuel known as B100 which has been designated as a substitute fuel by the U.S. Departments of Energy and Transportation. B100 can be used in its pure condition but normally used as an additive for conventional diesel fuel. [2, 9 and 10]. Biodiesel can be manufactured by various methods such as pyrolysis (thermal cracking), micro emulsion, dilution and transesterification (alcoholysis). Transesterification is known to be unsurpassed method among other approaches due to its economic feasibility and simplicity.

2. Methodology

The detailed transesterification reaction of Mahua oil is shown in the Figure 3. In this reaction, methanol and ethanol are the two major alcohols used for transesterification. Transesterification consists of a number of consecutive, reversible reactions. Transesterification reaction is carried out in a pressure reactor shown in Figure 4. In these reactions, the triglycerides are converted step wise to diglycerides, monoglyceride and finally glycerol which sinks to the bottom and biodiesel which floats on top and can be siphoned [3-24]. The percentage blending of biodiesel with diesel is shown in Figure 5.

![Figure 1. Mahua seeds](image1.png)  ![Figure 2. Mahua tree](image2.png)

**Figure 3. Transesterification reaction of Mahua Oil**
Fuel properties such as Viscosity, density, cetane number, flash point, cloud point are calibrated for MOEE. The performance of biodiesel from mahua oil and its blend with four stroke Variable Compression Ratio (VCR) naturally aspirated diesel engine has been presented in this paper jointly with some of its fuel properties. These properties were found to be comparable to diesel. Engine performances like brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), compute the behaviour of the diesel engine operating on biodiesel.

3. Results and Discussion
The biodiesel extracted from the mahua seeds is used to operate the 4- stroke diesel engine to carry out the performance test. The specifications of the engine used are listed in Table 1. The calibrated, Fuel properties of MOEE are shown in Table 2.

Table 1. Specifications of the engine

| Parameter          | Specification         |
|--------------------|-----------------------|
| Rated Power        | 3.5 KW at 1500 rpm    |
| Stroke length      | 110 mm                |
| Cylinder Diameter  | 87.5 mm               |
| Compression Ratio  | 12 to 18:1            |
| Number of Strokes  | 4                     |

Table 2. Fuel properties of MOEE

| Blending | Density at 15°C (Kg/m³) | Kinematic Viscosity at 15°C (mm²/s) | Flash point °C | Cloud Point °C | Cetane number | Calorific Value (MJ/kg) |
|----------|--------------------------|-------------------------------------|----------------|----------------|---------------|-------------------------|
| B5       | 827                      | 2.35                                | 58.5           | 0.5            | 51.3          | 41.7                    |
| B10      | 829                      | 2.4                                 | 64             | 2              | 51.6          | 41.55                   |
| B15      | 832                      | 2.55                                | 70             | 2.5            | 51.9          | 41.45                   |
The biodiesel extracted from the reactor is mixed with diesel in different proportions for better assessment of the fuel produced. B-5 (5% bio-fuel and 95% diesel), B-10 and B-15 proportions were selected for the analysis.

Properties of fuels like kinematic viscosity, flash point, cloud point and density were studied for varying biodiesel blends. From Figure 6 it is evident that the kinematic viscosity of the fuel increases continuously with increase in percentage of blend. It was observed that B-15 biodiesel blend has kinematic viscosity of 2.55 mm$^2$/sec.

![Figure 6. Variation of kinematic viscosity with respect to biodiesel blends.](image)

![Figure 7. Variation of flash point with respect to biodiesel blends.](image)

Figure 7 shows the variation of flash point with respect to varying blending ratio. It is observed that the flash point of the fuel increases continuously with increase in blend ratio.

Cloud point of the fuel for different blend ratios was also studied and it was observed that magnitude of cloud point increases with increase in blend percentage. From Figure 3 it was observed that slope of the cloud point curve reduces after blend percent of B-10.

Study was also extended to understand the variation in density of the fuel with respect to increase in percentage of blend. From Figure 8 it is evident that the density of fuel increases with increase in the blend percentage. The magnitude of mass of fuel consumed (MFC) for different compression ratios (CR) of engine were investigated for selected blend percentages of bio-fuel. From Figure 9 it is clear that MFC value decreases with increase in compression ratio for all the blend percentages. It was also observed that variations of B-10 and B-15 blends are almost in line with each other whereas blend B-5 is has lesser magnitude as that of other to blend percentages. Figure 10 shows the variation of Break specific fuel consumption (BSFC) values for different compression ratios. From Figure 11 it is apparent that BSFC reduces with rise in compression ratio.

Break thermal efficiency (BTE) of the engine for different blends of fuel was also studied for varying compression ratio. From Figure 12 it is evident that BTE increases with increase in CR and B-5 blend perform better than B10 and B15.
Figure 8. Variation of cloud point with respect to biodiesel blends.

Figure 9. Variation of density with respect to biodiesel blends.

Figure 10. Variation of mass of fuel consumed with respect to compression ratio.

Figure 11. Variation of brake specific fuel consumption with respect to compression ratio.
4. Conclusion
The bi-fuel was extracted from the mahua seeds in pressure reactor through transesterification process. Mahua oil was mixed with diesel to obtain the proper blend ratios to understand the performance characteristics. It was observed that physical properties like kinematic viscosity, flash point, cloud point and density of the fuel increases with increase in blend percentage. The investigation was further extended to understand the effect of blending ratio and compression ratio on the engine performance characteristics like mass of fuel consumed, brake specific fuel consumed and brake thermal efficiency.

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