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# Experimental Investigation on Performance of DI Diesel Engine Using Madhuca Indica Biodiesel and its Diesel Blends

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## ABSTRACT

The lack and high price of fossil fuel forced the scientific community look forward towards alternative renewable energy sources. The past research results revealed that vegetable oils can be used as fuel in unmodified dieel engine. But the direct use of edible and non-edible oils as fuel in diesel engine causes severe damage/reducing the operating life of the engine as well as releasing very hazardous exhaust emissions due to number of unfavorable properties such as high kinematic viscosity, density, acid value and lower cetane number. In the recent time, to overcome the mentioned problems, the transesterified biodiesels are gaining momentum further as fuel in diesel engines as one of the alternative renewable energy source. In this research work, the experimental performance evaluation of 4-stroke, single cylinder, and water cooled direct injection diesel engine was carried-out using mahuca indica oil methyl ester (MIOME) and its diesel blends as alternative biodiesel fuel to diesel. The experiment results revealed that B20M blend of mdhuca indica biodiesel has comparable brake thermal efficiency as diesel fuel. B20M has lowest and B100M has highest BSFC, BSEC among all the tested biodiesel blends. B20M has demonstrated comparable performance as diesel fuel and it can be considered as alternative to diesel.

**Keywords :** Biodiesel, Mahuca Indica Oil, Methyl Ester, Engine Performance, Diesel Blends

## I. INTRODUCTION

The energy is an essential for development of industrial growth as well as living standards of human beings. At present, the global energy demand is growing rapidly and conventional fuels are contributing the maximum in order to meet the requirement. The cost and limited reserves of fossil fuels caused to focus on alternative fuels even though the initial production cost is little higher than the conventional petroleum fuels.

Vegetable oil and/or blended with diesel can be directly used in diesel engine without any modifications in the engine [1]. The past research results revealed that edible oils such as sunflower oil, palm oil, soybean oil, rice bran oil etc., can be directly used as fuel in diesel engines, but not preferable [2,3]. The vegetable oils and its diesel blends causes many problems in engine operations such as choking, high carbon deposits around piston rings and valves which further has triple impact such as knocking/detonation. Moreover the biodiesels are prepared from edible oils have raised a concern about cost of the food products, especially in densely populated developing countries such as India, China and other South Asian countries. Because of this, the present research and production of biodiesel is moved towards using non- edible oils such as Cotton seeds oil, Jatropha curcas oil, Karanja (pongamia) oil, Mustard oil, Linseed oil, Neem (Azadirachta) oil etc., as biodiesel feed stock. The usage of non-edible oils as feed stock will obviously encourages the economic growth of rural area, reduces the dependency on fuel imports and reduces the environmental pollution. Even though, the seeds of non-edible oils can be grown in uncultivated, unfertile baron lands with no or very less water in irregular interval, the usage pesticides and fertilizers are increasing the cost of production of feedstock and became as costly as edible oil feedstock. Moreover edible oils have higher heating value and lower density when compared with non-edible oils [4].

Technically, methyl/ethyl esters of free fatty acids are known as biodiesel. The chemical properties of biodiesel such as kinematic viscosity, density, cetane number, calorific value and etc., are almost compatible with fossil diesel fuel. Hence, the recent studies revealed that biodiesel is a potential alternative fuel which can meet the growing need for sustainable energy and gaining ground as a bio-degradable, environmental friendly, easily available, energy conservation and management [5,6]. Biodiesel can be prepared from renewable feedstock such as vegetable oils or animal fats, but non-edible oils have been already successfully employed in biodiesel production in USA and European countries [7].

Using vegetable oils in diesel engine is not recent research idea because the diesel engine was ran with peanut oil at World Exhibition in 1900 by the inventor 'Rudolf Diesel'. Due to abundant supply of petro-diesel, the diesel became one fuel in diesel engine. Nevertheless, recently it received more focus when conventional petroleum fuels are depleting rapidly. Goyal (1994) has conducted off-road test with rapeseed methyl ester of rapeseed oil in a 4239T model of Deere diesel engine and observed 6-8% of power loss with high carbon deposits in ports and piston rings for short-term operations. During the long-term engine operations, the damage of the test engine parts such as gaskets were noticed [8]. Shasidharan et al. (2003) were conducted experiments to evaluate the engine characteristics of a single cylinder, direct injection CI engine using methyl ester of sunflower oil and castor oil and revealed that the thermal efficiency of methyl ester of sunflower oil and castor oil were comparable with diesel. It had been further reported that the esters of sunflower oil were found to be better than ester of castor oil. It was also noticed 25% of less smoke emissions for both the methyl esters than diesel fuel [9]. Milán et al. (2010) were investigated the performance and emissions of Kubota IDI natural aspirated agricultural diesel engine fueled with biodiesel of methyl ester derived from mixture of 75% (v/v) sunflower oil and 25% (v/v) used cooking oil and its diesel blends and reported that engine performance was satisfactory without a substantial decrease in torque with diesel blends, but higher fuel consumptions with biodiesel was noticed [10]. Sirivella (2017) has carried-out an experimental analysis on performance of diesel engine using jatropha curcas oil methyl ester as fuel and his experimental results revealed that B20J biodiesel blend has comparable brake thermal efficiency to that of petro-diesel fuel and the lowest BSFC, BSEC with EGT in all tested biodiesel blends [11].

## II. METHODS AND MATERIAL

The mahuca indica (mahua) oil was purchased from local vendor in Chennai, Tamilnadu, India and transesterified using methyl alcohol. The crude Mahua oil has higher viscosity and density which raising problems in the diesel engine and therefore transesterification process was used to improve the properties and make it compatible for combustion without any further problems. The chemical reaction of transesterification process was given in figure 1.

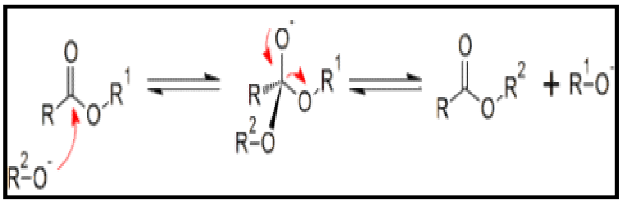

**Figure 1.** Transesterification process

In this process, the carbonyl carbon of the starting ester carry out nucleophilic attack by the arriving alkoxide (R2O–) to give a tetrahedral intermediate, which either reverts to the starting material or proceeds to the transesterified product (RCOOR2).

### A. Fuel Characteristics

For this research study, madhuca indica (mahua) oil methyl ester-diesel fuel blends were prepared by mixing 20% (B20M), 40% (B40M), 60% (B60M) and 100% (B100M) respective methyl ester with diesel fuel on volume basis. The chemical properties of diesel fuel and madhuca indica oil methyl ester (MIOME) were evaluated . The properties of diesel and biodiesel blends are presented in Table 1.

**Table 1.** Fuel Properties of Diesel and Biodiesel Blends

| Property | Diesel | MIOME |
|---|---|---|
| Kinematic Viscosity at $40^{0}$ C (Cst) | 3.58 | 4.8 |
| Density at $15^{0}$ C (Kg/m$^3$) | 830 | 862 |
| Flash Point ($^{0}$C ) | 51 | 127 |
| Cetane Number | 50 | 65 |
| Calorific Value (KJ/kg) | 42000 | 38200 |
| Total Sulphur (% by mass) | 0.01 | Nil |

### B. Experimental Setup

For the present experimental research study of emission characteristics, a single cylinder, 4-stroke water cooled compression ignition direct injection (CIDI) engine was used when it is fueled with MIOME. The specifications of the test engine are presented in Table II.

**Table 2.** Specifications of Test Engine

| | |
|---|---|
| Engine Make | Kirloskar AV1, India |
| No. of Cylinders | One |
| Engine Details | Four stroke, Water cooled |
| Injection Type | Direct Injection |
| Bore & Stroke | 80 × 110 mm |
| Rated Power | 3.7 KW (5 HP) at 1500 rpm |
| Speed | 1500 rpm |
| Injection Pressure | 200 bar |
| Compression Ratio | 16.5:1 |
| Dynamometer | Eddy Current |

The experiment setup is illustrated as schematic diagram below at figure 2 (a) and photographic view is presented in figure 2 (b). The setup consists of 3.7 KW diesel engine, eddy current dynamometer, smoke meter, and exhaust gas analyser. The eddy current dynamometer was coupled with a test engine to operate the engine at various loads such as 25, 50, 75 and 100% load conditions.

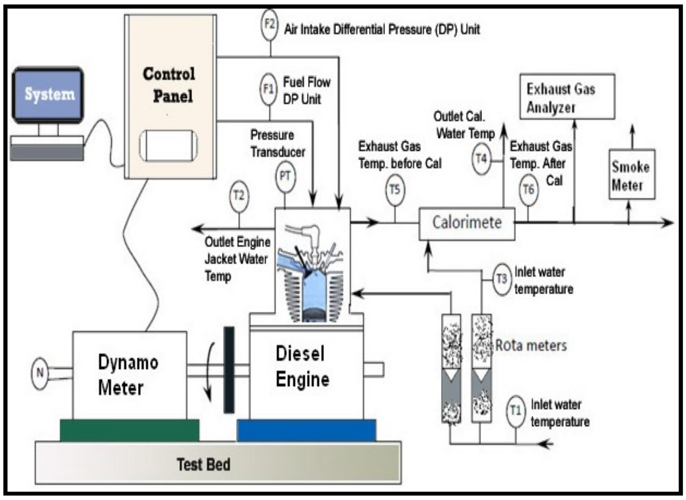


**Figure 2 (a).** schematic diagram of experimental setup

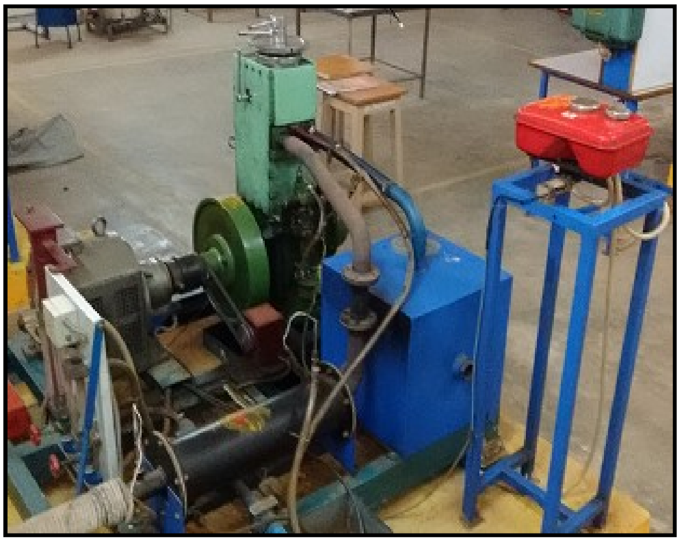

**Figure 2 (b).** Photographic view of experimental setup

The engine was initially started with diesel and then repeated with MIOME biodiesel and its diesel blends. After the engine has reached the stabilized working condition at constant rated speed of 1500 rpm, time for 10ml of fuel consumption was recorded for each applied load for diesel and each biodiesel blend in order to calculate the performance characteristics of DI diesel engine. The engine rated fuel injection pressure of 200 bar was maintained for all experimental tests.

## III. RESULTS AND DISCUSSION

The engine performance characteristics in terms of brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and brake specific energy consumption (BSEC) were investigated using single cylinder, 4-stroke, water cooled, direct injection (DI) diesel engine when fueled with mahuca indica oil methyl ester (MIOME).

### A. Brake Thermal Efficiency (BTE)

The brake thermal efficiency (BTE) evaluates the engine efficiency that can change the supplied fuel energy into useful mechanic work. The majority of the supplied fuel energy may be lost as heat with the engine cooling water, lubricating oil, and exhaust gas [12]. The variation of BTE with engine load is presented in figure 3. As shown in figure, the brake thermal efficiency (BTE) is decreasing with the increase of MIOME biodiesel percentage in the blends and diesel has higher BTE among all tested fuels.

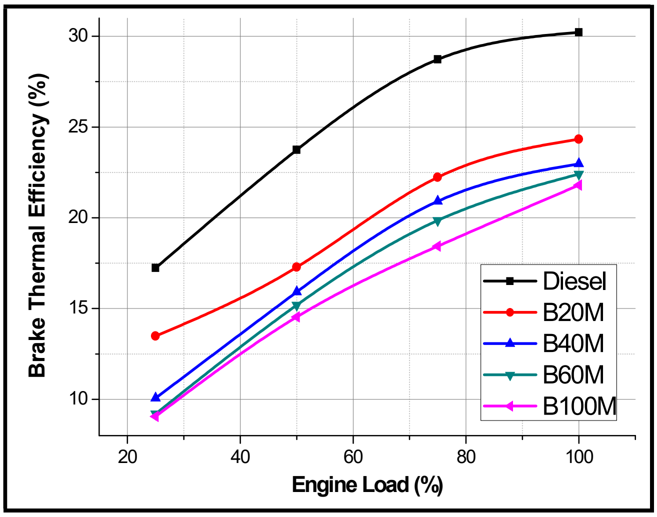


**Figure 3.** Variation of brake thermal efficiency (BTE) with engine load for different test fuels

As the engine load increases, the brake thermal efficiency (BTE) also increased and at full load condition both diesel and biodiesel were performing efficiently and producing highest BTE. Among all the mahuca indica oil biodiesel blends, B20M blend has nearest brake thermal efficiency with diesel when compared to all other blends of mahuca indica oil methyl ester (MIOME). It was also identified that the rate of increase in brake thermal efficiency (BTE) is higher at lower loads and low at higher engine load conditions.

### B. Brake Specific Fuel Consumption (BSFC)

The specific fuel consumption (BSFC) measure of the amount fuel supplied to the engine to develop unit power. Figure 4 shows the variations of brake specific fuel consumption (BSFC) for all tested biodiesel blends with engine load. Diesel has lowest BSFC in all fuels and B20M blend showed lowest BSFC in among all the MIOME blends. As shown in figure, BSFC increased with increase of biodiesel blend percentage. It is also noticed that with increase of load, the specific fuel consumption has decreased for both diesel and MIOME biodiesel. At part loads the increase in specific fuel consumption is higher but as the load increases this value decreases and reached to lower at full load condition.

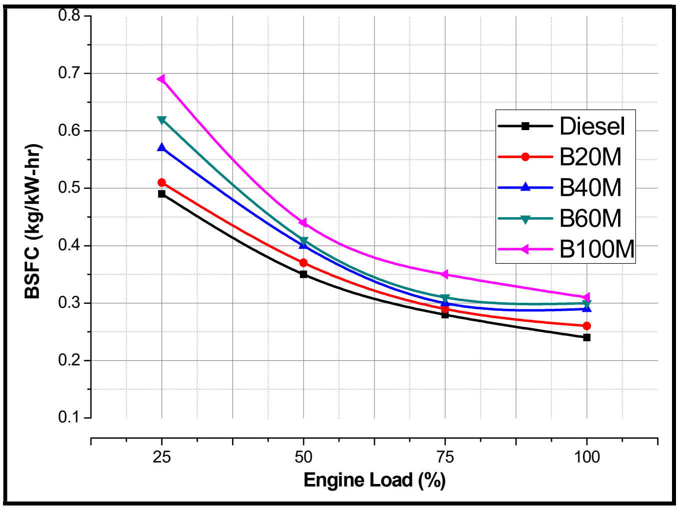


**Figure 4.** Variation of BSFC with engine load for different test fuels

### C. Brake Specific Energy Consumption (BSEC)

The variations of BSEC for all tested fuels with engine load are shown in Figure 5. The brake specific energy consumption of the engine with MOME biodiesel operation at all loads is higher when compared to petro-diesel fuel. This is due to higher density and lower heating value, higher density of MIOME than diesel. It is observed that the BSEC has increased with increase of blend percentage and diesel has shown lowest BSEC among all the tested fuels. Apparently, B100M blend of MIOMME has exhibited highest BSEC throughout the range of engine load conditions. B20M blend demonstrated lower BSEC compared to all others blends other than diesel fuel. At lower load conditions the BSEC is higher and gradually decreasing when load is increasing. At higher loads, it is noticed that the BSEC is lowest for all tested fuels.

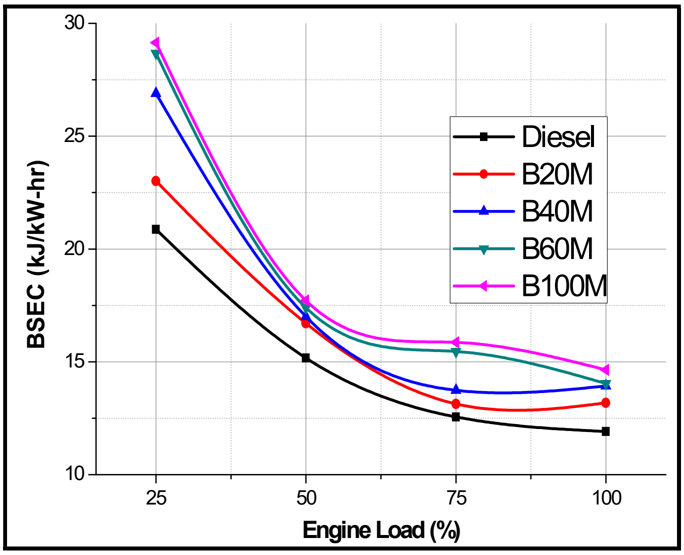


**Figure 5.** Variation of BSEC with engine load for different test fuels

## IV. CONCLUSION

The experimental investigation on performance of a single cylinder, 4-stroke, and water cooled DI diesel engine using madhuca indica oil methyl ester (MIOME) and its diesel blends as biodiesel have established the following conclusions:

- ✓ MIOME can be used as a fuel in DI diesel engine without any modification(s)
- ✓ The B20M blend of biodiesel has almost similar performance characteristics as diesel fuel followed by B40M blend
- ✓ The brake thermal efficiency (BTE) of the test engine with biodiesel is slightly lower than diesel for all load conditions of the engine
- ✓ The brake specific fuel consumption (BSFC) of the engine is slightly more with MIOME biodiesel for same power developed due to its lower heating value and higher density
- ✓ The brake specific energy consumption (BSEC) of the engine is significantly higher at lower loads and slightly more with biodiesel for same power developed.

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