Experimental investigation of performance and emissions of CI engine fuelled with mahua oil blended camphor fuel

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Abstract. Rapid increment in the energy sector is forcing all countries to look forward to find an alternate solution for their improvements. Biofuel is best alternative which can be easily used in the CI engines. This paper deals with emissions and performance characteristics of CI engine fuelled with Mahua oil blended Camphor Biofuel blend (M70C30, M50C50 and M30C70). Blending the Camphor oil with mahua oil will increase the Brake thermal efficiency. BSFC for M70C30 was found higher than other blended Fuel. Increasing the percentage of camphor in blended fuel will escalate the NOx emissions and will lower the CO, HC and Smoke emissions. M30C70 has higher Thermal efficiency and lower BSFC and which also supports for lowering the HC, CO, Smoke Emissions and high NOx emissions

1. Introduction
Many countries are doing research to find the alternative to fossil fuels because of the adverse effects in the usage of petrol and diesel. So many researchers are trying to find out new solution. One of the primary source of power supply to automobiles are diesel and petrol engine because of compactness, good thermal efficiency and reliability on operational criteria. Diesel engine fuel consumptions are increasing in rapid phases day by day. But internal combustion engines have nearly 40 % energy conversion in terms of useful work and remaining energy is wasted. Recent scenario also demands major utilization of IC engine by reducing the energy loss. In the meantime it also polluting environment. Strict regulation was imposed by many countries for controlling and regulating the emissions of internal combustion engines.

Biofuel have properties of higher viscosity, low volatility and higher molecular weight and moderate calorific value which therefore can be used as best alternative for the Diesel fuel. Clean burning biofuel can be produced from non-edible plants that won’t affect the food supply. Viscosity of biofuel has linear function of temperature and supports that fuel in direct usage in diesel engine. Biofuel from non-edible source is the main focus by many developing countries which reduces the pressure on the economics involved. Most of the sources for biofuels are grown in the countries waste land so that can be utilized well without affecting the cultivation lands.

Hwai chyuan ong et al [1] studied three biofuels which was Jatropha curcas, Ceiba pentandra and
Calophyllum inophyllum. He found that lower blended fuel (B10) has better performance characteristics with compensation of the higher value for NOx Emission. Alcohol has higher latent heat of vaporization because of which it has the high rate of heat release and produces the higher NOx emissions. The stoichiometric air fuel ratio of ethanol, n-butanol and n-pentanol is high but still it is less than that of diesel fuel. From that we can say that engine using alcohol can be effectively used in terms of Air fuel ratio requirements. High order alcohol has a lower cetane number which makes them not feasible in diesel engine. But butanol and pentanol have moderate cetane number and calorific value which supports them to use in the IC engine. Methanol and ethanol have greater octane numbers with lower cetane number. Owing to the high octane number, methanol and ethanol can be used in the dual fuel method by injecting through manifold injections [2].

Adding of biodiesel with ethanol at lower blending ratio has influence on the engine emissions. The flow properties of ethanol at low temperatures can be increased by addition of the biodiesel [3]. Methanol has the cetane number of 5 and lower heating value of 19.7 MJ/kg, which is not an alternative fuel when comparing to Diesel fuel. But it can be used through fumigation techniques. Adding 10% methanol by fumigation lowers NOx and CO. Higher the level of methanol in fumigation results in higher emissions [4]. Ethanol has cetane number of 8 and latent heat evaporation of up to 904 M/kg, which acts as a drawback for ethanol in utilizing it in diesel engine. Oxygen content in most of the biofuels like ethanol (34.8% wt), Dimethoxymethane (42.1 5 wt), Diglyme (35.8 % wt), Diethyl adipate (31.7 5 by wt), etc is in such quantities that supports better combustion [5].

Madhuca Indica and Madhuca longifolia are two types of Species available in India. Nearly 35% of oil was content of the mahua kernel. Mahua tree is found almost all over India. Mahua oil has the tendency to attract the insects which make the problem in storing the mahua oil for longer days. Pumping the high viscous mahua oil need more power and also results in improper atomization. The long terms use of high viscous biofuel leads to higher carbon deposits in injectors, sticking of oil ring, for formation because of the reaction of oil with lubricating oil. High viscosity of the biofuel dominates at lower loading conditions because of greater air fuel ratio. But at higher loading conditions because of low air fuel ratio, oxygen content of the biofuel supports better combustions [6].

Addition of the higher viscosity biofuel to lower viscous biofuel leads to reduction in viscosity of the blended biofuel which supports for better combustions. Blending the low cetane number biofuel with higher cetane number biofuel has the moderate cetane number which improves the ignition characteristics of fuel [7].

2. Methodology

![Figure 1. Engine Setup.](image)

Three fuel blend was prepared namely M70C30 (70% mahua oil and 30% of camphor oil by volume...
basis), MSOCSO (50% mahua oil and 50% of camphor oil by volume basis) and M30C70 (30% mahua oil and 70% of camphor oil by volume basis) whose properties are listed in the table 1. The experiment setup was shown in the figure 1. It contains the Kirloskar make four stroke diesel engine of 5.2 kW at rated speed of 1500 rpm. Eddy current dynamometer was utilized to exert load on the engine and was noted from Load indicator coupled to strain gauge. The air flow rate was measured using the air box, orifice meter and U type manometer. The fuel tank with two way value with burette was used to measure mass flow rate of fuel. Thermocouples were utilised to detect the temperature of the Engine cooling water and Exhaust gas. The AVL gas analyzer and Bosch smoke meter was utilised to detect the various pollutants from the engine. The specifications of the engine were mentioned in table 2. Experiment was conducted for different loads at a constant speed of 1500rpm for all 3 blend and reference fuel of diesel.

### Table 1. Properties of Biofuels.

| Description                              | Diesel | Camphor Oil | Mahua Oil |
|------------------------------------------|--------|-------------|-----------|
| Density (kg/m³)                          | 830    | 894         | 924       |
| Calorific value (MJ/kg)                  | 42.5   | 38.2        | 37.6      |
| Kinematic Viscosity (cST at 40°C)        | 4.59   | 1.9         | 24.60     |
| Chemical Formula                         | C12H24 | C           | C55H107O6 |
| Molecular weight                         | 168    | 152         | 865       |
| Air fuel ratio                           | 14.9   | 13.6        | 12.69     |
| C (% by wt)                              | 86     | 78.94       | 76.47     |
| H (%@y wt)                              | 4      | 10.52       | 12.39     |
| O (% by wt)                              | 0      | 10.52       | 11.12     |
| C/H ratio                                | 0.52   | 0.625       | 0.51      |
| Cetane Number                            | 48     | 5           | 43        |

### Table 2. Specifications of the Engine.

| Engine and set up details               |
|----------------------------------------|
| Engine power                           | 5.2 kW @1500 RPM |
| Cylinder bore, Stroke length           | 87.5 m X 110 mm   |
| Temperature sensor                     | Range :0-1200 °C, Type k |
| Load sensor                            | Range : 0-50 kg, Type S beam |
| Cylinder pressure                      | Make PCB Piezotronics. |
| Crank angle sensor                     | Make Kubler-Gemiany Model 8.3700.1321 .0360 |

### 3. Results and Discussion

#### 3.1. Brake Thermal Efficiency

Figure 2 shows us the variation of the Brake thermal efficiency with respect to Brake power. Brake thermal efficiency has density and the calorific value of the fuel, Power loss, load acting on the engine...
as the dependent variables. Maximum efficiency was found for diesel fuel because of the lower density and lower mass fuel consumed for the power generation. M70C30 has the lower BTE because of larger momentum and poor depth penetration of the fuel droplets in the air field. M30C70 has the higher BTE owing to the greater calorific value and low density of camphor fuel compared to diesel.

![Figure 2](image1.png)

**Figure 2.** Variations of the BTE against Brake power.

### 3.2. Brake specific Fuel

The figure 2 shows the variation of the BSFC w.r.t. Brake power. The lower BSFC was found for Diesel fuel because of the higher fuel conversion ability to diesel fuel. M70C30 has the higher BSFC owing to the lower heating value and greater density of the Mahua oil. Increasing the camphor oil supports better combustion because of its lower viscosity.

![Figure 3](image2.png)

**Figure 3.** Variation of the BSFC with respect to brake power.

### 3.3. Emission - Carbon mono oxide

The figure 4 shows the variation of the carbon monoxide w.r.t. brake power. Carbon monoxide emissions mainly depend upon on the air fuel ratio, incomplete combustion. Carbon mono oxide emission was found higher for M70C30 because of the improper atomization due to high viscous mahua oil. Increase the Mahua oil in Blended fuel increase the CO emissions. Increase in camphor oil reduces the CO emissions. Among blended fuel M30C70 has the lower CO emissions.

![Figure 4](image3.png)

**Figure 4.** Variation of the CO with respect to Brake power.

### 3.4. Unburnt hydrocarbon

Figure 5 displays the variation of unburnt HC emission w.r.t brake power. Unburnt HC emissions mainly depend on the Hydrogen carbon length of the fuel, incomplete combustion etc. M70C30 has the higher HC emissions and diesel has the lower HC emissions in all loading conditions. Adding mahua oil to the blended fuel increases the HC emissions and increasing the Camphor oil decreases
the HC emissions. Among blended fuel M30C70 has the lowest HC emissions. Addition of camphor oil in fuel reduces the viscosity and density and increase the calorific value of the fuel which supports for good combustion.

![Figure 5. Variation of the Unburnt HC with respect to brake power.](image)

3.5. Oxides of Nitrogen
The figure 6 shows the variation of the Oxides of Nitrogen w.r.t. Brake Power. The NOx emission is mainly dependent upon high temperature hot gas along with Nitrogen and oxygen available for the reaction and also combustion duration. M30C70 has the higher NOx emissions because of the lower cetane number of the camphor oil which leads to high rate of heat release rate in rapid combustion phase. Higher viscosity of Mahua oil leads to longer physical delay and accumulation of the charge and results in high rate of heat release which results in higher NOx emissions. Diesel has the lowest NOx emissions because available oxygen content to react with nitrogen was lower than blended fuel.

![Figure 6: Variation of the Oxides of Nitrogen w.r.t. brake power.](image)

3.6. Smoke
Smoke emissions mainly depends upon the air fuel ratio, efficiency of the combustion and local fuel rich zone and also turbulence inside the engine. The Figure 7 shows variation of the Smoke w.r.t. brake power. At lower loading conditions, the M70C30 has the higher Smoke emissions because of the viscosity of the blended fuel. Additions of camphor oil lowers the smoke emission at lower loading conditions because of the low amount fuel is supplied which reduces the rich mixture zone. At full load conditions because of the Viscosity of the mahua oil and low cetane number of the Camphor oil leads to higher smoke emissions. That’s why M50C50 has the higher Smoke emissions at full load conditions.
4. Conclusion
Brake thermal efficiency was found lower for all blended fuels because of the greater viscosity and lower calorific value of the blended fuel. Among blended fuel M30C70 has the higher brake thermal efficiency because of the lower viscosity of camphor oil. M30C70 has the lower BSFC compare to M50C50 and M70C30 but lower than Diesel Fuel. The M30C70 has the Lower CO, HC but Higher NOx and Smoke emissions.

5. References
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