

# Performance and Emission Analysis of Compression Ignition Engine with Methyl Ester of Jatropha and Diesel

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## Abstract

**Background/Objectives:** The alternate fuel is required worldwide to rectify the future demand and to deduce the emission in the IC engine. The main objective of this work is to analyze the characteristics of Methyl Ester of Jatropha as alternative fuel. **Methods/Statistical Analysis:** The various fuel blend ratio of MEOJ (Methyl Ester of Jatropha) was used in compression ignition engine with diesel fuel at constant speed. The different blends B20MEOJ, B40MEOJ, B60MEOJ, B80MEOJ and B100MEOJ were used for engine testing purpose. **Findings:** Performance, combustion and emission characteristic of the diesel engine was compared with the blends of jatropha for better efficiency and to reduce the emission. In maximum load, for B20MEOJ blend the efficiency is 27.93% and for diesel is 28.18%. Smoke density for B20 blend of MEOJ at maximum load is 61.9 HSU while that for diesel is 81.2 HSU. The heat release rate is about 57.75 J/degree with diesel, 53.57 J/degree for B20 blend MEOJ. **Application/Improvements:** Biodiesel blend has performance closer to diesel, but emission is reduced in all blends of MEOJ compared to diesel. Thus the work marks for the suitability of biodiesel blends in diesel engine as an alternate fuel.

**Keywords:** Combustion, Compression Ignition Engine, Exhaust Emission, Methyl Ester of Jatropha, Performance

## 1. Introduction

The consumption of diesel is more in percentage in sectors like transport compared to other field of utilization like power generation and agriculture. In developing countries, the economic growth is affected mainly due to the import of the petroleum product. Many researchers in the field of vegetable oil proved it as the most appropriate substitute fuel for diesel. The physical property of vegetable oil is similar to diesel properties. Raw vegetable oil resulted in issues like carbon deposit on injector of the engine with long term running. Generally vegetable oil structure is having longer molecular chain with more number of oxygen and hydrogen. The longer molecular chain is broken by the method of transesterification. After transesterification process, there is no physically modification required to run the engine. This oil has higher flash point and lower heating value, so it can be

transported easily. It is having higher carbon content compare to diesel, which leads to emit more smoke density from the engine.

Whenever we consider the cost analysis, the vegetable oil cost is high against to petroleum products. The reason is the lower availability of vegetable oil in the market. However, the cost could be reduced in the future by increasing the yield of vegetable oil and low cost converting method. Indeed, even now it is conceivable in specific areas to buy various non-eatable oils at low costs. Because of the atmospheric temperature, soil conditions and contending employments of area, various countries need to consider various vegetable oils as potential fuel. Various vegetable oil is tried throughout the world to analyze various characteristics in diesel engine. Some of them are rubber seed oil, jammun seed oil, pongima seed oil, cashew shell oil, mahua oil, and jatropha oil<sup>1</sup>.

In <sup>2</sup> investigated different technique for production

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of biodiesel from three different non eatable oils. Performance and emission tests were conducted on three different biodiesel in diesel engine and concluded the jatropha oil showed better values compared with karanja biodiesel and cottonseed biodiesel. In<sup>3</sup> evaluated the diesel engine with six different biodiesel like sunflower, soya bean, coconut, rape seed, cotton seed and corn oil in comparison with diesel. Biodiesel exhibited lower NO<sub>x</sub>, high particulate matter with some amount of power losses<sup>4-6</sup>. Experimental investigation on compression ignition engine with various ratio of jammun seed biodiesel and diesel at constant engine speed was conducted<sup>7</sup>. It was proved that biodiesel mixture had lower brake thermal efficiency and smoke density. An experimental study<sup>8</sup> was conducted on the four stroke diesel engine with methyl ester of mahua in various blends. The biodiesel blends B10MEOM, B20MEOM, and B30MEOM are seen to have same trends of efficiency as that of diesel fuel<sup>9</sup>.

## 2. Jatropha curcas

*Jatropha curcas* has been cultivated in various places in India. In *Jatropha curcas*, the oil substance is around 42 percent and origin of the family is from Euphorbiaceae. It is grown in semi forest and any type of climatic condition. The south India is identified as suitable environmental condition with high yield of seed, also grown in the fissure of rocks. It requires less amount of water. The life time of the *Jatropha curcas* approximately 51 years and starts the seed yield within three to four years and the seed content is not poisonous.

The cetane number is higher and it is closer to diesel fuel. This is the best suitable alternate fuel for diesel compare to other biodiesel. When it is compared to diesel the flash point and viscosity is higher. Because of its higher flash point it is safe to transport and storage. Some of the disadvantage of higher flash point is that in cold conditions it results in starting problem. Due to higher viscosity, the fuel is sprayed in large size and carbon deposits in the injector nozzle. The fatty acid composition is Myristic 0.5-1.4%, Palmitic 12-17%, Stearic 5-9.7%, Oleic 37-63 % Linoleic 19-41% and Arachidic 0.10.3%<sup>10,11</sup>.

## 3. Transesterification Process

Alcoholysis process is also called transesterification

process. In this process ester is removed by using alcohol. By this process, long chain of molecular structure is broken into the simple structure, by this viscosity is reduced. The below equation mentions the reaction taking during the transesterification process.



Both ethanol and methanol are used in the process. If ethanol is used in this process it is said as ethanolysis and formethanol it is called methanolysis. The alkaline based catalyzed and acid based catalyzed are used to increase the reaction time. The vegetable oil, alcohol and catalyzed is mixed to together with the help of mechanical stirrer and heated up to 65°C at one hour. The subsequent blend is permitted to stay through night. The base deposit comprises of soap water and glycerin. The base deposit is depleted from flask. The purification of biodiesel is carried by water washing method. Using distillation process the excess methanol can be recovered and sent to amending segment for filtration and after that reused. Some factors affect transesterification process, such as time, temperature, FFA content, methanol ratio, catalyst and presence of water content<sup>12,13</sup>.

The process strongly depends on temperature. The room temperature is sufficient to take the reaction with sufficient reaction time. At temperature 60°C to 90°C, the ester gets higher yield. Molar ratio is most important parameter for yield rate of biodiesel. Another parameter is the presence of water that affects the reaction. It produces more amount of soap formation. Free fatty acid is most important parameter, which selects the nature of transesterification method as whether single stage or double stage<sup>14</sup>.

## 4. Experimental investigation

The investigation was conducted in compression ignition engine with different ratio of B20MEOJ, B40MEOJ, B60MEOJ, B80MEOJ and B100MEOJ and diesel. The detail of experimental engine is shown in table 1. Properties of Methyl Ester of Jatropha are provided in table 2. Engine loads varying by eddy current dynamometer. Single cylinder water cooled, four stroke direct injection compression ignition engine with a compression ratio of 17.5:1, developing 5.2 kW at 1500 rpm was used for this study. An analysis various characteristics of the engine

in various loads with rated speed. The loading device is connected to control panel and loads can be varying in the control panel. The exhaust temperature was measured by using of thermo couple. A provision was made in the cylinder head surface to mount a piezoelectric pressure transducer for measuring the cylinder pressure. Exhaust emission parameters were noticed from exhaust gas analyzer and smoke density is noticed from smoke meter as shown in figure 1.

**Table 1.** Engine specification

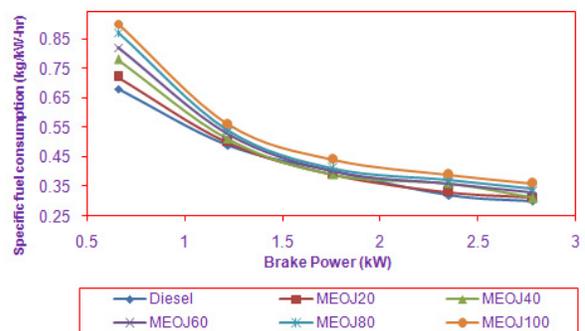
Model	Kirlosker TV – I
Type	Vertical cylinder, DI diesel engine, VCR engine
Cylinder	Single cylinder
Stroke x Bore	110 mm x 87.5 mm
Compression ratio	17.5
Speed	1500 rpm
Power	5.2 kW
Cooling method	Water cooling
Fuel	Diesel

**Table 2.** Fuel properties

Properties	MEOJ
Density at 15° C kg/m <sup>3</sup>	868.2
Kinematic Viscosity at 40°C	4.36
Flash Point (PMCC) °C, (min)	138
Gross Colorific value kJ/kg	43032
Pour point °C	4
Cetane Number (min)	55

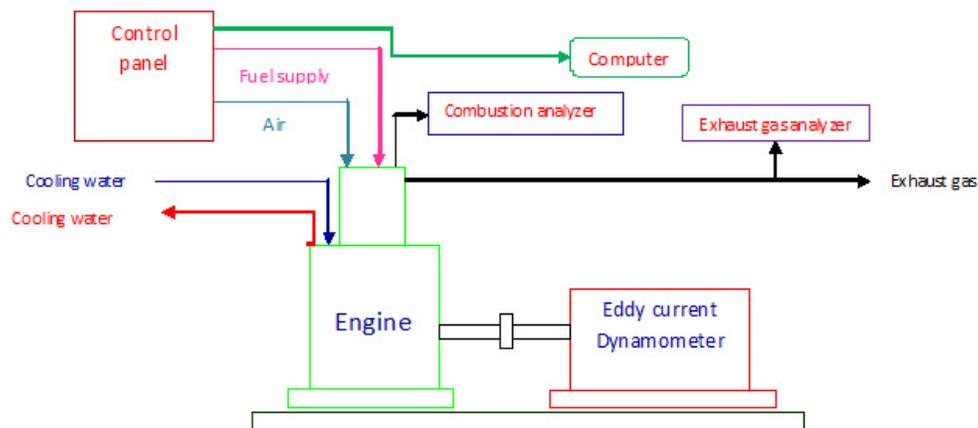
## 5. Result and Discussion

The specific fuel consumption plotted in figure 2. It shows as the blends ratio increases with increases in specific fuel consumption. During the full load condition diesel have the lower specific fuel consumption compared to various blends of B20MEOJ, B40MEOJ, B60MEOJ, B80MEOJ and B100MEOJ. The results indicate that there is no appreciable change in specific fuel consumption values with the diesel and B20 blend of MEOJ oil, the values for maximum load being 0.3 kg/kw-hr and 0.31 kg/kw-hr respectively.



**Figure 2.** Specific fuel consumption with different blends of MEOJ.

The brake thermal efficiency with various blends ratio of MEOJ plotted in figure 3. The efficiency of B20MEOJ is similar to diesel, this is due to the more amount of diesel



**Figure 1.** Line diagram for experimental setup.

presence in B20MEOJ. The amount of diesel is decreased in the B40MEOJ, B60MEOJ, B80MEOJ blends, this results recorded loss in efficiency. In maximum load, for B20MEOJ blend the efficiency is 27.93% and for diesel is 28.18%. The reason for this is lower in viscosity, higher carbon in the B20MEOJ and also due to higher calorific value compare to other MEOJ blends.

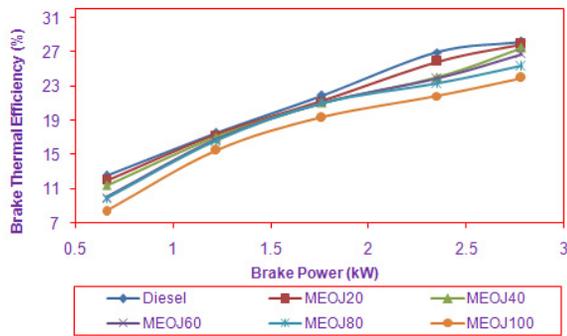


Figure 3. Brake thermal efficiency with different blends of MEOJ.

The variant of smoke density against brake power for B20MEOJ, B40MEOJ, B60MEOJ, B80MEOJ and B100MEOJ and diesel fuel are shown in figure 4. From that plots noticed that the smoke density for B20 blend of MEOJ at maximum load is 61.9 HSU while that for diesel is 81.2 HSU. The smoke density is lower for B20 MEOJ compared to other percentage blends. This is due to heavy molecular structure and higher viscosity which leads to poor atomization during the combustion for other blends of the biodiesel<sup>15</sup>.

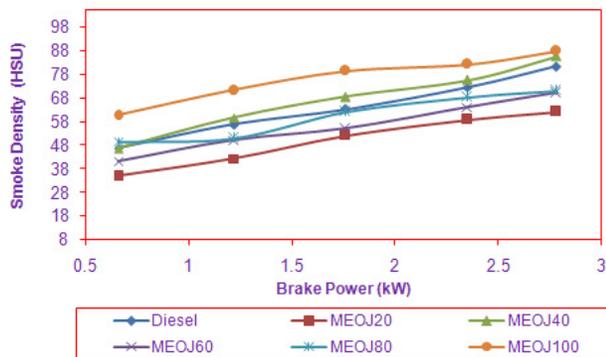


Figure 4. Smoke density with different blends of MEOJ.

Figure 5 indicates that B20 blend of MEOJ always

results in low NOx emission compared to that of diesel and other blends of MEOJ. The trend noticed that as brake power increases NOx emission also increases and attains maximum at maximum load. This is due to high combustion temperature and the excess availability of oxygen and nitrogen. The reduction of NOx emission from diesel fuel value is due to reduced premixed burning rate<sup>16</sup>. When compare to B20MEOJ and diesel fuel, the lower heat release rate for premixed burning stage<sup>17</sup>.

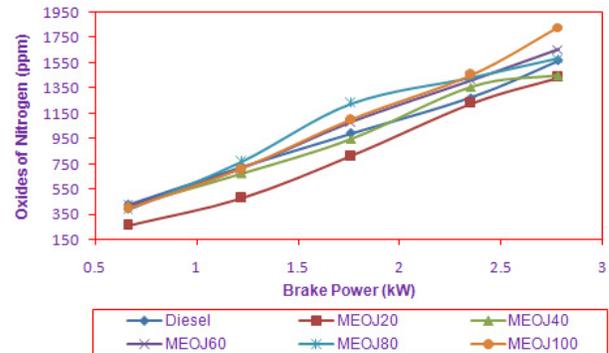


Figure 5. NOx with different blends of MEOJ.

Figure 6 indicate that hydrocarbon emission with various blends of MEOJ and diesel. The data clearly depicts, the emission rate of hydrocarbon was higher for diesel compared to blends of biodiesel. During full load condition, an exception arises, where emission rate was higher for B20, B40 blends of biodiesel. Emission is decreased in biodiesel, because of presence of oxygen higher in MEOJ blends. The complete combustion is done by excess oxygen, thus the reduction in HC emission<sup>18</sup>.

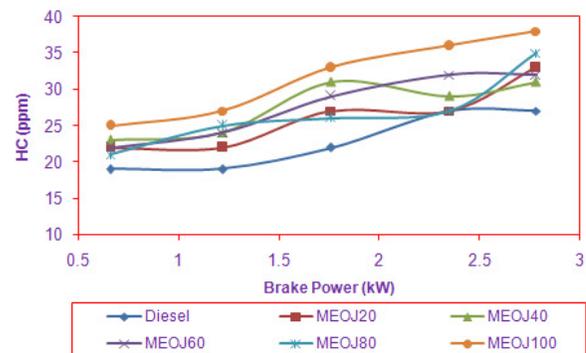


Figure 6. HC with different blends of MEOJ.

Figure 7 indicates the variant of CO emission against brake power. It was found that CO emission directly proportional to the brake power. Plots shows that the CO emission was low in all blends of MEOJ compared to diesel. For B20MEOJ, the CO emission was reduced at maximum load, compared to other fuels. This improved combustion efficiency results in lower CO emission.

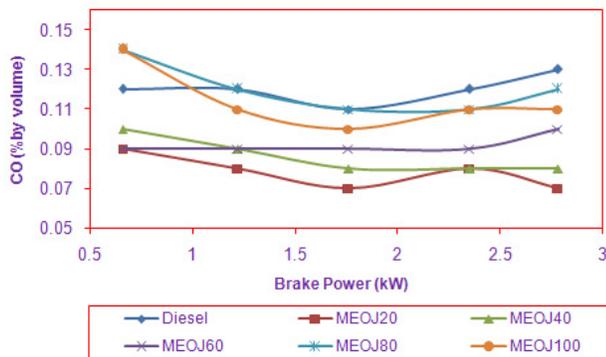


Figure 7. CO with different blends of MEOJ.

Figures 8 indicate the cylinder pressure variation with crank angle. Peak pressure was found to be 72.55 bar for diesel at a crank angle of 1 deg and 71.44 bar for B20 at a crank angle of 2deg. From the pressure curves, inferred that the delay period was increasing with the increase of biodiesel blends<sup>19</sup>. This is reason for more viscosity of biodiesel. The longer delay period directs to reduction the cylinder pressure. During the MEOJ blend operation, the cylinder pressure is always lower.

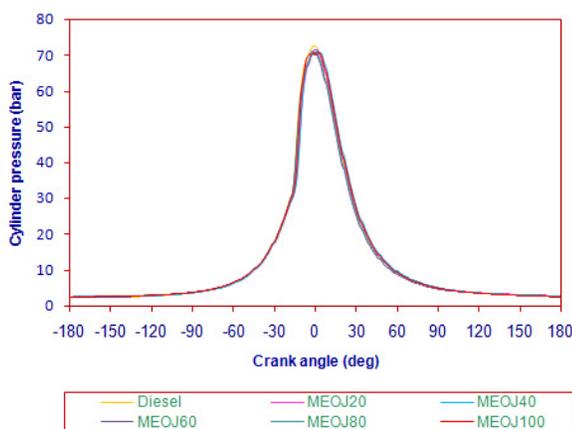


Figure 8. Cylinder pressure with different blends of MEOJ.

The heat release rate of various blends MEOJ blends

and diesel is plotted in figure 9. From this plots, observed that the maximum heat release rate is recorded in diesel at condition of maximum load. The heat release rate is about 57.75 J/degree with diesel, 53.57 J/degree for B20 blend MEOJ. The main reason is poor mixture formation which in turn leads to delay for start of combustion<sup>20</sup>.

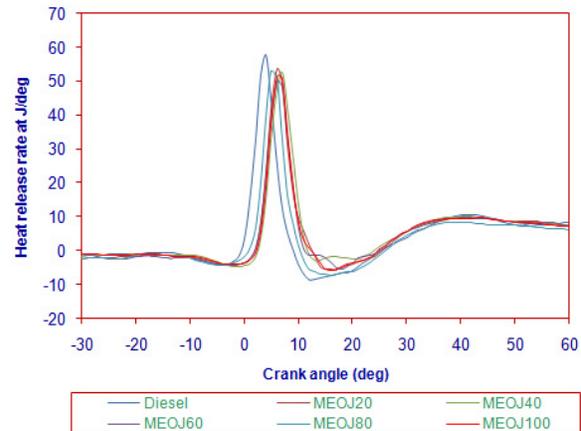


Figure 9. Heat release rate with different blends of MEOJ.

## 6. Conclusion

The properties of Jatropha biodiesel were analyzed as per ASTM standard. All the properties are higher for diesel with the calorific value being an exception. Full load condition diesel has the lower specific fuel consumption compared to various blends of B20MEOJ, B40MEOJ, B60MEOJ, B80MEOJ and B100MEOJ. The efficiency of B20MEOJ is similar to diesel, this is due to the more amount of diesel presence in B20MEOJ. In maximum load, for B20MEOJ blend the efficiency is 27.93%. Though the emission parameters are lower in B20 MEOJ, NO<sub>x</sub> increases with increase in percentage of MEOJ blends. For B20MEOJ, the CO emission was reduced at maximum load, compared to other fuels. For both diesel and MEOJ blends were noticed emission is higher with higher engine loads. From the analysis done, it is inferred that B20MEOJ blends run the engine not required for external and internal modification to achieve performance closer to diesel and this is a right option fuel for diesel.

## 7. References

- Jindal S, Nandwana P, Rathore NS, Vashistha V. Experimental investigation of the effect of compression ra-

- tio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester. *Applied Thermal Engineering*. 2010; 30(5):442–8.
2. Pramanik K. Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine. *Renewable Energy*. 2003; 28:239–48.
  3. Shehata MS, AbdelRazek SM. Experimental investigation of diesel engine performance and emission characteristics using jojoba/diesel blend and sunflower oil. *Fuel*. 2011; 90:886–97.
  4. Qi DH, Chen H, Geng LM, Bian YZ. Effect of diethyl ether and ethanol additives on the combustion and emission characteristics of biodiesel diesel blended fuel engine. *Renewable Energy*. 2011; 36:1252–8.
  5. Sahoo PK, Das LM. Process optimization for biodiesel production from jatropha, karanja and polanga oils. *Fuel*. 2009; 88:1588–94.
  6. Altin R, Cetinkaya S, Yucesu HS. The potential of using vegetable oil fuels as fuel for diesel engines. *Energy Conversion and Management*. 2001; 42:529–38.
  7. Manieniyan V, Senthilkumar R, Sivaprakasam S. Performance, Combustion and Emission Analysis on a Diesel Engine Fueled with Methyl Ester of Neem and Madhua Oil. *International Journal of ChemTech Research*. 2015; 7(5):2355–60.
  8. Agarwal D, Kumar L, Agarwal AK. Performance evaluation of a vegetable oil fuelled compression ignition engine. *Renewable Energy*. 2008; 33:1147–56.
  9. Manieniyan V, Sivaprakasam S. Performance, Combustion and Emission evaluation In DI Diesel Engine using Diesel and Bio diesel. *Elixir journal of Mechanical Engineering*. 2012; 52:11305–8.
  10. Sayin C, Gumus M. Impact of compression ratio and injection parameters on the performance and emissions of a DI diesel engine fuelled with biodiesel blended diesel. *Fuel*. 2011; 31:3182–8.
  11. Adaileh WM, KhaledAlQdah S. Performance of Diesel Engine Fuelled by a Biodiesel Extracted From A Waste Cooking Oil. *Fuel*. 2012; 18:1317–34.
  12. Martins J, Torres F, Torres E, Pimenta H. The Use of Biodiesel on the Performance and Emission Characteristics of Diesel Engined Vehicles. SAE. 2013-01-1698.
  13. Senthil Kumar M, Ramesh A, Nagalingam B. Use of hydrogen to enhance the performance of a vegetable oil fuelled compression ignition engine. *International Journal of Hydrogen Energy*. 2003; 28(10):1143–54.
  14. Sayin C, Gumus M. Impact of compression ratio and injection parameters on the performance and emissions of a DI diesel engine fuelled with biodiesel blended diesel. *Fuel*. 2011; 31:3182–8.
  15. Sehmus A, Husamettin B, Cengiz O. The comparison of engine performance and exhaust emission characteristics of sesame oil-diesel fuel mixture with diesel fuel in a direct injection diesel engine. *Renewable Energy*. 2008; 33:1791–5.
  16. Jha SK, Fernando S, Columbus E, Willcutt H. A comparative study of exhaust emissions using diesel biodiesel-ethanol blends in new and used engines. *Transactions of the ASABE*. 2009; 52(2):375–81.
  17. Sivaganesan S, Chandrasekaran M. The Influence of Thermal Barrier Coating on the Combustion and Exhaust Emission in Turpentine Oil Powered DI Diesel Engine. *ARPN Journal of Engineering and Applied Sciences*. 2015; 10(22):10548–54.
  18. Qi DH, Chen H, Geng LM, Bian YZH, Ren XCH. Performance and combustion characteristics of bio-diesel diesel-methanol blend fuelled engine. *Applied Energy*. 2010; 87:1679–86.
  19. Hanumantha Rao YV, Sudheer Voleti R, Sitarama Raju AV, Nageswara Reddy P. Experimental Investigations on Jatropha Biodiesel and Additive in Diesel Engine. *Indian Journal of Science and Technology*. 2009 Apr; 2(4). Doi: 10.17485/ijst/2009/v2i4/29426.
  20. Krishnamani S, Mohanraj T, Murugumohan Kumar K. Experimental Investigation on Performance, Combustion and Emission Characteristics of a Low Heat Rejection Engine using Rapeseed Methyl Ester and Diethyl Ether. *Indian Journal of Science and Technology*. 2016; 9(15). Doi: 10.17485/ijst/2016/v9i15/87322.