Optimization of Rice bran biodiesel blends on CI engine and investigating its effects

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Abstract. Bio-diesel can be produced from various plant oils like soybean, sunflower or rice bran. Here the focus is on converting the rice bran oil into bio-diesel which is produced by transesterifying the rice bran oil with a low molecular weight alcohol (methanol) and a non-conventional catalyst (lipase). Using a lipase based catalyst brings down the cost of biodiesel production significantly by reducing the number of washing cycles and its ability to be reused further. Four different blends of B10, B20, B30, B40 and straight diesel are tested in a single cylinder, fourstroke, vertical air cooled Kirloskar Diesel Engine having ignition timing of 23° before Top Dead Centre (TDC). As compared to straight diesel the Brake Thermal Efficiency (BTE) value for all the blends are higher. The Specific Fuel Consumption (BSFC) values for most of the blends are less as compared to diesel. Emissions of CO, CO2 and HC for all the blends decreased quite significantly. As a summary, the blend B20 records better performance as well as emission characteristics as compared to diesel.

1. Introduction
In the current context, compression ignition engines are aimed to deliver high thermal efficiency and lowered specific fuel consumption. Due to recently imposed stringent emission norms, several tools and techniques were developed all over the world to limit the CI engine emissions within the specified limits [1]. Biodiesel, a form of diesel fuel produced from vegetable oils and animal fats. It is proven to be safe, biodegradable and emits less air pollutants than conventional diesel. Biodiesel is defined as a liquid fuel made as fatty acid methyl esters, fatty acid alkyl esters or the long chain mono alkyl esters. As purest form (B100) or blended with pure diesel the biodiesel can be used. Fuel properties of the blend will vary according to the amount of biodiesel in the blend. The smaller volume percentage of biodiesel with diesel in the blend performs better. Biodiesel for diesel engines is produced by chemically reacting a vegetable oil or animal fat with an alcohol such as methanol or ethanol. This reaction takes place for the oil in the presence of a catalyst, normally a conventional catalyst such as sodium or potassium hydroxide, and produces new compounds called methyl esters. Non conventional catalyst like enzymes may also be used. Because the carbon in the oil from carbon dioxide present in the atmospheric air, biodiesel is considered to contribute much less to global warming than petroleum fuels. A CI engine operated with biodiesel emits lower emissions of carbon monoxide, unburnt hydrocarbons, particulate matter, and air toxics than whenoperated on Diesel fuel. Biodiesel have advantages like, provides a market for huge production of animal fats and vegetable oils, and decreases a country’s dependence on imported Diesel.

Rice bran oil, a non conventional, inexpensive and low grade is also source of high value added by-product are derived from the crude rice bran oil and the resultant oil is used as a feedstock for biodiesel. Rice bran oil is the oil extracted from the germ and inner husk of rice. It is popular as...
cooking oil in several Asian countries including Japan and China. Several reports were already supports the use of Rice bran oil in CI engine. Calorific value of the Rice bran biodiesel is very much nearer to diesel value and it is possible to convert high FFA rice bran oil into biodiesel [2]. Biodiesel fuel blend with a small portion of Rice bran biodiesel was technically feasible for a CI engine. The lesser amount of biodiesel will improve the Specific Fuel Consumption characteristic [3]. Biodiesel derived from Rice bran oil may be effectively used as a blended fuel in CI engine as its properties are within the suggested standard fuel limit. The biodiesel blends B20, B40 produced from rice bran oil are considered to be a better alternative to diesel without any modification on the CI engine [4]. In a test conducted on a single cylinder CI engine the peak pressures for the Rice bran oil biodiesel blends occurred within 1°-9° crank angle after TDC and it is very nearer to with that of diesel [5]. Viscosity of Rice bran biodiesel is normally higher. When its concentration increases in the blend, the viscosity of blend increases [6]. While the engine running with Rice bran Biodiesel, during the initial stage of combustion better intermixing of air and fuel were attributed [7]. It was tested and proven with Rice bran Biodiesel that the maximum yield of ester can be obtained working with an initial concentration of catalyst and operation temperature of 40°C [8].

The aim of the project is to produce biodiesel from rice bran and mixing it with straight diesel in the four proportions of B10 to B40 blends. Rice bran oil derived biodiesel’s fuel properties are observed and tested by following standard procedures. It is found that rice bran oil properties are almost similar to that of other commonly used bio-diesel. Then an experimental Test rig is used to investigate the combustion, performance and emission of rice bran oil biodiesel blends (B10, B20, B30 and B40). The standard injection timing of 23° before top dead center is adopted for all the blend testing. The various parameters are measured and calculated. The emission graphs are plotted against the varying load. Finally comparisons are made between the blends and with the standard value of the diesel.

2. Experimental Setup and Methodology

| Properties                                | Results                  |
|-------------------------------------------|--------------------------|
| Free Fatty Acid                           | 0.592 %                  |
| Kinematic Viscosity at 40°C               | 37.548 cSt               |
| Density                                   | 0.910 gram/cc            |
| Moisture Content                          | 0.002 %                  |
| Flash point (PMCC method)                 | 278°C                    |
| Fire point (PMCC method)                  | 307°C                    |
| Copper Strip Corrosion at 60° C for 3 hours | 1a (slight tarnish )    |
| Could point ° C                           | 16°C                     |
| Pour point ° C                            | 1°C                      |
| Calorific value                           | 3808.356 cal/gram        |

First 3000 ml of rice bran oil is obtained from a commercial store under the brand name POORNA RICE BRAN OIL. The various fuel properties of the raw rice bran oil were tested at Centre for Waste Energy and Management, Sathyabama University, Chennai. The Properties of the raw Rice bran oil are presented in Table 1. Here the FFA content of the raw rice bran oil is less than 4%. Therefore, no
further esterification is needed; it can be now directly transesterified to form biodiesel. The catalyst used in this work is Lipase (Steapsin), it is a digestive enzyme of pancreatic juices that catalysis the hydrolysis of fats to fatty acids and glycerol and it is a fat splitting enzyme. The advantages of lipase are it can be used again and again without loss in its effectiveness, the biodiesel which is produced after the transesterification process is not needed to be washed thereby reducing the cost of the biodiesel. The amount of catalyst used for this study is 3% of the total weight of oil sample!The oil sample is checked for its FFA. Oil is heated to 50°C and maintained thereafter till completion of the reaction. Lipase is added and stirred continuously with a magnetic stirrer. Methanol is added stage wise (every half an hour) to avoid deactivation of the catalyst. After the reaction completed, the contents are transferred into a separating funnel; two layers were seen in the container, the upper layer is biodiesel and lower layer is Glycerol. Lipase is settled down at the bottom. The variables in the transesterification process are presented in Table 2. The biodiesel obtained after the transesterification process is tested for various fuel properties and are presented in Table 3.

Table 2. Transesterification variables report

| Parameters                        | Value                       |
|-----------------------------------|-----------------------------|
| Amount of Lipase added            | 3% by weight of oil sample  |
| Total Amount of Methanol added    | 210 ml for 1000ml oil sample|
| Amount of Methanol Added in every half an hour | 52.5 ml |
| Reaction Temperature             | 50°C                        |
| Reaction time                     | 2 hours                     |
| Magnetic Stirrer Speed            | 1000 rpm                    |
| Washing                           | No                          |
| Yield                             | 96%                         |

Table 3. Properties of Rice bran oil Biodiesel

| Properties                               | Values                       |
|------------------------------------------|------------------------------|
| Kinematic Viscosity at 40°C              | 3.906 cSt                    |
| Density                                  | 0.873 gram/cc                |
| Moisture Content                         | 0.001%                       |
| Flash point (PMCC method)                | 166°C                        |
| Fire point (PMCC method)                 | 198°C                        |
| Copper Strip Corrosion at 60°C for 3hours| 1a (slight tarnish)          |
| Cloud point °C                           | 10° C                        |
| Pour point °C                            | -3° C                        |
| Calorific value                          | 8214.692 cal/gram            |

The Engine Test rig used in this work is a Kirloskar, Four stroke, Single Cylinder, Vertical Air Cooled Diesel Engine having ignition timing of 23° before TDC. the specifications of the engine is shown in
the Table 4. After property testing, the samples are then taken to next process for performance, combustion and emission test. Four different blends B10, B20, B30, B40 and pure diesel are tested on a four stroke, single cylinder, vertical air cooled CI engine. While the engine is in running condition, load is increased gradually (0%, 25%, 50%, 75% and 100%). The exhaust gases temperature coming out of the engine is noted down for different load conditions after 10g of fuel is consumed. The time taken for consuming 10g of fuel for a particular load is noted down at the same time the difference in manometer reading is also noted. The engine is set to run till the full load condition and all the readings are noted down. After this the engine is stopped. The performance results are calculated from the various readings which are noted down during engine testing. On the other hand the emission results are calculated with the help of supporting system.

Table 4. Specifications of the engine

| Specification           | Value         |
|-------------------------|--------------|
| Rated power             | 4.4 kW       |
| Rated speed             | 1500 rpm     |
| Bore Diameter (D)       | 87.5 mm      |
| Stroke (L)              | 110 mm       |
| Compression ratio       | 17.5 : 1     |
| Orifice Diameter        | 13.6 mm      |
| Coefficient of discharge (C_d) | 0.6     |
| Loading Device          | Swing field Electrical Dynamometer |

3. Results and Discussion

The combustion, performance and emission characteristics of straight diesel and tested rice bran blends B10, B20, B30 and B40 are discussed in this section.

3.1. Brake thermal efficiency

The Figure 1. illustrates the comparison of Brake thermal efficiency values of biodiesel blends and straight diesel against BMEP. Most of the blends have higher BTE than diesel. This is due to the
inhumed mixing of biodiesel-air along with better combustion results leading to maximum thermal efficiency. The BTE of the diesel increases initially but as the BMEP keeps on increasing; the BTE decreases and gradually has the least BTE value. The BTE values for all the blends vary drastically except for the blend B20 which increases continuously.

3.2. Brake specific fuel consumption

![Figure 2. BMEP vs. BSFC](image)

Figure 2. Depicts the variation of BSFC values against BMEP for the tested biodiesel blends. When brake mean effective pressure of the cylinder increases, specific fuel consumption will decrease. The specific fuel consumption values of blends normally decreases for all the blends and straight diesel with increase in the BMEP values. The blend B30 and diesel show sudden increase in fuel consumption at pressure between 2 to 3 bar. The reason is at higher pressure fine atomized fuel mixes homogenously with air and additives and hence less fuel is needed.

![Figure 3. BMEP vs. Exhaust Gas Temperature](image)

3.3. Brake specific fuel consumption
The Figure 3. delivers the comparison of exhaust gas temperature values of tested fuel blends against BMEP. The exhaust gas temperature is the temperature of the gas which comes from the engine. The EGT of the engine is considered as a most important parameter which measures utilization of heat energy of the fuel. The graph shows that the exhaust gas temperature values for all biodiesel blends and diesel increases with increase in BMEP. A gradual increase in the exhaust temperature for all the blends was identified but the exhaust gas temperature for the straight diesel is least at BMEP of 5 bar.

3.4. Carbon monoxides
The CO emission of various biodiesel blends and straight diesel at different load conditions are shown in the figure 4. The carbon monoxide emission is found to be maximum for diesel among all tested fuels at all loads. The reason for this is due to the incomplete combustion of diesel fuel in the engine cylinder. When the engine load increases the CO emission for diesel increases but this trend could not be seen in the biodiesel blends. At No load the CO emission is least for the blends B30 and B40 and at load full load condition the CO emission is least for the blend B20.

3.5. Hydro carbons
The emission of unburnt hydro carbons in the exhaust gasses has many adverse effects on the atmosphere which leads to global warming. The Figure 5. Illustrate the HC emission at different loads for diesel and biodiesel in conventional engines. Diesel records the highest HC emission at all loads. The other blends have fluctuation values at different loads. At load 0 the HC emission is least for B30 and B40. At load 50 the emission is least for B40 and for load 100 the emission is least for B40.

3.6. Carbon di oxides
The Figure 6. Presents the variation of CO2 emissions in the exhaust gases of tested blends and straight diesel. The straight diesel has almost same emission as that of the biodiesel at various loads with little variations. This indicates that the combustion pattern of the biodiesel blends is similar to that of the straight diesel. At No load condition the CO2 emission is less for the biodiesel blend B40 and at the maximum load condition the CO2 emission is least for the blends B10 and B20.

3.7. Nitrogen oxides
Figure 7. Furnishes the NOX emission values for the biodiesel blends and diesel against rated loads. NOX emission is least for diesel among all the tested fuels at all loads. The highest value of NOX emission was recorded by the blend B40 at all applied loads.
Figure 5. UHC Emission for the blends and diesel

Figure 6. CO₂ Emissions for all blends and straight diesel
4. Conclusion
The summarized conclusions drawn from the combustion, performance, emission and characteristics investigation conducted for the four blends of Rice bran with straight diesel are discussed here.

- When the Brake Mean Effective Pressure increases the Brake Thermal Efficiency value increases for all blends B10, B20, B30 and B40.
- The fuel consumption is less for all the tested blends than straight diesel except for the blend B30 at pressure between 2 to 3 bar. The Blend B20 shows a remarkable decrease in the fuel consumption values.
- The Exhaust Gas Temperature values are is higher for all the biodiesel blends than the straight diesel at all pressure. The Exhaust temperature increases gradually with the increase in pressure for the all the fuel types.
- The CO, HC, CO$_2$ emission values for straight diesel is quite higher than the biodiesel blends at all loads.
- The NO$_x$ emission values for the biodiesel blends are higher than the straight diesel at all loads.

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