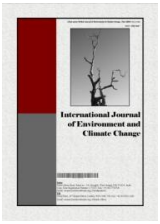

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Emission Characteristics of Methyl Ester of Rice Bran Oil Blends with Ethanol in CI Engine

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RKS and JS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AN and DA managed the analyses of the study. Author DA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Increasing demand and rapid depletion of fossil fuels have together prompted the researchers of many countries to look for alternate renewable fuels. This study is an attempt to test the feasibility of rice bran oil as fuel in C. I. engine in its original and in its refined form. It is generally produced from rice bran which is a by-product produced during paddy processing. Its viscosity though relatively higher than diesel can be reduced by natural sedimentation process. In this attempt, the performance and emission characteristics of rice bran oil and its refined form were studied and compared with diesel by employing them as a fuel in a single cylinder, direct injection, 4.4 KW, air cooled diesel engine. The performance characteristics revealed that the brake thermal efficiency of the rice bran oil was higher than its refined form and were marginally lower than that of diesel. Emission measurements were carried out using MRU Delta 1600L gas analyzer and the soot concentration was measured with AVL smoke meter. It was found that though blends of rice bran oil with ethanolexhibited greater soot concentration characteristics than rice bran oil and diesel at all loads, it exhibited desirable characteristics for other emissions such as lower CO, HC, NOx emissions and lower exhaust gas temperatures with increasing load.

Keywords: Emission characteristics; rice bran oil; fuel; biofuel.

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1. INTRODUCTION

All developing countries particularly India import crude oil to meet their energy demand. Awareness of shortage of crude oilstarted from the worldwide fuel crises in the 1970s [1]. After that significant attention was drawn to the importance of alternative fuels. Along with transportation and domestic vehicle demand of fuel in Indian agriculture increasing day by day [2,3]. India, renewable liquid fuels viz. biodiesel, ethanol etc. are gaining utmost popularity because India being an agricultural country has a huge potential of 3 billion liters/year [4]. The vegetable oils as alternative source of fuel for CI engine have been tried by various researchers across the globe and it has been found that vegetable oil perform satisfactory in unmodified diesel engine. Above all, these fuel can be readily incorporated into energy pool if the need arise due to sudden shortage of petroleum fuels. Both edible oil such as Soybean, Rapeseeds Canola, Sunflower, Cottonseeds etc. and non-edible oils like Rice bran oil, Neem, Jatropha etc. have been tried to supplement diesel fuel in various countries [5,6,7,8].

The performance of these vegetable oils in CI engine was observed satisfactory. Besides this attention towards the energy crisis, today another important concern for us is the degradation of the environment due to fossil fuel combustion [9,10]. Exhaust gases such as carbon monoxide (CO), sulphur dioxide (SO_2), and nitrogen oxides (NOx) are responsible for the greenhouse effect in the atmosphere, which in turn causes global warming [11]. That is why it is essential to develop alternative fuels with low emissions for use in diesel engines. The efficient sourcing of fuels from renewable sources is an option for meeting these challenges. Due to its availability in large volume, among all the renewable fuel sources, biodiesel can be a good option for diesel engines, especially because it is biodegradable, oxygenated, non-toxic, and environmentally friendly [12,13].

Rice is a staple food for most of the world population. Rice bran oil is extracted from rice bran, which is a by-product of rice milling process [2,13]. During this process, rice bran is separated from paddy to produce rice. As rice production is a renewable process the availability of rice bran for oil extraction is also renewable in nature. Crude rice bran oil can be extracted from rice bran and refined to make an edible oil that is consumed in some countries such as Japan and India [4,14]. Crude rice bran oil with low free fatty acid content is the feedstock for the above refining process.

Several past studies on application of rice bran oil have concluded that the performance of rice bran oil in the similar conditions exhibited a similar performance to that of diesel in a diesel engine without any operational difficulties. The heating of the rice bran oil can be used in diesel engines in rural areas for stationary applications like irrigation, processing of agricultural products, and electric generation [15].

Due to significance of biofuel in CI engine, this study aim to investigate the environmental impact of rice bran methyl ester oil and its emission characteristics in CI engine.

2. METHODOLOGY

2.1 Test Fuels and Experimental Apparatus

This study investigates the effect of methyl ester of rice bran oil blends with ethanol on engine performance and exhaust emissions. Anhydrous ethanol was used as one of the constituent of blended fuel for the experiment. Rice bran oil methyl ester was used as another constituent of the blended fuel. The ester was prepared from transesterification of the refined rice bran oil, procured from local market. The process parameters used for transesterification of rice bran oil is presented in Table 1.

Table 1. Transesterification process parameter selected to produce rice bran oil methyl ester

Sl. no.	Process parameter	Standardize value
1	Molar ratio	5:1
2	Preheating time, min	30
3	Preheating Temperature, ℃	60
4	Reaction Temperature, ℃	60
5	Reaction Time, h	1
6	Settling time, h	24
7	NaOH concentration	0.33%

Rice bran oil methyl ester-ethanol blends were prepared by blending 10 to 60 per cent ethanol with rice bran oil methyl ester in the proportions of 90:10, 80:20, 70:30, 60:40, 50:50 and 40:60 on volume basis.

A four cylinder four strokes water cooled MPFI (Multi point fuel injection-Hindustan Motors) diesel engine was used. The basic specifications of the engine are shown in Table 2. The experimental setup has stand-alone fully powder coated panel box consisting of air box, fuel tank, manometer, fuel measuring unit, digital indicators and transmitters for measuring various parameters. The engine setup is coupled to a hydraulic dynamometer with the help of shaft and coupling arrangement. The technical specifications of hydraulic dynamometer are presented in Table 3. The engine performance was tested at no load, 20, 40, 60, 80, 100 and 110 percent load by keeping the engine speed at 2000 ± 10 rpm. The load was varied by the hydraulic controller. The speed and load were recorded from digital indicator of test rig. The load on the dynamometer was measured by a cantilever type load cell which was mounted on the loading end of dynamometer, as the loading arm hits the load cell which sense the load and read out would be indicated in terms of torque in terms of torque (N-m) by the digital torque indicator.

Table 2. Specification of engine

Make	Hindustan motors
Max Brake Power (bhp/kW)	50/37.3 at 4200 rpm
Max Torque (N-m)	106 at 2000 rpm
Number of Cylinders	4
Bore x Stroke (mm)	84 x 90
Displacement Volume (cc)	498.76
Compression Ratio	21:1
Strokes	4

Table 3. Specification of hydraulic dynamometer

Make	Techno - mech
Model	TM-50
Brake Power (kW)	Upto 50 kW
Water pressure requirement	1.11 kg/cm^{2}upto 3500 rpm

2.2 Exhaust Emissions Measurement

The emissions of carbon mono oxide, unburnt hydrocarbons, carbon di oxide, oxygen, carbon mono oxide and oxides of nitrogen by different fuel blends at various loads were measured with INDUS 5 Gas Analyser PEA 205. The instrument works on the principle of no dispersive infrared for measurement of CO and CO_2 and electrochemical sensors for measurement of O_2 and NO_x.

The stainless steel probe was inserted into the exhaust pipe for suction of the exhaust gas. The gas was pumped into the analyser through probe and high pressure tube, then measurement done within the analyser and the result was displayed on the indicator. The specification of INDUS 5 Gas Analyser is shown in Table 4.

3. RESULTS AND DISCUSSION

3.1 Carbon Mono Oxide Emission

The carbon mono oxide (CO) emission from the engine on diesel and the selected blends at different loads is given in Fig. 1. It was observed that the emission of CO from the engine on diesel varied in the range of 0.016 to 0.128 per cent between no load and 110% brake load. Emission of CO for the same load conditions was found in the range of 0.013 to 0.108, 0.011 to 0.097, 0.008 to 0.058, 0.007 to 0.054 and 0.005 to 0.030 percent on the blends of rice bran oil methyl ester and ethanol of 100:0, 90:10, 80:20, 70:30 and 60:40 proportion respectively.

It was observed from the study that almost all the blends of rice bran oil methyl ester and methanol showed much lower emission of CO in comparison with diesel fuel on entire range of brake loads 0-110 percent). This reduced CO emission of blended fuel may be because of an increased combustion efficiency due to presence of additional oxygen molecules in blended fuels. [15,16].

3.2 Hydrocarbons Emission

The levels of hydrocarbon emission from the engine when operating on blends of rice bran oil methyl ester and ethanol in different proportions remained almost similar to that of diesel up to 80 percent load conditions. Fig. 2 shows the variation in HC emission with varying brake load for selected fuel blends. One can observe that emission of hydrocarbons on diesel fuel remained constant up to 40 percent brake load and then it decreases at brake loads between 40 to 60 percent. The study also indicate that at 100 percent load the emission of hydrocarbon was less on all the fuel blends as compared to diesel.

3.3 Oxides of Nitrogen Emission

The levels of oxides of nitrogen emitted from the engine operating on diesel and other selected

Table 4. Specification of 5 gas analyser

	Make	Indus scientific pvt. ltd. Banglore
1	Model and Software Version	PEA 205, V 5G-09.02
2	Gases Measured	Carbon monoxide, Hydrocarbon, Carbon di oxide, Oxygen and Nitric oxide
3	Range	Carbon monoxide: 0 to 15.00% Oxygen: 0 to 25.00% Carbon di oxide: 0 to 20.00% NO_X: 0-5000 ppm Hydrocarbons: 0-30000 ppm (Propane) : 0- 15000 ppm (Hexane)
4	Accuracy	CO: ±0.06 % Vol. CO_2: ±0.05 % Vol. Hydrocarbon: ±0.12 ppm Vol. O_2: ±0.1 % Vol.
5	Gas flow rate	500 to 1000 ml/min
6	Sample handling system	S.S. probe, PU tubing with easily detachable connectors, water separator cum filter, disposable particulate fine filter
7	Operating Conditions	Temperature: 5-45 ℃ Humidity: 0-90 % (non-condensing)
8	Dimensions (W X H X D)	340 X 130 X 240 mm

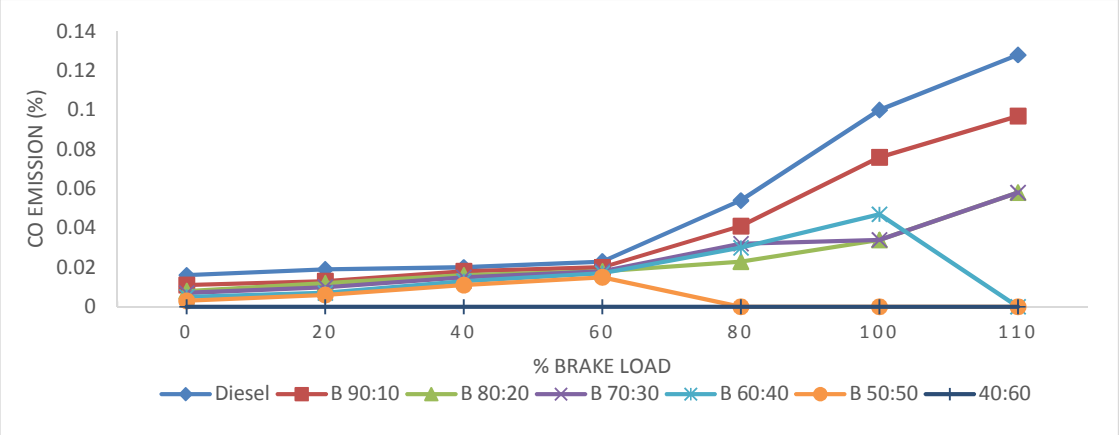

Fig. 1. Emission of CO on diesel and selected fuel blends

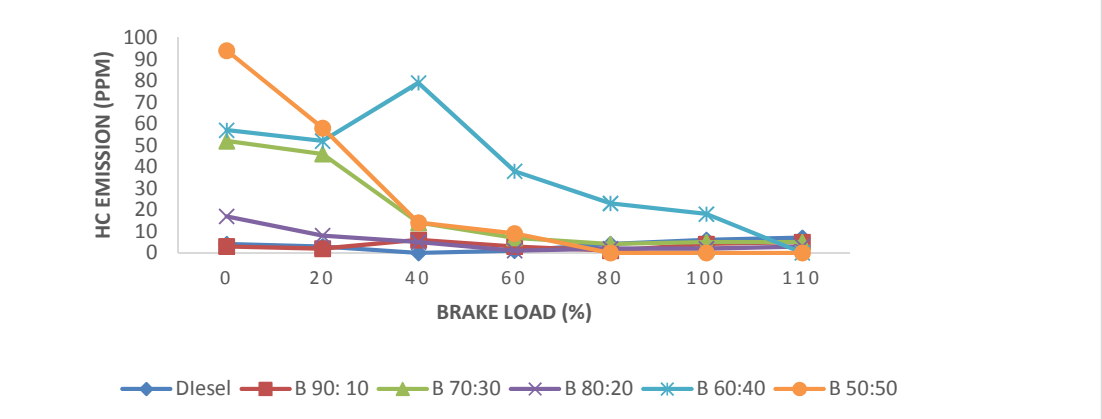

Fig. 2. Hydrocarbons emission on diesel and selected fuel blends

fuel is shown in Fig. 3. The emission of nitric oxides from the engine on diesel fuel is found to be in the range of 2 to 97 ppm at various brake loads. The NOx emission found to vary between 8 to 196, 10 to 148, 4 to 137, 2 to 110 and 3 to 64 ppm on the blends of rice bran oil methyl ester and ethanol mixed in the proportion of 100:0, 90:10, 80:20, 70:30 and 60:40 respectively between no load and 110 percent brake load. The observed values of NOxemission at full load (100 per cent load) condition was found 187, 145, 131 and 107 ppm for the fuel proportions 100:0, 90:10, 80:20 and 70:30 respectively.

It is evident from the results that emission of NOx increased with increase in brake load when the engine was operating on different blends of the rice bran oil methyl ester and ethanol. This increase in NOx emission from the engine on blended fuels is due to fact that the presence of nitrogen in the lipid compounds combine with oxygen molecules present in a vegetable oil and it may cause an increase in combustion temperature thereby enhancing the emission of NOx. However, as the amount of ethanol increases the NOx emission decreases, this may be due to decreased volume of the rice bran oil ester [17].

3.4 Carbon Dioxide Emission

Fig. 4 shows the emission of carbon di oxide (CO_2) from the engine on diesel and the selected blends at different loads. It was found that emission of CO_2 from the engine on diesel varied in the range of 3.89 to 13.03 per cent between no load and 110 percent brake load. Emission of CO_2 for the same load condition was found in the range of 3.15 to 11.34, 2.89 to 10.11, 2.89 to 10.11, 2.98 to 9.54, 2.57 to 8.29 and 3.07 to 5.84 per cent on the blends of rice bran oil methyl ester and ethanol 100:0, 90:10, 80:20, 70:30 and 60:40 proportions respectively.

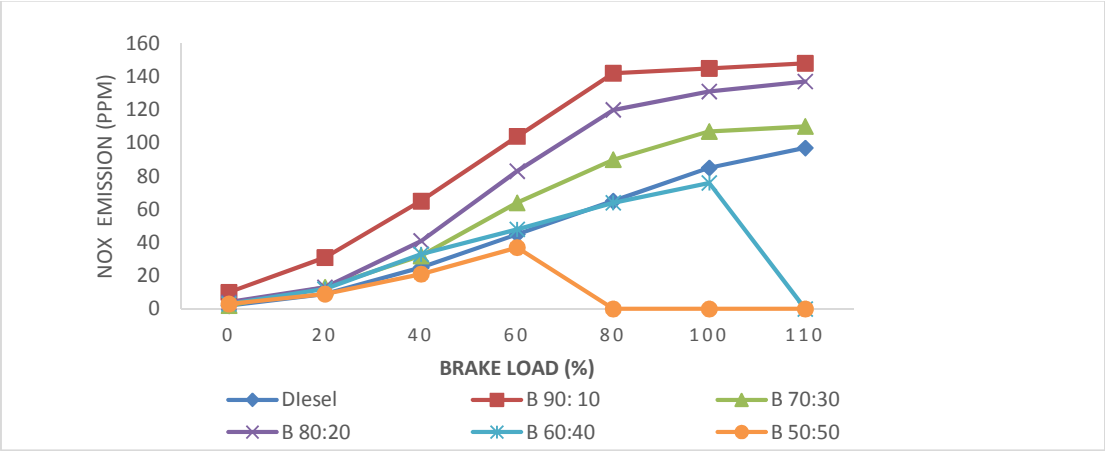

Fig. 3. Emission of NOx on diesel and selected fuel blends

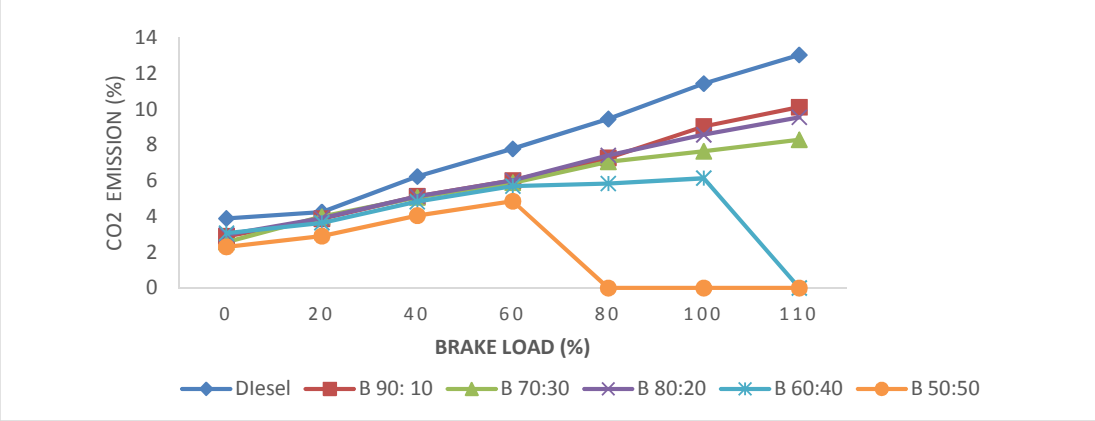

Fig. 4. Emission of CO_2 on diesel and selected fuel blends

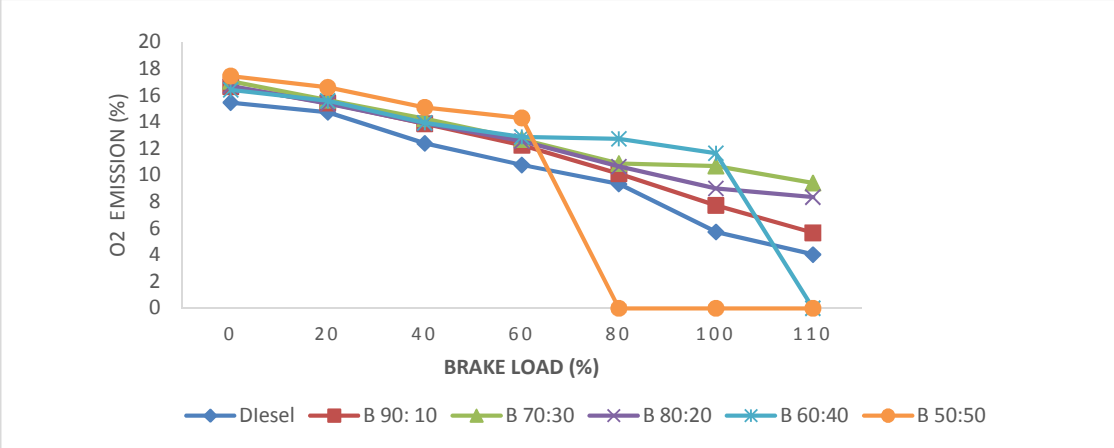

Fig. 5. Emission of oxygen on diesel and selected fuel blends

It is observed from the figure that almost all the blends of rice bran oil methyl ester and ethanol showed much lower emission of CO_2 in comparison of diesel fuel on entire range of brake loads (0-110 per cent). This reduced carbon di oxide emission of blended fuels may be due to an increased combustion efficiency as reflected in terms of comparable brake thermal efficiency due to presence of additional oxygen molecules in blended fuels [18,19].

3.5 Oxygen Emission

The oxygen emission from the engine on diesel and the selected blends is presented in Fig. 5. It was found that the emission of oxygen from the engine on diesel varied in the range of 4.03 to 15.45 per cent between no load and 110 percent brake load. Emission of oxygen for the same load conditions was found in the range of 5.40 to 16.58, 5.67 to 16.64, 8.34 to 16.70 and 9.41 to 17.04 percent on the blends of rice bran oil methyl ester and ethanol 100:0, 90:10, 80:20 and 70:30 proportions respectively.

4. CONCLUSION

The experimental results shows the emission characteristics of methyl ester of rice bran oil blends with ethanol in CI engine. It is observed from the study that almost all the blends of rice bran methyl ester and ethanol showed much lower emission of CO_2, CO, HC in comparison with diesel fuel on entire range of brake loads (0-110 percent). Only a marginal increase in NOx emission was observed. This reduced emission of blended fuels may be due to increased combustion efficiency as reflected in terms of comparable brake thermal efficiency due to presence of additional oxygen molecules in blended fuels. Thus in an automotive engine blends of rice bran oil methyl ester with ethanol has better emission characteristics than diesel. Hence efforts can be made to utilize methyl ester of rice bran oil effectively in future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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