Effect of Rice Bran Oil Methyl Ester on Emission Characteristics of CIDI Engine

Sirivella Vijaya Bhaskar, G. Satish Babu

Abstract— Ever rising prices of crude oil, dearth of conventional fossil fuel reserves, ever-growing energy demands and global erratic climatic changes due to emission of hazardous green gases, has all led to concentrated and escalating research efforts in search of environmental friendly, alternative renewable energy sources. In recent times, biodiesels have emerged as the prospective substitute to diesel fuel, as alternative energy source. This can be attributed to the abundance of feed stocks in all regions, eco-friendly nature of the bio-fuels and the ability to be easily used in diesel engines without any modifications. The present investigation aims to evaluate the emission characteristics of diesel engine fuelled with rice bran oil methyl ester (RBOME). The experimental results of single cylinder, 4-stroke, water cooled, direct injection compression ignition engine fuelled with different blends (BR20, BR40, BR60 and BR100) of RBOME and diesel have revealed that biodiesel has lower CO emission, lower smoke density, lower particulate matter and moderately higher NOx emission when compared with diesel.

Index Terms— Biodiesel, Transesterification, Rice Bran Oil, Emission Characteristics, Vegetable Oil, Methyl Ester.

1 Introduction

Today's worldwide crisis of meeting the fuel exigency, concern about diminution of fossil fuels and frightening impacts on environmental pollution has caused focus in alternative energy sources. The research reviews shows that biodiesels are the most promising and anticipative renewable energy resources to meet the energy demand as well as to reduce environmental pollution. Compression ignition (CI) diesel engines are widely used for transportation and agriculture purposes across the globe. The emission of diesel engines are one of the main causes for the severe impact on environmental pollution and consuming more fuel than any other engines which is casuing and accelerating the global energy crisis. Hence many nations have focussed their attention on research and development for an alternative source for diesel fuel.

Biodiesels are perhaps the most suitable alternative to diesel because they have almost similar chemical properties [1], nearly compatible energy efficiency with more environmentally friendliness. Moreover biodiesels can be used directly in any existing, unmodified diesel engine [2]. From an environmental standpoint, biodiesels are much better than diesel fuels in terms of sulphur content, aromatic content, flash point, and biodegradability [3]. The research literature revealed that already many countries such USA, Brazil, Australia, Italy, Canada, Germany, Malaysia, India were using various kinds of commercial biodiesels that include methyl esters of Soybeans, Rapeseed oil, Canola oil, Olive oil, Animal fat, Palm oil, Corn oil and Sunflower oil [4]-[5].

The perception of using vegetable oils as fuel in diesel engines is nearly as old as the diesel engine itself. The inventor of the diesel engine, Rudolf Diesel, reportedly used peanut (groundnut) oil as a fuel for demonstrating the engine at World's Fair in Paris in 1900. Investigation on vegetable oils for their aptness as biodiesel is those which occur abundantly in the country of testing, therefore soybean oil was of principal interest in USA as biodiesel source while many European countries were concerned with rapeseed oil, and tropical countries such as asian countries prefer to utilize coconut oil or palm oil. Other vegetable oils, including sunflower, safflower, etc., have also been investigated [6]. Furthermore, other sources of biodiesel studied include animal fats and used or waste cooking oils.

In 1981, Humke and Barsic were conducted experiments on a naturally aspirated, single cylinder DI diesel engine to evaluate the performance and emission characteristics of soybean oil and its blends with diesel and Crude Degummed Soybean (CDSO) oil. In comparison to diesel, thermal efficiency lowered, lower NOx, more CO, more hydrocarbons and more particulates with vegetable oils [7]. Recep Alton et al., have investigated the effects of vegetable oil fuels and their methyl esters (raw sun flower oil, raw cotton seed oil, raw soybean oil and their methyl esters, refined corn oil, and refined rapeseed oil) on a 4- stroke, single cylinder direct injection diesel engine. The results revealed that from the performance point of view, both vegetable oils and their esters were promising alternatives as fuel for diesel engines. Because of their high viscosity, drying with time and thickening in cold conditions, vegetable oil fuels still have problems like low atomization and heavy particulate emissions [8]. Lakshmi Narayana Rao et al., studied the combustion and emission characteristics of diesel engine fuelled with Rice Bran oil methyl ester and its diesel blends. Rice bran oil methyl ester (RBOME) was derived through the transesterification process and the properties of RBOME thus obtained were comparable with ASTM Bio-diesel standards. Tests were conducted on a 4.4 kW, single cylinder, naturally aspirated, direct injection, air cooled stationary diesel engine to evaluate the feasibility of RBOME and its diesel blends as alternate fuels. The ignition delay and its

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peak heat release for RBOME and its diesel blends were found to be lower than that of diesel and that the ignition delay decreases with increase in RBOME in the blend. Maximum heat release was found to occur earlier for RBOME and its diesel blends than diesel. It was also observed that, as the amount of RBOME in the blend increased, the HC, CO and soot concentrations in the exhaust decreased when compared to mineral diesel. The NOx emissions of the RBOME and its diesel blends were noted to be slightly higher than diesel [9]. Qi et al., have investigated the performance and combustion characteristics of diesel engine using soybean biodiesel and revealed that as the engine delivers fuel on volumetric basis and the density of biodiesel is higher than that of diesel, the power output of biodiesel engine is almost the same as diesel engine [10]. Nabi et al. have conducted experiments on diesel engine fuelled with biodiesel mixtures of cotton seed oil and found that the emissions of CO and PM were lower than that of pure diesel fuel and NOx level was higher. This is because biodiesel mixtures contain extra oxygen in their molecules that result in complete combustion of the fuel and supply the necessary oxygen to convert CO to CO2. This additional oxygen is also responsible for higher NOx emission compared to neat diesel fuel. A mixture of 70% neat diesel and 30% biodiesel significantly reduced emissions of CO, NOx and particulate matter. The reduction of NOx with biodiesel may be possible with the proper adjustment of injection timing and using exhaust gas recirculation technique [11]. For both 100% biodiesel and 100% petroleum diesel, a narrow range of reductions of emissions were observed for CO and HC, but CO2 emissions from using biodiesel and diesel fuel were at almost similar levels [12].

2 Materials and Methods

For the present study, the rice bran oil, methanol, sodium hydroxide and distilled water were used as raw materials. Generally vegetable oils have more viscosity, low volatility and it needs transesterification process which is a benchmark in order to reduce the viscosity, improve the performance of vegetable oil, and eventually prepare biodiesel from oil/fats. The same process was adopted for the present study and prepared rice bran oil methyl ester (RBOME) which was used in CIDI engine as biodiesel.

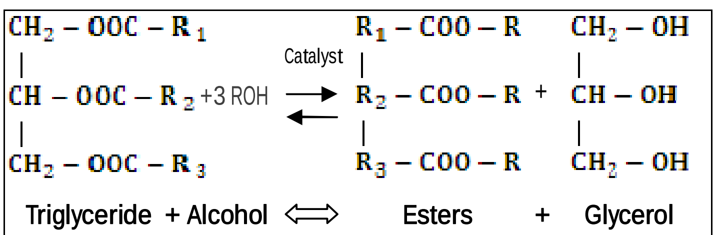
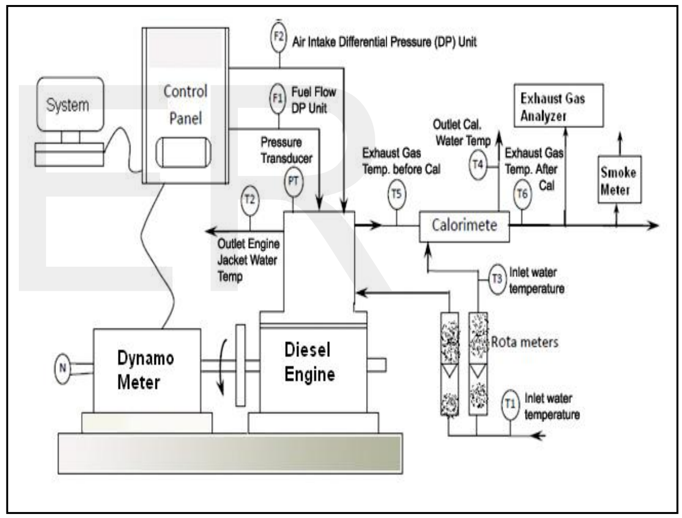


Fig 1. Chemical Process of Transesterification Process

Transesterification is the reaction of fat/oil triglycerides to fatty acid alkyl esters and low molecular weight alcohols in the presence of catalyst [13]- [14] as shown in Figure 1. Short-chain alcohols such as methanol, ethanol, and butanol are the most frequently employed in the transesterification process. Methanol is the most widely used alcohol as it is less expensive and easily obtainable [15].

TABLE 1
Fuel Properties

Fuel Property	Unit	ASTM Standards	Diesel	RBOME
Kinematic Viscosity @ 40^{0}C	Cst	D445	3.52	5.37
Flash Point	^{0}C	D93	49	165
Density @ 15^{0}C	kg/m^3	D1298	830	880
Calofic Value	kJ/kg	-	42000	38952
Cetane Number	-	D613	50	52
Ash	% by mass	D1119	0.01	Nil



Methanol produces methyl esters, ethanol produces ethyl esters and is base catalyzed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, but either base can be used for methyl ester production.

3 Experimental Setup

For the present study, a 5 HP Kirloskar diesel engine was used as it's a widely used engine in agriculture and small to medium scale industrial purpose. The experimental setup consisted of a single cylinder, 4-stroke, water cooled 3.7 KW diesel engine. An eddy current dynamometer was used as loading unit. The instrumentation available in the test rig are used to measure air consumption, fuel consumption, cooling water flow rate, cylinder pressure, exhaust gas temperature. A separate gas analyzer was used which was coupled to the computerized test rig to measure CO, and NOx emissions. A smoke meter was used to measure the smoke density. An oblique manometer was used to measure air consumption. The lubricating oil, fuel and ambient temperatures were measured by thermocouples. The computed values were recorded by considering the error analysis of the respective devices. The schematic diagram of experimental setup is given in Figure 2. The specifications of the engine are given below in table 2.

TABLE 2
SPECIFICATIONS OF TESTING ENGINE

Type	Kirloskar Engine
Engine Details	Single cylinder, 4-Stroke, Compression Ignition, Water cooled engine
Injection System	Direct injection
Bore & Stroke	80 × 110 mm
Rated Power	3.7 KW at 1500 rpm
Compression Ratio	16.5 :1
Speed	1500 rpm

The engine was initially operated with diesel for 15 minutes and once the engine has warmed up, then a series of emission tests were conducted with different load conditions while recording the readings. Subsequently, the same was repeated using different blends of rice bran oil methyl esters and the readings of each blend for different load conditions were recorded. For each operation, speed of the engine was verified and maintained almost constant. Each experiment was repeated with similar operating condition and each reading was recorded as arithmetic mean of two readings for accuracy. The test data was then analyzed using graphs and results are given in the subsequent paragraphs for each emission parameter. The emission parameters of CIDI engine analyzed in the present investigation were Carbon Monoxide (CO), Smoke Desnity, Particulate Matter (PM) and Oxides of Nitrogen oxide (NO).

4 RESULTS AND ANALYSIS

4.1 CO Emission

The variation of CO emission with load (%) for diesel and different blends of RBOME at constant speed of the engine was illustrated in Figure 3. The CO emission is found to increase with the increase in load and decrease with increase in percentage of methyl ester of rice bran oil (RBOME) in biodiesel blend. It was observed that the percentage of carbon monoxide in all the blends was found to be low at all load conditions when compared with diesel fuel. It was also noted that RBOME biodiesel releases CO emission almost an average of 40% less than diesel and for every 20% addition of RBOME in biodiesel blend, the CO emission is reduced by an average of 12-13%. Since RBOME is an oxygenated fuel, it leads to enhanced fuel combustion resulting in the decrease in CO emission, as CO is mainly formed due to the inadequate quantity of oxygen to form CO_2.

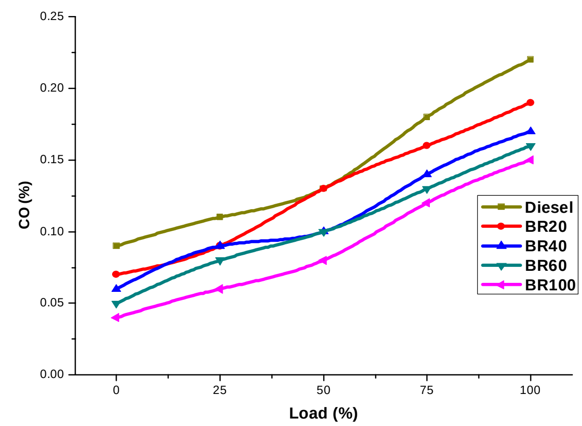


Fig. 3. Load vs. CO Emission

The graph shown in Figure 4 indicates that neat biodiesel has low CO emission and diesel has the highest in comparison to all the RBOME blends. CO is mainly formed due to the lack of oxygen and biodiesel is an oxygenated fuel, so it leads to enhanced fuel combustion that resulting in the decrease in CO emission.

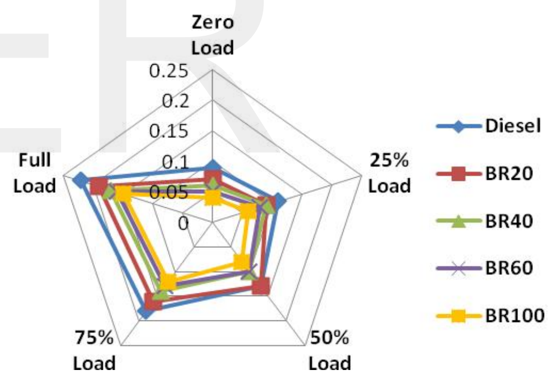


Fig. 4. Load (%) and CO Emission

4.2 Smoke Density

The variation of smoke density of diesel and biodiesel blends for different loads is graphically represented in Figure 5. The graph illustrates that the smoke density of neat biodiesel (BR100) is more than 20% less than diesel fuel and increases with the increasing of load for all blends and diesel. It is observed that smoke density decreases by 6% with the increase of every 20% of RBOME in biodiesel blend.

As shown in Figure 6, the graph confirms that the BR100 has very low smoke density and diesel has highest among all the RBOME blends. Past researcher reviews have revealed that that biodiesels are oxidized fuels, and releases less smoke density than petroleum diesel [16].

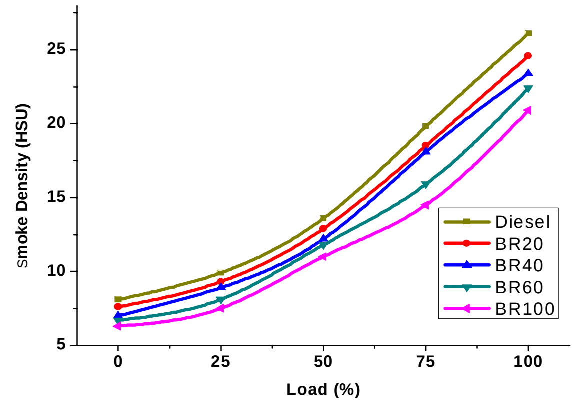


Fig. 5. Load vs. Smoke Density

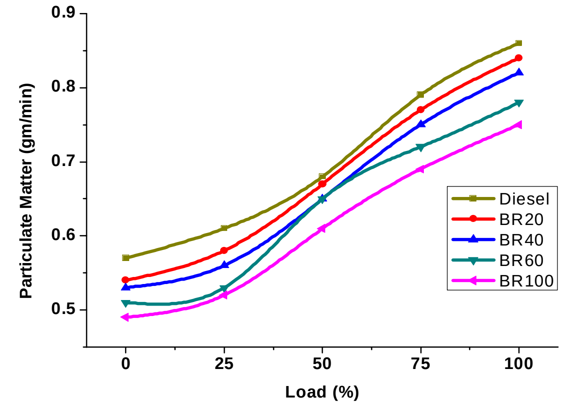


Fig. 7. Load vs. Particulate Matter

This is because the oxidation of biodiesel improves fuel combustion and may lead to fewer unburnt fuel particles impinging on cylinder walls.

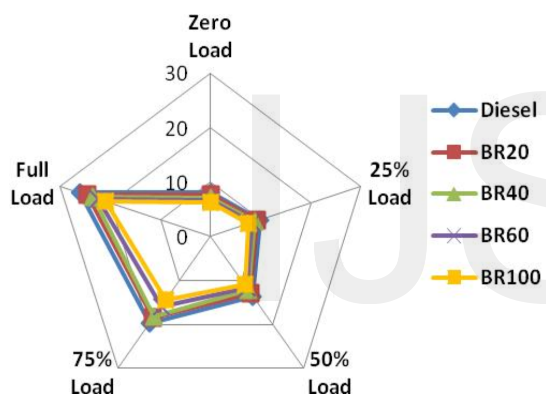


Fig. 6. Load and Smoke Density

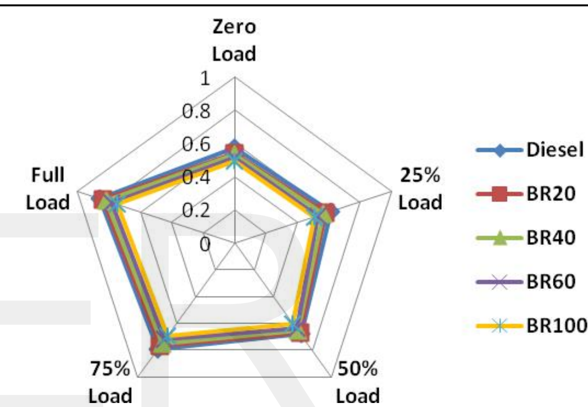


Fig. 8. Load and Particulate Matter

4.3 Particulate Matter (PM)

Figure 7 shows the variation of particulate matter with respect to the load for diesel fuel and RBOME blends at constant speed of the engine. The particulate matter, also known as particle pollution rises with the increasing of load for diesel and all blends of RBOME but shows reduction with the increase in percentage of RBOME in biodiesel. Particle pollution decreases by about an average of 13% of neat RBOME when compared with neat Diesel and falls by around 3-4% for every 20% addition of RBOME in the blend. The graph represented in Figure 8 demonstrates that the particle pollution of neat RBOME is very low compared to neat diesel fuel and diesel has releasing highest particulate matter in comparison to all the RBOME blends.

The graph represented in Figure 8 demonstrates that the particle pollution of neat RBOME is very low compared to neat diesel fuel and diesel has releasing highest particulate matter in comparison to all the RBOME blends.

4.4 NOx Emission

The variation of NOx emission with biodiesel blends and diesel for different load conditions is graphically depicted in Figure 9.

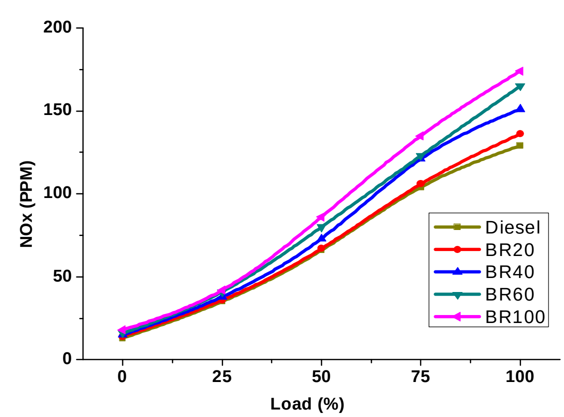


Fig. 9. Load vs. NOx Emission

It is observed that NOx emission increases with the increase in load for all fuels at constant speed of the engine and increasing with the increase in percentage of RBOME in biodiesel blend. At partial load conditions, the variation of NOx emission of both biodiesel and diesel are comparable. At medium and full load conditions, NOx emission of RBOME is distinct with neat biodiesel (BR100) having higher values than diesel and their blends. The NOx emission of neat RBOME biodiesel was higher than diesel by an average of 23-24% and increased by an average of 7% for every 20% addition of RBOME percentage in the biodiesel.

The graph shown in Figure 10 reveals that the BR100 has very high NOx emission than diesel because RBOME blends have higher oxygen content than diesel. This results in enhanced combustion of fuel that increases the temparature of the combustion chamber, causing increase in NOx emission.

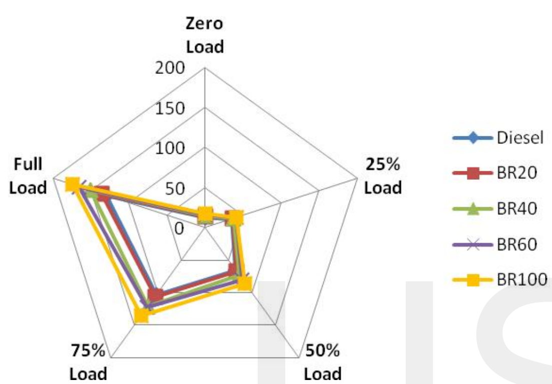


Fig. 10. Load and NOx Emission

4 Conclusion

An experimental evaluation was conducted on single cylinder, 4-stroke, water cooled, compression ignition direct injection engine using diesel, rice bran oil methyl ester (biodiesel) and its blends (BR20, BR40, BR60 and BR100). The results confirmed that all tested emission characteristics of biodiesel (CO, smoke density, PM) except NOx were less when compared with diesel fuel. NOx emission of neat biodiesel was found to be higher than petro-diesel and all its blends. As a result of transesterification, biodiesel are oxygenated fuel and supports better combustion that results less CO emission, less smoke density and reduces the emission of particulate matter. Methyl esters with their lower stoichiometric air-fuel ratio can burn biodiesel with less air that causes increase in NOx emission and increases with increase in percentage of methyl esters in the RBOME blends. All emission characteristics were increased with the increase of load at constant engine speed. Test results corroborated that biodiesel prepared from rice bran oil can be directly used in diesel engine without modifications and were eco-friendly in nature. It was also observed that as the proportion of rice bran oil methyl ester in the biodiesel was increased, the engine emissions were decreased.

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