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Article

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Comparative evaluation of the performance of rice bran and cotton seed biodiesel blends in VCR diesel engine

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Abstract

In the country like India, it is very advantageous to use the cotton seed oil and rice bran oil as the primary source for producing the biodiesel, as India is known as the larger producer of these seeds in the universe. This current research mainly focuses on the emission and performance of the cotton seed oil and rice bran oil for the effective utilization of biodiesel. The chemical properties of rice bran, cotton seed methyl ester were established and the properties of 5%, 10%, 15% and 20% blends known as B5, B10, B15 and B20 are measured. The blends of biodiesel were evaluated at 0, 3, 6, 9 and 12 kg of load and at a compression ratio of 15, 16, 17 and 18. Engine performance test results shows that the B20 blends of MECISO (Methyl ester cotton seed oil) and MERBO (Methyl ester rice brown oil) produce slightly less BP and more BSFC values compared to diesel. B20 (MECISO and MERBO) reduces carbon monoxide emission by 18.4% and 17.5% and also hydrocarbon emission by 3.86% and 3.13% compared to diesel. B20 blends of MECISO and MERBO produce low emissions than diesel, thus these fuel blends be the replacement of diesel in the standard diesel engine to cut down the worldwide energy demand and to reduce the environmental pollution hazards.

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Keywords: Cotton seed oil; Rice bran oil; Variable compression ratio; Cetane number; Methyl ester cotton seed oil; Methyl ester rice bran oil; Brake thermal efficiency; Brake specific fuel consumption; Emissions

1. Introduction

For the growth of the major sectors like agriculture, transport, and manufacturing industries and also to meet the other major needs of human, the petroleum fuels act as a major role in these developments. Globally fossil fuels are used almost 11,000 million tons per year. Due to this consumption, the resources will be drained very soon [1]. While the need of the energy increases, the environmental effect of its production also increases. The combustion and ignition of these fuels are the fundamental cause for the human health and other pollution hazards

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of the atmosphere [2]. Performance and environmental benefits are realized by the use of biodiesel over the non renewable fuels in the engines with regard to the ignition quality and to lower green house gas emissions [3]. The usage of biodiesel among the public is less due to the unawareness of the biodiesel benefits [4]. Due to the high cost of the biodiesel it has not reached out more to the people for using biodiesel in the diesel engines and thus reduces the pollution problems to save the environment. This may be overcome only by the government support in terms of subsidies [5].

1.1. Literature review

Gopinath [6] have conducted experiments, with cotton seed biodiesel in the diesel engine and they concluded that it leads to higher NO_x, lower HC and CO. Kassaby [7] with the experiment on VCR engine by using waste cooking oil, report increase of BTHE (Brake thermal efficiency), CO₂, NO_x and reduction of HC and CO and state that they are because of increase in compression ratio. Saravanan [8] have studied that CI engine with crude rice bran methyl ester and they have found the reduction in BTHE, CO and HC. Banapurmath [9] have conducted the test on CI diesel engine with rice bran, neem and honge biodiesel with producer gas and they have found that BTHE is lower. Muralidharan [10] have conducted the emission analysis of the waste cooking oil on the VCR engine and is observed that CO, HC, CO₂ are lower and NO_x is higher. Bora [11] have conducted the test on diesel engine with pongamia, palm and rice bran biodiesel along with bio-gas, it results in reduction of CO and HC. They have found that rice bran oil gives better performance compared to all biodiesel blends. Sharma [12] conducted tests on VCR diesel engine with pyrolysis of waste tyres biodiesel. They found that when increasing the compression ratio BSFC increases and BTHE decreases. Kaimal [13] conducted the test on diesel engine with plastic oil and rice bran oil. They found that thermal efficiency was lower for plastic oil, rice bran biodiesel compared to diesel. The above review of literature has concluded that biodiesel decrease the emission without compromising much on performance, thus in our current work we propose to investigate the comparative evaluation of the cotton seed oil and rice bran oil in the VCR diesel engine with respect to performance and emission.

1.2. Objective of the paper

The production of MECISO and MERBO biodiesel and its potentiality for usage in IC engines have been analyzed only by few authors. Hence, there is a lack of detailed report on the comparative interpretation of the performance of MECISO and MERBO in the diesel engines. The major objective of the current research is to evaluate the 20% of MECISO and MERBO with 80% of diesel fuel. The fuel properties are characterized for biodiesel and their various blends. Finally, the engine performance and the emission of various blends of biodiesel have been found experimentally using a VCR diesel engine.

2. Biodiesel production

For producing biodiesel from various feed stocks the investigators and the industrialists have upgraded most of the technologies. For using the biodiesel in typical diesel engine without modification, vegetable oils must endure some techniques and strategies to convert it into the biodiesel. There are various technologies used to produce a good standard of biodiesel. Transesterification of oils is known as the promising technique for the production of biodiesel from the raw vegetable oils. Table 1 shows the various steps involved in biodiesel production.

Table 1. MECISO AND MERBO production steps [14–16].

Activity	Guidelines
Production process	Transesterification method
Selected oil	1 L of CSO and RBO
Reactant, catalyst	250 ml of methanol, 13 g of potassium hydroxide
Reaction period, temperature and speed	1 h, 60 °C and 600 rpm
Settling time and washing period	15 h and 5 times
Final heat-up and product	103–105 °C, Methyl ester

The produced fuels MERBO and MECISO were combined with diesel by using homogenizer that have been regulated at the speed of 2000 rpm for 20 min. The properties of the tested fuels were characterized as per ASTM

Table 2. Fuel properties and measuring instruments.

Properties of fuel	Measuring device and standard
Viscosity	Red - wood viscometer & ASTM D445
Density	Hydrometer & ASTM D941
Calorific value	Bomb calorimeter & ASTM D240
Flash and fire point	Penkys martins apparatus & ASTM D93
Cetane number	Ignition quality tester & ASTM D613

Table 3. Properties of biodiesel and diesel.

Properties	MERBO	MECSO	Diesel
Calorific Value (MJ/kg)	39.94	40.02	45.21
Cetane Number	54.0	54.2	51.0
Density (kg/m ³) @ 15 °C	890	875	815
Viscosity (mm ² /s) @ 40 °C	5.8	5.4	2.57

Table 4. Properties of MERBO and MECO biodiesel blends.

Properties	MERBO				MECSO			
	B5	B10	B15	B20	B5	B10	B15	B20
Calorific value (MJ/kg)	44.75	44.68	44.42	43.76	44.98	44.39	44.43	44.53
Cetane Number	50.88	51.30	51.45	51.06	51.14	51.39	51.49	51.86
Density (kg/m ³) @ 15 °C	814.3	822.5	826.3	838.9	813.6	821.0	824.0	826.7
Viscosity (mm ² /s) @ 40 °C	2.70	2.89	3.05	3.27	2.68	2.85	2.99	3.11

norms. To evaluate the biodiesel properties [Table 2](#) shows the standards and equipments utilized in this research. The [Tables 3](#) and [4](#) represent the properties of diesel, MECO and MERBO. Hence the test result shows that blending of biodiesel with diesel has an improvement in the final properties of the blends to be used in the engines.

2.1. Engine test setup

Kirloskar, single cylinder, four-stroke, diesel engine with rated power of 3.5 kW and speed 1500 rpm is used for the current research. The engine is operated without load, till the steady state condition is attained and then it is allowed to run for 20–30 min for testing at different loads. Stop watch is used to measure the fuel consumption and fuel measuring burette is used. The time duration for the fuel consumption of 0cc–20cc is measured. Initially engine is operated with diesel and after several minutes the same test procedure is repeated with biodiesel blends. These tests are evaluated at various loads from 0 kg to 12 kg at different CR 15, 16, 17 and 18. The blends chosen for the research study are diesel with MECO blends and diesel with MERBO blends and they are presented in [Table 5](#). For the engine performance and emission tests, for a clear graph interpretation 0 kg is not considered.

Table 5. Nomenclature of MERBO and MECO fuel.

Name of the fuel	Fuel composition (MECSO)	Fuel composition (MERBO)
B0	Diesel 100%	Diesel 100%
B5	5% MECO & 95% Diesel	5% MERBO & 95% Diesel
B10	10% MECO & 90% Diesel	10% MERBO & 90% Diesel
B15	15% MECO & 85% Diesel	15% MERBO & 85% Diesel
B20	20% MECO & 80% Diesel	20% MERBO & 80% Diesel

3. Engine performance and emissions analysis

3.1. Brake power (BP)

The variation of BP with loads at CR18 for diesel and various blends are represented in [Fig. 1](#). At tested load (12 Kg) at CR 18 the average brake power obtained for B0, B20 (MECSO) and B20 (MERBO) were 2.9 KW, 2.44

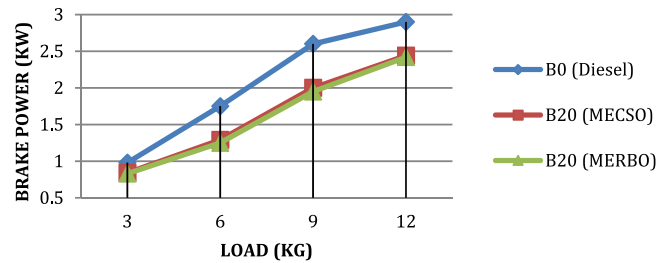


Fig. 1. Variation of Brake power with load at CR18 for different blends.

KW and 2.42 KW respectively. MECSO and MERBO blends produce less brake powers at 15.86% and 16.55% while comparing with the brake power of diesel. It is observed that when the engine load and compression ratio increases BP also increases steadily for all tested fuels. The brake power for biodiesel decreases due to the low calorific value and high viscosity as found out by other researchers. The trend represents that the power in diesel engine decreases while the concentration of biodiesel increases. It is noticed that while comparing MERBO to the MECSO, the MECSO has 0.82% higher brake power.

3.2. Brake thermal efficiency (BTHE)

Fig. 2 represents the effects of BTHE at different loads at CR 18 for various blends. BTHE is known as the fundamental framework for IC engines. If the BTHE is higher, it means the fuel combustion is proper and the fuel is efficiently utilized, thus it drives to reduce the fuel consumption. While comparing the brake thermal efficiency of diesel, B20 (MECSO) and B20 (MERBO) blends have produced lesser efficiency by 4.13% and 4.35% respectively this may be due to biodiesel blends contains high oxygen content, lesser heating value and high viscosity. It is noticed that MECSO has 0.23% more brake thermal efficiency compared to MERBO, and also all biodiesel blends have low brake thermal efficiency than diesel. Biodiesel contains higher Cetane number that helps improve the fuel ignition performance. As the result of the high power produced at higher loads it steadily increase the BTHE with increase of loads. BTHE increased with increase of compression ratio.

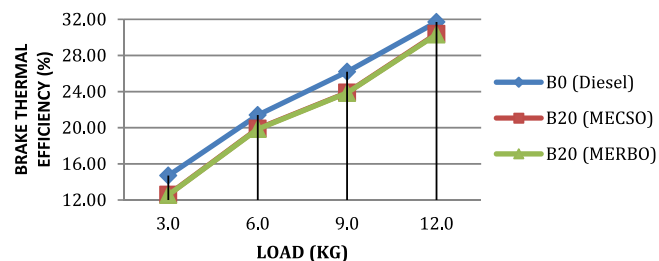


Fig. 2. Variation of Brake thermal efficiency with load at CR18 for different blends.

3.3. Brake specific fuel consumption (BSFC)

The BSFC at various loads with CR 18 for various blends are shown in Fig. 3. From the graph it is noticed that when the engine load increases the BSFC decreases. The BSFC increases by 17.1% and 18.3% for B20 (MECSO) and B20 (MERBO) compared to B0. The biodiesel blended fuel shows more BSFC value compared to diesel. The lesser calorific value of B20 blends results in high fuel consumption. When CR increases from 15:1 to 18:1 the BSFC is decreasing due to better combustion. The MECSO blend indicates the lower fuel consumption by 1.4% due to the lesser viscosity and density compared with the MERBO.

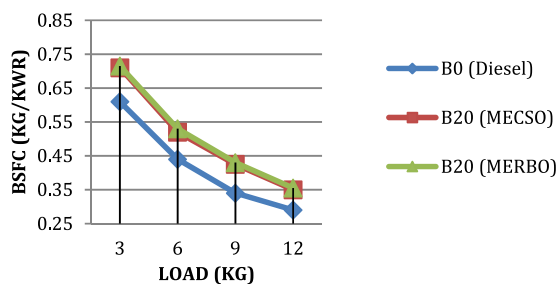


Fig. 3. Variation of Brake specific fuel consumption with load at CR18 for different blends.

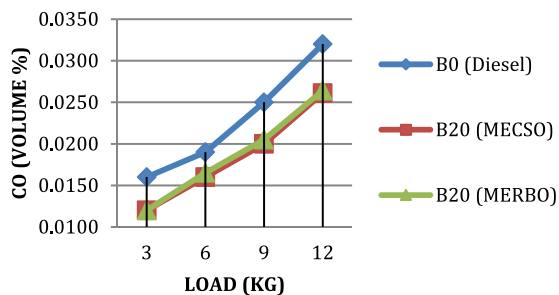


Fig. 4. Variation of Carbon monoxide with load at CR18 for different blends.

3.4. Carbonmonoxide (CO)

Fig. 4 represents the variation of CO emissions at CR 18 with different load for various blends. When the load increases from 0 kg to 12 kg, the CO emission is increased for all the tested blends, this may be due to the higher amount of fuel consumed that leads to high fuel air mixture. B20 of MECSO and MERBO have produced CO emission lower by 18.4% and 17.5% when compared to the diesel. This may be because of higher Cetane Number in renewable fuel as it has good ignition properties. Complete fuel combustion happen as it allows a higher extent of carbon molecules burn completely due to the higher oxygen content in the biodiesel. It is observed that MECSO has 1.0% lower CO emission compared to MERBO and MECSO has a good atomization due to the lesser density and viscosity. For all tested blends, when the CR increases the cylinder air temperature would increase, which would decrease the delay period and ensure complete burning of the fuel, resulting in less CO emissions.

3.5. Carbon dioxide (CO₂)

Fig. 5. shows the variations of CO₂ emissions at CR18 with different loads and blends. When the engine load is increased, CO₂ emission increases because of the higher fuel consumption. B20 (MECSO) and B20 (MERBO) blends produced CO₂ emission higher by 14.0% and 13.1% compared to the diesel. When the diesel engine burn

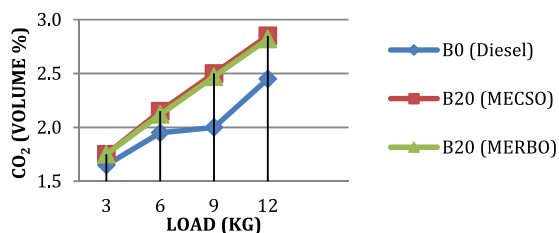


Fig. 5. Variation of Carbon dioxide with load at CR18 for different blends.

with the biodiesel, CO₂ emission increases because of biodiesel have higher oxygen content and this may lead to complete combustion. In this process it is observed that the MECSO have 1.0% greater CO₂ emission compared to MERBO. CO₂ emission from renewable fuel may be utilized by the trees and plants to retain CO₂ level at constant in the atmosphere.

3.6. Unburnt hydro carbon (HC)

Fig. 6 indicates the variation of HC emissions with different biodiesel blends at CR18. The HC emissions are lower when the load is lower for all the experimented biodiesel blends and diesel. B20 (MECSO, MERBO) blends have produced lower HC emissions by 3.86% and 3.13% respectively compared to the HC emission of diesel. High Cetane Number in biodiesel may reduce the HC emission. When the biodiesel blend increases it results in the reduction of HC emission. It is due to presence of higher oxygen content in the biodiesel that produce good combustion. It is observed that MECSO has 0.75% lower HC emission compared to MERBO.

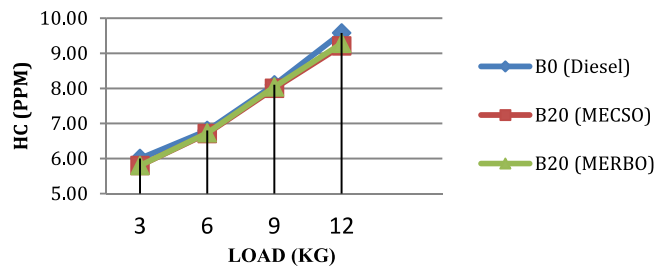


Fig. 6. Variation of Unburnt hydro carbon with load at CR18 for different blends.

3.7. Oxides of nitrogen (NO_x)

The production of NO_x emissions with different loads for various blends at CR 18 is represented in Fig. 7. B20 (MECSO, MERBO) blends have produced higher emissions by 8.0% and 8.25% respectively compared to the NO_x emission of diesel. Because of the vegetable based oils contain small amount of Nitrogen, all tested biodiesel blends have more NO_x emissions compared to diesel. As an engine load increases, cylinder combustion temperature increases and the resulting higher adiabatic flame temperature results in increase of NO_x emission. It is realized that MECSO has 0.26% lesser NO_x emission while comparing to the MERBO. MERBO contains high unsaturated fatty acid and supplementary oxygen which may be accountable for additional NO_x.

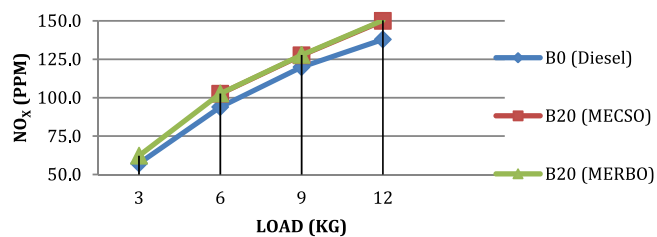


Fig. 7. Variation of Oxides of nitrogen with load at CR18 for different blends.

4. Conclusions

From the experimental results it is found that there is an increase in BSFC by 17.1% and 18.3% for B20 (MECSO and MERBO) compared to B0. On the other hand, 1.4% less in MECSO compared to MERBO. When the engine operates with both biodiesel blends the performance characteristics like BP and BTHE are similar with very minimal difference and this is due to similar properties of tested biodiesel blends. The emission parameters of CO and HC for B20 (MECSO, MERBO) blends are lower by 18.4%, 17.5% and 3.86%, 3.13% respectively compared to diesel. The MECSO and MERBO have same performance and emission characteristics which could be the substitute for the fossil fuel in the standard diesel engine for reducing the exhaust emission in the environment. Further research work can be conducted by using the dual biodiesel blends and by adding fuel additives to reduce the NO_x emissions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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