International Journal of Multidisciplinary Research and Growth Evaluation.

Research on the combustion, performance, and emission characterization of DI engines powered by diesel/biodiesel blends as well as experimental investigations on the biodiesel production parameters optimization of sunflower, soybean oil and cotton seed oil mixture

Musumba Mark [1*], Ntakirutimana Mugisha David [2], Om Prakash Shukla [3]

[1] Research Scholar Department Of Mechanical Engineering, Parul University, Limda, Waghodia Road, Vadodara, Gujarat, India

[2] Department of Biochemistry, Faculty of Science, the Maharaja Sayajirao University Of Baroda, Vadodara, India

[3] Assistant Professor, Department Of Mechanical Engineering, Parul University, Limda, Waghodia Road, Vadodara, Gujarat, India

* Corresponding Author: **Musumba Mark**

Article Info

ISSN (online): 2582-7138
Volume: 03
Issue: 06
November-December 2022
Received: 04-11-2022;
Accepted: 25-11-2022
Page No: 516-522

Abstract

The effects of various engine loads and a constant speed of 1500 rpm on engine combustion, performance, and exhaust gas emissions have been studied through experimental testing. Volumetric mixtures of biodiesel and diesel A single cylinder diesel engine was designed to run on D70B30 (70% diesel and30% biodiesel), D50B50 (50%diesel and 50 % biodiesel), and D30B70 (30% diesel and 70% biodiesel). The engine findings demonstrate a 34.8% decrease in the rate of change of CO for D50B50 when compared to diesel fuel. Due to biodiesel's low calorific value and shorter ignition delay, greater percentages of biodiesel blends result in a modest fall in maximum cylinder pressure. the HRR difference between biodiesel blends and diesel fuel. HRR was around 31.7, 52.4, and 63.5 (J/deg) for 10%, 30%, and 60% of the maximum engine power, respectively. For diesel fuel, D30B70 had the biggest reduction in HC emissions, which was roughly 4.18%. Blends of biodiesel have higher NOx emissions than pure biodiesel. Diesel and biodiesel operations had fairly comparable combustion onset and burn times. CA50 for biodiesel was delayed by 0.4 CA under both operating circumstances. The BTE of the engine decreased by around 0.6% when biodiesel was used as fuel. While this was happening, gains of around 2%, 11%, and 17% in BSEC, BSFC, and volumetric BSFC were noted. Comparing exhaust mass flow suggested that using biodiesel fuel could help engines operate at high altitudes with less fresh air usage 20% methanol and 0.75% To produce a maximum of 77% biodiesel, sodium hydroxide was mixed. The engine experiment findings showed that all biodiesel mixes decreased exhaust emissions, including carbon monoxide (CO), particulate matter (PM), and smoke emissions. However, the emissions of nitrogen oxides (NOx) from biodiesel blends did marginally increases.

Keywords: Biodiesel, Sunflower oil, Soybean oil, Cottonseed oil, Performance, Emission, Transesterification

1. Introduction

The increase in automobiles led to the widespread concern about cars running on traditional fossil fuels and about the deteriorating air quality in cities, which leads to pollution. These have prompted a search for more cost effective, renewable, and eco - friendly benign fuels. Numerous studies have been directed at the idea of utilizing alternative fuels in place of traditional fossil fuels as a result of increased awareness of energy and environmental issues [1]. Among these, biofuel made from vegetable oils found promising since it results in no Sulphur compounds and reduced carbon dioxide output when blended with diesel as fuel additive [2].

Having a strong cetane number and stability for transit and storage is another benefit. Chemically, biodiesel is a blend of mono-alkyl esters produced by the transesterification of long chains of fatty acids in the presence of a catalyst and possessing characteristics similar to those of diesel [3]. Therefore, it may be replacement for diesel oil in CI engines without needing major changes. Researchers' focus is directed to the CI engine's contribution to the addition of Green House Gases, which, out of total emissions, increased by about 25%, according to one result [4]. Some of these pollutants, such NOx, HC, and CO, have a direct negative effect on health, whereas ozone is a secondary pollutant that interacts with the atmosphere and puts people at danger [5]. Due to rigorous exhaust gas laws, it was challenging to simultaneously minimize smoke and NOx as a function of engine performance, although this is one of the main environmental protection concerns. Alternatives to CI engines include biofuels like alcohols and biodiesel [6]. Biodiesel makes the claim to be a replacement for diesel since it is harmless, biodegradable, and may reduce harmful emissions and CO2 release from the engine when used as a fuel. Particulate matter (PM) is one of the main byproducts of the combustion process in diesel engines [7]. PM is mostly to blame for respiratory tract diseases in people. More oxygen can help cut the amount of PM in the combustion chamber, and biodiesel's higher oxygen content minimizes PM to some level. Some of them have extremely rapid yearly growth, including China (1.3 Mt), Argentina (1.1 Mt), Canada (0.83 Mt), Thailand (0.69 Mt), Colombia (0.42 Mt), and India (0.35 Mt) [8]. The remaining other planet is equivalent to around 1.2 Mt. Methane consumption in natural gas typically ranges from 68 to 96% and ethane consumption from 3 to 30%. Natural gas is composed of 90% methane (CH4), a combination of other gases, like ethane (C2H6), propane (C3H8), carbon dioxide (CO2), and hydrogen, depending on the origin gas fields (H2). The application of natural gas as a fuel for vehicles is endorsed by the aforementioned number of justifications [9]. The oxygen in methanol's structure lowers its calorific value to 18500 kJ/kg. In essence, the energy density of biodiesel is very similar to that of typical diesel [10]. By trans-esterifying of sunflower, soybean and cottonseed oil and methanol in the presence of acid catalysts, biodiesel may be produced. Biodiesel has a greater viscosity (1.9 to 6.0 cSt) and has been observed to cause gum development on injectors, cylinder liners, and other components when utilized in 100% pure form [11]. There are four methods for using fresh vegetable oils in a diesel engine. Transesterification is the most popular and best process for using neat vegetable oils of the four. Mahua is likely India's second most well-known tree, after mango. Aside from oil, flower and fruit produce high economic rewards. Almost every component of the Mahua tree is for sale. As a "clean energy source," biodiesel can replace fossil fuel [12]. It can help the environment by lowering CO2, SO2, CO, and HC levels. There are various non-edible oils found in India, including Jatrofa (Jatrofa curcas).

2. Apparatus and methodology

2.1 Engine's specification

To conduct the experiments, a four-cylinder, four-stroke, naturally aspirated, indirect injection, water-cooled CI engine was employed. Table 1 listes the engins specification.

Table 1: Engine's specification

Particulars	Specification
Make & Model	Stride Engine 1.5 E2 DSL make
General Details	Four strokes, Four-cylinder, Compression ignition,
Bore	73 mm
Stroke	88.9 mm
Capacity	1489 cm^3
Compression Ratio	23:1
Max. Power	26.6 kw@4000 rpm
Max. Torque	8.5 kg at 2250 rpm
Clearance Volume	16.913 cm3 / cylinder

2.2 Methodology

The experiments outlined in this paper were carried out using an on-board engine bench system that included an engine dynamometer, a combustion test subsystem, and an emission measuring subsystem. The CW440D eddy-current dynamometer was used in this system to regulate the rotation speed and torque of the test engine. Engine speed and torque control resolutions were 1 r/min and 1 N m, respectively [13]. To simulate typical operations of heavy-duty trucks in urban and country driving, two operating conditions, 244 N m at 1200 r/min and 528 N m at 1800 r/min, were chosen to represent high-load output at low and high speed, respectively. Besides the in-cylinder pressure measurement, no changes were made to the engine [14]. When the test engine was fueled with diesel and biodiesel, the engine calibration held steady. When the engine was fueled with diesel or biodiesel, the SOI and rail pressure of the common-rail system stagnated. However, because of the comparatively low heat value, biodiesel operation needed a longer injection period when the engine was controlled at fixed torque. Hence, with fixed brake torque, the injection length of biodiesel was longer than diesel. The thermal efficiency of brakes in this article was calculated using the first law of thermodynamics. An overall average of at least 50 cycles was used to calculate the gross heat release rate and fuel mass burning. Three times FFT (Fast Fourier Transform) smoothing was performed to remove the unwanted variation in the heat release curvatures. Soybean oil, cottonseed oil and sunflower oil were used in this experiment and compared with diesel in terms of performance and emissions. Physical and chemical properties of the commercial diesel and numerous vegetable oils present in table 2.

Table 2: Physical and chemical properties of the diesel and numerous vegetable oils.

Vegetable oils	Viscosity at 38^0C	Cetane no	Heating value (MJ/Kg)	Cloud point (^0C)	Pour point (^0C)	Flash point (^0C)	Density (Kg/l)
Cottonseed	33.5	41.8	39.5	1.7	-15	234	0.9148
Crambe	53.6	44.6	40.5	10	-12.2	274	0.9048
Linseed	27.2	34.6	39.3	1.7	-15	241	0.9236
Peanut	39.6	41.8	39.8	12.8	-6.7	271	0.9026
Rapeseed	37	37.6	39.7	-3.9	-31.7	246	0.9115
Safflower	31.3	41.3	39.5	18.3	-6.7	260	0.9144
Sunflower	33.9	37.1	39.6	7.2	-15	274	0.9161
Palm	39.6	42	31	-	-	267	0.918
Soybean	32.6	37.9	39.6	-3.9	-12.2	254	0.9138
Diesel	3.06	50	43.8	-	16	76	0.855

3. Results and discussion

Biodiesel is significantly impacted by transesterification conditions. The fuel used will have an impact on the output and exhaust emissions of a DI diesel engine. As a result, our research concentrates on the analysis and optimization of reaction parameters to identify the ideal circumstances to maximize the biodiesel output. Examine how various biodiesel blends affect engine efficiency and emissions traits as well. The effects of different reaction factors that helped turn sunflower, soybean and cottonseed oil into methyl esters were assessed. The kind and quantity of catalyst, the molar ratio of methanol to oil, the reaction temperature, and the degree of agitation were among the factors impacting transesterification that were evaluated. It is because the transesterification reaction is reversible. The best ratio, however, will vary depending on the quality and type of vegetable oil being utilized.

3.1 Direct injection engine performance analysis

1. Brake Thermal Efficiency (BTE)

The BTE of a diesel engine displays the effectiveness of converting fuel chemical energy into real practical work. As shown in *figure 1 and 2*, Due to the clarified fall in BSFC rates, the BTE rises with engine load rises. Consequently, it was discovered that the BTE for biodiesel blends was lower than that of pure diesel fuel. Due to the higher viscosity, density, and surface tension of biodiesel than commercial diesel fuel, which causes poor atomization and mixture formation with air and results in slow combustion and low BTE, the average value of the BTE was decreasing by about 1.59%, 4.39%, and 7.32% for D70B30, D50B50, and D30B70 blends than pure commercial diesel fuel.

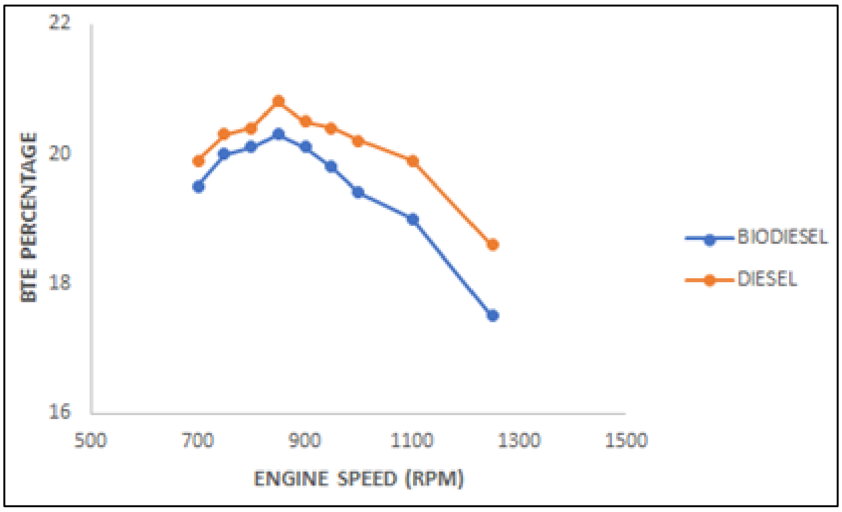

Fig 1: Variation of BTE with different engine speed for different test fuels.

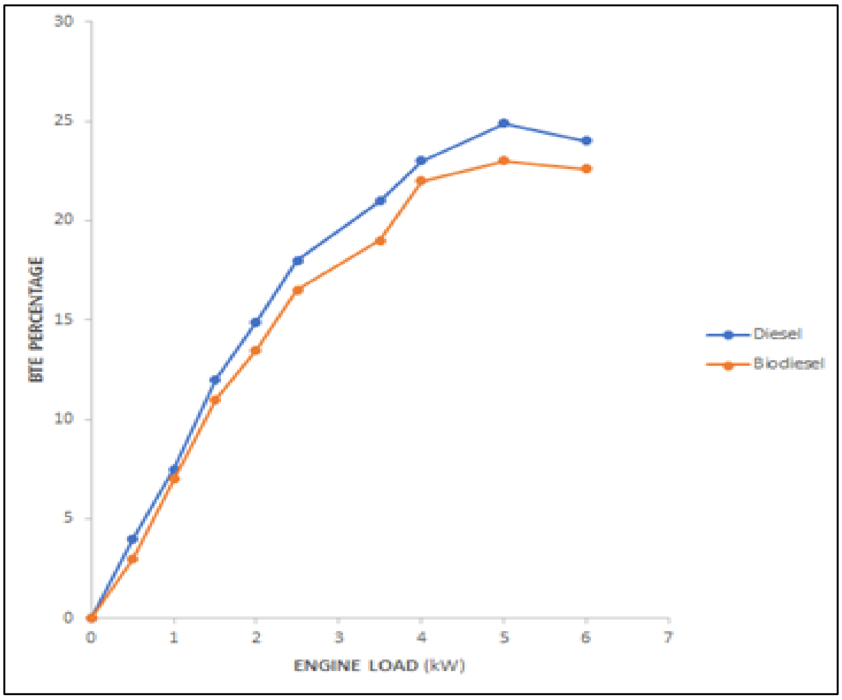

Fig 2: Variation of BTE with different engine loads for different test fuels.

2. Brake-Specific Fuel Consumption (BSFC)

Figure 3 shows how BSFC falls with increasing engine load since greater engine power made fuel consumption less of an issue than it had been. At various engine loads, BSFC increased as the proportion of diesel/biodiesel blends increased. an average increase in BSFC for D70B30, D50B50, and D30B70 mixes over pure diesel of 2.44%, 7.1%, and 11.43%, respectively. Because biodiesel has a lower calorific value than other fuels, more fuel is needed to create the same amount of power, which results in a higher BSFC increment for biodiesel blends.

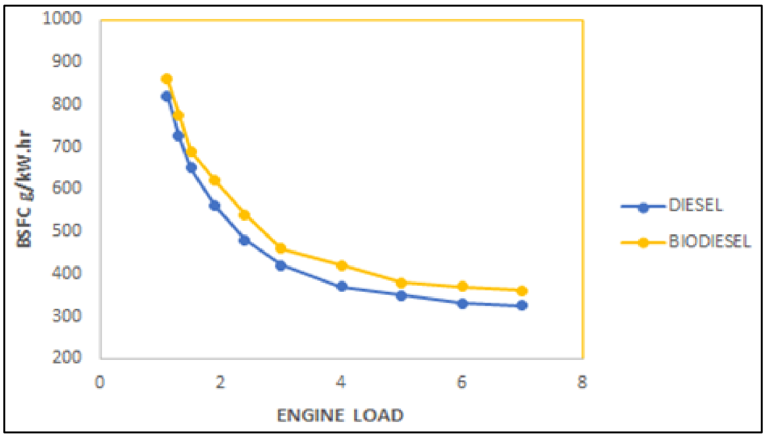

Fig 3: Variation of BSFC with different engine loads for different tested fuels.

3. Brake Specific Energy Consumption (BSEC)

The fuel's energy, which is used to produce a unit of engine power, is referred to as BSEC. BSEC provides further insight on fuel efficiency and usage. *Figure 4* show for all load conditions of the engine, BSEC falls as the biodiesel blending percentage rises. For biodiesel compared to pure diesel fuel.

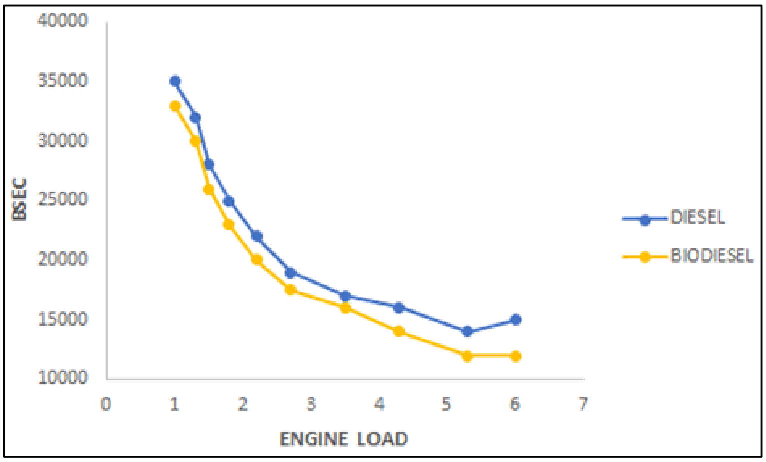

Fig 4: Variation of BSEC with different engine loads for different test fuels.

3.2 Emission

1. Carbon Monoxide (CO) Emissions

Figure 5 show that the concentration of CO emissions was raised for all tested fuels by increasing engine load. Due to the rich mixture required for incomplete combustion at higher loads, there was a noticeable rise in CO emissions. Due to their higher oxygen content and lower carbon to hydrogen ratio, biodiesel blends generally emit less carbon monoxide (CO) than diesel fuels, with average reductions of 15.02, 33.81%, and 30.73% for D70B30, D50B50, and D30B70, respectively.

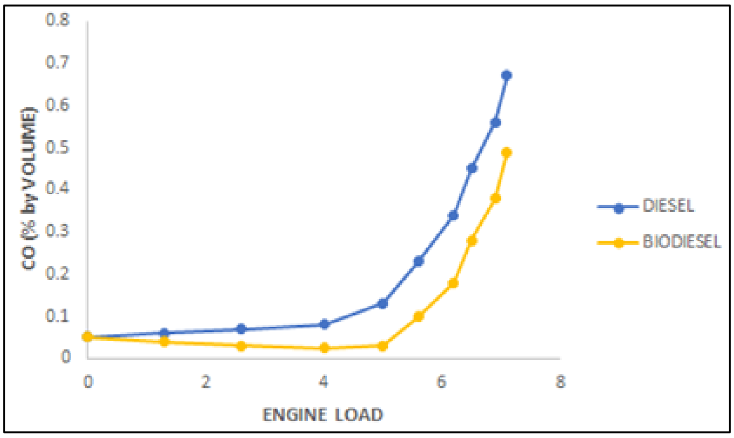

Fig 5: Variation of CO emissions with different engine load for different test.

2. Hydro-Carbon (HC) Emissions

It is clear from *Figure 6* that both no load and partial load states are found to have lower HC emissions than higher engine loads. because when more fuel is injected under situations of higher loads, there is less oxygen available to complete the combustion reaction. However, HC emissions fell as the proportion of diesel to biodiesel in blends increased because biodiesel has a higher oxygen content than diesel, which promotes clean and complete combustion. Therefore, compared to pure diesel, biodiesel blends of D70B30, D50B50, and D30B70 produce an average reduction of 1.83%, 2.94%, and 4.18%, respectively.

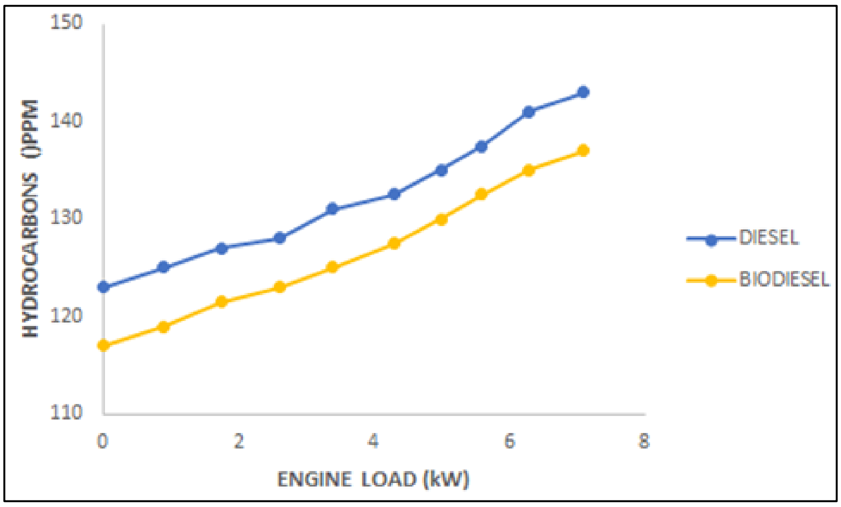

Fig 6: Variation of HC emissions with different engine loads for different test.

3. Carbon Dioxide (CO_2)

In *Figure 7* Over the course of the entire measured loads of operation, CO2 emissions for pure diesel and diesel/biodiesel mixes increased. Due to incomplete combustion, particularly at higher engine loads and possibly also low C/H ratio, CO2 emissions for diesel/biodiesel blends of D70B30, D50B50, and D30B70, respectively, show an average drop of 6.06%, 11.68%, and 14.17% when compared to pure diesel. The impact on lowering greenhouse gas emissions is good, nevertheless, as evidenced by this reduction.

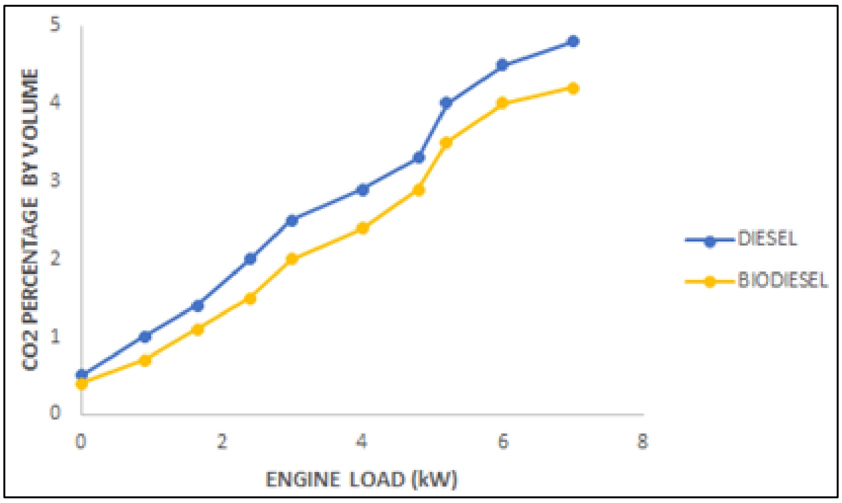

Fig 7: Variation of CO2 emissions with different engine loads for different test fuels.

4. Nitrogen Oxide (NOx)

In *Figure 8* For all studied fuels, it has been found that NOx increases with increasing engine load due to rising combustion temperature. Due to the higher oxygen concentration in biodiesel fuels, which causes a faster rate of NOx generation, biodiesel blends emit more NOx than pure diesel fuel under all load situations. Average increases for diesel/biodiesel blends of D70B30, D50B50, and D30B70 were found to be 4.28%, 5.52%, and 11.9%. One of the most dangerous emissions from an engine is NOx, which may be decreased using several techniques such exhaust gas recirculation (EGR) and the lean burn combustion strategy, which lowers the in-cylinder temperature.

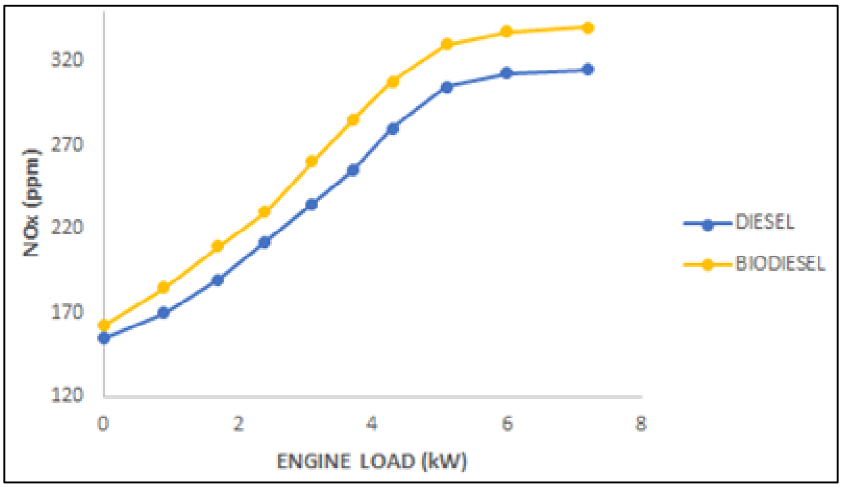

Fig 8: Variation of NOx emissions with different engine loads for different

5. Smoke Opacity

Figure 9 shows that the smoke rises with increasing load until it reaches its maximum value in conditions of high load. High loads result in incomplete combustion, which raises the smoke level. With increasing biodiesel percentage in the tested blended fuel, smoke was seen to decrease under all load circumstances. Because biodiesel has more oxygen and less carbon than diesel fuel, it produces less smoke. The diffusive combustion phase, which is where smoke is primarily created, is improved by biodiesel. For diesel/biodiesel ratios of D70B30, D50B50, and D30B70, respectively, a reduction in smoke of approximately 5.4%, 18.02%, and 34.09% was seen when compared to diesel fuel. For 10% biodiesel mixtures, smoke emission was less compared to neat diesel fuel. The maximum reduction of smoke emission with 10% biodiesel mixtures was observed by 14%. Smoke formation occurs primarily in the fuel-rich zone of the cylinder, at high temperatures and pressures. If the applied fuel is partially oxygenated, locally over-rich regions can be reduced and primary smoke formation can be limited. Smoke emission with engine torque for neat diesel fuel and 10% mixture

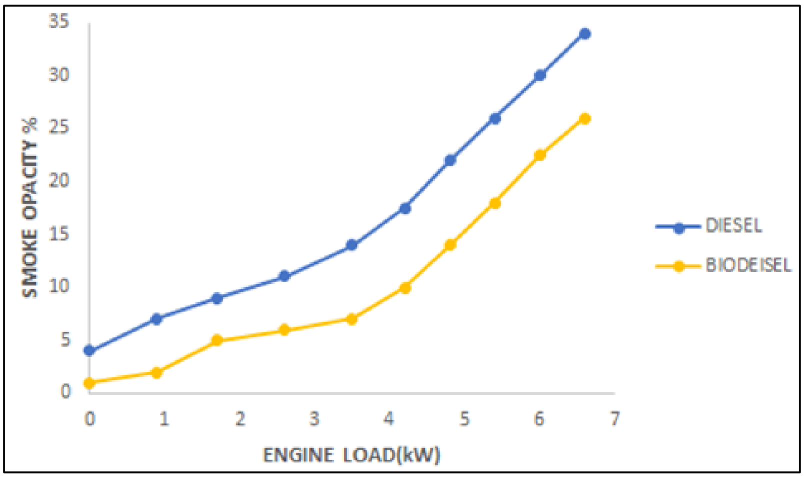

Fig 9: Variation of Smoke Opacity with different engine loads for different test fuels.

4. Conclusions

Only a small number of oil-bearing crops such as sunflower, soybean, and cottonseed oil are possible sources of biodiesel. It has been established that base catalysts outperform acid catalysts and enzymes, and that biodiesel combustion properties are similar to those of diesel. The use of vegetable oil/diesel blend is also implied to have resulted in lower engine performance as the high viscosity oil contaminated the lubricating oil and caused coking of the injectors. Performance test results with refined oil mixes showed a significant improvement. In comparison to diesel, it was discovered that all fuel blends had higher engine emissions of unburned hydrocarbon. Comparing all fuel mixes to diesel, it was discovered that the engine's emissions of nitrogen oxides were higher When compared to diesel fuel, biodiesel volumetric percentages of 30%, 50%, and 70% reduced CO, HC, and CO2 emissions by 2.54 to 10.15%, 1.83 to 4.18%, and 6.06 to 14.17%, A reduction in BSEC of approximately 5.67%, 4.38%, and 1.15% was seen for biodiesel percentages of 30%, 50%, and 70% in mixed fuel, The average reduction in smoke for the diesel/biodiesel blends D70B30, D50B50, and D30B70 was around 4.7%, 2.86%, and 0.51%, Up to 70% of diesel can be blended with biodiesel made from a mixture of sunflower, soybean, and cottonseed oils. This fuel is essential for running diesel engines without any changes respectively.

5. References

1. Shenawy EA, Elkelawy Medhat, Alm-Eldin Bastawissi Hagar, Panchal Hitesh. Comparative study of the combustion, performance, and emission characteristics of a direct injection diesel engine with a partially

premixed lean charge compression ignition diesel engine. Fuel. 2019; 249:277-85.
2. Alm El DinBastawissi Hagar, Elkelawy Medhat, Panchal Hitesh, Sadasivuni Kishor Kumar. Optimization of the multi-carburant dose as an energy source for the ap plication of the HCCI engine. Fuel. 2019; 253:15-24.
3. Chandra Sekhar S, *et al*. Biodiesel production process optimization from Pithecellobium dulce seed oil: performance, combustion, and emission analysis on compression ignition engine fuelled with diesel/biodiesel blends. Energy Convers Manage. 2018; 161:141-54.
4. Anwar M, Rasul MG, Ashwath N. Production optimization and quality assessment of papaya (Carica papaya) biodiesel with response surface methodology. Energy Convers Manage. 2018; 156:103-12.
5. Keera S, El Sabagh S, Taman AR. Castor oil biodiesel production and optimization.Egpt J Petrol. 2018; 27(4):979-84.
6. Onukwuli DO, Emembolu LN, Ude CN, Aliozo SO, Menkiti MC. Optimization of biodiesel production from refined cotton seed oil and its characterization. Egpt J Petrol. 2017; 26(1):103-10.
7. Ezekannagha CB, Ude CN, Onukwuli OD. Optimization of the methanolysis of lard oil in the production of biodiesel with response surface methodology. Egpt J Petrol.
8. Elkelawy M, et al., Numerical and Experimental Investigation of Ethyl Alcohol as Oxygenator on the Combustion, Performance, and Emission Characteristics of Diesel/Cotton Seed Oil Blends in Homogenous Charge Compression Ignition Engine, 2018. doi: 10.4271/2018 01 1680.
9. Chauhan BS, Kumar N, Cho HM, Lim HC. A study on the performance and emission of a diesel engine fueled with Karanja biodiesel and its blends. Energy. 2013; 56:1-7.
10. Sekhar SC, *et al*. Emission analysis on compression ignition engine fueled with lower concentrations of Pithecellobium dulce biodiesel-diesel blends. Heat Trans Asian Res. 2019; 48(1):254-69.
11. Can Ö. Combustion characteristics, performance and exhaust emissions of a diesel engine fueled with a waste cooking oil biodiesel mixture. Energy Convers Manage. 2014; 87:676-86.
12. Lahane S, Subramanian KJF. Effffect of difffferent percentages of biodiesel-diesel blends on injection, spray, combustion, performance, and emission characteristics of a diesel engine. Fuel. 2015; 139:537-45.
13. Cheung C, Man X, Fong K, Tsang OK. Effffect of waste cooking oil biodiesel on the emissions of a diesel engine. Energy Procedia. 2015; 66:93-6.
14. Abed K, El Morsi A, Sayed M, El Shaib A, Gad MS. Effffect of waste cooking-oil biodiesel on performance and exhaust emissions of a diesel engine. Egpt J Petrol. 2018; 27(4):985-9.
15. Özener O, Yüksek L, Ergenç AT, Özkan MJF. Effffects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics. Fuel. 2014; 115:875-83.
16. Raman LA, Deepanraj B, Rajakumar S, Sivasubramanian VJF. Experimental in vestigation on performance, combustion and emission analysis of a direct injection diesel engine fuelled with rapeseed oil biodiesel. Fuel. 2019; 246:69-74.
17. Can Ö, Öztürk E, Serder Yücesu H. Combustion and exhaust emissions of canola biodiesel blends in a single cylinder DI diesel engine. Renew Energy 2017; 109:73-82.
18. da Costa Cardoso L, De Almeida FNC, Souza GK, Asanome IY, Pereira NC. Synthesis and optimization of ethyl esters from fifish oil waste for biodiesel production. Renew Energy. 2019; 133:743-8.
19. Kucek KT, César-Oliveira MAF, Wilhelm HM, Ramos LP. Ethanolysis of refned soybean oil assisted by sodium and potassium hydroxides. J Am Oil Chemists Soc. 2007; 84(4):385-92. Encinar J, González J, Rodríguez-Reinares AR. Ethanolysis of used frying oil. Biodiesel preparation and characterization. Fuel Process Technol. 2007; 88(5):513-22.
20. Sekhar SC, *et al*. Biodiesel production process optimization from Pithecellobium dulce seed oil: performance, combustion, and emission analysis on compression ignition engine fuelled with diesel/biodiesel blends. Energy Convers Manage 2018; 161:141-54.
21. Saydut A, Erdogan S, Kafadar AB, Kaya C, Aydin F, Hamamci CJF. Process optimization for production of biodiesel from hazelnut oil, sunflower oil and their hybrid feedstock. Fuel. 2016; 183:512-7.