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Experimental Analysis of Performance and Emission Characteristics of Simarouba Biodiesel and its Blends at varying Injection Pressures on CI Engine

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Abstract

Biodiesel is one of the most promising alternatives for diesel needs. Biodiesel produced from edible oils is not economically feasible and may also create shortage of oil for daily food. This required identification of new kinds of non edible vegetable oils. Non edible feed stocks such as Mahua, Jatropha, Pongamia, Simarouba, Calophyllum Inophyllum and Neem etc are reported to be feasible choices for developing countries including India. This paper presents the results of investigation of performance and emission characteristics of diesel engine using Simarouba oil biodiesel. In this investigation, the blends of varying proportions of Simarouba biodiesel with diesel (S10, S20, S30, S40 and S100) were prepared, analyzed, and compared the performance and exhaust emission with diesel using 5.2 kW single cylinder, 4 stroke DI diesel engine. The performance and emission characteristics of blends are evaluated at variable loads, variable injection pressures and at constant rated speed of 1500 rpm and found that, with increase in injection pressure, increases the BTHE and reduces BSFC, whereas harmful pollutants such as HC and CO emissions are reduced using Simarouba biodiesel.

Keywords: Biodiesel, Simarouba, performance, emission, injection pressure.

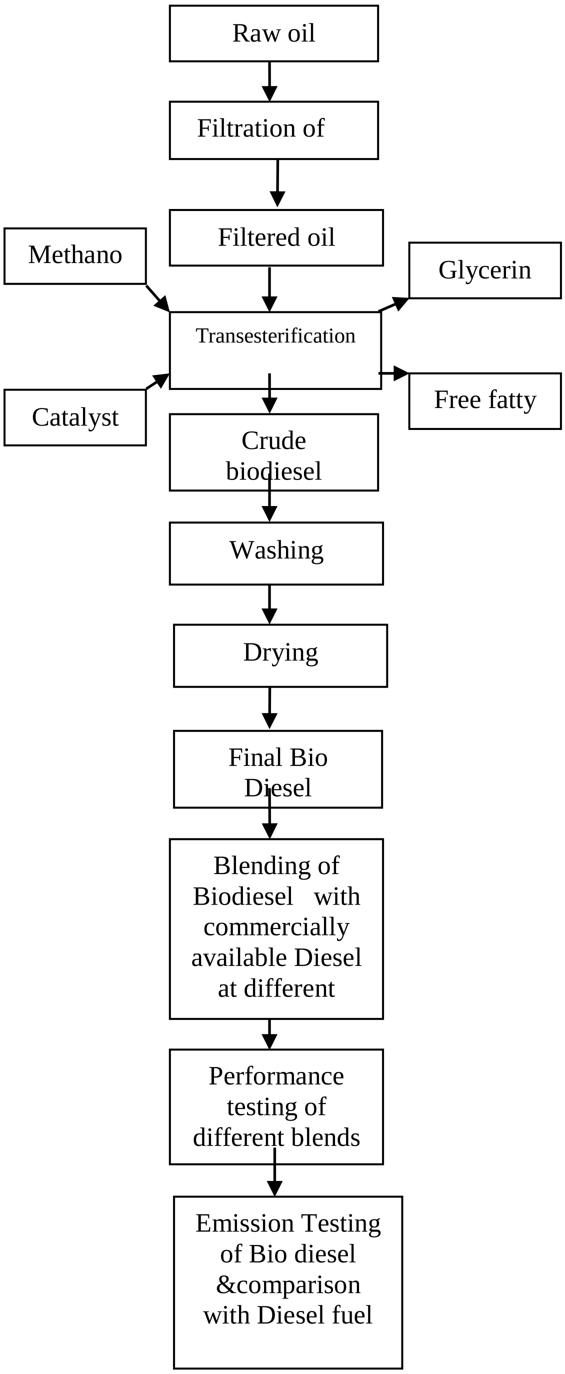
1. INTRODUCTION

Biodiesel is an alternative to petroleum-based fuels derived from a variety of feed stocks, including vegetable oils, animal fats, and waste cooking oil[1]. The cost of biodiesel is the main obstacle to commercialization of the product. Biodiesel produced from edible oils is currently not economically feasible. On the other hand, extensive use of edible oils for biodiesel production may lead to food crisis[2]. These problems can be solved by using low cost feed stocks such as non edible oils such as Mahua, Pongamia, Neem, Jatropha, Simarouba, Calophyllum Inophyllum and waste cooking oils for biodiesel production[3]. In this work we have adopted Simarouba glauca oil. Simarouba belongs to family simarubaceae.

2. MATERIALS AND METHODS

The extraction of biodiesel is carried by base catalyzed transesterification method.

Process of extraction



To a 1 litre of raw oil Simarouba is heated upto 70ºC, 300 ml of methanol and 5-7 gms of NaOH(Catalyst) is added and the mixture is maintained at 65-70º C at about 1½ hours and stirred continuously. The mixture is allowed to settle for 20-30 min until the formation of biodiesel and glycerin layers. The glycerin is removed from the bio diesel in a separating funnel. The biodiesel produced from Simarouba oil is ready to use.

3. TRANSESTERIFICATION

There are several methods are available for the production of bio diesel. transesterification of natural oils and fats is most widely used method of production of biodiesel[4-5]. The main purpose of this process is to reduce the viscosity of the oil. Transesterification is basically a sequential reaction. Triglycerides are first reduced diglycerides, which are subsequently reduced to mono glycerides, which are finally reduced to fatty acid esters.

This mechanism is represented in chemical equation as follows:

Triglycerides + CH_3OH ⇆ Triglycerides + $RCOOCH_3$
↓
Diglycerides + CH_3OH ⇆ Monoglycerides + $RCOOCH_3$
↓
Monoglycerides + CH_3OH ⇆ Glycerine + $RCOOCH_3$

Physical and chemical properties are more improved in esetrified vegetable oil contains more cetane number than diesel fuel. These parameters induce good combustion characteristics in vegetable oil esters. Hence un burnt hydrocarbon level is decreased in the exhaust [2]. It results in lower generation of hydrocarbon and carbon monoxide in the exhaust than diesel fuel.

Properties of Simarouba biodiesel and diesel fuel

After transesterification process the properties of simarouba oil blends was determined. It was found that the properties of Simarouba oil blends were similar to diesel.

Table 3.1 Properties of fuels

Properties	S10	S20	S30	S100	Diesel
Kinematic viscosity at 40ºC (Cst)	2.6	2.8	3.1	5.6	2.54
Density(kg/m^3) at 15ºC	835	835	845	875	830
Calorific Value (kJ/kg)	41129	41880	42701	37687	42856
Flash Point (ºC)	64	79	87	165	54
Fire Point (ºC)	77	89	98	185	64

4 EXPERIMENTAL SETUP

The experimental setup enables to study the performance, combustion and emission characteristics. The experimentat have been carried out on a Direct Injection (DI) compression ignition engine for various blends of Simarouba oil with diesel (S10, S20,S30,S40 and S100) The experiments carried out at constant rated speed of 1500 rpm, constant compression ratio of 17.5:1 by varying brake power and at different injection pressures of 180 bar, 200bar and 220 bar.

Figure 4.1 Engine setup

Table 4.1 Engine Specifications

Sl.No	Particulars	Specifications
1	Manufacturer	Kirloskar oil engines Ltd, India
2	Model	TV1-SR, naturally aspirated
3	Engine	Single cylinder, Direct Injection(DI)
4	Bore / Stroke	87.5mm / 110mm
5	Compression Ratio	17.5:1
6	Speed	1500 rpm, constant
7	Rated Power	5.2 kW
8	Working cycle	4 stroke
9	Injection pressure	200 bar / 23° before TDC
10	Response Time	4 micro seconds
11	Type of sensor	Piezo electric
12	Crank angle sensor	1º Crank angle
13	Resolution of 1º	360º with a resolution

5. RESULTS AND DISCUSSION

Performance characteristics

Brake Thermal Efficiency

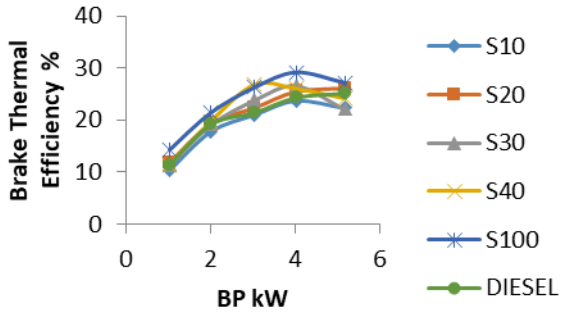


Figure 5.1 Variation of brake thermal efficiency with brake power for diesel and simarouba blends

Variation of brake thermal efficiency with brake power for diesel, Simarouba biodiesel and its blends are shown in the Figure 5.1. It shows that brake thermal efficiencies of all the blends are lower at almost all load conditions. Among all the blends S20 is found to have the maximum thermal efficiency of 25.55% at brake power of 4.02 kW while for diesel it is 24.27%.The decrease in brake thermal efficiency with increase in simarouba biodiesel concentration is due to the poor atomization of the blends due to their high viscosity and reduction in heat loss and increase in power with increase in the load.

Brake Specific Fuel Consumption

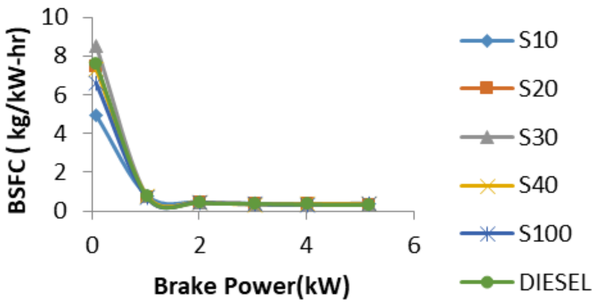


Figure 5.2 Variation of brake specific fuel consumption with brake power for diesel and simarouba blends

The variation of brake specific fuel consumption with respect to brake power is presented in Figure 5.2 for different blends of Simarouba biodiesel and diesel. In diesel engine due to less temperature initial combustion takes with maximum fuel consumption. At higher brake power the BSFC decreases. This may be due to fuel density, viscosity and heating value of the fuels. The curve S20 is almost tracing the path of diesel curve and this indicates that blend S20 can be favorable to existing diesel engine.

Air Fuel Ratio

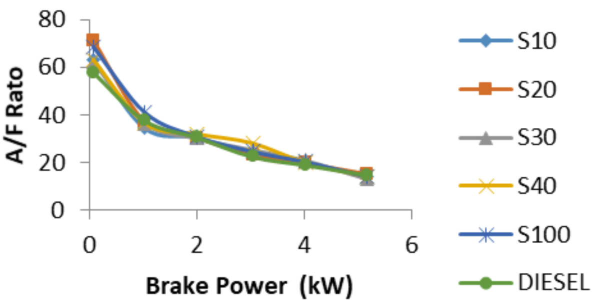


Figure 5.3 Variation of air fuel ratio with brake power for Diesel and Simarouba blends

The variation of air fuel ratio with brake power for diesel and Simarouba blends are shown in the Figure 5.3, It can be observed that the air fuel ratio decreases as the load increases. This is due to the fact that the compensation of the load can only be done with increasing the quantity of fuel injection to develop the power required to bare the load.

Exhaust Gas Temperature (EGT)

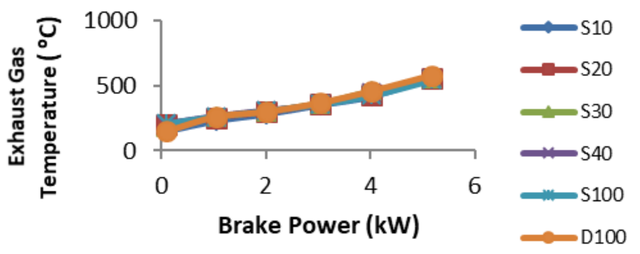


Figure 5.4 Variation of exhaust gas temperature with brake power for Diesel and Simarouba blends

The variations of exhaust gas temperature with brake power for diesel and other blends of Simarouba biodiesel are shown in Figure 5.4, the exhaust gas temperature of all biodiesel are similar to that of diesel. Exhaust gas temperature for 100% diesel and 10%, 20%, 30% and 40% blends for varying loads can be observed and stated as they are slightly parallel to each other. The exhaust gas temperatures of all the blends and 100% diesel increases as the load increases. It is evident from the graph that, at full load the exhaust gas temperature is maximum, this is due to the fact that, at full load the chemically correct ratio of air and fuel used, due to chemically correct ratio of air and fuel, high heat is generated inside the engine cylinder.

Emission characteristics

Carbon monoxide

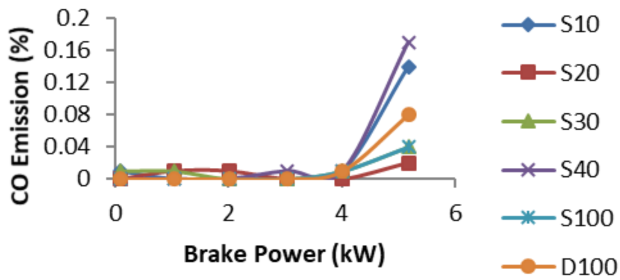


Figure 5.5 Variation of carbon monoxide with brake power for Diesel and Simarouba blends

Figure 5.5 shows the comparison of brake power with carbon monoxide for different Simarouba biodiesel blends. The CO emission depends upon the strength of the mixture, viscosity of the fuel, and availability of the oxygen. It is observed that the CO emission initially decreases at lower loads sharply and increases after 4 kW of power for all test fuels and diesel. Simarouba oil with 40% blend has more emission of CO compared with blends of simarouba oil like S10, S20,S30 and S100.This is due to incomplete combustion at higher loads which results in higher CO emissions. It is also seen that the CO emission decreases with increase in percentage of additive in the blends. From the graph, it is evident that S20 shows the lowest carbon monoxide emission compare to all other test fuels up to 4kW of power and then increases due to incomplete combustion. This is due to high viscosity and small increase in specific gravity suppresses the complete combustion process, which produces small amount of CO.

Hydrocarbon

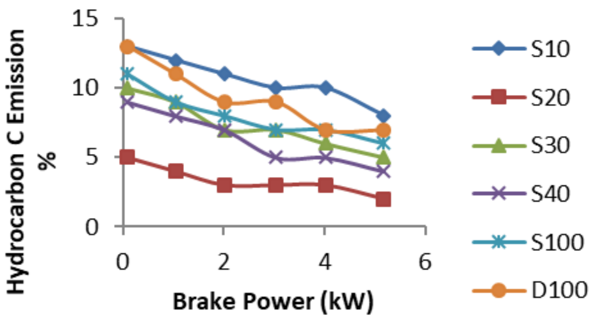


Figure 5.6 Variation of hydrocarbon with brake power for diesel and simarouba blends

Figure 5.6 shows the variation of emission of hydrocarbon with brake power for different blends of simarouba biodiesel and pure diesel. From the graph, we observe that S20 blend has the least emission of HC as compared to other blends and diesel. Thus, it can be confirmed that the conventional diesel and biodiesel had the same functional group of C-H, However, the conventional diesel had no oxygen group. Whereas the biodiesel shows the oxygen functional group. Hence, the biodiesel with existence of oxygen could be promoted cleaner and complete combustion. On the other hand, the conventional diesel without any oxygen produced more black smoke and incomplete combustion during burning. Hence the reason is as the cetane number of ester based fuel is higher than the diesel. It exhibits shorter delay period and results in better combustion leading to low HC emission.

Nitrogen oxide emission

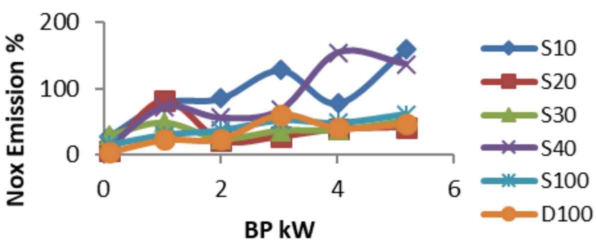


Figure 5.7 Variation of nitrogen oxide with brake power

Figure 5.7 shows the variation of nitrogen oxide with brake power for diesel and Simarouba blends. The average percentage of change in NO_x emission for S10,S20, S30,S40,S100 and D100 are shown in the graph. This shows that the NO_x emission is increased with increase in percentage ratio of biodiesel. NO_x emission is primarily a function of total oxygen inside the combustion chamber, pressure, temperature, compressibility and velocity of sound. The increase in NO_x emission is due to the higher cetane number of the biodiesel which will reduce the ignition delay.The NO_x emission for biodiesel and its blends is higher than that of diesel except S20 at lower loads.It is increased with increase in engine load.

Combustion characteristics

Crank angle

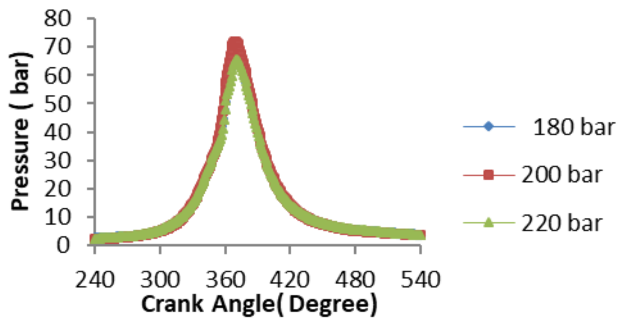


Figure 5.8 Variation of cylinder pressure versus crank angle

In a CI engine the cylinder pressure depends on the fuel burning rate during the premixed burning phase, which in turns leads better combustion and heat release. The variation of cylinder pressure with respect to crank angle for diesel and different blends of simarouba biodiesel are presented in the Figure 6.7. Peak pressure of 68.67 bar and 67.95 bar for diesel and S40 respectively. From the test results, it is evident that the peak pressure variations are less since the properties such as calorific value, viscosity and density are brought closer to diesel after transesterification of vegetable oil, no major variations in the pressure found.

Heat Release Rate

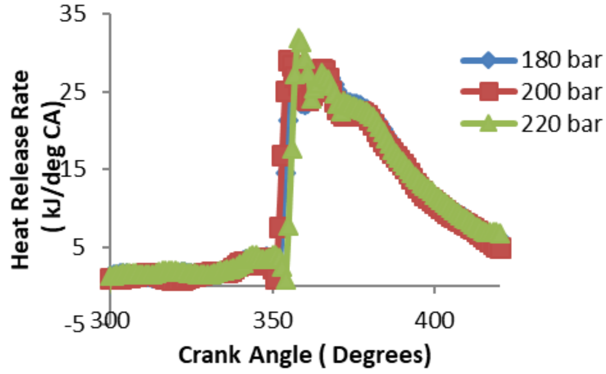


Figure 5.9 variation of heat release rate with crank angle

Figure 5.9 shows the variation of heat release rate with crank angle. It is observed from the graph that all the blends of Simarouba S10, S20, S30, S40 and S100 traced the path of pure diesel. The maximum heat release rate found to be 28.25 kJ for S30 blend as compared to 26.84 kJ for pure diesel.

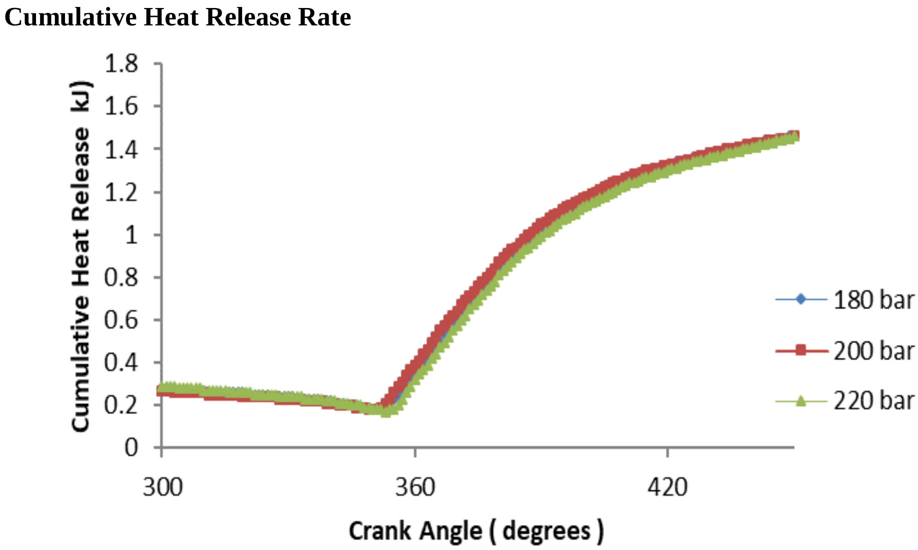


Figure 5.10 Variation of crank angle versus cumulative heat release rate

Figure 5.10 shows the variation of cumulative heat transfer with crank angle. It is observed from the Figure that all blends of simarouba biodiesel traces the same path as that of diesel. Initially cumulative heat transfer decreases at first cycle and then increases in the second cycle as shown in the Figure.

CONCLUSION

- Properties of Simarouba oil Methyl ester(SOME) and diesel fuel are similar, it can be concluded that the blends of SOME can be used without any modifications in the diesel engine
- Specific fuel consumption increases as the concentration of Simarouba biodiesel increases, so we can observe that, 20% simarouba biodiesel blend almost matches with diesel fuel
- From the experimental investigations, it is evident that air fuel ratio for diesel is lesser than simarouba biodiesel and its blends
- Brake thermal efficiency of simarouba biodiesel at 20% blend has slightly higher efficiency than the diesel.
- The exhaust gas temperature of all biodiesel is higher than the diesel and observed that at full load condition, it is maximum due to chemically correct ratio of air and fuel.
- The S20 has lower average percentage of change in CO and HC compared to diesel fuel. Yet S20 is producing higher NO_X emission. Nevertheless, the S20 is still most suitable biodiesel blend among all blends, as NO_X emission can be reduced with the advanced technologies.
- The combustion characteristics of all blends of simarouba oil are almost same as that of diesel.
- With increase in Injection Opening Pressure (IOP) from 180 bar to 220 bar results in increase of Brake Thermal Efficiency (BTE), increase is higher at low and medium load regions and this is higher than neat diesel.
- The CO and HC emission decreases but NO_X emission increases as Injection Opening Pressure increases from 180 bar to 220 bar.

Increase in Injection Opening Pressure (IOP) from 180 bar to 220 bar results in a faster heat release (combustion), improved premixed combustion and almost same ignition delay.

From the experimental investigations, it is concluded that simarouba biodiesel could be safely blended with diesel up to 20% without significantly affecting the engine performance (BTE, BSFC) and emissions (CO, HC and Smoke) and thus could be a suitable alternative fuel for diesel. A blend of SOME with diesel could be used in single cylinder CI engines in rural areas for agriculture, irrigation and portable electricity gensets.

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