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Performance and emission level studies of Simarouba Glauca biodiesel as an alternative fuel for diesel engine

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ABSTRACT

Biodiesel is a non–toxic, biodegradable and renewable alternative fuel that can be used with little or no engine modifications. Biodiesel is currently expensive but would be more cost effective if it could be produced from low–cost non-edible oils. The objective of this study was to investigate the effect of the biodiesel produced from non-edible oils on engine performance and emissions. In this work, biodiesel was produced from Simarouba glauca oil using base catalyzed transesterification. The properties of the biodiesel was determined as per ASTM standards and compared with the diesel. From the property analysis, it is observed that the properties of the biodiesel are better than the raw oil and close to the diesel. From the engine tests, it is observed that the engine performance is close to the diesel.

Keywords: *Biodiesel, Renewable, Non-Edible Oils, Simarouba Glauca, Performance, Combustion, Emission, ASTM Standards.*

1. INTRODUCTION

The growth of national economy and energy consumption are closely related. It is clear that a growing economy will demand much higher levels of energy consumption. India is spending about U$ 53.37*10^8 per annum in foreign exchange on importing petroleum fuels due to the increasing gap between demand and supply of the petroleum products [1]. Vegetable oils present a very promising alternative fuel to diesel oil due to their better properties compared to other alternative fuels such as ethanol and methanol [2].

2. MATERIALS AND METHODS

Table-1: Materials required for biodiesel production

Raw Material	Specification
Raw oil	*Simarouba glauca*
Alcohol	Methanol
Catalyst	Potassium hydroxide (KOH)
Acid	Sulphuric acid(H_2SO_4)

2.1 Transesterification

It is most widely used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol [3]. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called transesterification [4]. Physical and chemical properties are more improved in esterified vegetable oils because they contain more cetane number than the diesel fuel [6]. These parameters induce good combustion characteristics in vegetable oil esters. Hence, un-burnt hydrocarbon level is decreased in the exhaust [8]. It results in lower generation of carbon monoxide and hydrocarbon in the exhaust compared to diesel fuel [5]. The methyl esters of vegetable oils contain more oxygen and lower calorific value than diesel. Hence; it enhances the combustion process and generates low emission compared to diesel fuel [9, 10].

2.2 Properties of diesel and biodiesel blends

After Transesterification process the properties of *Simarouba glauca* blends was determined. It was found that the properties of *Simarouba glauca* oil blends were similar to diesel.

Table-2: properties of diesel and *Simarouba glauca* blends

Properties	diesel	*Simarouba glauca biodiesel blends*		
		B20	**B40**	**B100**
Kinematic viscosity at 40ºC (Cst)	3	2.9	4	6.3
Calorific Value(kJ/kg)	42856	42705	40105	35811
Density(kg/m^3)	830	850	855	900
Flash point (ºC)	54	59	76	174
Fire point (ºC)	64	64	93	186

3. EXPERIMENTAL WORK

3.1 preparation of biodiesel for testing

The oil is preheated to a temperature of 100^{0}C for about two hours to remove the moisture content and then poured into reaction flask. It is then mixed with a measured quantity of methanol and the catalyst (KOH).The heater is set to a desired temperature and stirring speed. The reaction is allowed to continue for a pre-set time. The products of reaction are allowed to settle for three hours. Two distinct layers are observed with high density glycerol settling down low density methyl esters floating on top. The methyl esters in the top layer are removed and washed with de-ionized water to remove the impurities present in it. The water washed biodiesel is heated to 100^{0}C for about an hour to remove the moisture present in it. It is then cooled and stored in PVC cans for further use.

3.2 Experimental setup

Table-3: Specifications of the Engine

Particulars	Specifications
Manufacturer	M/s., Kirloskar Oil Engines Ltd, India
Model	TV-1 SR, Naturally aspirated
Engine	Single Cylinder, Direct Injection
Bore / Stroke	87.5 mm / 110 mm
Compression Ratio	17.5 : 1
Speed	1500 RPM
Rated Power	5.2 kW
Working cycle	4 stroke
Injection Pressure	200 bar / 23º before TDC

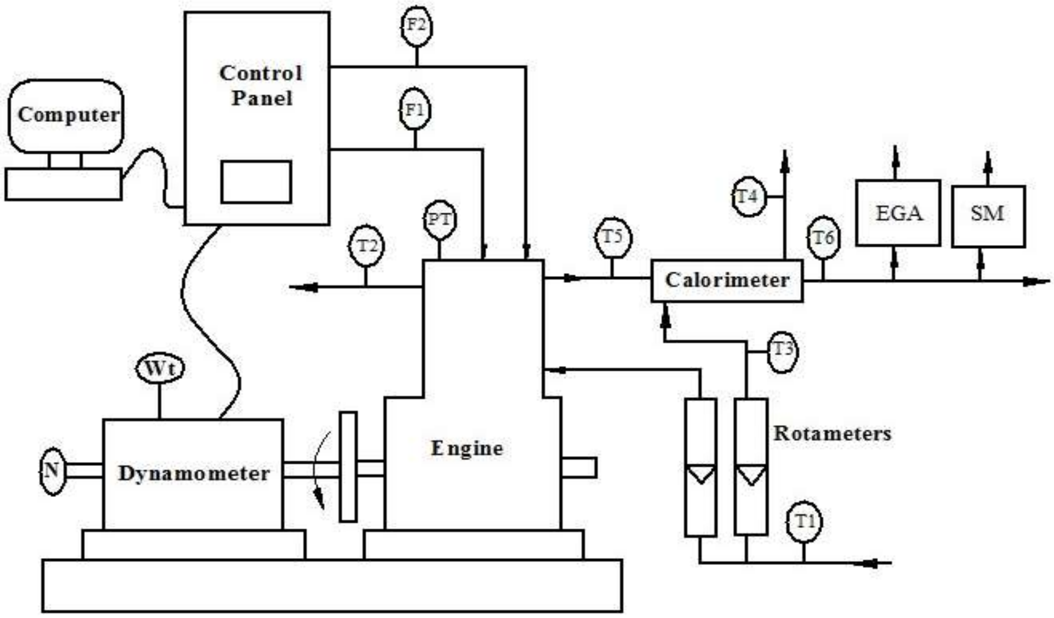

Figure-1: Schematic representation of engine

The experimental setup includes a four-stroke, single-cylinder, diesel engine which is coupled to eddy current or else hydraulic type dynamometer for loading purpose. It is equipped with other required instruments for the measurements of combustion pressure as well as crank angle measurements.

4. RESULTS AND DISCUSSIONS

4.1 Performance Characteristics

4.1.1 Brake Thermal Efficiency

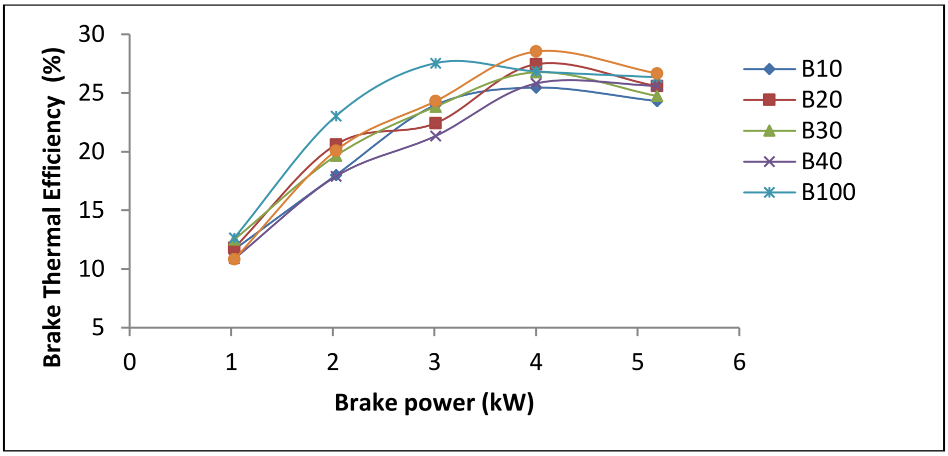

Figure-2: Variation of brake thermal efficiency with brake power.

Figure-2 shows the variation of brake power with brake thermal efficiency. It is evident that brake thermal efficiency increased with an increase in brake power for all the bends of biodiesel and diesel. Amongst all the blends, *Simarouba glauca* blend B20 shows the highest brake thermal efficiency of 25.55% against 24.27% for diesel fuel at 4.02 brake power.

4.1.2 Mechanical Efficiency

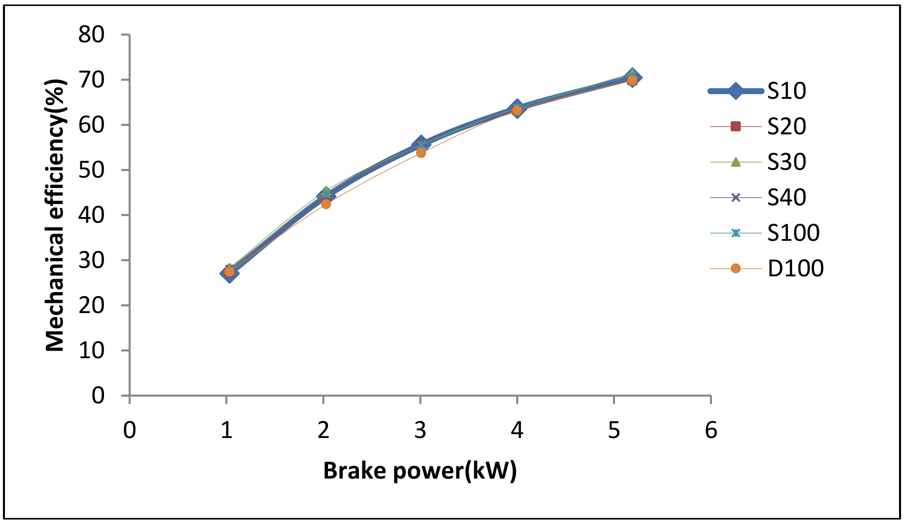

Figure-3: Variation of mechanical efficiency with brake power

The variation of mechanical efficiency with brake power is shown in Figure 3. It was observed during experimental work that, there was a decrease in mechanical efficiency as the concentration of *Simarouba glauca* biodiesel in the neat diesel increased. Lower blends for example; blend B20 showed similar mechanical efficiency as that of diesel fuel at all load conditions.

4.1.3 Exhaust Gas Temperature

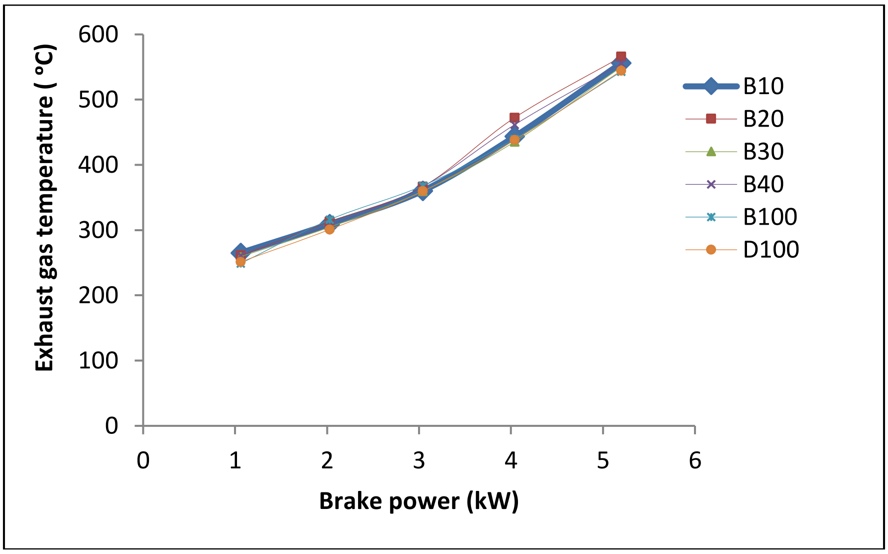

Figure-4: Variation of exhaust gas temperature with brake power

Figure-4 shows the variation of exhaust gas temperature with brake power. It was observed that the exhaust gas temperature of all the biodiesel blends is identical to that of diesel. Exhaust gas temperature was higher at maximum load conditions, because of stoichiometric air-fuel ratio was used at maximum load conditions resulted in superior heat generation in the engine cylinder [19].

4.1.4 Air-Fuel Ratio

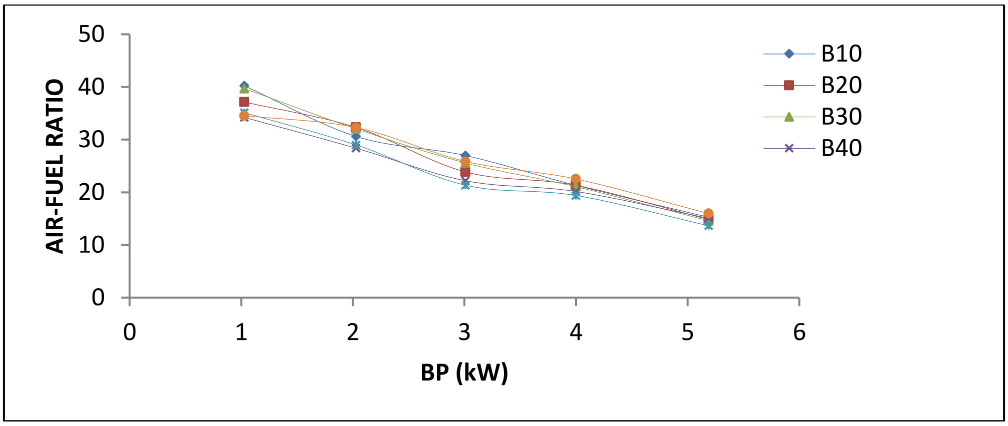

Figure-5: Variation of air-fuel ratio with brake power

The variation of air fuel ratio with brake power at different injection pressures are shown in the Figure-5, from the graph, it is evident that, air fuel ratio decreases as the load increases. This is due to the compensation of the load can only be done with increasing the quantity of the fuel injection to develop the power required to bare the load [20].

4.2 Emission Characteristics

4.2.1 Hydrocarbon Emission

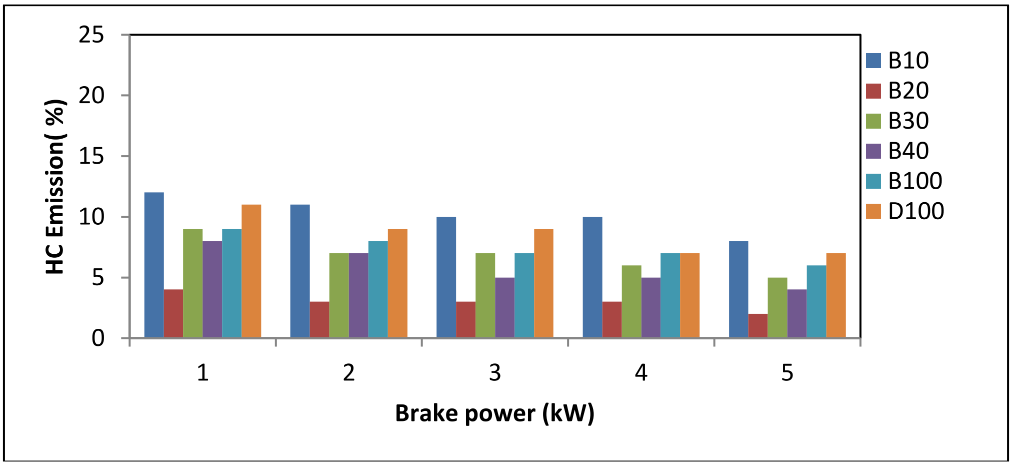

Figure-6: Variation of hydrocarbon emission with brake power

Figure 6 shows the variation of hydrocarbon emission with brake power. It is evident that, among all the blends, blend B20 showed less emission of hydrocarbon as compared to other blends and diesel. It was mainly due to, diesel and biodiesel comprised of a similar functional group of carbon and hydrogen.

4.2.2 Carbon monoxide emission

4.2.3

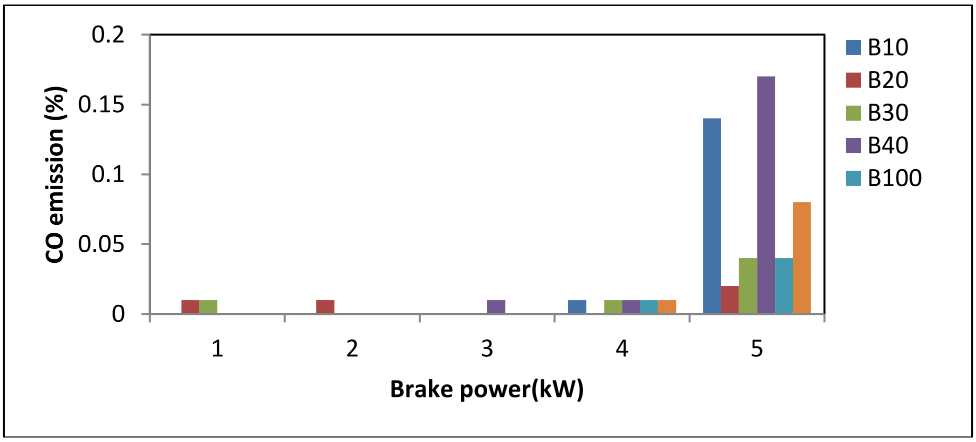

Figure-7: Variation of carbon monoxide emission with brake power

Figure-7 shows the variation of carbon monoxide emission with brake power. It is evident that in the beginning carbon monoxide emission reduced at lesser loads and then increased after 4 kW of brake power for all biodiesel blends including diesel fuel. Among all the biodiesel blends, B20 blend indicated the lowest carbon monoxide emission. Biodiesel blend B40 showed more carbon monoxide emission as compared to other blends of biodiesel. This was mainly due to imperfect combustion at upper load ranges which lead to high carbon monoxide emissions [16].

4.2.4 Nitrogen oxide emission

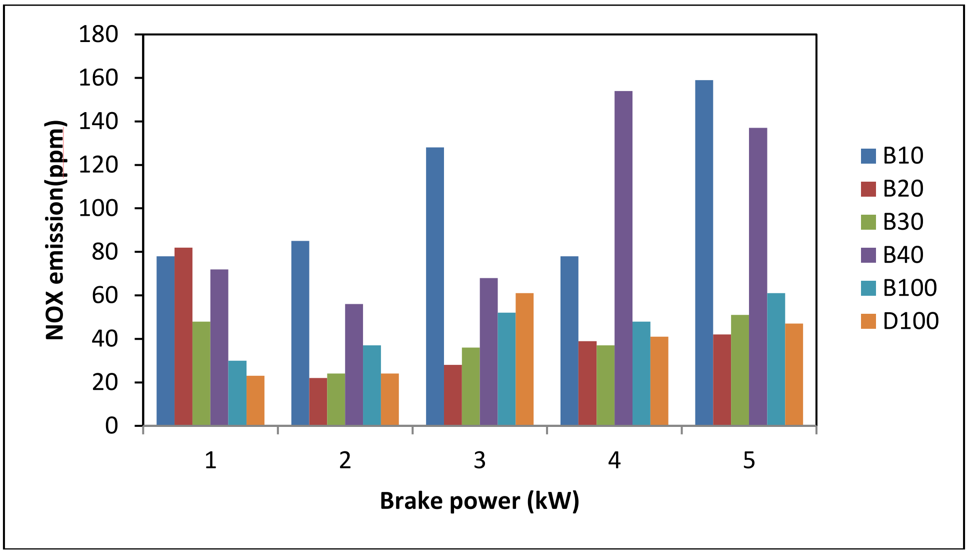

Figure-8: Variation of nitrogen oxide emission with brake power

Figure-8 shows the variation of nitrogen oxide emission with brake power. It is evident that, all other exhaust emissions such as CO, HC etc. is less compared to diesel fuel except NOx emission, this is mainly due to the existence of a higher cetane number in biodiesel compared to conventional diesel fuel resulted in a small delay period, improved combustion as well as a reduction in CO and HC emission. Inherent oxygen present in the biodiesel helps to reduce CO and HC emissions[17].

5. CONCLUSIONS

From the test results, the following conclusions are drawn.

- Experimental investigations on *Simarouba glauca* biodiesel and its blend's performance characteristics on regular engine indicate that the blend B20 of *Simarouba glauca* biodiesel has approximately similar fuel consumption and mechanical efficiency compared to that of diesel fuel.
- Practical investigations show that blend B20 of *Simarouba glauca* leads the similar fuel properties as that of diesel. Hence blend B20 of *Simarouba glauca* seems to be the best and most appropriate alternative choice in the direct injection diesel engine.
- From the experimental investigations, carbon monoxide and hydrocarbon emissions for the engine fueled with biodiesel was significantly lesser than the engine fuelled with diesel. NO_X emission for the engine fuelled with biodiesel was higher than that of the engine fuelled with diesel.
- A single-cylinder CI engine can be fueled *Simarouba glauca* oil methyl ester with diesel for farming and irrigation purposes in rural areas.
- The methyl esters of *Simarouba glauca* oil can be efficiently used as a substitute fuel in the diesel engine without any engine modifications.

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