An Experimental Investigation on Four Stroke CI Engine by Comparing Performance Parameters and Emission Characteristics with Two Bio-Diesel Blends and Diesel as Fuel: Hazelnut and Safflower

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Abstract: ***An experimental evaluation was made to investigate and compare the results of two non edible bio-diesels namely Hazelnut and safflower. Bio-diesel blends will be prepared with these fuels by mixing with normal diesel fuel with suitable proportions of 5%, 10%, 15%, 20% and 25% of hazelnut ang safflower bio-diesels separately by volume and used as a fuel in a vertical, four stroke, water cooled, mono cylinder, Compression Ignition engine by using the above fuel blends as fuel, numbers of experiments will be computed with the engine working at different loads. A comparative investigation was executed on the performance parameters such as Brake Thermal efficiency (BTHE), Brake Specific fuel Consumption (BSFC) and Exhaust Gas Temperatures (EGT) and on exhaust emission like oxides of nitrogen (NOx), oxides of carbon (CO), total and partially unburned hydro carbons and smoke density. The bio diesels which are considered as most promising alternative fuels are prepared from vegetable oils. Among all the industries in the world bio fuel production is one of the rapidly growing industries. Here in this study hazelnut bio-diesel blands are giving better performance parameters and lower exhaust emissions compared with remaining bio-diesel blends made with safflower.***

Keywords: hazelnut, safflower, bio-diesel blends, diesel, performance parameters and emission characteristics

1. Introduction

Apart from renewability, bio-fuels are more advantageous than normal diesel in some aspects like they are having very less sulphur content and aromatic contents, higher lubricity, higher flash point, non-toxicity and higher bio-degradability. On the other side the disadvantages of bio-fuels includes very high pour point, very high viscosity, the lower cetane number, lower volatility and lower calorific value. One of the great disadvantages of bio-fuel is its highly increased viscosity, which is approximately 10-20 times greater than normal diesel fuel. More over short term tests by using bio-fuels are giving promising results but when engine has been operated for longer periods then problems are appearing, which includes more carbon deposits, injector coking with trumpet formation, piston oil ring sticking, as well as the thickness of engine lubricating oil also increases. The following methods are adopted to avoid the problems associated with their high viscosity. Micro emulsification with methanol or ethanol blending in small blend ratios with diesel fuel, cracking, preheating and conversion in to bio-fuel mainly through the transisterification process. [22–25].

The advantages of bio-diesels as diesel fuel, apart from renewability, are the minimal sulfur and aromatic content, the higher flash point, the higher lubricity, the higher cetane number, and the higher biodegradability and non-toxicity. On the other hand, their disadvantages include the higher viscosity (though much lower than the vegetable oils one), the higher pour point, the lower calorific value and the lower volatility. Furthermore, their oxidation stability is lower, they are hygroscopic, and as solvents they may cause corrosion of components, attacking some plastic materials used for seals, hoses, paints and coatings. They show increased dilution and polymerization of engine sump oil, thus requiring more frequent oil changes.

Because of all the above reasons, maximum up to 25% of bio-fuels and vegetables are generally accepted as blends with diesel fuel and can be used in existing diesel engines without modifications. Experimental studies on the CI engines with the use of bio-fuels blending with neat diesel have been reported.

The present experimental work studies and compares the above bio-fuels of various origins, in blending with ordinary diesel fuel, by fuelling a single cylinder, direct injection, naturally aspirated CI engines. A companion paper extended the present investigation for hazelnut oil and its methyl esters for different blend ratios, followed by another paper dealing with their heat release and stastical analysis using insulated combustion chamber of the same engine.

As mentioned above, the results of performance and emissions have been evaluated by this research work by using blends of neat diesel fuel with two bio-fuels (hazelnut oil and safflower oil) [28], in the single-cylinder, water-cooled, direct injection, 'kirlosker' diesel engine concerning the present work. The interpretation of the experimental measurements was based on the differences of properties between the fuels tested.

Most of the experimental works reported on the use of bio-fuels in the compression ignition engines are referred to mainly single-cylinder naturally aspirated engines have been used only one or two bio-fuel oils. But the present research work steps forward in reporting on the use of two bio-fuel oils on a single-cylinder, four stroke and water-cooled diesel engine.

Widely differing chemical and physical properties of bio-fuels against those of diesel fuels, are combining with the theoretical aspects of diesel engine combustion, and are used to aid the correct interpretation of the observed engine emissions and performance wise behavior.

2. Description of the Engine Test Facility

Facilities to monitor and control engine variables were installed on a test-bed, Kirloskar single cylinder, four stroke, vertical, water cooled, compression ignition engine (Fig. 1) was used and mounted on the ground. The test engine was directly coupled to an eddy current dynamometer with suitable switching and control facility for loading the engine. Engine specifications were as follows: bore & stroke, 87.5 mm x 110 mm; compression ratio, 17.5: 1; speed, 1500 rpm; fuel timing, 27° by spill (btdc); clearance volume, 37.8 cc; and rated power, 5 hp.

For fuel consumption measurement a tank and flow metering system is used for various blend samples as follows. A piezometer of known volume was used with the measurement of time for the complete evacuation of the sample fuel which is feeding to the engine. In order to have a quick drain of a fuel sample, including the return fuel from injector and pump and refilling of fuel metering system with new fuel sample a system is provided with valves and pipes.

A system which is used for the measurement of exhaust gases consists of group of analyzers for measuring carbon monoxide (CO), oxides of nitrogen (NO_x), hydrocarbons (HC), smoke density (SD), particulate and soot. The concentration of CO (in ppm) present in the exhaust gases was measured by using 'Signal' Series-7200 non-dispersive infrared analyzer (NDIR) equipped with a 'Signal' Series-2505M Cooler. 'Bosch' RTT-100 opacimeter, is used to measure the smoke level in the exhaust gas the readings of which are provided as equivalent smoke density in (mg of soot/ m^3 of exhaust gases). The concentration of nitrogen oxides in ppm (parts per million, by vol.) present in the exhaust gases was measured by using 'Signal' Series-4000 chemiluminescent analyzer (CLA) that was fitted with a thermostatically controlled heated line. The total unburned hydrocarbons concentration (in ppm) present in the exhaust gases was measured with a 'Ratfisch-Instruments' Series RS55 flame-ionization detector (FID) that was also fitted with a thermostatically controlled heated line.

Figure 1: Experimental Setup

Table 1: Engine Specifications and Injection System Basic Data

Engine model and type : Kirlosker single-cylinder, four, stroke, compression ignition, direct injection, water-cooled.	
Speed	1500 rpm
Engine total displacement	661 cm3
Bore/stroke	87.5 mm/110 mm
Compression ratio	17.5:1
Maximum power	5.2 HP @ 1500 rpm
Maximum torque	29.0376 Nm @1500rpm
opening pressure	250 bar

3. Properties of Fuels Tested

Two typical types of straight Bio-diesel oils, viz. safflower and hazelnut oil are tested as supplements of the normal diesel fuel, at blend ratios of 05/95% ,10/90%, 15/85% and 20/80% 25/75% (by vol.) with the conventional diesel fuel.

Diesel fuels which contains very less amount of sulphur content approximately (0.035 wt %) forms the base line for present study. To reduce the viscosity of bio-fuels they are to be de-gummed and refined, nearly the edible type without any pre-heating and adding any additives. All important properties of two bio-fuels and diesel are provided in table-2. All the values mentioned in the table are the mean values taken from various sites and references mentioned with this paper. In this study it required to note that the cetane number and kinematic viscosity values mentioned are not used computationally. In order to explain qualitatively the relative performance and emissions behavior of different fuel blends they are only referred to for indicative purposes.

Table 2: Fuel Properties

Fuel	Density at 15^0c. Kg/mm^3	Kinematic viscosity at 40^0c. cST	Calorific value. MJ/kg	Flash point
Diesel	837	1.3	42.70	369
Hazelnut	875	3.59	42.12	425
Corn	873	3.62	41.14	427

Table 3: Accuracy of Measurements and Uncertainty of Computed Results

Measurements	Accuracy
NOx	±5 ppm
HC	±0.5 ppm
CO	±0.2%
Smoke opacity	±0.1%
Speed	±5rpm
Specific fuel consumption	±1.5
Time	±5%
Torque	±0.5 Nm
Fuel volumetric rat	±1
Power	±1

4. Experimental Section, Transesterification Process

To reduce viscosity of vegetable oils, transesterification method is adopted for preparation of biodiesel[1]. In this process, non-edible oil (1000 ml) was taken in a three way flask. In a beaker, sodium hydroxide (NaOH, 12 g) and methanol (CH_3OH, 200 ml) were thoroughly mixed until it is properly dissolved. The solution obtained was mixed with non-edible oil in three way flask and stirred properly. Methoxide solution with non-edible oil was heated to 60°C and continuously stirred at constant rate for 1 h. The solution is poured down in a separate beaker and is allowed to settle for 4 h. Glycerin settles at the bottom and methyl ester floats at the top (coarse biodiesel). Methyl ester is separated, heated above 100°C and maintained for 10-15 min to remove untreated methanol. Certain impurities like NaOH etc. are still dissolved in the obtained coarse biodiesel. These impurities are cleaned up by washing with 350 ml of water for 1000 ml of coarse biodiesel. Cleaned biodiesel is methyl ester of non-edible oil[2].

5. Parameters Tested and Experimental Procedure

Engine testing was done in a laboratory at a constant temperature. Engine was started and warmed-up at low idle, long enough to establish the recommended oil pressure, and was checked for any fuel, oil leaks. After completing warm-up procedure, engine was run on no- load condition and speed was adjusted to 1800 rpm by adjusting fuel injection pump. Engine was run to gain uniform speed, after which it was gradually loaded. Experiments were conducted at different levels of load. For each load condition, engine was run at a minimum of 10 min and data were collected during the last 4-min of operation. Simultaneously, engine exhaust emissions were also determined.

The series of tests are conducted using each of the above mentioned blends, with the engine working at speed of 1500 and at different torque mentioned above. Because of the differences in oxygen content and calorific values of different fuels tested, the analysis is effected at the same engine brake power and not the air fuel ratio or same injected fuel mass.

In each test exhaust smokiness, volumetric fuel consumption rate, and exhaust gas emissions such as carbon monoxide, nitrogen oxides, and total unburned hydrocarbons are measured. From the first measurement brake thermal efficiency (BTHE.) and brake specific fuel consumption (b.s.f.c.) are computed using the fuel sample density and lower calorific value. Table 3 shows the uncertainty of the computed results of various parameters and the accuracy of the measurements.

The analysis of experimental work was started with a preliminary investigation of the compression ignition engine fueled with neat diesel fuel, to find out the exhaust emission levels and engine operating characteristics which constitute a base line can be used to compare with the corresponding cases when using each of the blends forming with the combination of neat diesel and bio-fuel with appropriate proportions. By keeping the same operating conditions the same procedure was repeated for each fuel blend. For every time when the fuel is changed, the lines through which fuel flows were cleaned and then the engine is allowed to run for about 30 minutes to reach and stabilize its new desired conditions.

6. Results and Discussion

Test engine was run with different fuels and time for 10 cc fuel consumption was calculated. Among two biodiesels, Hazelnut biodiesel showed lesser viscosity than other oils at various temperatures (Fig. 2), may be due lower density of hazelnut biodiesel than others.

A. Brake Thermal Efficiency (BTHE)

Fig. 2 shows, the brake thermal efficiency (BTHE.) for the neat diesel fuel, and 20% blends of the hazelnut and safflower oils with bio-diesels with normal diesel fuel, at various loads. BTHE of diesel fuel is higher compared with other bio-diesels blends at various loads (Fig. 3). In the listed bio-diesels blends of present work, hazelnutio-diesel blend is showing higher BTHE than remaining blends. BTHE graph of 20% blend of bio-diesel is as HB20 > SB20. It is also observed that as the load increases BTHE also increases with load up to three fourth of full load from there it starts decreasing.

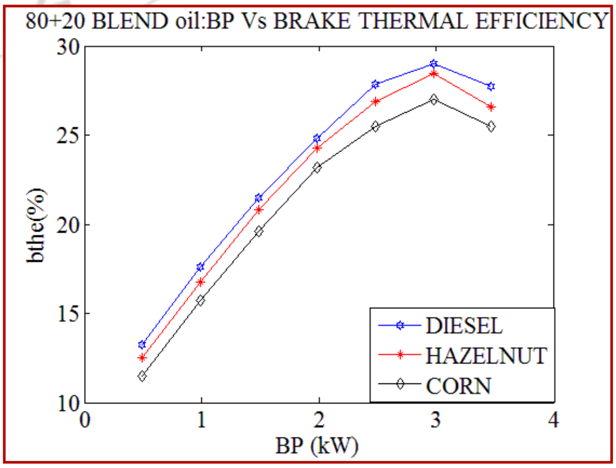

Figure 2: Brake Thermal Efficiency

B. Hydrocarbon (Hc) Emissions

HC emission of neat diesel fuel is higher when compared with bio-diesels blends of hazelnut and safflower at all loads (Fig. 3). Among all bio-diesel blends, Hazelnut is showing lesser HC emission than other bio-diesel blends. HC emissions trend at 20% blend of biodiesel is as H20 > S20, may be because all biodiesels contain oxygen, which favors better combustion when compared with diesel. Hence, HC emissions are very less for biodiesel. For other blends, trend is similar to that for 20% blend. As load increases, HC emissions decrease. However, hazelnut blend HC emissions are less when compared with 20% blend of other bio-diesel blends.

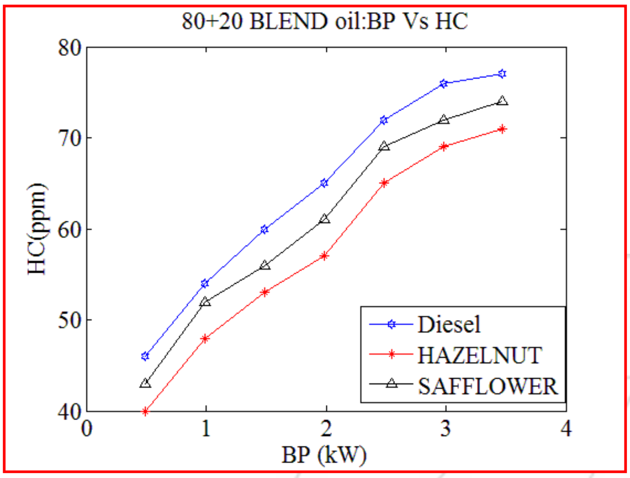

Figure 3: Hydrocarbon Emissions

C. NOX Emissions

Fig. 4 shows, the emissions oxides of nitrogen (NOx) in ppm for conventional diesel fuel, and 20% blends of hazelnut and safflower bio-diesel blended with diesel, and used as fuel in the IC engine at various loads. One can observe that the NOx emitted by all bio-diesel blends are higher than corresponding diesel fuel. According to the discussion of the previous subsection the lower cetane number of vegetable oils (higher ignition delay) may play a role in this increase, apart from the delicate distribution of the fuel–air 'packets' inside the sprays as influenced by the fuel bound oxygen. Among all biodiesels Hazelnut bio-diesel blend is showing minimum NOx emissions than other bio-diesels. NO_x emissions trend at 20% blend of biodiesel is as H20 > S20, may be due to the low cetane number of biodiesel , which lead to ignition lag and causes to accumulate large amount of un burned mixture of air and bio-fuel. This accumulated charge after reaching the self ignition condition will burn at a time causes better combustion than diesel. As a result, the adiabatic flame temperature or maximum temperature inside cylinder is more in case of biodiesels than diesel. Hence, this catalyzes reactions for oxidation of nitrogen and hence NOX emissions are more for biodiesels. For other blends, trend is similar to that for 20% blend. As load increases, NOX emission increases. However, emissions are less when compared with 20% blend.

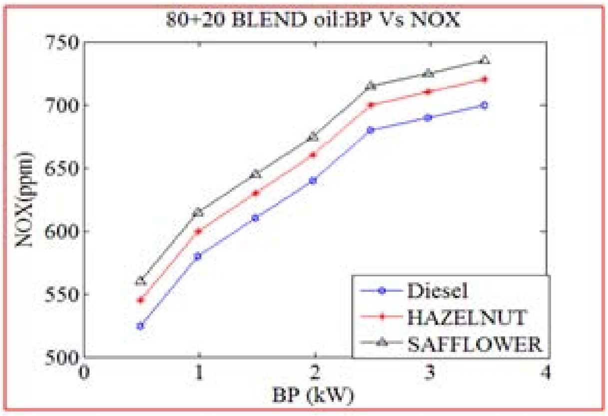

Figure 4: NO_X

D. Co Emissions

Fig. 5 HC emission of neat diesel fuel is higher when compared with bio-diesels blends of hazelnut and safflower at all loads (Fig. 3). Among all bio-diesel blends, Hazelnut is showing lesser CO emission than other bio-diesel blends. CO emissions trend at 20% blend of biodiesel is as H20 > S20, may be because all biodiesels contain oxygen, which favors better combustion when compared with diesel. Hence, CO emissions are very less for biodiesel. For other blends, trend is similar to that for 20% blend. As load increases, HC emissions decrease. However, hazelnut blend CO emissions are less when compared with 20% blend of other bio-diesel blends.

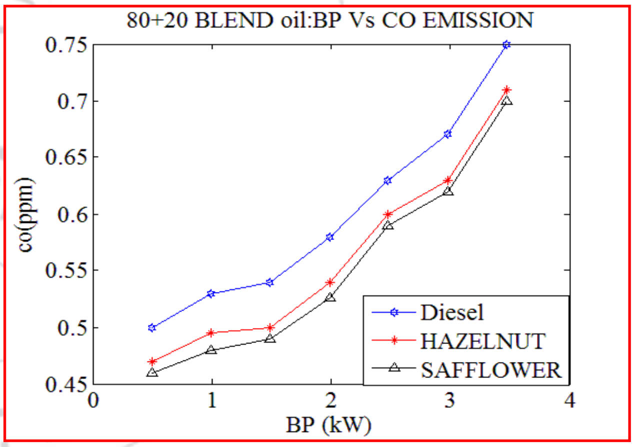

Figure 5: Co Emissions

E. Smoke Density

Fig.6 shows the smoke density for the conventional diesel fuel, and 20% blends of the hazelnut and crambe bio-diesel blended with diesel fuel, at different loads. One can observe that the density of all bio-fuel blends is higher than the ones for the corresponding neat diesel fuel.

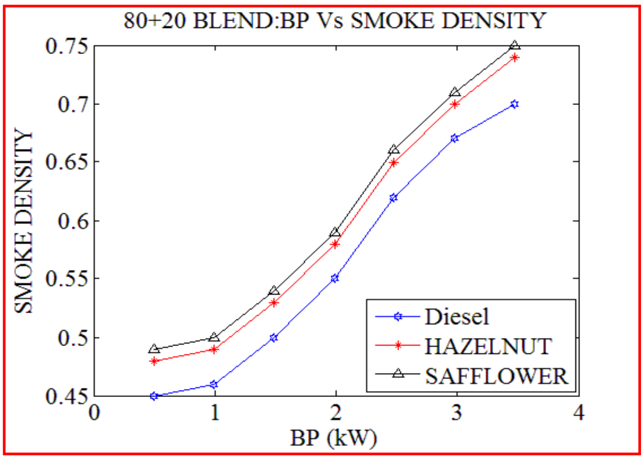

Figure 6: Smoke Density

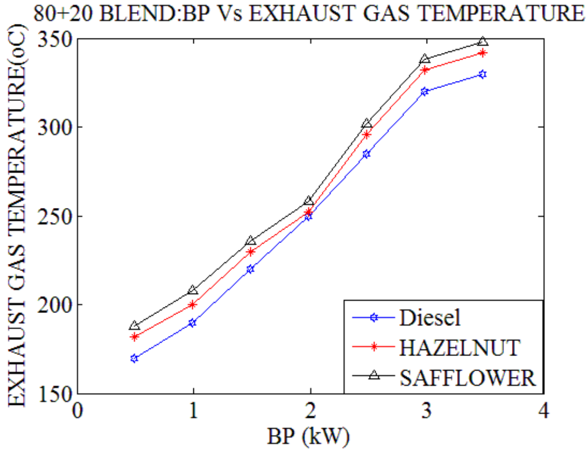

Figure 8: Exhaust Gas Temperatures

F. Brake Specific Fuel Consumption

Fig. 7 shows the brake specific fuel consumption (b.s.f.c.) expressed in kg/kW h (kilograms per kilowatt and hour) for the conventional diesel fuel, and blends of 20% of hazelnut and safflower bio-diesel blends and neat diesel fuel at different loads. The mass flow rate of fuel blend is calculated from the respective volume flow rate value which is measured and the density of the fuel blends which is computed by considering the densities of the fuel using and the ratio of fuel blends involved in the experimental work. Since the evaluation of work is made on the constant speed and same load which is translated in to the same engine power, and these values are proportional to the mass flow rate of fuel. It is to be observed that the air mass flow rate remains same under the same operating conditions.

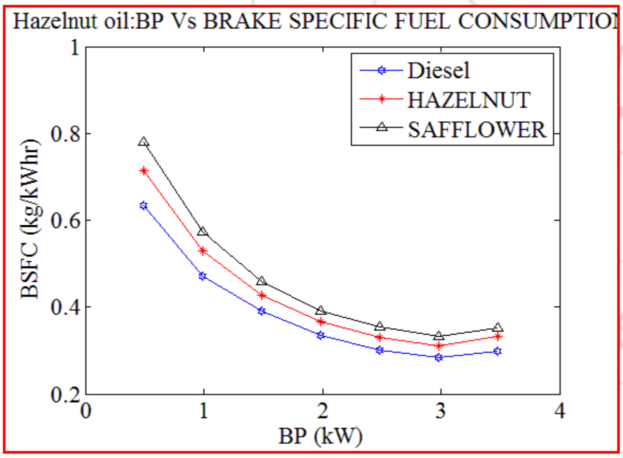

Figure 6: BSFC

G. Exhaust Gas Temperatures

Exhaust gas temperature Exhaust gas temperature (EGT) varied with load and the results for different fuels are presented in Figure 8. EGT of all the tested fuels increased with load. EGT of B20 was higher than that of diesel fuel at the highest load due to the blends' higher viscosities, which resulted in poorer atomization, poorer evaporation, and extended combustion during the exhaust stroke. As the amount of bio-fuel content increases then viscosity also increases, and, as a result, EGT of the blends was higher than that of diesel fuel due to deterioration in combustion and more fuel being oxidized.

7. Summary and Conclusions

An experimental work was carried out to evaluate and compare the performance parameters and exhaust emission levels of two different bio-fuels viz. hazelnut oil and safflower oil as supplements in the diesel fuel at blend ratios of 20/80 (by vol.).

A series of experiments have performed with the above bio-diesel blends, with the engine working at various lods. In each test exhaust smokiness, exhaust gas, temperatures and exhaust regulated gas emissions such as nitrogen oxides (NOx), carbon monoxide (CO), and total unburned hydrocarbons (HC) are analyzed. brake specific fuel consumption and Brake thermal efficiency were computed from measured fuel volumetric flow rate and calorific values.

The exhaust smoke emissions were reduced by the use of all bio-diesel blends along with the respective neat conventional diesel fuels, hazelnut oil blends perform better when compared with remaining blends.

The NOx emissions were marginally increased with the use of bio-diesel blends as fuel when compare to those of the neat conventional diesel fuel, with this increase being higher the higher the percentage of bio-fuel in the blend.

The CO emissions were considerably decreased with the use of all bio-fuel blends with respect to those of the neat diesel fuel, with this increase being higher the higher the percentage of bio-fuel in the blend.

The HC emissions were decreased with the use of all bio-diesel blends with respect to those of the neat diesel fuel, with this being further decreases as the higher the percentage of bio-fuel in the blend.

The engine brake thermal efficiency is higher for neat diesel fuel than hazelnut and safflower bio-diesel blends and for blends of hazelnut oil which is having less BTHE than diesel fuel and giving better performance than remaining bio-diesel blends.

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