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Experimental Investigation of Waste Cooking Oil and Honge Oil as Biodiesel in Single Cylinder Electronic Direct Injection Diesel Engine

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Abstract

Diesel engine is a popular prime mover in rural areas, particularly in the places where electrical power is not available. The rapid depletion of fossil fuel with increased environmental concern has stimulated worldwide efforts to produce alternative to diesel. Use of bio-origin fuel as an alternative fuel can contribute significantly towards the twin problem of fuel crises and environmental pollution. The fuel of bio-origin may be the biodiesel obtained from edible or non-edible vegetable oil through Transesterification process. Most of the properties of biodiesel compare favorably with the characteristics required for CI fuel. This fuel in the form of blend with diesel performs almost as well as neat diesel fuel with little or no engine modification. In the present study, test is conducted to evaluate and compare the use of various diesel supplements at B20, B40 blend ratios, in a standard, fully instrumented, four stroke, and Electronic direct injection CI engine. Production of biodiesels from waste cooking oil, Honge oil and study of the fuel properties according to ASTM methods are shown that both biodiesels are meeting the standards. The series of test was conducted using biodiesels blends with engine working at 1500rpm constant speed. Performance and emissions characteristics are studied and results are compared with that of the WCObiodiesel blends and Honge biodiesel blends.

Keywords: Bio Diesel, Honge Oil, Waste Cooking Oil (WCO), Electronic Diesel Engine.

INTRODUCTION

Compression ignition engines have become an indispensable part of modern life style because of their role in transportation and mechanized agriculture sector. The dwindling sources of conventional fossil fuels, their ever increasing demand and prices have prompted the scientists and researchers to find alternate fuels for diesel engines. Known crude oil reserves are estimated to be exhausted in less than 50 years at present rate of consumption. Consequently, countries lacking such resources are facing foreign exchange crisis, mainly due to the import of the fuels.A number of alternative fuels such as ethanol, methanol, hydrogen, Compressed Natural Gas (CNG), liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), Dimethyl-ether (DME) and vegetable oils have been used as alternative fuels, however biodiesel has received a considerable attention to be used as a substitute fuel for conventional petroleum.

Biodiesel is a fuel made up by mono-alkyl-esters of long chain fatty acids, derived from vegetable oils or animal fat. It can be used in compression ignition engines for automotive propulsion or energy generation, as a partial or total substitute of fossil diesel fuel. Different bio-diesel types can be classified according to their source and manufacturing process as well

Esterificated oils: They are produced through reaction with methanol or ethanol in the presence of catalyst, in order to obtain methyl or ethyl ester, depending on the alcohol employed to oils of oleaginous seeds. This is the most wide-spread kind of bio-diesel. It can be injected into Diesel engines either pure or blended with fossil diesel.

Non-esterificated oils: These oils may be employed only in modified engines with special characteristics. Oils with high acidity degree or other characteristics that could make them unacceptable for human consumption could be included in this group as well.

Waste cooking oils can also be used as bio- diesel. However, before the “transesterification” process, they have to be pre-processed, including cleaning and refining. It is required, because of the degradation undergone from the high temperatures reached in their original use. In the present work comparative study is conducted for biodiesels of Honge oil and Waste cooking oil in terms of FFA content, fuel properties, and performance and emission characteristics.

In India Honge oil is already using as the biodiesel for running pump sets and Gen-sets. But the availability of seeds for the biodiesel production is less due the lack of awareness among the farmers, seeds are available in the months of March to June and the cultivation of this plants requires considerable amount of time and land. By choosing the waste cooking oil for the biodiesel production, risk of health hazards can be minimized, dependency on the seasonal plants can be minimized, and water pollution and use of decorticator can also be minimized.

Single cylinder four stroke diesel engine was used in the study and mechanical injectors was replaced by the electronic direct fuel injector. Since biodiesels are having the higher viscosity than diesel, electronic direct fuel injectors helps in the accurate metering of fuel and precise control of injection timing with higher injection pressures.

METHODOLOGY

Production of biodiesel:

Figure 1a shows production procedure followed during the Biodiesel conversion. The esterified oil (below 4% FFA) was poured into the reactor and heated at 60°C to optimize the temperature of reaction for maximum yield. A mixture of NaOH in methanol was heated at the same temperature for 5 min and added slowly to the heated oil.

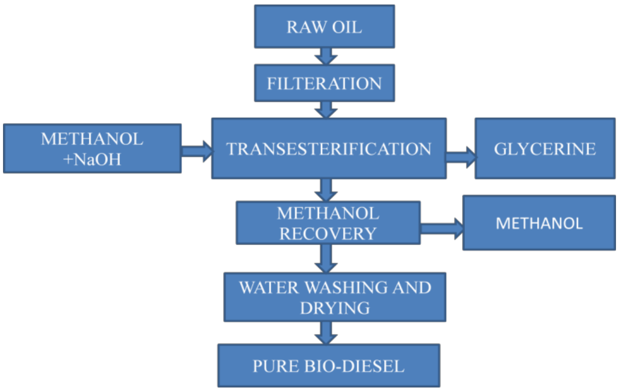

Figure 1(a)Production of biodiesel

The reaction mixture was heated, re-circulated for about 3 hours. After 3 hours, two distinct layers were formed and the mixture was allowed to settle for 2 hours or overnight. The heavier glycerol layer was separated from the lighter Methyl ester layer by separating tank. Then, the obtained Biodiesel is transferred into the washing tank where it is washed by spraying the 40°C warm water without any agitation to remove the NaOH content and it was allowed to settle for 15 minutes. A bottom layer of soap is formed. Bottom layer of soap was carefully drained out, this procedure was repeated 3 times and the pH value of the third time drained water is checked using the pH paper. Washing is continued to till the pH of the soap water reaches 7. After final wash the biodiesel is heated to the 100°C to remove the water. After removing the moisture content it is allowed cool gradually, and then the obtained biodiesel is transferred to the clean and dry container.

Fuel Properties Test

Kinematic Viscosity:

Table 1: Kinematic Viscosity of the Biodiesel and its blends at 40˚C:

Kinematic Viscosity of biodiesels (mm^2/s)		
Blends	**WCO biodiesel**	**Honge biodiesel**
B100	5.3	5.68
B80	5	5.2
B60	4.42	4.8
B40	4.034	4.18
B20	3.69	3.84

Flash and fire point test:

Table 2 Flash and fire point of biodiesels

Biodiesels	Observation	Temperature
Honge biodiesel	Flash	163°C
	Fire	170°C
WCO biodiesel	Flash	160°C
	Fire	164°C

Density test:

Table 3: Density of biodiesels and its blends

Density of biodiesel (kg/m^3)		
Blends	**Honge biodiesel**	**WCO biodiesel**
B-0	822.7	822.7
B-20	839.2	836.2
B-40	846.3	840.3
B-60	865.2	859.7
B-80	882	878
B-100	890	883

Determination CalorificValue:

Table 4: Calorific value of biodiesels and its blends

Calorific value of Bio diesel(MJ/kg)		
Blends	**Honge biodiesel**	**WCO biodiesel**
B-0	42.01	42.01
B-20	41.467	40.686
B-40	41.080	39.516
B-60	40.490	38.54
B-80	40.101	37.76
B-100	39.711	37.37

Engine Test Setup

This type of engine is familiar to the agriculturists and any encouraging results derived from the present study can be implemented by the farming community to gain the benefits(Figure 1(b).

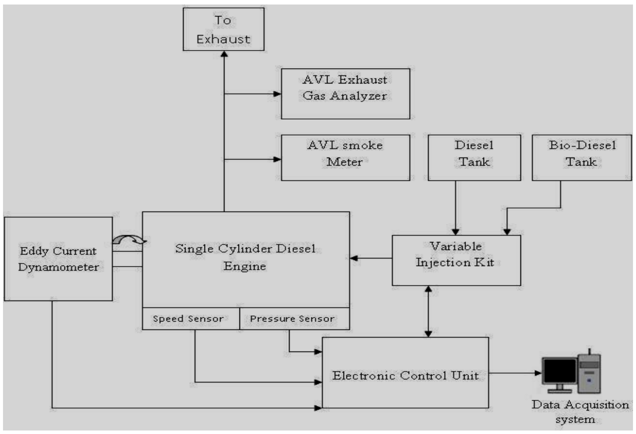

Figure 1(b) Schematic diagram of Experimental test setup

RESULTS AND DISCUSSION

Biodiesel Production:

Biodiesel yield:

Table 5: Biodiesel yield for one liter batch

Oil	Oil Used (ml)	Methanol Used (ml)	FFA Contant %	NaOH Used (gram)	Biodiesel Obtained (ml)	Glycerol (ml)
Honge	1000	300	3.83	7.33	800	350
WCO	1000	300	3.249	6.8	750	300

Table 5 shows the Biodiesel yield for one liter batch of both oils. It is noticed that FFA content for the both oils are less than 4%, which signifies that only one step alkali transesterification processes is enough for the biodiesel conversion of both oils.

Comparison of fuel properties:

Table 6: Comparison of fuel properties

Fuel properties	Raw Honge oil	Raw WCO oil	ASTM Standards	Honge Biodiesel	WCO biodiesel	Diesel
Kinematic viscosity (mm^2/s) at 40°C	43	41	1.6 - 6	5.68	5.3	2.9
Flash point (°C)	250	320	≥130	168	163	52
Density kg/m^3	930	920	870-900	890	883	822.7
Calorific value (MJ/kg)	-	-		39.711	37.37	42.01

Table 6 shows the comparison of fuel properties of Diesel, Honge B100 and WCOB100. Both biodiesels are meeting the ASTM standards.

Engine performance:

Brake Specific Fuel Consumption (BSFC)

Figure 2 shows variation of BSFC with Brake Power for Diesel and B20 biodiesels. It was noticed that BSFC decreases with increase in load for all the fuels. The maximum value of BSFC for diesel, HongeB20 and WCOB20 are 0.503kg/kWh, 0.5247 kg/kWh and 0.5411 kg/kWh respectively at low load. At higher load the value BSFC for diesel, Honge B20 and WCOB20 are 0.2734kg/kWh, 0.2791kg/kWh, 0.2991kg/kWh respectively.

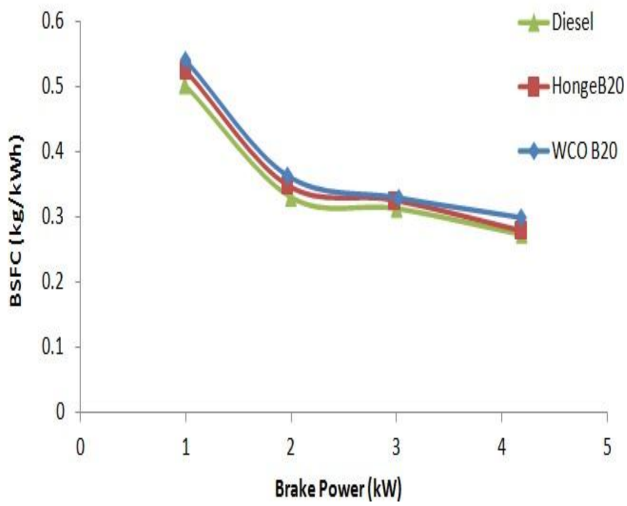

Figure 2: Variation of BSFC with Brake Power for Diesel and B20

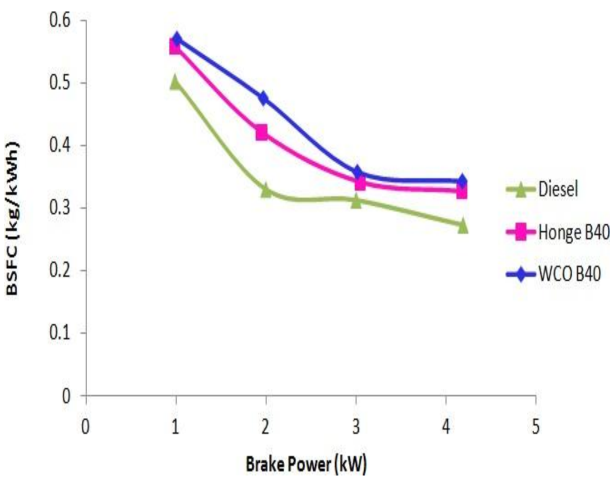

Figure 3: Variation of BSFC with Brake Power for Diesel and B40

Figure 3 shows variation of BSFC with Brake Power for Diesel and B40 biodiesels. Here also BSFC decreases with increase in load for all the fuels. The maximum value of BSFC for Diesel, HongeB40 and WCOB40 are 0.503kg/kWh, 0.5587 kg/kWh and 0.5709kg/kWh respectively. At higher loads value of BSFC for HongeB40 and WCOB40 are 0.3278kg/kWh and 0.3436kg/kWh respectively.

Brake thermal efficiency:

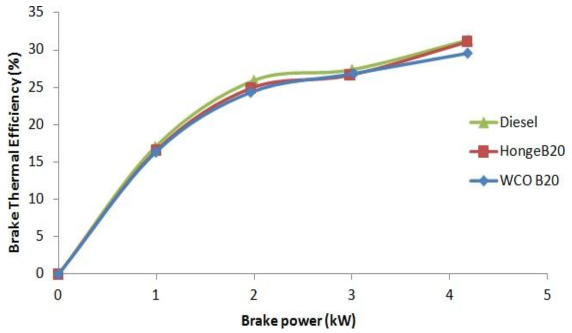

Figure 4: Variation of Brake thermal efficiency with Brake Power for Diesel and B20.

Figure 4 shows the variation of brake thermal efficiency with brake power for diesel and B20 Biodiesels. The brake thermal efficiency increases with increase in the load. Brake thermal efficiency for the diesel is 31.33% at higher load. At higher load brake thermal efficiency for HongeB20 and WCOB20 is 31.1% and 29.58% respectively.

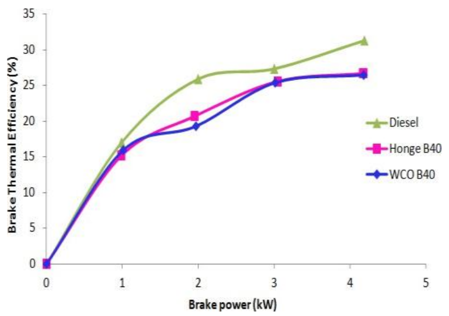

Figure 5: Variation of Brake thermal efficiency with Brake Power for Diesel and B40.

Figure 5 shows the variation of brake thermal efficiency with brake power diesel and B40 Biodiesels. The maximum efficiency recorded is 31.33% for diesel. At higher load, the efficiency for the HongeB40 and WCOB40 is 26.7% and 26.5% respectively.

Exhaust gas temperature:

Figure 6 shows the variation of exhaust gas temperature with brake power for diesel and B20 Biodiesels. The exhaust gas temperature increases with increase in load. At higher load the exhaust gas temperature for Diesel, Honge B20 and WCOB20 are 320°C, 382°C and 356°C.

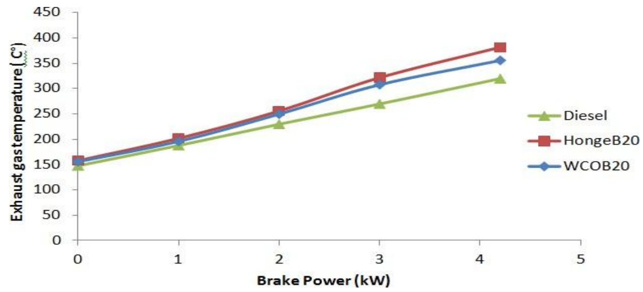

Figure 6: Variation of Exhaust gas temperature with Brake Power for Diesel and B20

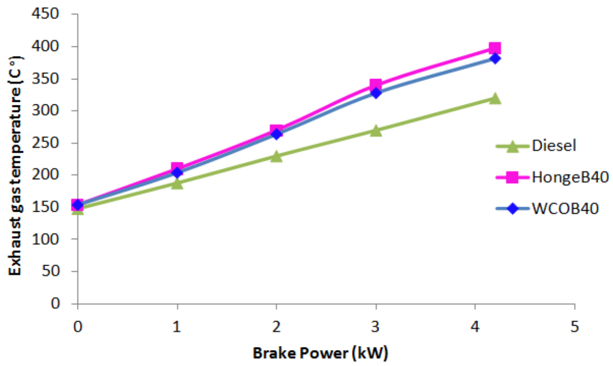

Figure 7: Variation of Exhaust gas temperature with Brake Power for Diesel and B40.

Figure 7 shows the variation of exhaust gas temperature with brake power for diesel and B40 Biodiesels. The exhaust gas temperature increases with increase in the load for all the fuels. The highest value recorded by the HongeB40 which is 398°C at higher load. The temperature of exhaust gas varies from 156°C to 382 °C for WCOB40.

Emission characteristics:

Carbon monoxide emission:

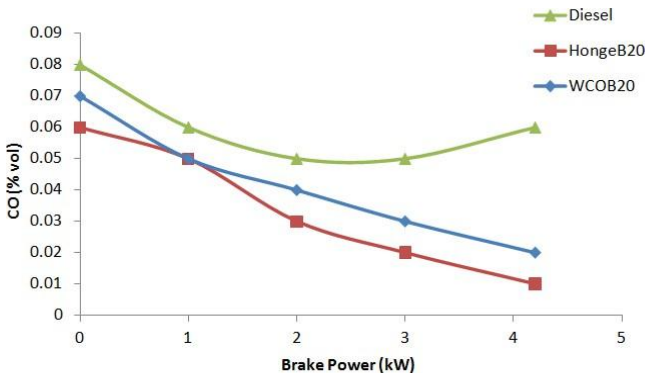

Figure 8: Variation of CO with Brake Power for Diesel and B20.

Figure 8 shows variation of CO with brake power for diesel and B20 Biodiesels. Biodiesels are showing higher emission at no load condition and lower emission at higher load. The highest is CO emission is recorded by the diesel at higher load is 0.06%. The value of the CO emission at higher load for HongeB20 and WCOB20 are 0.01% and 0.02% respectively.

Figure 9 shows variation of CO with brake power for diesel and B40 biodiesels. Due to higher density of HongeB40 and the lower oxygen content of the WCOB40, both biodiesels are shows the slight increase in CO emission at higher loads because of incomplete combustion. The value of the CO for Diesel, HongeB40 and WCOB40 are 0.06% 0.03% and 0.04% respectively. The reason may due to the increase of viscosity as the portion of biodiesel increased in the blend which results in poor volatility.

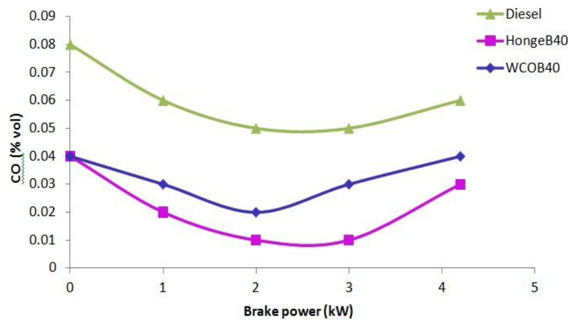

Figure 9: Variation of CO with Brake Power for Diesel and B40.

Hydrocarbon emission:

In the Figure 10 HC emissions varies with break power for diesel and B20 biodiesels. Diesel is showing the higher HC emission which is 18ppm at higher load. The values of HC for HongB20 and WCOB20 at higher load are 11ppm and 12ppm. This is due to the presence of oxygen in the biodiesels.

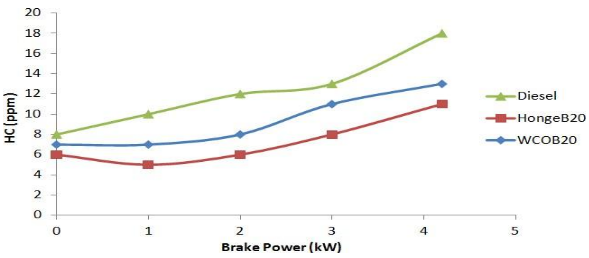

Figure 10 : Variation of HC with Brake Power for Diesel and B20.

Figure 11 shows the variation of HC emission with break power for diesel and B40 biodiesels. The values of the HC emission for diesel, HongeB40 and WCOB40 are 18ppm, 6ppm and 8ppm. Slight increase in the HC emission of biodiesels is due to the increase density which effects spray atomization of the fuel. The variation in the HC emission of Honge and WCO blends is due to the reduced oxygen content during the food processing and also the quantity.

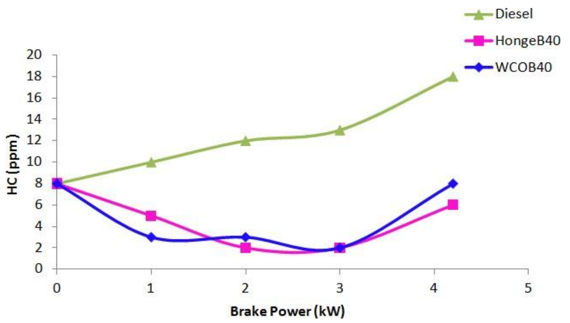

Figure 11: Variation of HC with Brake Power for Diesel and B40.

Oxides of Nitrogen emission:

Figure 12 shows variation of NO_X with Brake Power for diesel and B20 Biodiesels. The NO_X emission for the all the fuel increased with increase in load. At higher load NO_X emission both biodiesels are shows the higher value. The maximum NO_X emission is recorded for the HongeB20 which is 371ppm. For the other two fuels WCOB20 and diesel, NO_X emissions are 367ppm and 307ppm respectively.

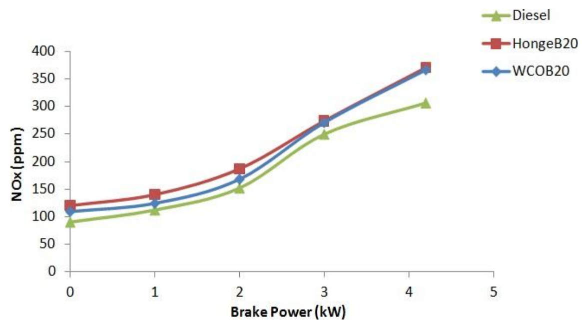

Figure 12: Variation of NO_x with Brake Power for Diesel and B20.

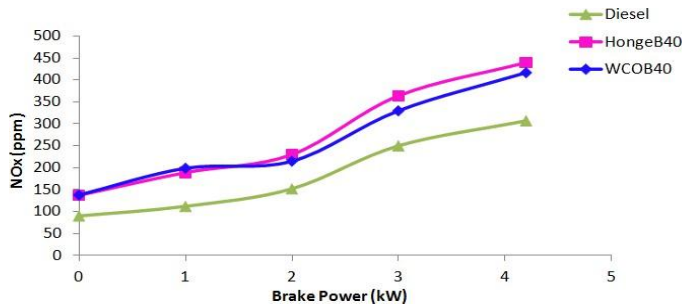

Figure 13: Variation of NO_X with Brake Power for Diesel and B40

Figure 13 shows variation of NO_X with brake power for diesel and B40 biodiesels. NO_X emission increases with increase in load. Maximum NO_X emission for Honge B40, WCOB40 and diesel are 440ppm, 417ppm and 307ppm respectively.

Smoke emission:

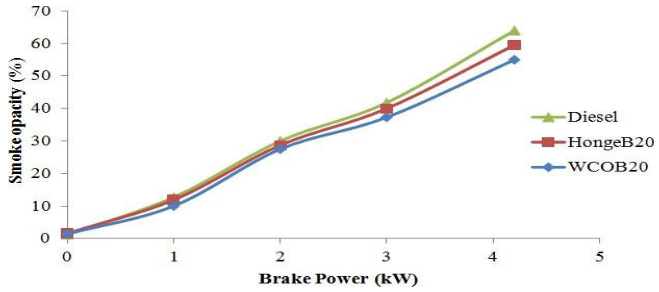

Figure 14: Variation of smoke opacity with Brake Power for Diesel and B20.

Figure 14 shows variation of smoke opacity with brake power for diesel and B20 Biodiesels. Smoke emissions are less than diesel for both biodiesels. The value of the smoke for diesel, HongeB20 and WCOB20 are 64, 59.5 and 55.5 respectively at higher loads.

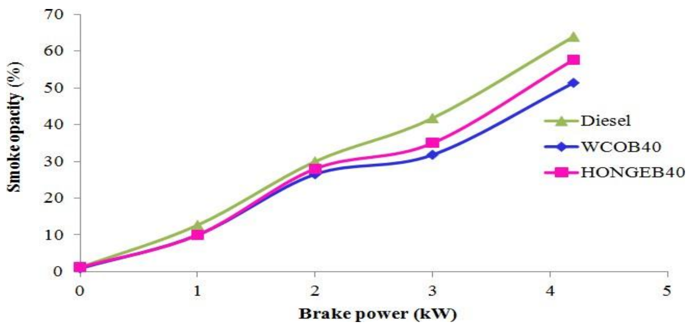

Figure 15: Variation of smoke opacity with Brake Power for Diesel and B40.

Figure 15 shows variation of smoke opacity with brake power for diesel and B40 Biodiesels. Smoke value diesel, HongeB40 and WCOB40 are 64, 57.7 and 51.4 respectively.

Combustion analysis:

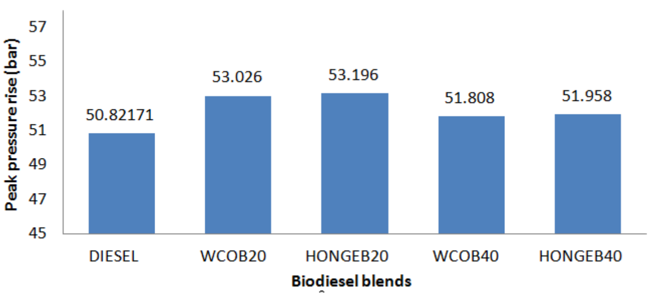

Figure 16 Variation of cylinder peak pressure rise with biodiesel blends at 4.2kW.

As the high load condition is dominated by diffusion phase of combustion, the biodiesel blends results in improved burning rate and higher peak cylinder pressure compared to diesel fuel due to the oxygen available in the biodiesel fuel molecule. But there is reduction in pressure for B40 may be due to increase in density which reduces spray atomization. Exact values of the peak pressure rise for different biodiesel blends are shown in Figure 16.

CONCLUSION

1. Both Honge and WCO are having the FFA value less than 4%, hence single step alkali catalyst Transesterification process is sufficient for biodiesel conversion.
2. Biodiesel produced from Honge and WCO are meeting the ASTM standards.
3. Use of WCO for the biodiesel production reduces the dependency on other non-edible oil plants which requires considerable amount of land and time for cultivation and also reduces the water pollution.
4. Following conclusions were drawn from the performance analysis and exhaust emission characteristics.

- Brake specific fuel consumption of the both biodiesel blends is slightly more than that of diesel. Compared to diesel at higher load, the BSFC of HongeB20 and WCOB20 is increased by 2.04% and 8.59% respectively. BSFC for HongeB40 and WCOB40 increased by 16.6% and 20.4% at higher load compared to diesel.
- Similar trend was observed for Brake thermal efficiency of both B20 biodiesels and diesel at all loads. But, reduction of brake thermal efficiency for HongeB40 and WCOB40 is 14.77% and is 15.41% were observed at higher load.
- Emission of CO and HC was considerably reduced as the load increased for both biodiesels compared to diesel. But these emissions are slightly higher for WCO biodiesel blends than Honge biodiesel blends.
- Compared to diesel, smoke opacity of HongeB20, WCOB20, HongeB40 and WCOB40 reduced by 7.03%, 13.28%, 9.84% and 19.68% respectively at higher load.
- NO_x emission increased with increase in the load and blends for both the biodiesels compared to diesel. The Honge biodiesel blends emits more NOx compared to WCO biodiesel blends at all loads.

5. Both biodiesels can be used as an alternative fuels for diesel engine at B20 and B40 blends.

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