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Research Article

Performance and emission characteristics of waste cooking oil as biodiesel in CI Engine

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Abstract

The petroleum products are very shortage, and these are depleting day by day in use. In this regards an alternatives fuel plays a very important rule. The biodiesel is one of the alternative fuels which can be produced from vegetable oils (edible or non edible oil), animal fats and Waste cooking oil. In these lessons, the biodiesel is produced from waste cooking oil by a method of transisterification, after this, the biodiesel is blended with diesel in proportion of 20%, 40%, 60%, and 80%, on quantity basis along with pure biodiesel, are analyzed and compare with diesel. The present work has mainly on the performance and emission characteristics of waste cooking oil and its blend with diesel, at variable loads (brake power) of 0, 1, 2, 3, 4 and 5.2 kW at constant rated speed of 1500 rpm. The experimental results show that the lower blends of biodiesel there is a raise in brake thermal efficiency, mechanical efficiency; volumetric efficiency and BSFC are well comparable with diesel. And there is reduce of CO, CO_2, and HC as compare with diesel. Hence it is seen that the use of biodiesel produced from waste cooking oil can be an alternative fuel in a diesel engine. And also up to B20 there is no modification needed to the engine.

Keywords: *Trasisterification process, Engine performance, Exhaust emissions, Fossil fuel, Biodiesel, alternative fuels.*

1. Introduction

Vegetable oil is used commonly in cooking and is needed particularly to fry food. After using the same oil over and over again, the remaining oil becomes spoiled with old food remains and can no longer be used for cooking the food. If this waste used cooking oil is disposed into a surrounding which can be a big problem Rickeard *et al*. Instead of disposing we can use this waste cooking oil in diesel engines as a fuel if it is cleaned and properly converted to combustible diesel oil Demirbas *et al*. If a large amount of waste cooking oil is used in the Diesel engine, it can reduce the large amount of using petroleum fuel Nwafor *et al*. The used cooking oil is fundamentally a waste product and for that reason it is cheaper than unused (virgin) vegetable oil. The some of the vegetable oil or Cooking oils are used for frying are sunflower oil, palm oil, coconut oil etc. these are easily available India Rakopoulos *et al*. The waste cooking oil samples used for the purpose is of usually palm oil because it is usually used oil in the restaurants and hostel kitchens. The waste cooking oil is generated from the Fraying of food with high temperatures are generated due to this changes in its chemical and physical composition, as well as in its organic properties which affect both the food and oil quality. Used cooking oil is normally black, a strong odor Dorado *et al*.

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Environmental problems for disposing waste cooking oil Pugazhvadivu *et al*.

1) When this waste cooking oil is dumped into river or any water source which can react with water and increases organic pollution in the water, and which alters the ecosystem.

2) This waste cooking oil is causes problem in the pipes drain obstructing them and creating odors and increasing the cost of wastewater treatment.

3) The hazardous odors create a negative impact on health, mainly by hydrogen sulfide (H_2S), which can cause irritation of the respiratory tract, skin problem, headaches and eye irritation

Table 1: Chemical composition of waste cooking oil

Features	Oil collected by the hotel sector
Acidity (%)	0.56
Moisture	0.25
Viscosity at 37^0 C (mm^2/s)	44.78
Iodine index (Cgl_2/g)	108.22
Un saponifiable material (%)	1.70
Saponification index (mg KOH/g)	195.87
Ash (%)	0.030
Refractive index 25°C	1.4700
Density 15°C (kg/m^3)	910

2. Methods for making biodiesel

The waste cooking oil (WCO) has properties different from the properties of refined / crude fresh cooking oils. During frying process there is a presence of heat and water which accelerates the hydrolysis of triglycerides and increases content of free fatty acids in oil. The Oxidation stability of the oil is disturbed because of the contact of hot oil with food, and peroxide value of oil increases Huzayyin *et al*. Viscosity of oil increases significantly, because of the formation of dimeric and polymeric acids and glycerides. Also density increases, due to its high viscosity, this oil get chemically modified into esters whose properties resemble those of fossil fuels. These chemically modified processes are called transisterification Jothi *et al*.. This process requires heat and a strong catalyst (alkalis, acids, or enzymes) to achieve complete conversion of the vegetable oil into the separated esters and glycerin Agarwal *et al*. During the transisterification reaction, glycerin is obtained as a by-product.

2.1 Transisterification procedures

It consists of four steps as follows:
1) Add the catalyst to neutralize the free fatty acids
2) Preparation of methoxide solution
3) Formation of biodiesel and glycerol
4) Clean the obtained bio-diesel

STEP: 1:In this step, find out the amount of catalyst required to neutralize the free fatty acids. This can be done by titration process.
The following are required for doing the titration process:1 ml of oil, 1 litre of distilled water, 10 ml isopropyle alcohol, 1 gm of catalyst, 2 drops of color indicator (phenapthelene).
First prepare the stock solution by adding 1gm of KOH in a perfect measured one liter of distilled water. Then this value becomes 1gm/1000ml or 0.001 alkali. Fill the stock solution in 25ml burette. Then take 1 ml of oil using pipette and dilute this in 10 ml of iso propyl alcohol. Add two drops of phenapthelene colour indicator and keep it closed. Then start the titration process. Then the colour of the oil changes into pink colour. Then watch the burette how much ml is consumed. If suppose it is consumed by 5 ml, then there is a 5% of free fatty acids and we require 20 gm of catalyst to neutralize fatty acids. In this our oil has 1% of FFA. Thus it requires 5gm of KOH with 200 ml of methanol.

STEP: 2:Prepare the methoxide solution by mixing of methanol with potassium hydroxide. Mix the 5gm of KOH with 200 ml of methanol and keep it safely.

STEP: 3:Take the one liter of oil, heat the oil up to 65^0 C and react with methoxide solution fastly by using a glass rod. Then pour the oil in a separate vessel and allow sufficient time for separation of bio-diesel and glycerol.After some time, we find two layers which are maximum at top and minimum at bottom. The top layer is called bio-diesel or methyl ester and the bottom layer is a byproduct called glycerol.

STEP 4: Clean the oil with the distilled water for two or three times. First clean the oil with distilled water to remove the untreated methoxide and then heat the oil to remove any water traces and finally we obtain a clear bio-diesel.The following are the proportions for transisterification process of waste cooking oil with no free fatty acids.

Table 2: chemical proportion of WCO

S .No	Chemical	Proportion
1.	Waste cooking oil	1000 ml
2.	Catalyst- KOH	5 gm
3.	Methanol	200 ml

2.2 Biodiesel blend preparation

The tests were carried out with B20 (20% bidoiesel-80% diesel by volume),B40 (40% biodiesel-60% diesel by volume), B60 (60%biodiesel -40%diesel volume), B80 (80% bidoiesel-20% diesel by volume) and B100 (net biodiesel).Blends were prepared on a volume basis at 25^{o}C.

Table 3: density and calorific value of different fuel blends

Sl. No	Blend of fuel	Density (Kg/m^3)	Calorific value(KJ/Kg)
1	B0	840	42500
2	B20	850	40750
3	B40	860	39100
4	B60	870	37200
5	B80	882	36640
6	B100	892	35640

Table 4: Properties of standard diesel and biodiesel

Property	WCO	Biodiesel	Diesel
Kinematic Viscosity At 40^{o}C (mm^2/s)	39.7	6.58	2.4
Calorific Value(MJ/kg)	34.23	35.64	42.5
Cloud Point (^{o}C)	0	2	-5
Pour Point (^{o}C)	-40.7	-8	-20
Flash Point (^{o}C)	278	180	75
Density (kg/m^3) At 15^{o}C	910	892	840

3. Experimental Work

Table 5: Specifications of the engine

Name of the engine: AV1 Kirloskar Oil Engines Ltd India
Model :TV SR II naturally aspirated
Engine : single cylinder, DI
Number of cylinders : 1
Bore: 87.5mm
Stroke : 110mm

Rated power: 5.2kW
Working cycle : four stroke
Injection pressure : 185 bar
Injection timing : 23 deg TDC
Type of sensor : piezo electric
Rated speed : 1500rpm constant
Compression ratio : 16.5:1

3.1 Experimental technique

This computerized test rig was used for recording the test parameters such as fuel flow rate, temperatures, air flow rate, load etc. and for calculating the engine performance characteristics such as brake thermal efficiency, brakes specific fuel consumption, Volumetric efficiency etc., the calorific value and the density of a particular fuel was fed to the software as input variables. Planet Equipment of gas analyzer isused to find out the emission character's on carbon monoxide (CO), carbon dioxide (CO_2), un-burnt hydro carbon.

3.2 Experimental procedure

The engine was run at a variable load (BP) of 0, 1, 2, 3, 4 and 5 kW at a constant rated speed of 1500rpm with fuel injector pressure of 185 bar cooling water exit temperature of 62^0C. The engine was sufficiently warmed up and stabilized before taking all readings. Different blends of biodiesel from waste cooking oil with diesel were prepared namely B20, B40, B60,B80 and B100. Before using blend, each one was mixed thoroughly. Then in the similar manner as in case of diesel fuel reading of each meter is noted down. During each blend, the filter of diesel engine was opened and complete mixture of biodiesel and diesel was drained so that it could not impure next blend by mixing with its previous blend. Then again for another blend, in the similar fashion, the experiment was repeated for knowing the above stated parameters. The performance characteristic of the engine is evaluated in terms of brake thermal efficiency, brake specific fuel consumption, and emission characteristics in terms of smoke, unborn HC, CO and exhaust temperature. These performance and emission characteristics are compared with the results of baseline diesel.

4. Result and Discussions

Fuel consumption (kg/h):The Figure shows variations of fuel consumption with brake power for different blends with diesel. It shows the fuel consumption increases corresponding to increase of brake power. The fuel consumption depends up on the calorific value of the fuels. With increase in the calorific value the fuel consumption reduces. The diesel fuel has more calorific value compared with the fuel blends. So the fuel consumption of the blends are higher than the diesel fuel due to lower calorific value of the fuel blends (B20,B40, B60 B80 and B100),the fuel consumption for diesel is 33.5(kg/h), whereas B20 is 34.7(kg/h), is higher by 1.2(kg/h) and we can say that fuel consumption of B20 is well comparable. For B40, B60 and B80, corresponding fuel consumption is 39.05, 49.6, and 52.6(kg/h).

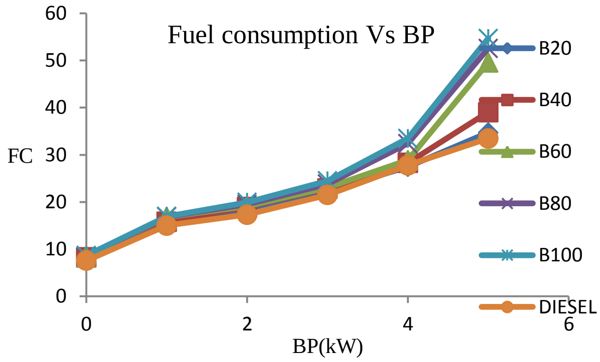

Figure 1: Fuel consumption Vs BP for different blends

Specific fuel consumption (kg/kW-h): The Figure shows the variations of the specific fuel consumption with brake power for different blends, with diesel. It shows the specific fuel consumptions are reduced with increase in the brake power. The specific fuel consumption of the Bio diesel blends are more than the diesel fuel. The specific fuel consumption depends upon the friction, high speed and the heat release rate. The fuel blends (B20, B40, B60, B80 and B100) have lower heat release rates. So the specific fuel consumption is higher than the diesel fuel. The SFC of B20 is 0.465(kg/kW-h) against diesel is 0.438(kg/kW-h) is higher by 0.027(kg/kW-h). We can say that fuel consumption of B20 is well comparable.

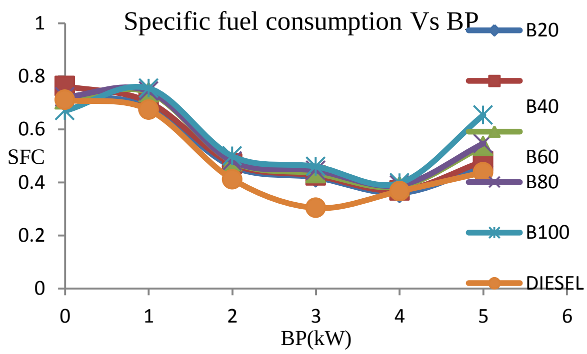

Figure 2: Variations of BP with specific fuel consumption for different blends

Brake thermal efficiency (%):The Figure shows the variations of BP with specific fuel consumption for WCO blends with diesel. The brake thermal efficiency for B20 and B40 was comparable to efficiency of diesel fuel. It indicates that higher cetane number and inherent presence of oxygen in the biodiesel produced better combustion. The maximum brake thermal efficiency of B20 BTE is 20.4% which is almost near to diesel, so we can say that B20 is comparable with diesel fuel.

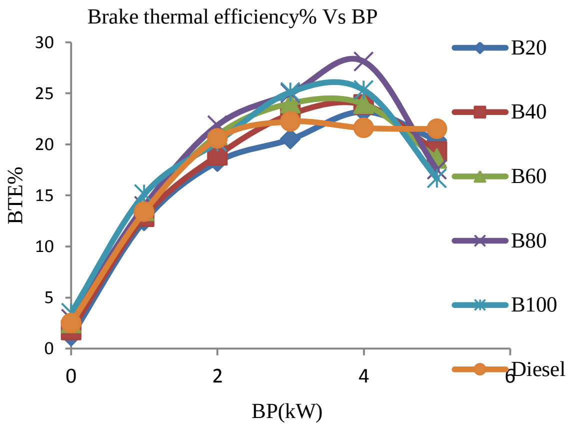

Figure 3: Variations of BP with Brake thermal efficiency for different blends

Mechanical efficiency (%):The Figure shows the Variation of mechanical efficiency with brake power for different WCO blends with diesel oil. The mechanical efficiency for B20 is similar to diesel oil. And at low load B80 and B60 are of mechanical efficiency higher than that of diesel oil. This is because of low viscosity, higher cetane number and inherent presence of oxygen in the biodiesel produced better combustion. The maximum mechanical efficiency for diesel oil is 62.71% and maximum mechanical efficiency for B20 is 61.35%.

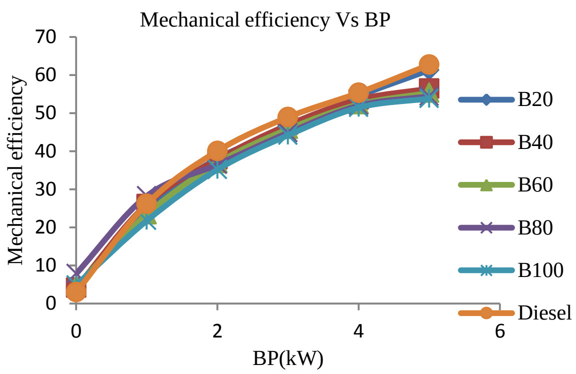

Figure 4: Variations of BP with mechanical efficiency for different blends

Volumetric efficiency (%): The Volumetric efficiency decreases with increase in concentration of waste cooking oil in diesel. The increase in exhaust gas temperature may be responsible for reduction in volumetric efficiency. The maximum volumetric efficiency for diesel oil is 100% is 85.4% but it is reduced by adding waste cooking oil in diesel oil. The volumetric efficiency for B20, B40, B60, B80 and B100% are 76.8, 74.9, 74.4, 73.7 and 71.38% respectively.

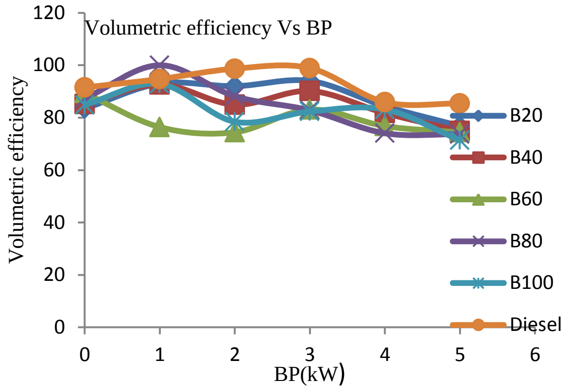

Figure 5: Variations of BP with volumetric efficiency for different blends

Carbon dioxides (CO_2):**T**he variations of carbon dioxide with brake power for different blends with Diesel as shown in figure.The addition of the biodiesel to the blend decreased the CO_2 emissions. At full load condition the carbon dioxide emission of diesel fuel is higher than blended fuels. This may be because of the vegetable oil containing oxygen elements, increasing percentage of biodiesel in the blend, decrease the emission of CO_2. For B20 and B40 biodiesel the emission is less than diesel at all load condition. There is reducing in CO_2 because of higher cetane number in Biodiesel as compared standard diesel CO_2 emission by improving combustion.

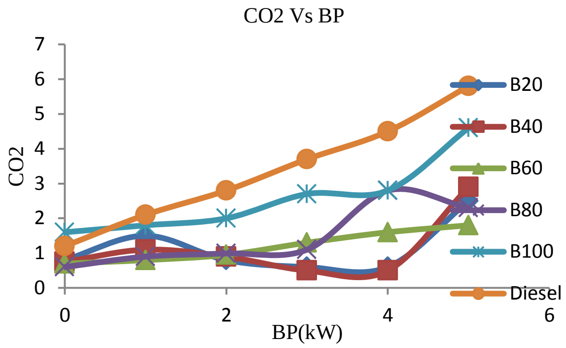

Figure 6: Variations of BP with CO_2 for different blends

Carbon monaxide (CO): The variations of the carbon monoxide with brake power for different blends with Diesel are shown in Figure. It is experientially seen that the engine emits more CO fordiesel as compared to biodiesel blends under all loading conditions. In engine, CO formations are as a result of incomplete combustion due to mainly lack of oxidants. At the maximum load condition carbon monoxide emissions decrease for B20, B40, B60 and B80. The CO emission of B20 blends decreased more significantly at full load. This may be due to the enrichment of oxygen in the waste cooking oil, in which an increase in the proportion of oxygen promotes further oxidation of CO during the engine exhaust process. At lower percent of waste cooking oil in diesel, leads to decrease the emission of CO due to the oxygen present in it, aids for complete combustion. However as the waste cooking oil concentration increases, the negative effect due to viscosity that shows the value in B100 (1.5PPM) and B80 (1.25).

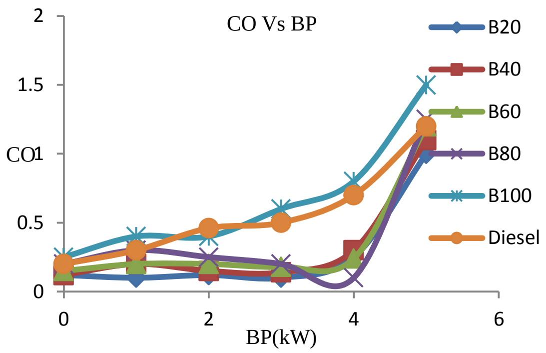

Figure 7: Variations of BP with CO for different blends

Hydro carbons (HC):The variations of hydrocarbon emission with brake power for different blends with Diesel are shown in Figure. The main reason for variations in HC Emission is due to the carbon and hydrogen content of the fuel. The HC emissions for blends are lower than diesel fuel, because biodiesel fuel having higher oxygen content in it due to this to complete combustion takes place in biodiesel. The fuel blends (B20, B40, B60, B80 and B100) have the lower carbon residue and hydrogen than the diesel fuel at all load conditions. The B20 has the lowest hydrocarbon emission than the other fuels. The maximum hydrocarbon emission for diesel fuel is 233ppm

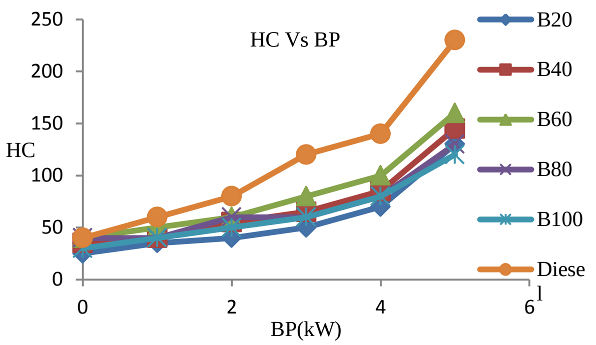

Figure 8: Variations of BP with HC for different blends

Conclusions

From the above Experiment, the following conclusions are drawn.

- The properties of density, viscosity, flash point, and fire point of waste cooking oil is higher and calorific values lower than diesel.
- The fuel consumption of the blends are higher than the diesel fuel due to lower calorific value of the fuel blends (B20,B40,B60 and B80).The fuel consumption for diesel is 33.5(kg/h), whereas B20 is 34.7(kg/h), is higher by 1.2(kg/h).
- The specific fuel consumption of the Biodiesel blends are more than the diesel fuel. The SFC of B20 is 0.465(kg/kW-h) againstdiesel is 0.438(kg/kW-h) is higher by 0.027(kg/kW-h).The brake thermal efficiency for biodiesel for all blends range was fond almost comparable to efficiency of diesel fuel.
- The maximum brake thermal efficiency of B100 is 28.9%, against 21.5% of diesel oil which is higher by 7.4%. B20 BTE is 23.9% which is almost near to diesel.
- The maximum mechanical efficiency for diesel oil is 62.71% and maximum mechanical efficiency for 100% blend is 65.92%. The higher the concentration of blend with biodiesel the lower the engine performance.
- The biodiesel blends have the high exhaust gas temperature. Due to this volumetric efficiency of diesel fuel is more.
- The smoke densities of the fuel blends (B20, B40, B60 and B80) are higher than the diesel fuel.
- There was a reduction in CO emission for B20 blend at full load condition.
- The standard diesel produced the highest CO2 concentrations.
- The hydrocarbon emissions of the blends (B20, B40, B60 and B80) are lower than the diesel fuel at all load conditions. The maximum hydrocarbon emission for diesel fuel is 230ppm.

So waste cooking oil used as Biodiesel in IC engine without any modification. And consider as alternative fuel for Diesel engine.

References

Rickeard, D. J. and Thompson, N. D. (1993) A review of the potential for biofuel as transportation fuels,SAE Technical Paper Series, SAE 932778.

Demirbas, A., 2006. Biodiesel production via non-catalytic SCF method and biodiesel fuel characteristics, Energy Conversion Management 47, pp. 2271– 2282.

Nwafor, O.M.I., 2004. Emission characteristics of diesel engine running on vegetable oil with elevated fuel inlet temperature, Biomass Bio energy 27, pp.507–511.

Rakopoulos, C.D., K.A., Antonopoulos, Rakopoulos D.C., D.T., Hountalas, and E.G., Giakoumis, 2006. Comparative performance and emissions study of a direct injection diesel engine using blends of diesel fuel with vegetable oils or bio-diesels of various origins, Energy Conversion Management47, pp.3272– 3287

Dorado, M.P., E.A., Ballesteros, J.M., Arnal, J.,Gomez, and F.J., Lopez., 2003.Exhaustemissions from a diesel enginefueled with transisterified waste olive oil, Fuel 82, pp. 1311–1315.

Pugazhvadivu, M., K., Jeyachandran, 2005. Investigations on the performance exhaust emissions of a diesel engine using preheated waste frying oil as fuel, Renewable Energy 30, pp. 2189–2202.

Huzayyin, A.S., A.H., Bawady, M.A., Rady, and A., Dawood., 2004. Experimental evaluation of diesel engine performance and emission using blends of jojoba oil and diesel fuel, Energy Conversion Management 45, pp. 2093–2112.

Jothi, N.K.M., G., Nagarajan, and S., Renganarayanan, 2007. Experimental studies on homogeneous charge CI engine fueled with LPG using DEE as an ignition enhancer, Renewable Energy 32, pp.1581–1593

Dr. Avinash Kumar Agarwal (2008), Experiment to study the properties and the performance of non edible vegetable oils in a diesel engine Indian Institute of Technology Kanpur.