Proceedings of 13th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2023 Month: April Volume: 13

Performance Analysis and Testing of Biodiesel from Waste Chicken Fat in Internal Combustion Engine

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Abstract

This work mainly focuses on synthesis of biodiesel using waste chicken fat and blending this biodiesel with the diesel to enhance the fuel properties and hence the overall characteristics of diesel engine. At first, the biodiesel was synthesized from waste chicken fat through transesterification process in the laboratory of NAST. Various blends were prepared; 10% biodiesel and 90% diesel (B10), 15% biodiesel and 85% diesel (B15) and 20% biodiesel and 80% diesel (B20). The physio-chemical properties of the biodiesel and B20 were tested and Nepal Oil Corporation lab. Then, the testing of diesel and the blends of biodiesel were conducted using various compression ratio on the Kirloskar Single Cylinder Compression Ignition Engine at 1500 rpm on varying loads and compression ratio. Various engine performance parameters like Indicated Power (IP), Brake Mean Effective Pressure (BMEP), Brake Power (BP), Specific Fuel Consumption (SFC) and Mechanical Efficiency (ME) against load in comparison to diesel fuel were obtained and those were verified with diesel fuel. IP for diesel, B10, B15 and B20 at full load (12kg) are 4.3kg, 5.18kg, 5.05kg, and 5.02kg respectively. ME of B20 at full load is less by 11.648 % than that of diesel. Difference in SFC of B20 and diesel at full load is 0.36 kg/kWh. The output data confirms that the IP of biodiesel was slightly higher than diesel and BP was found comparable to diesel fuel.

Keywords

Ferric oxide Nano Particle, Pine Oil, Diesel Engine, Engine Performance

1. Introduction

Biodiesel has got a lot of press in last decade because of its potential to replace the fossil fuels, which are expected to finish up in the next century. Biodiesel is a fuel that is made up of mono-alkyl esters of long chain fatty acids generated from the vegetable oils or animal fats that meets ASTM D 6751 specifications. The trans-esterification method is used to create biodiesel. Vegetable and animal fats are converted into esterified oil in this method. But direct use vegetable oil in the diesel engine because it cause various problem like poor atomization, incomplete combustion and clocking of fuel filter. High density and high viscosity of vegetable oil leads to such problems [1, 2]. Biodiesel has been demonstrated to emit less pollutants from the exhaust than normal diesel fuel. The biodiesel is typically prepared by chemical reaction between lipids and alcohol in the presence of catalyst which produce fatty acid methyl esters (Biodiesel or FAME) by the reaction termed as transesterification. Viscosity and density of the blend increase with the increase in concentration of the biodiesel as the viscosity and density of biodiesel is more than that of the diesel [3, 4]. Transesterification of triglycerides [5] is shown in Figure 1.

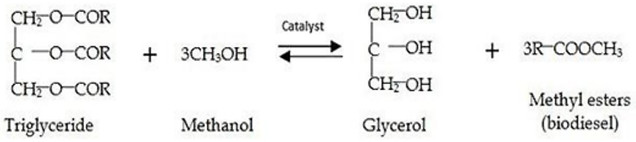

Figure 1: Transesterification

Transesterification process is affected by alcohol, catalyst, and reaction temperature, molar ratio of glycerides to alcohol, free fatty acids, and reaction time. Alkali catalyst is easily dissolved in methanol and methanol can quickly react with triglyceride [6]. Enzymes, acids and alkalies are the three primary types of catalysts which are utilized in the manufacturing of biodiesel [7]. Among the various alkali catalysts, KOH and NaOH are used because of their minimum cost and lower boiling point. Alkali catalysts are hygroscopic, so they can store water on larger quanitity [8] . NaOH concentrations range from 1.0 to 1.4 percent (weight/weight) for better conversion, while KOH concentrations range from 0.55 to 2.0 percent (weight/weight) [9] . Higher reaction temperature leads to vaporize alcohol that affects the conversion percentage of biodiesel yield [10]. The peak reaction temperature of the biodiesel while using alcohol is 60^0C [9]. For a reaction time of two hours, an intensity of 360 rpm and 600 rpm produced equal results, indicating that mixing intensity encourages the homogeneity of the reaction mixture and increases in the production of biodiesel [11]. FFA level exceeding 1% causes soap development in the sample and makes product separation challenging; as a result, transesterified biodiesel recovery is low[12] .The acid value is defined as the mass of potassium hydroxide(KOH) in mg needed for the neutralization of 1 gram of the taken oil sample [13].

2. Experimental Methods and Materials

2.1 Preparation of Biodiesel

Firstly, to conduct transesterification process, the waste chicken fat was collected, heated and then filtered using muslin cloth to remove the impurities and it was heated up to 60°C, which is measured by using mercury thermometer. KOH and methanol

(1% of oil weight of KOH and molar ratio of 6:1 methanol to oil of methanol) mixture was slowly added to the chicken fat and stirred at 600 rpm by using magnetic stirrer. Constant temperature of 60°C was maintained while stirring by heat block using the oil bath. The time of reaction was 60 minutes and after completing the reaction the solution is transferred to the separating funnel and left it overnight. Two layers will be observed, upper most layer is biodiesel and glycerol is the lower layer. The lower glycerol layer is removed using separating funnel. The remaining biodiesel layer was washed with distilled water until PH 7 was obtained which was checked using PH paper. The amount of biodiesel that was formed was divided by the total amount of the waste chicken fat taken initially to obtain the biodiesel yield and it was found to be 96.84%.

2.2 Preparation of Blends

The blends were prepared by blending diesel with biodiesel obtained after transesterification process by using measuring cylinder. Blend B20 was made by blending 20% by volume of biodiesel and 80% of diesel,B15 was made by blending 15% biodiesel and 85% diesel and B10 was made by blending 10% biodiesel with 90% diesel and characterization of the biodiesel blends were done.

2.3 Thermo-physical properties Test of Blended Biodiesel Fuel

B10, B15, B20 biodiesel blends were taken to Nepal Oil Corporation Lab to find different physio-chemical properties of the fuel blend. The properties that was tested were kinematic viscosity, density, flash point, pour point, and cetane number.

2.4 Fourier Transform Infrared (FT-IR) Test

FTIR test was done in Department of Plant, Thapathali, Kathmandu by using FT-IR spectrometer to find out the presence functional group in the biodiesel blend and diesel so as to make comparison of different types of functional groups present in them.

2.5 Engine Specifications

The Kirloskar diesel engine, which was available in Thapathali campus and this engine was used for the testing purpose. The specifications of the testing engine and the engine is shown in Table 1.

2.6 Experimental Test Procedure

Initially, testing of test engine was done by running about 15 to 20 minutes at constant speed of 1500 rpm with diesel fuel so that the stable working environment is attained. Also, it is essential to keep in mind that there is proper circulation of coolant water in the engine at around 1 atm pressure and this pressure is shown by pressure gauge which is setup in the engine. Various blends of biodiesel obtained from waste chicken fat was used to run the engine. Testing was done by loading the engine with 1kg, 3kg, 6kg, 9kg and 12kg load by using eddy current dynamometer at constant speed of 1500rpm. Then, the required data of the performance of the engine were taken. Same process was repeated for the diesel and its data were also obtained. Burette and stop watch setup was used to measure the rate of flow of biodiesel in 60 second.

Table 1: Engine Test Ring Specifications

S.N.	Features	Specifications
1	Make	Kirloskar diesel Engine
2	Type	Water cooled Diesel, 4 strokes
3	Number of cylinders	1
4	Method of starting	Electric motor cranking
5	Principle of combustion	Compression ignition
6	Loading	Eddy current dynamometer
7	Radius of Crank	55mm
8	Range of Compression ratio	15:1-18:1
9	Length of connecting Rod	300mm
10	Maximum speed	1500rpm
11	Maximum power	3.5 kW

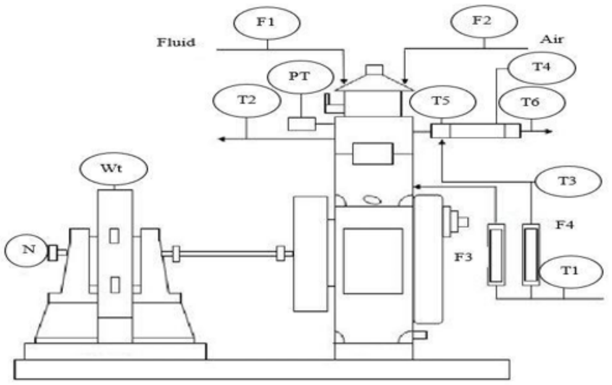

Figure 2: Block diagram of Test Engine

3. Results and Discussion

3.1 Physiochemical Properties of Fuel

Various properties like kinematic viscosity, Cetane number, calorific value, density, flash point Sulphur content, etc. will be found out by characterizing the biodiesel. This characterization helps to compare the properties of biodiesel and diesel.

3.2 FTIR Analysis

FTIR spectrum of diesel and biodiesel is as shown in figure 3. C-O/O-CH3 is associated to ester group and this is indicated by the biodiesel peak around 1195 cm-1. Also other sharp peak of the biodiesel at about 1745 cm-1 shows that C=O of the stretching vibration and this is allotted to the ester groups [11]. Some other strong peaks were observed in 2800-3000 cm-1 range which corresponds to stretching of CH2 group, that is associated with alkaline groups [14].

Thus, it can be validated that both the diesel and biodiesel have same C-H functional group .The diesel don't have oxygen group, while biodiesel have functional group like C-O at around 1745cm-1. Thus, the diesel without having C=O group produces comparatively additional black smoke due to incomplete combustion than biodiesel which contains oxygen which accelerates cleaner and complete combustion.

Table 2: Physicochemical Property of B20

S.N.	Characteristics	Test Method	Requirements	B20
1	Density at 15 ºC	ASTM D1298	810-845	835.6
2	Flash Point, ºC, Min	IP170	35	46
3	Cetane Number, Min	IS1448	51	57.5
4	Pour Point, ºC Max	ASTM D5949	15	-18
5	Kinematic Viscosity at ºC, Cst	ASTM D445	2-4.5	2.651
6	Calorific Value, KJ/kg	IS 1448	43200	4500

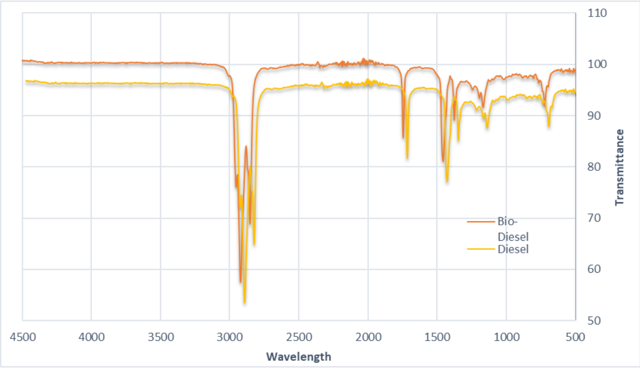

Figure 3: FTIR analysis of Biodiesel

3.3 Engine Performance Results

3.3.1 Indicated Power

The power that is obtained from burning of fuel inside the cylinder of an engine is its indicated power. For the diesel engine, high indicated power is preferred. The indicated power is gradually increasing when the load is increasing in an engine as shown in the graph below. From the graph we can see that the indicated power of B10 fuel is greater than the diesel fuel at same compression ratio of 15. At this compression ratio the initial value of B10 fuel is almost same to the pure diesel but when the load is increasing the value shows a gap between the IP values. Also, when we increasing the compression ratio the indicated power also increasing from initial load to the final load. The first figure shows the comparison of B10 fuel to pure diesel at two compression ratios of 15 and 16. Other two figure shows the comparison of different fuel blend at different compression ratio.

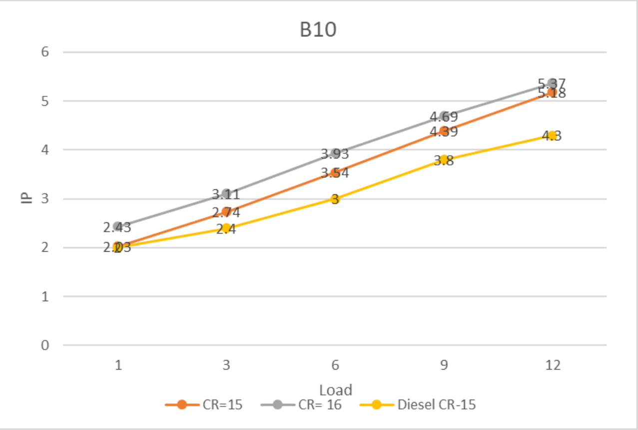

Figure 4: Indicated Power vs Load Graph of B10 and Diesel at Different Compression Ratio

3.3.2 Brake Power

The brake power BP of an internal combustion engine is the power which is available at the crankshaft. The brake power of the engine is always less than that of Indicated power of an engine. From the graph we can analyze that the BP of B10 fuel also slightly greater than that of pure diesel at same compression ratio. Also, when we increasing the compression ratio BP also increasing slightly at initial and final load but nearly same at the middle of the load. The BP of the fuel B15 are nearly same value slightly difference on the higher load at different compression ratio of 15 and 16. And the BP of B20 fuel at different compression ratio shows the clear gap means the BP is higher at higher compression ratio.

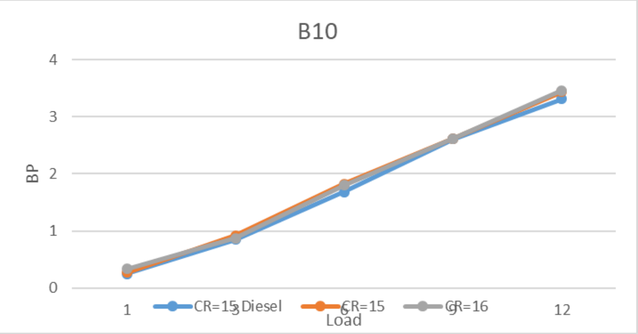

Figure 5: Brake Power vs Load Graph of B10 and Diesel at Different Compression Ratio

3.3.3 Indicated Thermal Efficiency (ITE) and Brake Thermal efficiency (BTE)

Indicated efficiency is derived from measurements taken at the flywheel. It is also defined as the work produced per cycle to the amount of fuel energy supplied per cycle ratio that can be released in the process of combustion. The ITE of B10 is greater than that of pure diesel at same compression ratio. When increasing the compression ratio, the ITE also increases at B10 fuel and other two fuel B15 and B20 but there were same and greater value at the middle load of B15 and B20 fuel as shown in figure. Brake thermal efficiency is the brake power to the fuel energy ratio. From the experiments, it is clearly seen that increasing the brake power increases the brake thermal efficiency. Brake Thermal Efficiency of Chicken fat fuel blend is lower than that of pure diesel and slightly closer at the initial load and final load. Thermal efficiency of fuel blends was found to be lesser as compared to diesel which is confirmed by earlier study [15]. Oxygen hat is present in the biodiesel improves combustion characteristics but poor atomization and combustion characteristics are led due to higher viscosity and poor volatility of the biodiesel. BTE of Chicken fat biodiesel of B10 is almost similar at same compression ratio, but when we increasing the compression ratio the BTE also increasing at other sample B15 and B20.

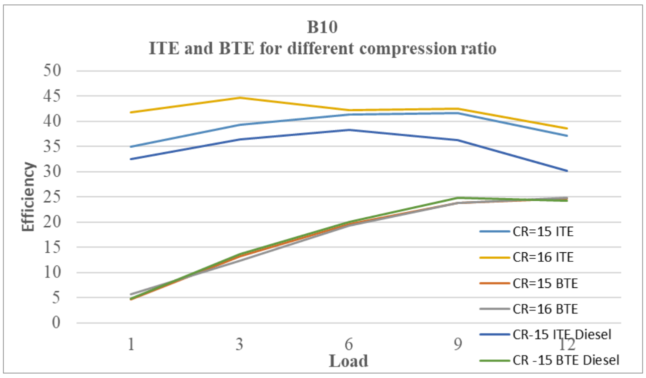

Figure 6: ITE and BTE vs Load Graph of B10 and Diesel at Different Compression Ratio

3.3.4 Mechanical and Volumetric Efficiency

The amount of brake power obtained for a unit indicated power supplied is termed as mechanical efficiency. From figure we can see that mechanical efficiency is decreased when we increased the compression ratio. The mechanical efficiency of pure diesel is higher than that of other blended biofuel because the higher losses in the engine cylinder. The ME of B15 and B20 fuel has slightly smaller value at higher compression ratio. The volumetric efficiency is almost same for all kind of fuel. The volumetric efficiency is higher at initial load and small decrement on the final load for all type of fuel blend.

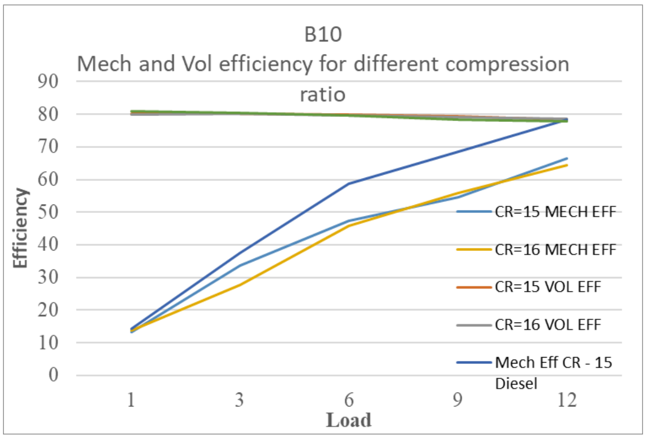

Figure 7: Mechanical and Volumetric Efficiency vs Load Graph of B10 and Diesel at Different Compression Ratio

3.3.5 Specific Fuel Consumption

Specific fuel consumption (SFC) is the measure of fuel that goes into the engine for every unit output power by the engine. The SFC of chicken fat fuel blend and diesel is decreasing in nature while increasing the load to the engine as shown in figure below. From the test experiment, we can see that there was low value of SFC when we increase the concentration of chicken fat on pure diesel. Since, the biodiesel have high calorific value and high densities than the diesel which needs lesser flow of mass fuel for the same output energy from the engine which leads to increase in SFC for biodiesel. We can see in graph a variation on SFC graph on different fuel blend as in B10 concentration the SFC is higher in low compression ratio and SFC is lower in higher compression ratio at initial load also the graph follow the same pattern in B20 fuel but the result is vice versa in B15 fuel at initial load. When the engine operates on full load to all types of concentration the SFC is almost same which is because the combustion is improved at high load due to the greater cylinder temperature after continuous working of engine at this load that would improve atomization of fuel and evaporation processes and improve mixing process of fuel air partially.

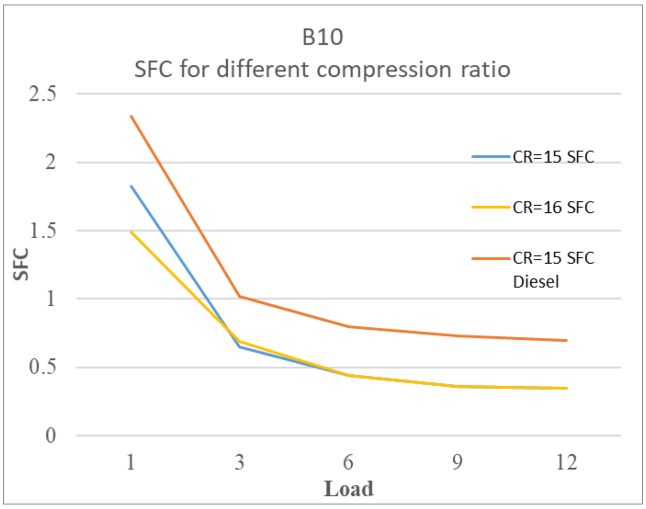

Figure 8: SFC vs Load Graph of B10 and Diesel at Different Compression Ratio

4. Conclusion

This study focuses on the synthesis of the biodiesel using WCF, and the blends of biodiesel were tested at varying compression ratio and at different engine loads and different nozzle holding pressure. Three fuel blends, B10, B15, and B20 were prepared and tested. From the results obtained, the followings conclusions are drawn:

- Free Fatty Acid Concentration on waste chicken fat was less than 1% so one step transesterification process was selected for the maximum yield.
- The physiochemical properties of biodiesel were found to be within the limits when compared with ASTM standard.
- Blends of biodiesel and diesel were made; 10%biodiesel and 90% diesel (B10), 15% biodiesel and 85% diesel (B15) and 20% biodiesel and 80% diesel (B20).
- Engine testing of diesel and the blends of biodiesel were conducted using various compression ratio on the Kirloskar Single Cylinder Compression Ignition Engine at 1500 rpm on varying loads and compression ratio
- IP was found to be approximately same for all the biodiesel blends at full load (12kg) condition and it was slightly

more than that of diesel.
- SFC of biodiesel was also found to lesser than that of diesel.
- ME of biodiesel was lesser than that of diesel while the VE of biodiesel was found to be slightly more than that of diesel
- When the nozzle pressure was increased from 200MPa to 210MPa BP, IP,ITE was increased while BTE, SFC, ME, VE was decreased

Acknowledgments

The authors are thankful to Department of Automobile and Mechanical Engineering, Thapathali Campus for access to the lab.

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