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Biodiesel Production from Chicken Feather Meal and its Performance Analysis on Diesel Engine

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Biodiesel Production from Chicken Feather Meal and its Performance Analysis on Diesel Engine

Abstract

Biodiesel has intrinsic lubricating properties due to the presence of long chain fatty acids, which significantly help to reduce engine wear and tear. Poultry waste as an alternative energy source could aid in reducing greenhouse gases. Biodiesel acknowledges environmental issues as it is less toxic than diesel and is biodegradable too. It is much safer to handle due to its high flash point and consequently, air quality improves dramatically. From the energy point of view, as a renewable source of energy, it helps in energy conservation and ensures regular availability for production of fuel. The chicken feather meal with moderate fat content was utilized to produce biodiesel. In this study, blends were prepared with biodiesel and consist of fatty acid alkyl esters and diesel at different concentrations namely: 0%, 20%, 40%, 60% and 80%. These were analyzed for their engine performance characteristics. The blends from B20 to B80 fuels showed the decreased concentration of CO and NOx emissions at variable load when compared to diesel. The engine performance parameters such as brake power output, brake horse power and specific fuel consumption proved that the biodiesel from chicken feather meal can be used as an alternative fuel.

Keywords

Biodiesel, chicken feather meal oil, Diesel engine, Performance analysis

Cover Page Footnote

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1. Introduction

There is a long way to go before bio-fuels becomes a reality but researchers always made an effort to test it on different kinds of engines with the most recent examples being Spice jet airlines, Mercedes, BMW and John Deere [1,2]. Bio-fuels are good news for human kind, as it helps the environment and also the industry, which is battling against exorbitant fuel prices. It is made from any plant or animal material and thus becomes an alternative energy source [3]. Jatropha seed oil has been extensively used for producing bio-fuels along with other oils like Nahor Oil, Sapium Oil and cast-off cooking oil. The non-edible oils also serve as promising feed stocks and include Moringa oil, Lemon grass oil, Kusum oil and Tobacco oil [4]. Bio-fuels contribute around 60% reduction in the carbon footprint of industries and are a potential offset for CO_2 emissions. Demand for green fuels depends on the availability of the fuel and distribution of these fuels. The production cost of bio-fuels is higher than that of standard fuel [5,6]. India is deficient in the production of fossil fuel, and has an edge with bio-fuels because of its huge agricultural base. However, we still need a commercial set-up for it. True, alternative fuels such as CNG, LNG, LPG, and ethanol are environmentally acceptable, but they are neither renewable nor sustainable. The driving range of these fuels is limited due to low energy content per volume when compared to biodiesel and fossil fuels requires significant storage space in the vehicle and higher refilling frequency [6]. In order to achieve better performance of an engine, diesel and biodiesel were blended under various concentration levels. This affects both the physical and chemical properties of biodiesel and should be compared with ASTM standards [7,8]. Ethanol manufactured from molasses is renewable, but its calorific value is less than that of biodiesel. In terms of power and torque, biodiesel is comparable to low sulphur diesel, and it offers low operational and changeover costs. Switching to biodiesel would be far smoother and cheaper and it emerges as the most promising alternative fuel [9]. The aim of the study is to analyze the performance of diesel engines using biodiesel produced from poultry generated chicken feather meal. The use of chicken waste generated fat does not pose a threat to the environment and it would be economical on a long-term basis. It has the potential to bridge the growing gap between demand and supply of fuels as it is feasible to utilize chicken skin fat. Till-date, few studies have reported the production of biodiesel from chicken feather meal and hence, the present study was conducted to produce biodiesel through trans-esterification and its performance in diesel engine is tested.

2. Materials and methods

2.1. Extraction of fat from chicken feather meal

Chicken feather meal was obtained from local Poultry unit, Vijayawada, Andhra Pradesh, India. The collected feather meal was washed 2−3 times with distilled water. One kilogram of chicken feather meal was dissolved in one litre of distilled water and boiled at 120 °C to separate the oil layer from water layer [10].

2.2. Biodiesel production and blending

The obtained fat layer was mixed with 1% potassium hydroxide. Free fatty acids and water were removed by centrifugation and was heated at 70 °C to get homogenized solution. Transesterification was performed by dissolving potassium hydroxide in methanol and mixing with chicken feather meal oil. By placing it on a shaker at 70 °C, the bottom glycerol layer was separated from the upper diesel and methanol layer. Methanol was evaporated using rotary vacuum evaporator and excess catalyst was removed by adding 0.1N HCl solution. Finally, chicken feather meal produced biodiesel was heated at 100 °C to evaporate the water. Sediment test and methanol tests were performed for observing the quality of biodiesel. The blending percentage of biodiesel with commercial diesel was set to 0%, 20%, 40%, 60%, and 80% and they were mentioned as B0, B20, B40, B60, and B80 [10,11].

2.3. Physical and chemical properties of extracted biodiesel

The physical and chemical properties of extracted biodiesel were studied according to Martins et al., 2015 [12]. Acid value is measured as the number of sodium hydroxide molecules required to neutralize the free fatty acid per gram of biodiesel sample. Saponification value was estimated using one millilitre of biodiesel refluxed with alcoholic potassium hydroxide and

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values were obtained after titration. Iodine value was obtained by grams of iodine absorbed by 100 g of biodiesel. Kinematic viscosity of sample was measured using Viscometer at 40 °C. Specific gravity and Density was measured in Indian Standard 1964 and BIS standard methods. Flash point was measured using Flash Point apparatus.

2.4. Diesel engine test

The test engine was a 3.5 L four stroke oil cooled direct-injection diesel engine with glow plug and configuration is inline 4 with the displacement of 3298 cc with power 90 HP at 3600 rpm and Torque of 223 Nm at 2200 rpm. Rope brake dynamometer, smoke and gas analyzer were fixed to analyze the engine performance and emissions. Readings were measured at 1700 rpm for selected biodiesel blends. Engine setup was fixed by running it for 30 min initially to induce preheat and parameters of performance were analyzed after 45 min of each test with different blends. Motor speed, output voltage, output current, and specific fuel consumption were recorded. The brake load for the diesel engine testing was fixed at 100N with brake arm radius 0.25 m. The CO and NOx emissions were measured at variable rpm range (1200−2400) using electrochemical cells [13,14].

2.5. Evaluation of in−cylinder pressure and heat release rate parameters

Combustion parameters such as in−cylinder pressure and heat release rate were measured against the crank angle at full load. The diesel and biodiesel samples were filled in the fuel tank and the values are recorded. This experiment was repeated thrice and the average values are taken for plotting the graphs [2,15].

3. Results and discussion

3.1. Biodiesel yield and quality

The fat extracted from chicken feather meal was 350 g per kg of meal. The yield was found to be 35% after transesterification. The biodiesel quality was indicated by the acid value of 1.4 mg $KOHg^{-1}$ and kinematic viscosity of 5.65 mm^2s^{-1} and pH was found to be 7.63. Biodiesel leaves no traces with clear appearance and no sediments.

3.2. Physical and chemical properties of extracted biodiesel

The physical and chemical properties of feather meal based biodiesel were investigated for use in diesel engine. The properties like kinematic viscosity, flash point, saponification value, iodine value and acid values were studied and represented in the given Table 1.

3.3. Emission analysis

The smoke emitted from the biodiesel blends B20, B40, B60 and B80 were compared with diesel B0 and found that the smoke emission had reduced with the increase in blend percentage and almost no black smoke was observed at highest blend percentage B80, as shown in Fig. 1. Carbon monoxide emissions were reduced by 18% with B80. The reduction in emission is mainly due to the rich oxygen content in the atmosphere and the efficient carbon in biodiesel can make carbon dioxide reduce carbon monoxide. Nitrogen oxides (NOx) emissions of all blends were observed to show increase by 20% when compared to diesel as represented in Fig. 2.

Table 1
Physical and chemical properties of chicken feather meal based biodiesel compared with Biodiesel standard specifications.

Properties	Biodiesel	Biodiesel standard specifications ASTM D6751
Kinematic Viscosity at 40 °C	3.45	1.9−6.0
Density [kg/m^3] 30 °C	0.88	0.875−0.90
Specific gravity kg/m^3	0.865	0.88
Flash Point °C	240	100−170
Saponification Value (mg NaOH/g)	196	−
Iodine Value	103	−
Acid Value (mg NaOH/g)	1.5	<0.8
Ash content	−	<0.02
Water content	−	0.03

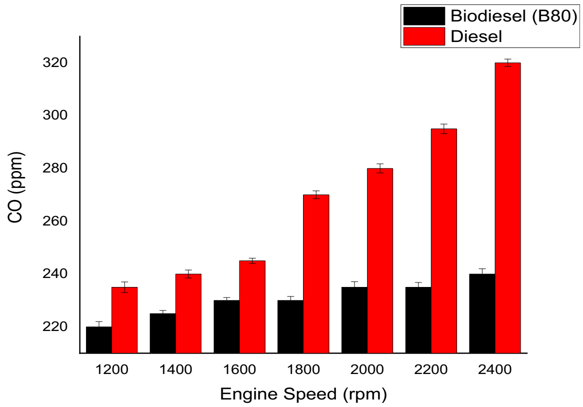

Fig. 1. Engine speed versus carbon monoxide emissions.

3.4. Engine performance test

Results were observed with the variable blending percentage of biodiesel from B0 to B80 at constant speed, brake horse power was found to be decreased with the increase in blending percentage, and engine power output decreased for B20 and B40 when compared to diesel and then increased at B60 and again decreased at B80. Specific fuel consumption was found to be increased as the low calorific value releases less energy in biodiesel and hence, results in the low engine power output. B60 yields the highest specific fuel consumption output value (see Figs. 3−5).

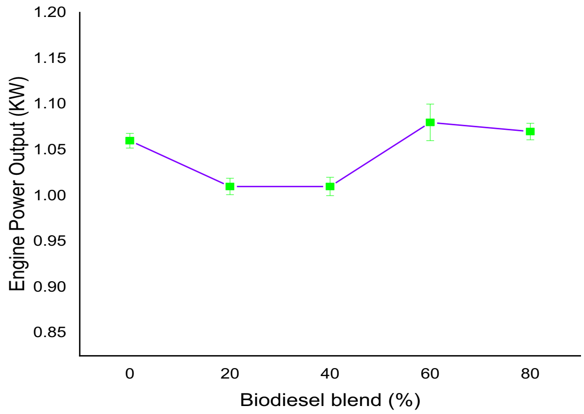

Fig. 3. Engine power output versus biodiesel blend.

3.5. Evaluation of in−cylinder pressure and heat release rate parameters

The cylinder pressure influences combustion and fuel behavior has been explained with the relation between in−cylinder pressure and crank angle at full load. The values obtained for diesel B0, B20, B40, B60 and B80 were observed as 74.24, 68.02, 65.12, 60.34 and 56.02 bar. The diesel sample showed higher in−cylinder pressure value followed by B0 to B80 as represented in Fig. 6.

Heat release rate gives information about combustion. The heat release rate at different crank angle was calculated using the following equation

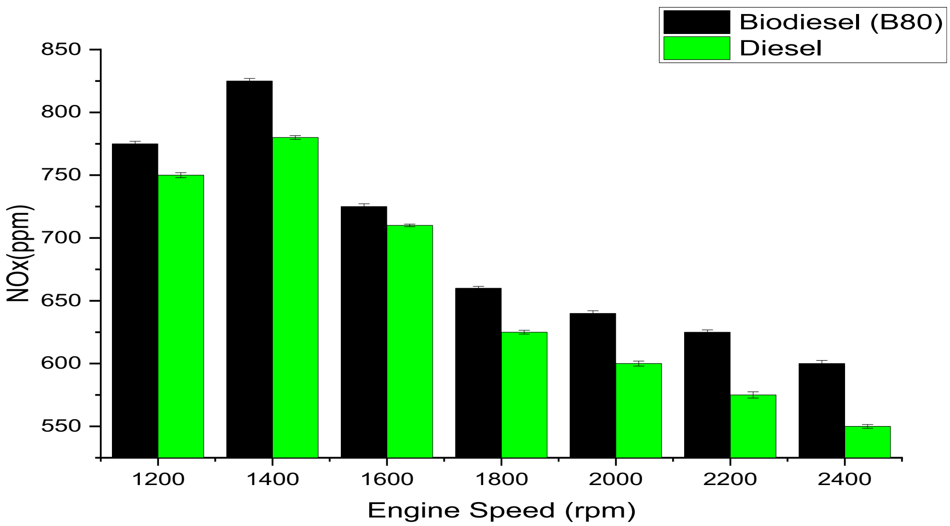

Fig. 2. Engine speed versus nitric oxide emissions.

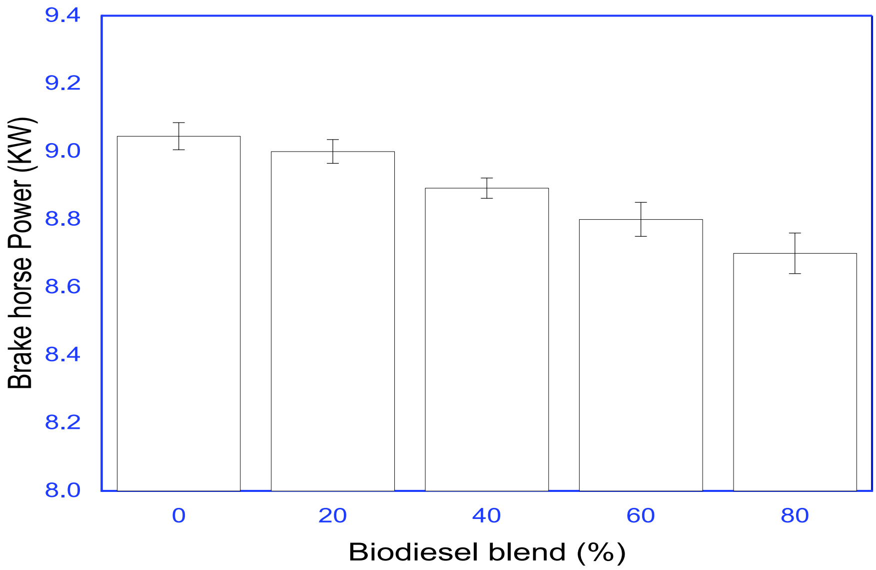

Fig. 4. Brake horse power versus biodiesel blend.

$$\frac{\partial Q_n}{\partial \theta}=\frac{\gamma}{\gamma-1}p\frac{\partial V}{\partial \theta}+\frac{1}{\gamma-1}V\frac{\partial P}{\partial \theta}$$

where Q_n represents the total heat release rate in J/deg, P and V are pressure and volume in bar and m^3, γ represents the ratio of specific heats in kJ/kgK and θ represents the crank angle in degrees. The results from Fig. 7 indicated that at first stage of combustion, reduced heat release rate was observed due to delay in the ignition, air-fuel mixing and fuel vaporization. Later, with the increase of few degrees in the crank angle, the positive heat release rate was observed which indicates the start of combustion. The heat release rate values at full load for diesel B0, B20, B40, B60 and B80 were 68.42, 62.8, 60.34, 58.02 and 52.6 J/deg. The values for biodiesel blends showed less heat release rate due to its low calorific value when compared with diesel.

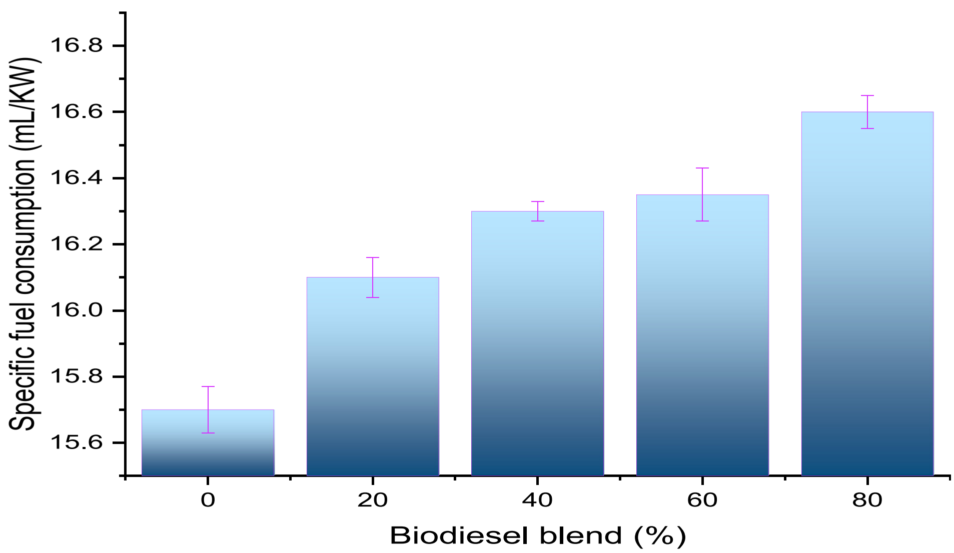

Fig. 5. Specific fuel consumption output versus biodiesel blend.

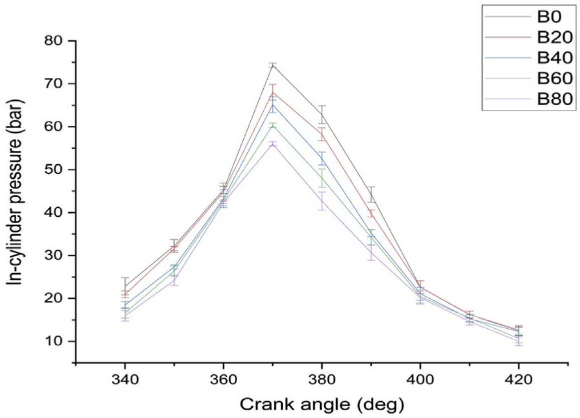

Fig. 6. Variation of in−cylinder pressure for diesel and biodiesel blends with crank angle at full load.

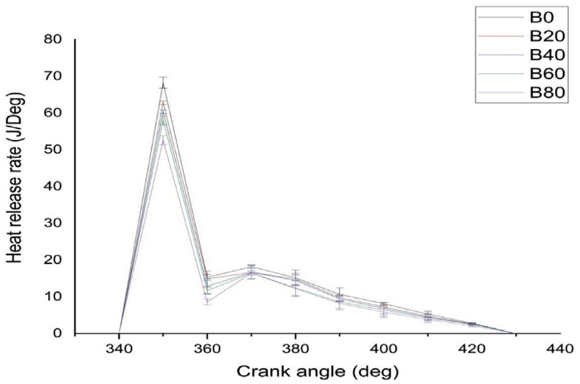

Fig. 7. Variation of heat release rate for diesel and biodiesel blends with crank angle at full load.

4. Conclusions

Biodiesel showed an increase in specific fuel consumption due to its lower heating value. However, using B40 diesel gave better engine performance and emission results. Engine performance based parameters such as brake power output, brake horse power and specific fuel consumption suggested that chicken feather meal based biodiesel could be used as one of the alternative fuels.

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