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Performance & Emission Analysis of a CI Engine Fueled with Biodiesel Blends Produced From Used Chicken Bones

Roydon Castelino[1], Shrinath Patkar[2], Souhardh K S[3], Shaikh Nabeel Zakariya[4], Kiran N. Bhat[5]

Abstract— Chicken bones are one of the sources of waste for the production of biofuel. In this paper, the production of biodiesel is attempted out of rich waste chicken bone feedstock and its performance is analyzed by comparing with pure diesel using ASTM standard. The biodiesel is a fatty acid alkyl ester produced from oil extracted from chicken bones by transesterification with glycerin as byproduct which is used in soap industry. The various properties of the fuel is studied and experiments were performed, using the blends of chicken oil biodiesel with diesel by 10,15,20,25 and 30% volume in a single cylinder, four stoke, direct injection, compression ignition diesel engine under different loading conditions. Results of emission test of B15 blend revealed that, CO_2 and smoke emission is reduced when compared with conventional diesel and the mechanical efficiency is comparable with conventional diesel. Hence it can be a good substituent for conventional diesel.

Index Terms— Biodiesel, Transesterification, Engine Performance, Emission Performance.

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1 Introduction

According to the survey of the oil and gas journal, crude oil production is exited to reach a peak within 2015 to 2030 and from then it is eventually going to decrease [12]. In India, the energy demand is increasing at a rate of 6.5% per annum. The crude oil demand of the country is met by import of about 80% [5]. Therefore, there is a need to explore an alternate fuel that can be procured in compression ignition (CI) engines. Any such alternative should not only meet the performance of diesel but also match or exceed the emission norms. The alternate fuel must be readily available, economically viable, technically feasible, and also meet the pollution norms [11]. India is one among the top 10 oil consuming countries in the world. The demand is of about 110 million tons while the country's existing annual crude oil production is about 32 million. In India, bulk of the passenger traffic (over 80%) and freight (over 60%) is carried by road; and petrol and diesel contribute to 98% of the energy consumed in the transport sector [11]. Biodiesel production is winning every day because of the increase in the petroleum price and the environmental advantages [12]. Compared to petroleum-based diesel, biodiesel is less toxic and more rapidly biodegradable, with a greater flash point than convectional diesel and nearly zero sulfur content so is environmentally beneficial. Biodiesel has physical properties similar to diesel.

Biodiesel, an alternative diesel fuel, is made from renewable biological sources such as vegetable oils and animal fats. It is biodegradable and nontoxic has low emission profiles and so is environmentally beneficial [7]. Biodiesel is also known as a carbon neutral fuel for the fact that the carbon present in the exhaust is originally fixed from the atmosphere. These oils are recommended as one of the future contenders to fulfill the gap demand produced by the depletion of fossil fuels [3]. In general, biodiesel is production is done from high quality vegetable oils. The common feedstock of biodiesel is rapeseed oil and soybean oil. But the major issue is the high cost for the commercialization of biodiesel. Therefore, low cost feedstock is required to overcome this issue. Chicken fat is a low cost feedstock to produce biodiesel compared to vegetable oils. Investigations have shown that chicken fat is a promising feedstock for biodiesel production [4].

The base catalyst performs better than acid catalyst and enzymes. The tests with refined oil blends showed considerable improvement in performance. The emission of unburnt HC from the engine is found to be higher on the all the fuel blends when compared to diesel. The emission of oxides of nitrogen found to be higher on the all blends when compared to diesel [14].

The biodiesel produced from chicken fat with high FFA, concludes the effect of variables on fuel properties such as catalyst type, reaction time and temperature. The fuel properties did not change with the reaction parameters significantly, but the effect of catalysts on fuel properties had to be studied further [4].

Using chicken fat as feedstock and producing biodiesel by transesterification reaction with methanol by using KOH as catalyst concludes, chicken fat can be introduced as a suitable feedstock for production of biodiesel [7].

Biodiesel produced from low FFA cooking oil using catalyst derived from chicken bones shows the calcinations is greatly influences the transesterification reaction. Thus the utilization of waste chicken bones provides a cheap catalyst for biodiesel production [10].

Emission analysis on Biodiesel from chicken bone powder by using Calcium Oxide as catalyst results the re-

- 1,2,3,4 Students, Department of Mechanical Engineering, Shri Madhwa Vadiraja Institute of Technology and Management, Bantakal, Udupi-574115, India.
- 5 Assistant Professor, Department of Mechanical Engineering, Shri Madhwa Vadiraja Institute of Technology and Management, Bantakal, Udupi-574115, India.
- roydoncastelino272@gmail.com, +91 9164289235

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duced emission of CO_2 when compared to conventional diesel. However the emission is high in higher engine speeds and loading conditions [1].

An investigation of CI engine by production of biodiesel from waste chicken oil resulted in the use of chicken oil biodiesel for substitution of convectional diesel fuel is good without any modification on engine up to B40. But the compression ratio had to be modified for using other blends for better performance of the engine. The conclusion of their result is comparison of pure diesel fuel with chicken oil biodiesel, 22.03% higher NO_x and 24.05% lower CO and 46.15% lower HC were observed [12].

Hence it can be used as a substitute for diesel fuel, either in neat form or in blends with it [1].

2 METHODOLOGY

2.1 Collection of used chicken bones.

Fig. 1: Used chicken bones

More than 100 kg's of used chicken bones are collected from various restaurants and stored in refrigerator after cleaning.

2.2 Extraction of Oil.

The oil is extracted using pressure cooker, where bones along with water are boiled for certain time duration. The advantage of using the pressure cooker is that the quantity of fuel consumption for boiling is minimized for making the process economical. The oil and water mixture present in the pressure cooker is heated in a different vessel to evaporate the water content.

Fig. 2a: Heating of oil

Fig. 2b: Oil stored in jars

2.3 Refrigerating the oil to avoid spoiling.

After the extraction of oil it is refrigerated to preserve its properties.

Fig. 3: Frozen Oil

2.4 FFA Test

Titration is performed in order to determine the Free Fatty acids in the oil. At first, standard solution is prepared by mixing 1g of NaOH with water in a 250ml standard Flask. The burette contained the standard solution i.e 0.1N NaOH and the conical flask contained 50ml of Isopropyl alcohol, few drops of 0.1N NaOH and 10g of raw oil. The solution is heated to 60°C and cooled. After cooling the solution to room temperature, few drops of phenolphthalein indicator is added and the titration is carried out. The end point is pale pink color which persists for a minute.

$$\text{FFA content} = \frac{28.2 \text{ x (Normality of NaOH) x (Titration value)}}{\text{weight of oil in gms}}$$

$$= \frac{28.2 \text{ x } 0.1\text{N x } 3.3\text{ml}}{10\text{g}}$$

$$= 0.9306\%$$

The titer value is 3.3ml and the percentage of free fatty acids in the oil is 0.9306%. The inference of titration is to use base catalyst for the production of biodiesel as the FFA content is less than 4% [15].

Fig. 4: Titration to determine the Free Fatty Acids.

2.5 Transesterification

Transesterification is the process of displacing alcohol functional group from an ester by another alcohol. This process is also known as alcoholysis. It is similar to hydrolysis in which water is used, but here alcohol is used [3].

The catalyst is prepared by mixing CH_3OH and NaOH. The triglyceride reacts with 3 moles of CH_3OH, once the catalyst is prepared. To ensure complete reaction excess CH_3OH should be present in the reaction. The three attached carbons with hydrogen react with OH- ions to form glycerin, while the CH_3 group reacts with the free fatty acid methyl ester.

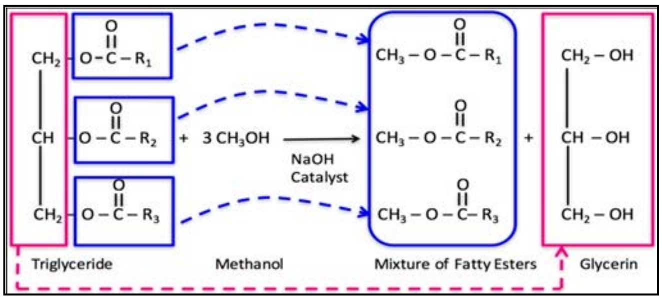

Fig. 5: Transesterification Process

NaOH is used as the base catalyst in this process. Initially one liter of Oil is measured and is transferred into a 3-Neck flask with a magnetic pellet in it. The flask is then placed on the magnetic stirrer along with the heating system provided in it. The reflex condenser is fixed to the central neck of the 3-Neck flask while the other two necks remained closed and water pipeline is connected to the condenser and proper flow of water into the condenser is ensured.

The Magnetic stirrer is turned on and is set to 950rpm to get uniform heating of oil and the control is set up to 60^{o}C. The setup is left to stabilize for some time. Concurrently methoxide solution is prepared by weighing NaOH based on FFA% (i.e. for 0 FFA, 3.5gms of NaOH) and adding 300ml methanol per 1 liter of oil in a separate beaker.

Fig. 6: 3-Neck Flask with uniform heating and stirring

The speed of stirrer is lowered (to prevent bumping action) and the methoxide mixture is slowly poured to the hot oil through one neck of the flask and closed with a stopper. Then the speed of stirrer is again raised to 950rpm and the process is allowed to run for span of 90 minutes maintaining a uniform temperature of 60^{o}C-63^{o}C till the mixture in the 3-neck flask turned chilly red. Then the stirring and heating mechanism is switched off and reflex condenser is removed allowing the mixture to settle for some time. The production yield is found to be 98%.

2.6 Separation of biodiesel

After completion of transesterification reaction, the mixture is then transferred into the separating funnel and is allowed to settle say for 30 mins. During this time the bi-product of transesterification reaction Glycerin settles at the bottom and Bio-diesel separates at top layer. The glycerin is drained and is stored separately. It is noted that the glycerin is crude glycerin containing wax, NaOH and methanol traces.

Fig. 7 a: Separating Funnel

Fig. 7 b: Glycerin

2.7 Washing, Drying & Filtering of Biodiesel

The biodiesel is transferred to the washing funnel and water at 45^{o}C is sprayed into the funnel without any agitation and is allowed to settle for 10-15 minutes. The soap water started to form at the bottom of the washing funnel and this is drained carefully. This procedure is repeated till the pH of water becomes 7.

Fig. 8a: Drying of Washed Biodiesel

Fig. 8b: Filtering

Fig. 8c: Pure Biodiesel

The biodiesel is then transferred into a beaker and is heated above 100^{o}C so that the moisture content is evaporated resulting in biodiesel free from water. The biodiesel is allowed to cool till the temperature drops to room temperature. Then the biodiesel is filtered in order to remove any foreign particle that gets dispersed during the previous processes. The pure biodiesel produced is shown in the figure 8 c.

2 BIODIESEL PROPERTY CHART

The properties of the biodiesel and its blend are found and the results are tabulated in the table 2.

Table 1: Biodiesel property chart

SL No	Properties	Measurement Apparatus	Standard	B10	B15	B20	B25	B30	B100	Diesel
1	Flash point (°C)	Cleaveland Open Cup	ASTM D92	64	65	65	67	69	170	55
2	Fire point (°C)	Cleaveland Open Cup	ASTM D92	68	69	69	70	72	174	57
3	Density (g/cc)	Redwood Viscometer	ASTM D445	0.82	0.82	0.82	0.82	0.84	0.86	0.82
4	Kinematic Viscosity at 40°C (centistokes)	Redwood Viscometer	ASTM D445	4.20	4.20	4.59	4.98	4.59	5.37	4.2
5	Calorific value (kJ/kg)	Bomb Calorimeter	ASTM D240	39561.9	44738.7	48675.8	47340.0	44631.2	38387.3	42701.0

3 ENGINE SETUP

Fig. 9: Engine Setup

The performance test is conducted on Kirloskar engine of type TV1 which is a single cylinder four stroke diesel engine, the specification of which are shown in the table 2. The Engine consists of an electrical dynamometer which is rated 5.2 kW at 1500rpm and 2bhp. The specific fuel consumption is 251g/kWh. The engine setup is shown in figure 9.

Table 2: Engine Specification

No. of cylinders	1
No. of strokes	4
Rated Power @1500RPM	5.2 kW
Cylinder diameter	87.5mm
Stroke length	110mm
Compression ratio	17.5:1
Dynamometer arm length	185mm

Performance test is conducted for various blends (B10, B15, B20, B25 and B30) and pure diesel at constant speed of 1500 rpm at various loads (0, 4.5602kg, 9.1204kg, 13.6806kg, and 18.2408kg). The test includes evaluation of brake thermal efficiency, specific fuel consumption and mechanical efficiency. Emission characteristics test of the biodiesel blends and pure diesel is also carried out.

4 PERFORMANCE RESULTS

4.1 Effect of Mechanical Efficiency on Brake Power

Figure 10 shows the variation of Mechanical efficiency with Brake Power for pure diesel and biodiesel blends. It is found that the mechanical efficiency of various biodiesel blends and pure diesel are approximately equal with no appreciable change.

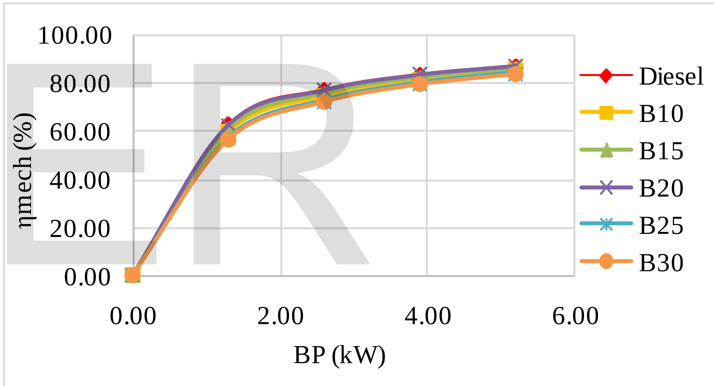

Fig. 10: Mechanical efficiency v/s Brake Power

4.2 Effect of Brake Thermal efficiency on Brake Power

Figure 11 shows the variation of Brake thermal efficiency with Brake Power for pure diesel and biodiesel blends. It is revealed that the Brake thermal efficiency B10, B15, B25, B30 is higher than conventional diesel at various loads.

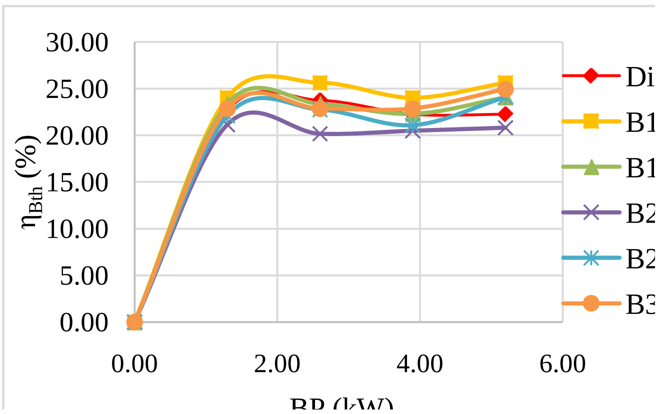

Fig. 11: Brake Thermal efficiency v/s Brake Power

4.3 Effect of Specific Fuel Consumption on Brake Power

Figure 12 shows the variation of Specific fuel consumption with Brake Power for pure diesel and biodiesel blends. Specific fuel consumption engine for all the blends is lower than the consumption for conventional diesel at maximum load. Hence it is evident that the fuel consumption of the engine is improved with the biodiesel blends.

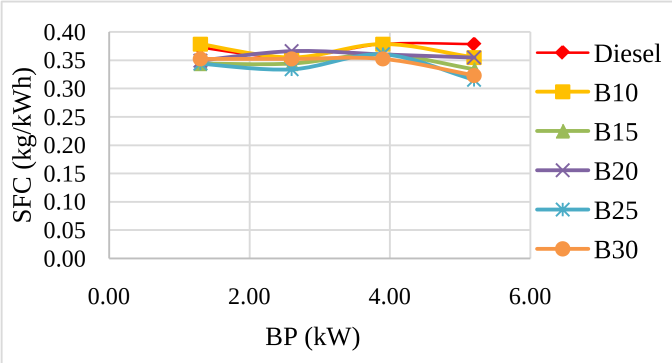

Fig. 12: Specific Fuel Consumption v/s Brake Power

5 EMISSION RESULTS

The emission test is conducted on the same engine setup. A Gas Analyzer is used to determine CO, HC, CO_2 and NO and smoke opacity is measured using smoke meter.

Fig. 13a: Gas Analyzer

Fig. 13b: Smoke Meter

5.1 Effect of Carbon Monoxide on Load

Figure 14 shows the variation of carbon monoxide emission for pure diesel and different biodiesel blends at different loads. The CO emission increases as the percentage of diesel increases and it is maximum for pure diesel. This shows the oxygen needed for producing CO is used by engine for complete combustion as the bio diesel content increases.

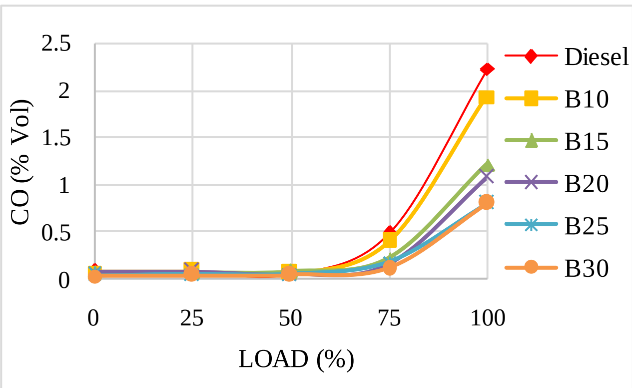

Fig. 14: Carbon Monoxide v/s Load

5.2 Effect of Carbon dioxide on Load

Figure 15 shows the variation of carbon dioxide emission for pure diesel and different biodiesel blends at different loads. The CO_2 emission is approximately same for all fuels up to 75% load. At full load blend B15 emits lowest CO_2 emission due complete combustion that lowers the availability of oxygen for CO_2 emission.

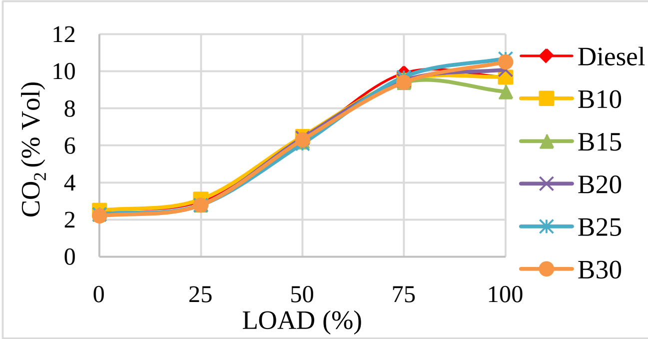

Fig. 15: Carbon dioxide v/s Load

5.3 Effect of Hydro-Carbon on load

Figure 16 shows the variation of Hydro carbon emission for pure diesel and different biodiesel blends at different loads. Here the biodiesel blends have lower ppm of HC emission than pure diesel due to the insufficient oxygen and misfiring in engine at all loads.

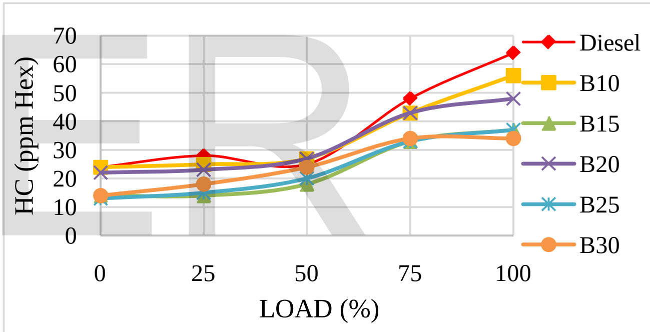

Fig. 16: Hydro Carbon v/s Load

5.4 Effect of Nitrous oxide emission on load.

Figure 17 shows the variation of Nitrous oxide for pure diesel and different biodiesel blends at different loads. The NO emission for all blends is higher than the pure diesel. This is because in biodiesel the oxygen content is more, which results in complete combustion. So this results in increased temperature which can be minimized by providing effective cooling.

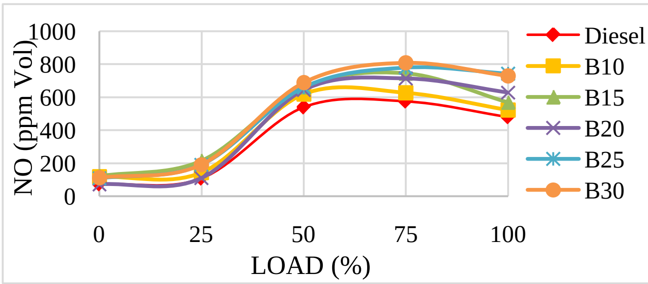

Fig. 17: Nitrous oxide v/s Load

5.5 Effect of smoke on Load.

Figure 18 shows the variation of Smoke for pure diesel and different biodiesel blends at different loads. The smoke of all blends is less than pure diesel at all loads except at full load because of complete combustion. Only B20 exhibited high smoke emission greater than pure diesel at 50% load.

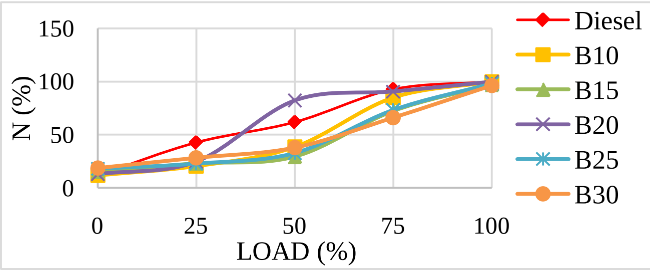

Fig. 18: Smoke v/s Load

6 CONCLUSION

Mechanical efficiency of all the blends is comparable with conventional diesel at various loads.

Brake thermal efficiency of B10, B15, B25, B30 biodiesel blends is higher than conventional diesel.

Specific fuel consumption engine for all the blends is lower than the consumption for conventional diesel.

B10 at load 4.5602kg, B20 at load 9.1204kg shows higher specific fuel consumption with respect to varying brake power in comparison of conventional diesel.

B10 blend shows higher brake thermal efficiency, B20 blend shows lower brake thermal efficiency with respect to varying brake power in comparison of conventional diesel.

Emissions characteristic such as CO, CO_2, HC and smoke of blends exhibited lower than the pure diesel.

Emission of NO is higher for all blends at different loads when compared with conventional diesel.

B15 shows lower CO_2 emission compared to conventional diesel at all loads, other blends has comparable CO_2 emissions with respect to conventional diesel.

Smoke in all blends is less except B20 at 50% load condition shows high smoke emission compared to conventional diesel.

Based on the need and application an appropriate biodiesel blend can be selected as an alternate fuel.

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