Experimental Analysis of Biofuel Produced from Fat Derivatives of Bird and Animal as an Additive Fuel in CI Engine

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Abstract- In the present work, an alternative form of biofuel for the Compression Ignition (CI) Engine is generated from inedible disposable chicken skin and pig tallow. The collected resources are heated up to 80˚C to extract fat and subjected to a trans-esterification process to obtain biofuel. The process resulted in 730ml and 950ml of high viscous biofuel from 1000ml of fat from waste chicken skin (WCS) and pig tallow (PT) respectively. The pure biofuels from WCS and PT have 38.07% and 41.68% higher viscous than diesel. The obtained biofuel is blended with diesel at 10, 20, and 30% by volume. The thermal, physical, and chemical properties of blended fuel are determined and found closer to the diesel properties. The engine tests indicate that the brake power of the B30 blend was decreased by 15.78% while the B10 combination produces 11.02% less power as compared to diesel at full load. The efficiency was reduced by 22.15, 7.59 % for B30, and B10 respectively at full load condition. About 3.9% and 34% of reduction in NOx, 22.5%, 27.5% of reduction in HC emission were recorded for respective blends at the same operating condition. This paper emphasizes on deriving value-added products from waste resources and its effective utilization. The findings from work indicate that the derived biofuel could be used in combination with diesel for the adequate partial replacement of diesel in CI engines without any significant alterations.

Keywords: Catalyst, Calorific Value, Pig Tallow, Trans-esterification, Waste Chicken Skin.

Nomenclature
CI - Compression Ignition
WCS - Waste Chicken Skin
PT- Pig Tallow

1. Introduction

Current scenario indicates that there will be a significant rise in demand on fossil fuels in the future decades due to higher population growth and rise of living standards, thus the production of crude oil should increase two folds by 2030, which is a major concern in the era of depleting oil wells all around the globe [1]-[15]. Finding alternatives for diesel is always a pressing need and challenge to researchers worldwide. Thus biofuels will play a major role, especially in the field of transportation and energy sectors [16]–[21]. Energy sources will thus be a key area of focus to overcome the scarcity in fossil energy resources in the future course of time [22]. Even, as a sustainable development outlook, it is very essential to guard an energy source that will cater to a prolonged period, while saving the local and global environment to reduce greenhouse gas emissions[23], [24]. Massive biomass sources such as animal fats have tempted research scholars to develop a technology to derive a preferred energy source. Thus, Biofuel is a possible energy source trans-esterified from animal fats, vegetable oils, waste plastics, used tires, agricultural wastes, and used waste cooking oil[25]–[29]. Presently, biofuel is produced from agro fats such as groundnut, soya, rice bran oil, and mustard oil [30]–[32]. However, these feedstock's are consumed by human beings as food, and their costs are expected to be higher and increase to a greater extent in the coming days. The biofuel from these edible oils will be producing lesser pollution levels as compared to available petroleum-based fossil fuels [33]–[35]. Henceforth, the factors mentioned above facilitate the utilization of economically viable waste resources for the production of biofuel. In the urge of searching such kinds of waste and low-cost resources, animal fats from the meat stall occupy the first order[36]–[41]. Animal fats are viable; and can be procured from meat stall houses and subjected to various processes involving trans-esterification for the conversion of raw products to biofuel[42], [43]. The extraction of biofuel from animal fats add up to the eco-sustainable modes of harnessing energy resources. The main obstacle in converting these low-cost fats is that they consist of a higher quantity of Free Fatty Acids (FFA) that cannot be directly translated into biofuel utilizing an alkaline catalyst. The direct trans-esterification reaction process is a much important step since it will enhance the yield rate of biofuel, simultaneously FFA will affect the properties of the biofuels derived from fats extracted out of animal wastes[44]–[48].

The fossil fuel and energy crisis in a developing country like India is of primary concern since it has drawn the attention of several researchers to develop alternative fuels for the future use. One of the essential and promising substitute fuel is the biofuel derivative of plant and related organic matter and animal fats and wastes [49]. Further, down the lane, by establishing and utilizing biofuel, several developed nations have decreased their over-dependence on crude oil imports and also there is a significant reduction in exhaust gas emissions. Also, the emissions of particulates, soot particles, and carbon monoxide in Engines are in the least range due to oxygenated biofuel blends [50]. By considering all these factors, a comparative study is carried out to analyse the performance and emission characteristics of a diesel engine using bird and animal tallow as a fuel additive.

1.1. Work description

The current work deals with the extraction of biofuel fuel compounds from waste chicken skin and pig tallow. These are the two types of resource materials that can be readily sourced from the meat stalls in local markets. The sourced primary waste resources from different meat stalls are subjected to the heating process to obtain the required fat. The extracted fat is effectively processed into biofuel by adopting the base-catalyzed trans-esterification process. Further, the physical, thermal, and chemical characteristics such as kinematic viscosity, flashpoint, fire point, heating value, and the carbon content of the extracted fuels and its mixtures with conventional diesel blends have been determined in the present research. The extracted biofuel blends are examined in a single chamber, CI Diesel Engines. The obtained results of derived fuels and the corresponding results of engine studies are described in the subsequent sections.

2. Materials and Methods

The primarily required resources like waste chicken skin and pig tallow are gathered from the local meat stall markets, which are sourced locally and economically. The baseline survey is carried out through scientific research studies to estimate the total quantity of waste generated in a day at Kengeri Satelite Town, Bangalore. Further down, it is estimated through the scientific survey that nearly 200 kg of waste chicken and pig tallow is available to be sourced for a single day. Figure 1 shows the photographic images of waste chicken skin and pig tallow utilized in the present work for biofuel generation.

Fig. 1. Waste chicken skin and pig tallow

2.1. Fat extraction

The process of fat extraction is carried out through several trials by considering samples of 1 kg each. The waste resources are heated between the temperature ranges of 60 to 100ºC by conventional methods utilizing gas burners. Fat extracted during the heating process are separated with the help of a filter. The Process of fine filtration is effectively carried out to strain out the water, blood tissues, feathers, dirt, etc. At the end of the fine filtration process, pure fat from waste chicken skin and pig tallow is obtained, which is an essential source for biofuel generation.

Fig. 2. Fat from waste chicken skin and pig tallow

Fig. 3. Chicken skin and pig tallow after heating Process

2.2. Fat Processing into Biofuel

The base-catalyzed trans-esterification process is the method effectively adopted in the present work to convert obtained fats from waste chicken skin and pig tallow into biofuel. The process is effectively carried out by using alcohol and catalyst, namely methanol and potassium hydroxide in the required ratio. The conversion process takes place by trial and error process by considering 1000 ml of the purified fat sample. The KOH and methanol are used at the rate of 3 to 6 gm. and 230 to 280 ml respectively in a round bottom flask facilitated with a magnetic stirrer at 60°C for about 90 to 150 min. The mixture is then allowed to cool down to room temperature for around one hour and then poured into a separation flask for the formation of biofuel at the top of the flask and glycerin layer at the bottom of the flask as shown in figure 4.

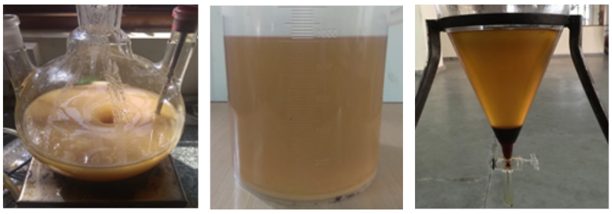

Fig. 4. Trans-esterification process, separation, biofuel.

2.3. *Investigations on engine*

The effect of extracted fuel and their blends of 10, 20, and 30% ratio (D90-1, D80-2, and D70-3) on a single-cylinder, CI diesel engine is investigated. The engine test rig and gas analyzer are exhibited in figure 5. The engine test rig is computerized, manually changeable VCR, a multi-fuel engine with an eddy current dynamometer. To measure the rate of tailpipe emissions, a typical 5-gas analyzer is used, which records carbon monoxide, carbon dioxide, hydrocarbons, oxygen, and oxides of nitrogen in the automotive exhaust system.

The engine power discharge and emission tests are effectively carried out at 18:1 compression ratio, and a constant speed of 1500 rpm. The effectively blending two different biofuel variants extracted from waste chicken skin and pig tallow blended with petroleum-based diesel on a volume basis at the ratio of D90 [90 Vol.% Diesel, 5 Vol.% Chicken Biofuel and 5 Vol.% Pig Biofuel], D80 [80 Vol.% Diesel, 10 Vol.% Chicken Biofuel and 10 Vol.% Pig Biofuel] and D70 [70 Vol.% Diesel, 15 Vol.% Chicken Biofuel and 15 Vol.% Pig Biofuel]. Further down, the power discharges such as net output, the efficiency of the fuel, and the consumption of fuel are recorded. The tailpipe discharge emission parameters like CO, CO_2, NO_X, O_2, and HC are measured.

Fig. 5. Engine test rig and 5-gas analyzer

3. Result and Discussion

From the experiments, we found that 1000 ml of pig fat yields approximately 950 ml of biofuel, and 1000 ml of chicken fat yields up to 730 ml of biofuel. The quality of biofuel extracted is tested according to Indian standards. The fuel properties like the flashpoint, fire point, density, kinematic viscosity, calorific value, and carbon content are tested for diesel, biofuels waste chicken skin, and pig tallow and then for their blends with petroleum-based diesel. The results obtained are presented in Table 1.

3.1. *Engine Performance*

The performance parameters like brake power, fuel consumption, and thermal efficiency at a constant speed of 1500 rpm and CR of 18:1 for different loads and varied fuel blends are discussed in this section. These results are plotted and compared with corresponding values with diesel as a reference fuel.

The load is varied from 0.5kW to 3kW with a constant speed of 1500 rpm. Figure 6 shows, BP is obtained for three different blends of biofuel with diesel and diesel alone. D70 has lower values of BP than D90 and D80. At maximum load of 3kW, a decrease in power for D70, D80, and D90 blends are 15.7, 13.1, and 11.3% respectively as compared to diesel and the same at a mid-load of 1.5kW are observed as 20.4%, 18%, and 7% respectively.

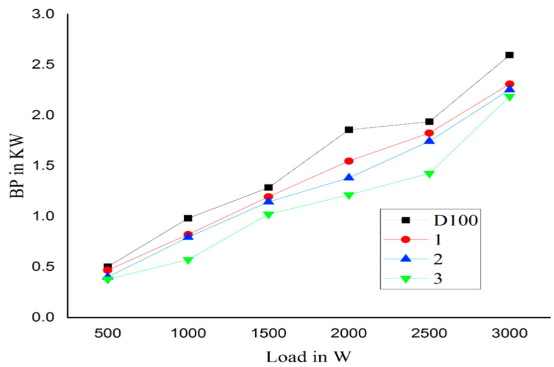

Fig.6. Deviation of BP for diesel and biofuel Blends

Table 1. Characteristics of Biofuels & blends

Parameters	D100	CB100	PB100	D90-1	D80-2	D70-3
Flashpoint (°C)	56	91	109	61	65	72
Fire point (°C)	62	107	121	73	76	81
Density at 40˚C (kg/m3)	841	951	976	853	865	871
Kinematic viscosity at 40˚C (mm^2/s)	2.30	3.714	3.944	2.596	2.61	2.698
Calorific value (kJ/kg)	44,820	38,267	37,978	43,273	42,871	41,873
Carbon content (% Weight) [ASTM 524]	0.6	0.36	0.34	0.43	0.43	0.37

The rate of fuel consumed to produce effective brake power is considered as specific fuel consumption. The experimental results show that there is a higher rate of fuel consumption with blends of biofuel than conventional diesel fuel. The changes in the consumption of fuel are represented in figure 7. It is noticed that the consumption of fuel gradually increases with increasing the percentage of biofuel in the mixtures, whereas it reduces when the load on the engine increases. At full load condition, an increase in SFC for D90 and D80 blends by 7.7% higher than diesel, whereas the D70 blend shows a 3.6% reduction as compared to diesel. The same at mid load condition is observed as 8.5, 18.6, and 29.1% greater than neat fuel for D90, D80, and D70 respectively.

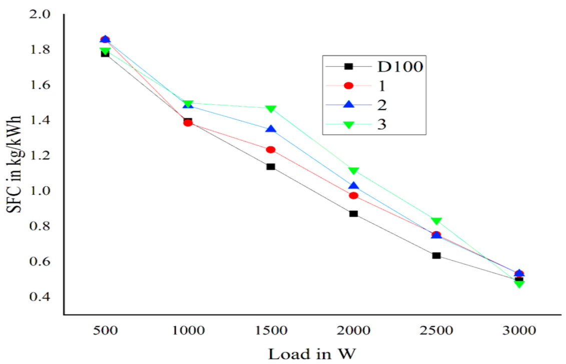

Fig. 7. Deviation of SFC for diesel and biofuel blends

The ratio of the productive output power discharged and energy supplied due to the efficient burning of fuel gives the thermal efficiency. The thermal efficiency reduces with the increased rate of biofuel percentage in the tested fuel mixtures and is presented in figure 8. The obtained results exhibit the fact that the thermal efficiency for all fuel mixtures reduces as compared to that of diesel fuel. The diesel has 17.11% whereas D90, D80, and D70 fuel mixtures provide 15.81, 14.79, and 13.32% of thermal efficiency at full load condition. The reason for such low efficiency is that the fuels generated from the fat have a higher value of fuel thickness, density, and lesser calorific value than that of high-speed diesel. The fuel atomization and vaporization are highly affected by the higher viscosity and density of fuel blend that lead to a reduction in combustion efficiency, which further reduces the overall thermal efficiency of the tested engine.

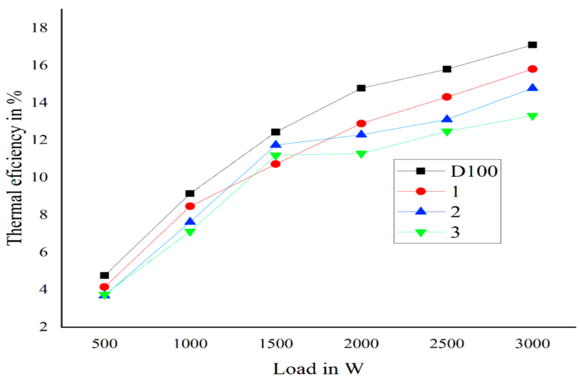

Fig. 8. Deviation of Thermal efficiency for diesel and biofuel blends

The CO discharge with tested samples is showcased in figure 9. The results are indicative of the fact that the level of CO exhaust emissions for biofuel blended samples is marginally lesser than neat diesel at all loading conditions except part load. The experimental results revealed that there is a significant reduction in CO emissions by 8.8, 16.1% with D90, D80, and 3.8% higher CO emission with D70 blend as compared to neat diesel fuel at full load condition.

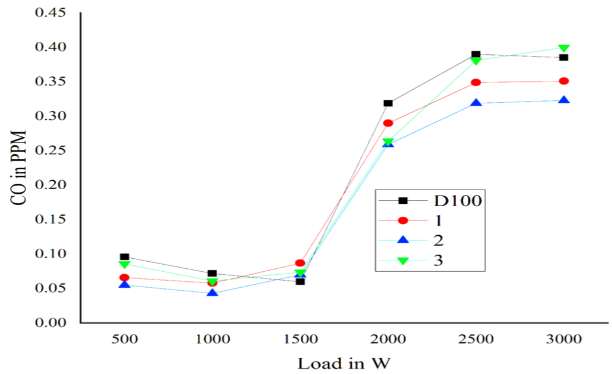

Fig. 9. Deviation of CO emission for diesel and biofuel blends

In the present day circumstances, all the automobile manufacturers are extending their vision towards the reduction of harmful exhaust emissions. On the other hand, due to the use of low-grade fuel in vehicles, vehicles tend to produce a higher rate of harmful emission, even if the vehicle is instrumented with an emission control device. The present study has showcased that the range of CO_2 for biofuel blend is higher than the diesel at full load operation. It is noticed that D90-23, D80-66, and D70-30% of higher CO_2 emission as compared to diesel fuel. This is analyzed because of the readily available oxygen rate with the extracted biofuels from animal fat. Figure 10 illustrates the level of carbon dioxide for predefined blends and diesel fuel.

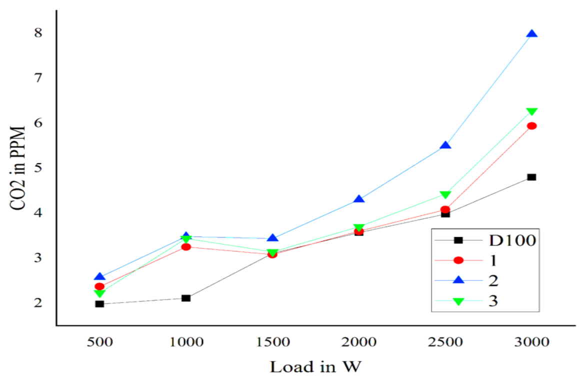

Fig. 10. Deviation of CO_2 emission for diesel and biofuel blends

Figure 11 shows that the increasing biofuel percentage derived from chicken waste skin and pig tallow affect the hydrocarbon emissions significantly. The total HC emissions reduced with different series of biofuel blends are close to each other. However, there is an increase in HC emissions for the D70 blend and conventional diesel fuel at medium as well as full load operating conditions. The study reveals that the D90-27.5, D80-53.7, and D70-22.5% of hydrocarbon reduction as compared to high-speed diesel fuel at full load condition.

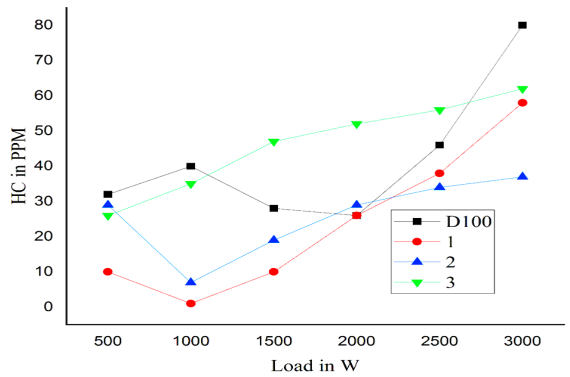

Fig. 11. Deviation of HC emission for diesel and biofuel blends

Figure 12 demonstrates the level of NOx discharge through tailpipe for the different fuel series at different loading conditions. The test results for petroleum-based diesel fuel and D70 show an increase in NOx emission along with the higher and mid operational load on the engine. The experimental study reveals that D90-34.1, D80-24.7, and D70-3.9% of reduction in NOx detection as matched with diesel fuel at full load conditions.

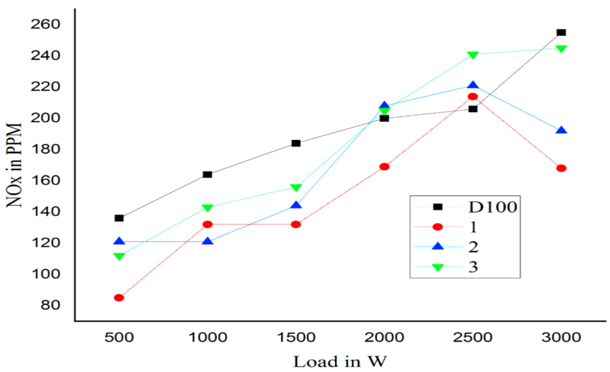

Fig. 12. Deviation of NOx emission for diesel and biofuel blends

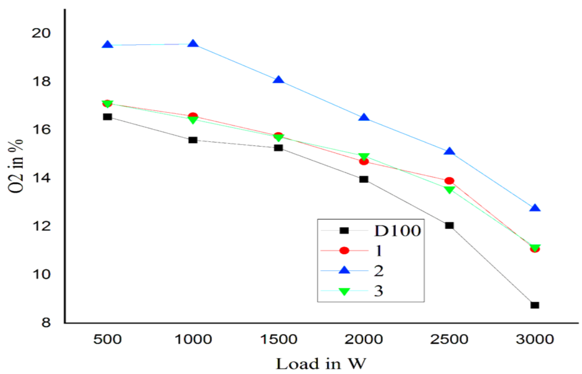

Fig. 13. Deviation of O_2 emission for diesel and biofuel blends

Oxygen plays its role in achieving the complete burning of supplied fuel in the engine cylinder. All varieties of fuels have their level of oxygen content, and they will help in the combustion process, even with lesser air supply. Many investigation studies result in terms of a higher level of oxygen content with biofuels derived from varieties of feedstock as compared to conventional fuels. The present study results demonstrate the higher value of O_2 emission with all series of fuel blends as matched to diesel; this simultaneously decreases with an increasing operating load on the engine because of a higher rate of oxygen utilized by the combustion process to develop necessary power. Figure. 13 demonstrates the O_2 emission for different blends and diesel fuel. As a result, D90, D80, and D70 blends show approximately 26.6, 45.8, and 27.5% of greater O_2 emission as compared to neat diesel fuel.

4. Conclusion

The present investigations on the production of biofuel from two different types of resources and its use in engine studies conclude that biofuel from waste chicken skin and pig tallow can be treated as a preferred fuel in the future. In case, the biofuel generation from the animal fats are seriously considered by the research community and made as a policy by the successive governments, the animal wastes which are readily available in huge quantity can be utilized for extraction of biofuel in a cost-effective manner.

Major inferences and conclusions are drawn based on the exhaustive investigation of the results.

- Density and viscosity of the extracted fuels are constructively higher than petroleum-based diesel and their blends, the tests are carried out as per ASTM standards. The calorific value of raw biofuel from fats are found to be lesser as compared to conventional diesel.
- The derived fuel from inedible fats and a series of fuel can be utilized as clean diesel fuel in CI, a direct-injection engine. The investigation results reveal that the blending of extracted biofuel with diesel reduces the productive brake power, fuel efficiency, however, the tailpipe discharge of the engine when it is fuelled with biofuel mixtures are lesser as compared to conventional diesel.
- The carbon monoxide, hydrocarbons, and nitrogen oxide emissions are reduced for all the variants of blended biofuels. This decrease in tailpipe discharge offers scope for developing a promising alternative energy source for diesel, and this kind of initiative contributes to the mission of controlling harmful emissions.
- If the process takes place on a mass-scale, then it can create greater employability at the local area and reduces the total production cost per liter of biofuel, on the other hand, decrease the difficulties of animal waste disposal and fear of disposal hazardous.

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