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Evaluation of Fuel Consumption and Exhaust Emissions in a Single Cylinder Four-Stroke Diesel Engine Using Biodiesel Derived from Chicken Waste with Additives

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Abstract

Biodiesel is a renewable, locally generated fuel made from vegetable oils, trans fats, or recycled restaurant grease for use in diesel automobiles and other diesel-powered equipment. The physical qualities of biodiesel are comparable to those of petroleum diesel. Biodiesel is used in compression-ignition engines in the same way as petroleum diesel. Biofuel can be made from biomass, but according to the Indian National Policy on Biofuels, biofuel extraction from edible oils is not permitted because it would result in a massive increase in consumer goods prices and perhaps lead to product scarcity. Hence, there is a need to search for alternative biofuel so that it does not affect our nation's national policy. Recently there has been a drastic increase in the consumption of chicken grown in farms. There is a huge problem in disposing of their waste. One major difficulty in waste treatment is poultry manure, often known as slaughter waste. This waste is sometimes dumped on wastelands, roadsides, and the banks of rivers, lakes, and ponds. This creates more sanitary problems for society. According to polls, poultry feces begin to decompose in around three hours. The odor of butcher's waste causes a lot of pollution in the air, as well as an increase in the density of bacteria in the atmosphere. Measures have been taken by the government for the safe disposal of these wastes. One of the

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major ways of disposal is to recycle this chicken slaughter waste in a useful manner so that it can serve society in a positive way. This could be done by converting this waste into fuel through various processes such as rendering, hydrolysis, extraction, acid esterification, alkaline transesterification, and finally by the extraction process. This produced fuel could be blended with existing diesel in varying concentrations and used in diesel engine-powered vehicles. In this work, the fuel is extracted from the chicken waste and blended with pure diesel and an Al_2O_3 additive in various proportions. These combinations are then tested on a single-cylinder diesel engine for fuel consumption and emission analysis. The results exhibited an overall better performance when compared to pure diesel.

Keywords:

Biodiesel, chicken slaughter waste, emission, fuel consumption, recycling.

Article history:

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Introduction

The usage of alternative fuel serves as a measure to reduce the pollution coming from vehicles Liu et al., 2022; Punriboon et al., 2019). An integrated assessment method for substitute marine fuels based on economic, physical, and social criteria has recently been requested (Ashrafi et al., 2022). Concerns about the depletion of resources have prompted researchers to look for alternative energies with efficiencies equivalent to those of conventional fuels. In existing diesel engines, using biodiesel reduces the amount of HC emissions, carbon monoxide, soot, and nitrogen oxides. Various alternate fuels have been compared with traditional fuels, and using blended fuels can significantly reduce the use of these fuels. Because many alternative energy sources have properties similar to conventional fuels, the technologies required to deal with them would be well understood (Chandrasekar et al., 2022). Diesel and petrol fuels will remain the main sources of energy for motor vehicles even after many years (Ghadikolaei et al., 2021). To move towards a more sustainable public transportation sector, the use of alternative fuels with reduced environmental impact is a major challenge (Jelti et al., 2021). As oil prices rise, people are becoming more interested in alternative fuels. Concerns over pollution levels in various parts of the world have increased the urgency of finding remedies. Alternative fuels are becoming more competitive as the price of barrel oil rises. The automobile industry is well-known for being one of the largest users of petroleum in the world (Johari et al., 2022). Biodiesel is preferred due to its structural features, increased oxygen supply, and biological components (Janakiraman et al., 2021). Cashew nutshell biodiesel is utilized as posing various benefits, including durability, lowering of CO, HC, and NOx, and several damaging pollutants (Karikalan et al., 2021). Bio-diesel generation is one of the various approaches to fully meeting the fuel needs of engines and automobiles. However, some researchers said the source of the manufacturing of bio-diesel is cheap and also expensive. This procedure is carried out with non-edible oils, which are readily available in homes and other food processing facilities, to lower total manufacturing costs and produce a large quantity of bio-diesel products (Gopan et al., 2021). Bio-fuel blends emitted higher HC, CO, and smoke, but much less NOx, than straight diesel (Mei et al., 2020). Nano additives added to the fuel resulted in lower NOx levels in the blends. When compared to diesel, carbon emissions from biodiesel blends are lower (Reddy et al., 2021). The Nano Al_2O_3 has improved combustion properties and a higher surface area to volume ratio, resulting in greater oxidation of the fuel mixture and thereby improving the test fuel's combustion sufficiency (Patel & Kumar, 2017). It is critical to seek green technologies. Vegetable oils are a renewable, theoretically infinite source of energy with a similar energetic content to diesel fuel. Because of its environmental benefits and the fact that it is derived from renewable resources, bio-diesel has grown more appealing as an alternative fuel for diesel engines in recent years (Barabash et al., 2020; Arasu et al., 2024). Because edible oil consumption exceeds domestic output, there is no way for this oil to be diverted to biofuel production in India (Dixit & Rehman, 2012). Bio-oils have been noted for their biocompatibility, renewable nature, oxygen levels, and lack of sulphur. However, viscosities, friction coefficients, and density due to the big structure may be the key factors impacting spray characteristics, mixture formation, combustion characteristics, and emission characteristics of bio-oil-powered diesel engines (Yağız et al., 2022; Hoang, 2019). Due to various poor fuel qualities, such as high viscosity and instability, biomass-derived bio-oil cannot be used directly in diesel engines (Nair et al., 2019). The problems of bio-oil could be solved by emulsification (Yuan et al., 2018).

Experimental Details

A single-cylinder 4-stroke water-cooled diesel engine with an electrical type dynamometer is used for the test. This is also linked to the software for viewing computerized engine soft labs. This software assists in the evaluation of engine performance metrics such as particular fuel consumption. As a result, this configuration comes with all of the sets for measuring this data. The equipment for measuring the emissions that come out of the exhaust gas after burning is a gas analyzer and a smoke meter. The diesel engine's specifications are listed in Table 1.

Table 1. Specification of diesel engine

Make	Kirloskar
Type	Single-cylinder, 4 stroke, vertical diesel engine
Rated Power	3.7 kW
Speed	1500 rpm
Type of governor	Centrifugal governor
Compression ratio	16.5:1
Cylinder Specification	No. of cylinder – 1 Bore – 80mm Stroke – 110mm Cylinder Capacity – 553cc
Dynamometer	Electrical AC alternator
Cooling	Air-cooled

The test is carried out on the engine described above using the composition and combination stated in Table 2. The table shows the four different combinations of fuel composition are taken into consideration in this work. This begins from pure diesel named F1, followed by a 20 % addition of oil extracted from the chicken waste which is named F2, this is followed by 30 mg/l of Al_2O_3 which acts as a nano additive named F3.

Table 2. Composition of bio fuel

Sl. No.	Abbreviation	Fuel composition
1.	F1	100% Premium Diesel
2.	F2	20% Chicken waste oil
		80% diesel
3.	F3	20% Chicken waste oil
		80% diesel
		Al_2O_3(30 mg/l)

Results and Discussion

The fuel consumption test is carried out on a lightweight single-cylinder diesel engine, and the emission test is carried out on a gas analyzer. The following findings were covered in this article.

Fuel Consumption

The inverse of fuel economy is fuel consumption. It is the amount of fuel used to travel a specific distance. In India and other parts of the world, it is measured in litres per 100 kilometers. Table 3 shows the fuel consumption of various fuels in various combinations at various loads.

Table 3: Load Vs Fuel consumption for various combinations of fuels

Load (kg)	F1 in (kg/hr)	F2 in (kg/hr)	F3 in (kg/hr)
0.04	0.3	0.22	0.23
3.30	0.6	0.47	0.50
8.07	0.81	0.70	0.74
11.56	1.06	1.01	1.06
16.05	1.26	1.15	1.19

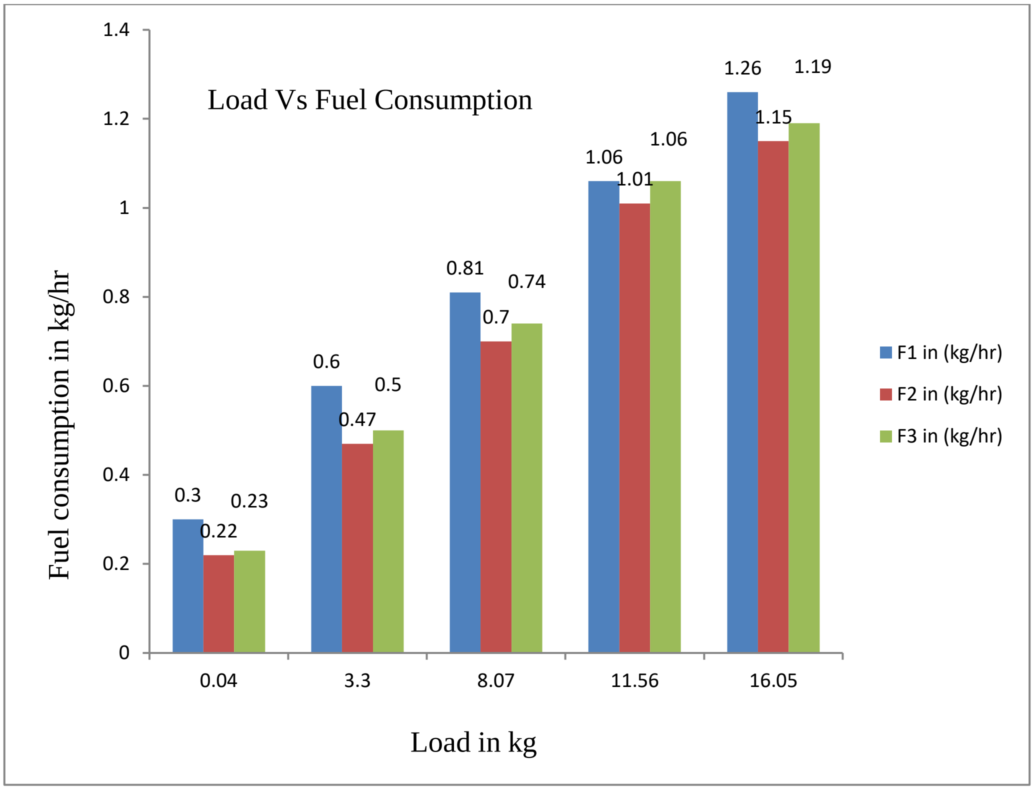

Figure 1. Load VsFuel Consumption for Various Fuels

The fuel consumption for the various fuels is shown in Figure 1. The figure clearly shows that the fuel consumption for pure diesel F1 is comparatively higher when compared to chicken waste-added fuel F2 as well as nano-additive added fuel F3 at all varying load conditions. The chicken waste oil added to fuel F2 consumption is lower than both F1 and F3. In most of the load conditions, F3 fuel consumption is more or less equal to that of F1. Hence, the property of the nano-additive added fuel F3 resembles pure diesel F1.

Emission Test

Here, an AVL DIGAS 444N gas analyzer and an AVL smoke meter are employed. This is a digital analyzer of the automatic type. It takes about two minutes for the output to appear. The smoke test is completed, and the results are shown in Table 4. The resulting output is in the form of an excel spreadsheet. CO emissions in percentage, UBHC emissions in ppm, NO_X emissions in ppm, and smoke opacity in % thus derived are compared for each fuel combination.

Table 4. Emissions from different combinations of fuels including diesel

Fuel Composition	Load (kg)	CO %	UBHC ppm	NO_Xppm	Smoke Opacity (%)
F1	**0**	0.15	17	192	3
	25	0.11	22	393	4
	50	0.105	25	652	6
	75	0.115	28	893	21
	100	0.18	34	1111	48
F2	**0**	0.13	15	198	4
	25	0.095	19	487	5
	50	0.07	21	681	8
	75	0.125	24	903	23
	100	0.14	30	1119	49
F3	**0**	0.09	11	188	6
	25	0.06	15	382	8
	50	0.06	16	636	11
	75	0.09	18	871	27
	100	0.10	21	1094	50

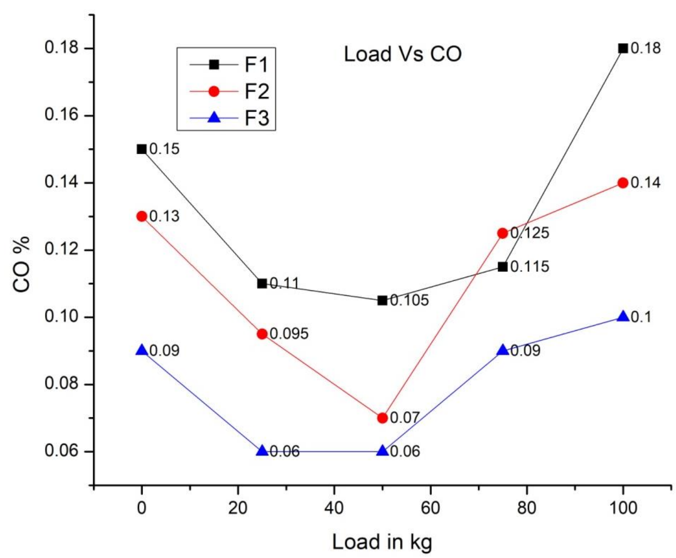

Figure 2. CO emission from diesel engine running with different fuel combinations

Figure 2 depicts CO emissions from a diesel engine running on various fuel combinations. The CO emissions of various fuels are tested for varied compositions. It is found that the CO emissions were found for the fuel, and pure diesel F1 is found to be higher at varying load conditions. It is greater at 0 kg load and decreases at 25, 50, and 75 kg load conditions before peaking at 100 kg load condition. Comparatively, the fuel F3 with chicken waste oil and Al_2O_3 nano additive outperforms both F1 and F2 in CO emission, as very low CO emission is noticed in F3 fuel.

Figure 3 depicts UBHC emissions from diesel engines using various fuel blends. The number of unburned hydrocarbons released increased as the amount of bio-oil increased. Similar to CO emission, the UBHC emission is also found to be higher for pure diesel F1. For the various fuel combinations, the amount of UBHC in ppm was found to increase concerning an increase in load. Among the three fuel compositions, fuel F3 outperforms F2 and F1 concerning unburned hydrocarbon emissions. The addition of nano-additive Al2O3 helps to increase the burning capability of the biofuel, in turn reducing the ppm of unburned hydrocarbon emissions.

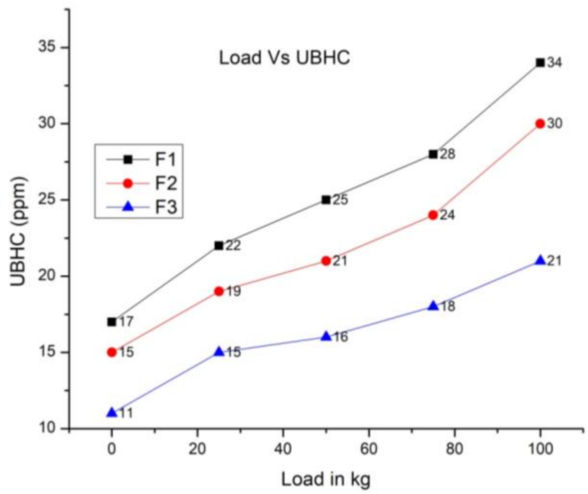

Figure 3. UBHC emission from diesel engine running with different load conditions

Figure 4 shows the NOx emissions in ppm for the fuels F1, F2, and F3 which were found to increase with an increase in load. At the same time, the biofuel F3 was found to exhibit comparably lower NOx emissions when compared to pure diesel F1 and, at the same time, the biofuel F2 was found to be the worst of all the three combinations in NOx emission.

Figure 5 shows the smoke opacity for the fuels F1 and F2 remains almost the same, leaving behind F2, which is found to be a little better in smoke opacity. At the same time, F3 with the Al_2O_3 additive emits smoke, which is found to be more opaque. For all the fuel combinations, the smoke opacity tends to increase with an increase in load. At higher loads, the smoke opacity is at its peak.

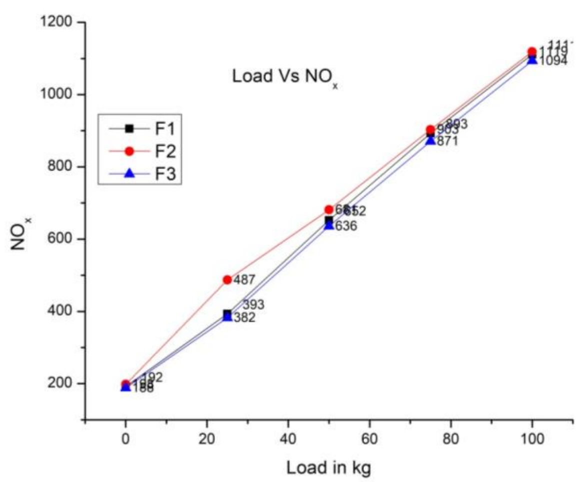

Figure 4. NOx emission from diesel engine running with different load conditions

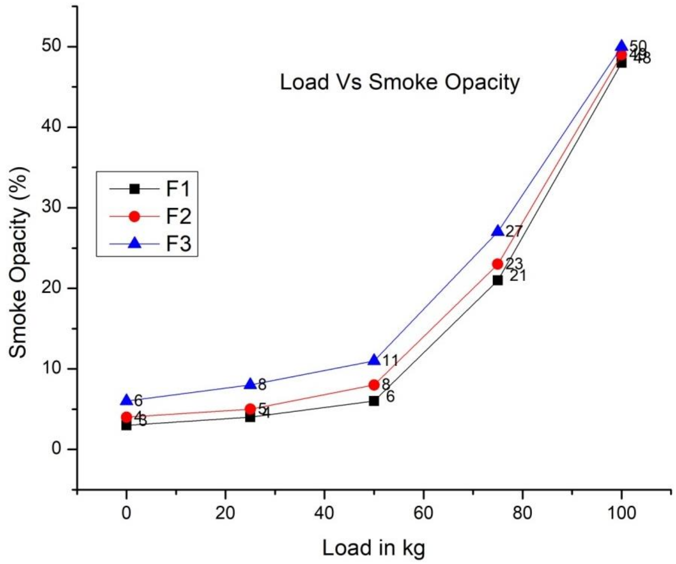

Figure 5. Smoke Opacity in % From Diesel Engine Running with Different Load Conditions

Conclusions

The use of chicken waste biofuel with and without additive in a diesel engine was evaluated to determine fuel consumption and emissions at various levels of biofuel combination, such as F1, F2, and F3 and varying load conditions. The following are the findings, which are presented as follows.

1. The biodiesel with F2 provides a reasonable fuel consumption at all varying load conditions. This is because the viscosity of the chicken waste oil is higher than that of pure diesel and the flow of fuel takes much more time when compared to pure diesel F1, this is made possible.
2. The overall CO emission for the Al_2O_3 nano-additive added fuel F3 was found to be significantly lower. This is made possible because the presence of nanofiller additive helps in completely oxidizing the fuel and making it completely burn and convert to CO_2, leaving behind a lesser amount of CO emission in % when compared to F1 and F2.
3. The UBHC content was found to be very low for the nano additive added fuel F3 due to the presence of nano filler. The possibility of unburned fuel vapors presence was found to be significantly reduced. The UBHC content in the emissions was found to be less when compared to F1 and F2.
4. It is observed that the NOx emission is found to be moderate for F1 when compared to F2 and F3. The biofuel F3 emits lower NOx emissions when compared to F1 and F2 and is found to be even more than F1. This proves that the presence of Al_2O_3 nano-additive tends to reduce NOx emissions.
5. The smoke opacity was found to be increased with an increase in load for all fuels as the acceleration due to an increase in load increases, leaving behind more dark smoke. Hence, the opacity of smoke increases with an increase in load. Among all the fuels, F3 was found to exhibit more smoke opacity when compared to F2 and F1.

The above findings show that chicken waste added oil with Al_2O_3 additive added fuel can be utilized as a diesel alternative to replace diesel and recycle chicken waste. Because of its performance and emissions, F3 proves to be a better candidate to be used as an alternative.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

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