E3S Web of Conferences **399**, 06003 (2023) https://doi.org/10.1051/e3sconf/202339906003
ICONNECT-2023

Investigate the emission characteristic of biodiesel from waste cooking oil

V. Rathinam[1], *K* Srinivasan[2], *M.* Prabhakaran[3], *P.* Munusamy[4], *B.* Radha Krishnan[5*]

[1]Assistant Professor, Department of Automobile Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, Telangana - 500090.
[2]Professor, Department of Mechanical Engineering, Adhiyamaan College of Engineering, Hosur - 635109,
[3]Professor, Department of Mechanical Engineering, Podhigai College of Engineering and Technology, Tirupattur, India.
[4]Assistant Professor, Department of Mechanical Engineering, Er. Perumal Manimegalai College of Engineering, Hosur,
[5]Associate Professor, Department of Mechanical Engineering, Nadar Saraswathi College of Engineering and Technology, Theni, India.

Abstract. This paper aims to investigate the emission characteristics of biodiesel prepared from the waste cooking oil. The characterization of the performance of the blended fuel in diesel engines results in an improvement and a reduction in hydrocarbon and carbon monoxide emissions. Various amounts of fuel were mixed with leftover cooking oil to create the final product. In order to explore the performance function, combustion range, and emission properties of diesel engines, the setup described here was developed. The combustion properties, including exhaust gas emissions of NOx, CO, CO2, HC, smoke, and O2, have been examined under various load scenarios.

1 Introduction

There are multiple reasons to consider biodiesel as an alternative fuel for internal combustion engines. Biodiesel offers several advantages over conventional fossil fuels. Due to its low carbon content, it is a promising alternative for diesel engines. By using biodiesel, we effectively recycle carbon in the atmosphere instead of releasing stored carbon. The carbon stored in plants during growth is released when biodiesel is burned, creating a positive energy balance. Energy balance is the ratio of energy stored in the fuel to the energy required for its growth, processing, and distribution. Biodiesel has an energy balance ratio ranging from 2.5 to 1, indicating a positive value. Additionally, biodiesel is environmentally friendly, easily degradable, and non-toxic. It degrades at a rate similar to sugar, with pure biodiesel degrading 85-90% in water within a month. Biodiesel can also aid in the breakdown and degradation of oil spills. It can be safely stored and handled, with similar requirements to traditional diesel storage, although containers made of tin, zinc, copper, and lead should be avoided. To ensure energy security, organized biodiesel storage

* Corresponding author: radhakrishnankrce@gmail.com

is crucial, especially for countries like India. Although there is limited information on storing biodiesel and its blends, based on personal experience, a maximum storage period of six months is advisable. One of the key advantages of biodiesel is that it requires little to no modification of diesel engines. However, higher blend ratios should be avoided to prevent fuel filter clogging. The existing infrastructure for diesel distribution can be utilized for biodiesel distribution, as it can be blended and sold by oil companies. Biodiesel is a processed fuel derived from bio-based sources and is comparable to petro-diesel. It serves as a safe alternative fuel that reduces air pollution and is environmentally friendly. Biodiesel is mainly produced from renewable sources such as edible and non-edible vegetable oils, animal fat, and other biofuels like methanol and ethanol. Despite its potential, there is currently no mechanism for collecting and disposing of waste cooking oil, leading to underutilization. Lack of rules and policies regarding the reuse of used frying oil in India poses health risks as it is commonly used repeatedly in food processing, restaurants, and local food outlets.

2 Experimental Methodology

This experimental investigation involved the use of three types of fuels: diesel, biodiesel, and blends of both fuels. The reference fuel used was conventional diesel (referred to as Diesel). The blends consisted of different volumes of biodiesel mixed with diesel: 5% biodiesel + 95% diesel (referred to as B5), 10% biodiesel + 90% diesel (referred to as B10), 15% biodiesel + 85% diesel (referred to as B15), 30% biodiesel + 70% diesel (referred to as B30), 50% biodiesel + 50% diesel (referred to as B50), and 100% neat diesel. These fuels were tested under various loading conditions ranging from 3 to 9 kg of rated engine load.

Table 1. Blended Ratio

S.No	Blend	Description
1	B5	10% volume of biodiesel + 90% volume of diesel fuel
2	B10	20% volume of biodiesel + 80% volume of diesel fuel
3	B15	30% volume of biodiesel + 70% volume of diesel fuel
4	B30	40% volume of biodiesel + 60% volume of diesel fuel
5	B50	50% volume of biodiesel + 50% volume of diesel fuel

In this research performance parameters and emission characteristics with biodiesel fuel were tested on a water cooled, single cylinder direct injection 4-stroke Kirloskar AV1 5 BHP model of diesel engine with rated RPM of 1500 rpm. It can be seen in figure 1 that diesel engine Test rig has a engine testing bed together with a system of fuel supply along with different measuring and metering devices fitted in the test rig. Engine was tested at 5 different loads 3 kg, 4 kg, 5 kg, 7kg and 9 kg. Corresponding values of spring balance reading were 0.2, 0.4, 0.5, 0.7 and 0.9 kg:

 https://doi.org/10.1051/e3sconf/202339906003

Fig. 1. Engine Test Rig

3 Result and Discussion

3.1 Exhaust gas temperature

Figure 2 illustrates the relationship between variations in blends of biodiesel and exhaust gas temperature (EGT). It is evident that as the load increases, the EGT also increases for all the tested fuels. The variations in EGT show an almost linear trend. However, it is notable that the EGT of diesel fuel is higher compared to the blends of biodiesel. This is because of the fact that viscosity of blends goes on increasing so poorer atomization takes place. When load increases, speed of engine decreases. At low speeds of engine that is higher load, EGT is increases because at low speed because enough time is available for complete combustion to take place. EGT is an indicator of combustion taking place inside engine cylinder.

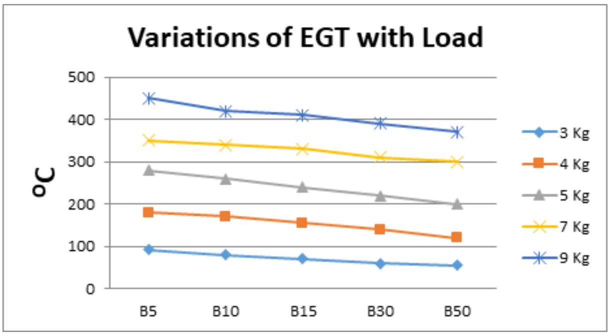

Fig. 2. Variations of EGT with Load

3.2 Emission Analysis

To compare performance of engine, emission analysis of engine was carried out. Probe of exhaust gas analyzer was connected to engine

3.2.1 Carbon monoxide emission

In Figure 3, the changes in carbon monoxide (CO) emissions are depicted for different fuel combinations, including diesel, biodiesel, and their blends. The graph clearly illustrates that the concentration of biodiesel in the blend has a direct impact on CO emissions. As the biodiesel concentration increases, the viscosity of the blends also increases, leading to poorer atomization. This can result in incomplete combustion, causing higher CO emissions. At low or medium loads, the CO emissions of most blends were comparable to those of diesel fuel, with only slight differences observed. However, at high loads, there was a notable reduction in CO emissions for biodiesel blends compared to diesel fuel. This can be attributed to the higher oxygen content in biodiesel, which leads to lower CO emissions under full load conditions. Among the blends, B50 exhibited the lowest CO emissions. This reduction in CO emissions is an important factor driving the research focus on biodiesel usage, as CO has a greater greenhouse effect than CO2. Therefore, studying and understanding CO emissions are of significant importance.

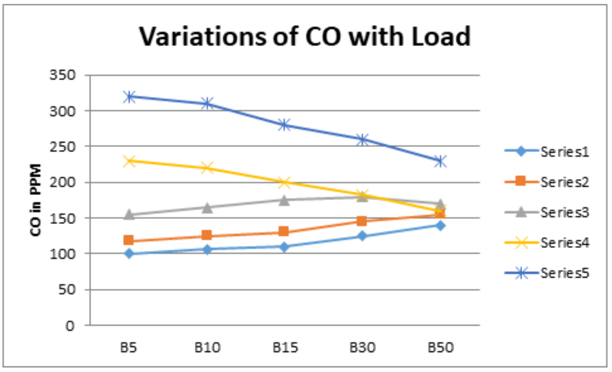

Fig. 3. Variations of CO with Load

3.2.2 Hydrocarbon emission

Figure 4 displays the correlation between hydrocarbon (HC) emissions, fuel blends, and engine load. It is evident that as the engine load increases, HC emissions also increase, regardless of the fuel type used in the tests. At low engine loads, blends containing higher percentages of diesel fuel showed higher HC emissions. This can be attributed to the lower viscosity of blends with higher diesel concentrations, leading to better dispersion of diesel within the combustion chamber. In contrast, at full engine load, diesel fuel exhibited the highest HC emissions. The introduction of biodiesel in the fuel blends resulted in a significant reduction in unburned hydrocarbon (UHC) concentrations. This reduction can be attributed to the higher oxygen content present in biodiesel and the elevated combustion temperature, both of which enhance the oxidation of UHC emissions. Among the blends, B50 demonstrated the lowest UHC emissions. In summary, the data depicted in Figure 4 indicates that HC emissions increase with engine load, but the addition of biodiesel in fuel blends can effectively mitigate UHC emissions due to its higher oxygen content and improved combustion characteristics.

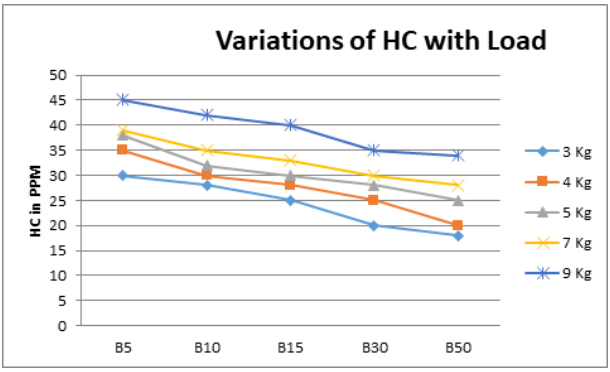

Fig. 4. Variations of HC with Load

3.2.3 Emission of nitrogen oxides

Figure 5 illustrates the changes in NOx emissions for biodiesel, diesel, and their blends. It is observed that the NOx emissions for biodiesel and its blends with diesel were slightly higher than those for diesel fuel across all engine loading conditions. This can be attributed to the higher viscosity of biodiesel blends and the increased heat release rate compared to diesel fuel. Previous studies in the literature have reported that the cetane number, which influences the ignition characteristics of compression ignition (CI) engines, plays a role in NOx emissions. A lower cetane number leads to increased ignition delay and fuel/air mixture accumulation, resulting in faster heat release during combustion and higher temperatures, which contribute to higher NOx formation. However, it is evident that biodiesel-fueled engines with higher cetane numbers exhibit NOx emissions comparable to those of diesel fuel. Furthermore, the data in Figure 5 shows that NOx emissions vary linearly with engine load, with only slight increases observed with changes in biodiesel concentration, similar to diesel fuel. Therefore, it can be concluded that diesel fuel does not demonstrate significant superiority over biodiesel in terms of NOx emissions. However, it is important to note that as the engine load increases, NOx emissions also increase, as clearly demonstrated in Figure 5.

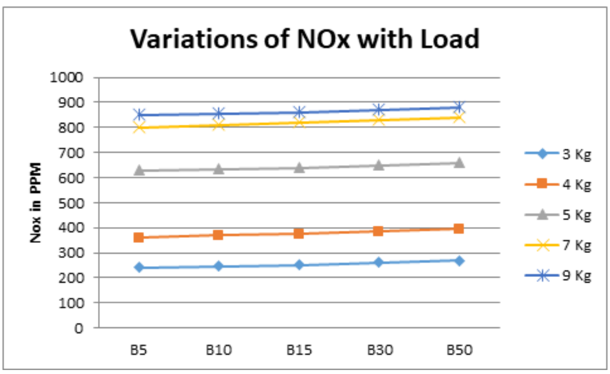

Fig. 5. Variations of NOx with Load

3.2.4 Smoke opacity

Figure 6 depicts the changes in smoke opacity for diesel, biodiesel, and their blends. It is evident that as the concentration of biodiesel in the blends increases, the smoke opacity decreases. This decrease in smoke opacity can be attributed to the lower carbon content present in biodiesel compared to diesel fuel. Among all the test fuels, the highest reduction in smoke opacity was observed for B50, which had the highest biodiesel concentration. This reduction is primarily due to the higher oxygen content in biodiesel, which contributes to a reduction in the amount of smoke produced during combustion. Comparatively, diesel fuel exhibited higher smoke opacity compared to biodiesel and diesel blends. Additionally, the figure clearly demonstrates that smoke opacity increases as the engine load increases. This increase in smoke opacity at higher loads could be attributed to a larger quantity of fuel burning within a shorter time period available for complete combustion, resulting in increased smoke production.

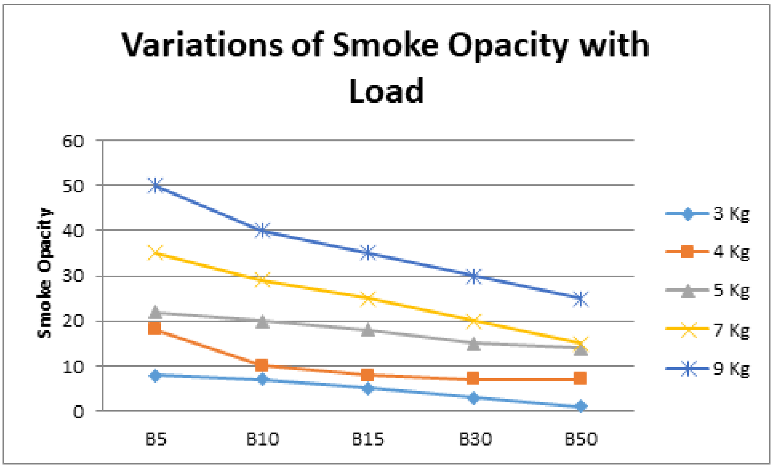

Fig. 6. Variations of Smoke Opacity with Load

4 Conclusion

In this research work, main focus was on production of biodiesel from only a single feedstock that is waste cooking oil/frying oil then experiment it on diesel engine so that performance of diesel engine for different blends can be compared. Form the research work carried out so far, following conclusions can be drawn:

- The highest exhaust gas temperature recorded for diesel at a load of 10 kg was 3.37% higher compared to the maximum exhaust gas temperature recorded for biodiesel.
- Biodiesel exhibited a maximum carbon monoxide (CO) emission that was 17.74% lower than the maximum CO emission for diesel, measured in parts per million (PPM).
- The hydrocarbon emission of biodiesel was 20% lower than that of diesel at its peak value.
- Concerning nitrogen oxides (NOx) emissions, biodiesel showed higher levels. The NOx emissions of B5 blends were very close to those of diesel, with a peak value for biodiesel being only 6.08% higher than that of conventional diesel fuel.

- The lowest smoke opacity for biodiesel was found to be 83.33% lower than the lowest smoke opacity of diesel, while the highest smoke opacity of biodiesel was 41.66% lower than the highest smoke opacity of diesel.

References

1. K.V. Miyuranga, U.S. Arachchige, T.M.M. Marso, G. Samarakoon, J. Catal. **13**, 3 (2023).
2. H. Wei, Q. Wang, R. Zhang, M. Liu, W. Zhang, Process Biochem, **125** (2023)
3. S.N. Gopan, A.V. Rajan, B.R. Krishnan, Mater. Today: Proc., **37** (2021)
4. R. Giridharan, A.V. Rajan, B.R. Krishnan, Mater. Today: Proc., **37** (2021)
5. M.R. Subbarayan, R.K. Beemaraj, T. Nagaraj, M. Rajkumar, Mater. Today: Proc., **60** (2022)
6. R.B. Durairaj, A. George, S.G. Kaushik, 2023. Mater. Today: Proc., (2023)
7. T. Sathish, K. Muthukumar, A. Abdulwahab, M. Rajasimman, R. Saravanan, K. Balasankar, Fuel, ***333*** (2023).
8. C.V. Rajam, G.V. Patil, M.I. Sakri, R.N. Jeeragal, M. Adimurthy, Appl. Therm. Eng**.** **231** (2023)
9. A.S. Yusuff, T. Dada, I.I Olateju, T.M. Azeez, S.O. Azeez, Energy Convers. Manag. **17** (2023).
10. T.S. Senthilkumar1, S. Rathinavel, S. Senthil Kumar, A. Ganesh babu, Tierärztliche Praxis, **41** (2021).
11. A. Parthiban, S. Sathish, R. Suthan, T. Sathish, M. Rajasimman, V. Vijayan, J. Jayaprabakar, Environmental Research, 220 (2023).
12. M. Ramesh, D. Jafrey Daniel James, G. Sathish kumar, V. Vijayan, S. Raja Narayanan and Aklilu Teklemariam, Bioinorganic Chemistry and Applications, Article ID 6344179 (2022).
13. Siranjeevi Ravichandran, Rajesh Jegathaprathaban, Jeyalakshmi Radhakrishnan, R. Usha, V. Vijayan and Aklilu Teklemariam, Bioinorganic Chemistry and Applications, Article ID 2335443 (2022).
14. SR. Parthiban, M. Loganathan, R. Venkatesh, V. Vijayan, V, Journal of Scientific & Industrial Research, 80, 7 (2021).
15. Senthil Kumar, S., Sudhakara Pandian, R., Pitchipoo, P., Senthilkumar, T. S., Ponnambalam, S. G., Journal of testing and evaluation, 51, 2 (2022).
16. L, S., K, V. & S, S.T. Silicon 15, 1747–1769 (2023).
17. T.S. Senthilkumar1, S. Rathinavel, S. Senthil Kumar, A. Ganesh babu, Tierärztliche Praxis, 41 (2021).
18. K. Rajaguru, T. Karthikeyan, V. Vijayan, Materials Today: Proceedings, 21, 1 (2020).
19. Vijayan Venkatraman, Sivachandran Sugumar, Saravanan Sekar & Sivakumar Viswanathan, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 41, 20 (2019).
20. V. Vijayan, S. Arun Kumar, S. Gautham, M. Mohamed Masthan, N. Piraichudan, Materials Today: Proceedings, 37, 2 (2021).