Journal of Positive School Psychology http://journalppw.com
2022, Vol. 6, No. 2, 535 – 544

Emission and efficiency characteristics study of palm/sunflower oil biodiesel blend for a sustainable environment

P. Gandhi[1], Y. Sathaiah[2], Ajith Raj Rajendran[3], P. Srikar[4], G. Dheeraj[5]

[1]*Principal, Sana Engineering College, Kodad, Telangana State.*
[2]*Ph.D. Scholar, OUCE, Hyderabad Telangana State.*
[3]*Associate Professor, Department of ANE, MRCET, Hyderabad, Telangana State.*
[4]*Associate Professor, Department of ME, MRCET, Hyderabad, Telangana State.*
[5]*Assistant Professor, Department of ANE, MRCET, Hyderabad, Telangana State.*

Abstract

Over the last few decades, research has focused on reducing environmental pollutants through the use of biodiesel blends, which have become a more important factor in transportation fuels due to their eco-friendliness. These biodiesel blends have higher density and viscosity than diesel, which is a significant barrier to commercial biodiesel exploitation. In this work, various fuel sources, such as sunflower oil and palm oil, were prepared for biodiesel in various proportions. Experimentally, the effects of various concentrations of biodiesel blends on efficiency and CO, NOx, and smoke opacity characteristics were investigated. The results revealed that the addition of ethanol to balm/sunflower oil biodiesel improves efficiency due to the good combustion process. The P5S5D85E10 bio diesel showed better efficiency with lower emissions for all the load conditions. At maximum loaded condition, P5S5D85E10 increased efficiency by 11% and P5S5D85E5 increased efficiency by 5% when compared to P5S5D90 biodiesel. Overall, palm/biodiesel fuel emission results like CO, NOx, and smoke opacity are reduced with ethanol addition.

Key words: Biodiesel, Diesel, Ethanol, Engine performance, Emissions

1. Introduction

The rapid depletion of fossil fuel reserves has been a major source of concern in recent decades, with approximately 80% of fossil fuels already exhausted [1-3]. Besides, energy demand is increasing as a result of the rapidly expanding population and the increase due to rapid urbanisation [4, 5]. To meet this energy demand, fossil fuels are widely used, but emission control is a significant challenge. Fossil fuels impact the environment by means of a large amount of carbon dioxide emissions [6-8]. Biofuels, which are derived from a wide range of natural resources, have recently emerged as a viable alternative natural source, such as sunflower oil, soybeans, palm oil, canola oil, safflower oil, coconut oil, algae, waste cooking oil, etc., due to its comparable engine efficiency and lower emissions [9-11]. On the other hand, waste cooking oil biodiesel plays a significant role in diesel engines due to its renewable and non-toxic nature. Biodiesel addition to diesel increases fuel consumption and nitrogen oxides (NOx) emissions while decreasing unburnt hydrocarbon (HC), and low carbon monoxide (CO). Moreover, this biodiesel fuel produces a moderate change in brake thermal efficiency [12, 13].

Many literature studies revealed that the fuel characteristics were improved by the biodiesel blend with alcohol, ethanol, and butanol fuel [14, 15]. Besides, biodiesel is blended with ethanol to reduce the viscosity. On the other hand, increasing the cold-flow and volatility Because ethanol has a higher oxygen content than biodiesel, the ethanol blend with biodiesel reduces PM emissions compared to biodiesel alone [16, 17]. There have been numerous studies conducted on the efficiency and emissions of various biodiesel blends. Bhale et al. [18] studied that the emissions of smoke, NOx, CO, and other pollutants are reduced with ethanal blended biodiesel when compared to neat biodiesel. Another investigation has been made by Zhu et al. [19] reported that the waste cooking oil/ethanol blends showed maximum in-cylinder pressure and heat release rate, while they had lower NOx and PM emissions compared with neat biodiesel. Alptekin [20] explored a diesel engine powered by biodiesel made from each of 50% volume of canola 50 and safflower oil biodiesel blended with 15% ethanal CS50BE15. It was reported that CS50BE15 produced higher BSFC than biodiesel while maintaining comparable peak cylinder pressures. Furthermore, when compared to biodiesel, CS50BE15 increased NOx emissions while decreasing CO2, THC, and CO emissions. According to some research studies, waste oil can be used as a biodiesel blend to improve fuel characteristics by varying the proportion of the blend [21, 22].

The above literature reveals that the concentration of biodiesel with ethanal affects the performance and emission characteristics of diesel engines. In this study, to investigate the different concentrations of biodiesel, such as palm oil, sunflower oil, and soybean oil blended with ethanol, on the brake efficiency, NOx, CO and smoke opacity emissions of a diesel engine.

2. Materials and experimental procedure

Palm and sunflower oil blend fuels are processed into biodiesel for different proportionalities of this work. The sample oils are mixed with a proportion of methanol and sodium hydroxide solution. A three-necked glass flask fitted with a condenser and a thermometer was used for filtration. The condenser was used to remove the methanol after two hours of the process. The reactant was heated to methanol's boiling temperature (50°C) and then slowly cooled to room temperature. The filtration is done with two layers, upper and lower. The lower layer contained glycerin, which sunk to the bottom. A total of six hours of process layer separation was done for the settle. After that, the ester was washed with water at room temperature to remove any methanol and sodium hydroxide residues.

Initially, residual water and particles were removed from the residual fuels by a heating process. Residual fuel was heated to 80°C and then removed the particulate matter by using a funnel and filtration process. Again, the fuel is heated to 120°C (one hour) for the removal of residual water. The next stage is the mixing of sodium hydroxide (NaOH) and methanol with the residual fuel. This fuel was added to a glass bowl and a mechanical stirrer was used to dissolve the fuel at 500 rpm. During this process, the temperature is constantly maintained at 60°C. After the mixing process, a chromatographic column was performed to carry glycerin separation from biodiesel and washed with water. A bio-diesel reactor, depicted in Figure 1, is a tank that can be used to mix oil, methanol, and a base catalyst. Mixing can be accomplished with a motor and a baffle because it is a simple machine with few moving parts. In total, four different biofuels were tested to determine the emission and engine performance characteristics. The blend fuels concentration is given in table 1.

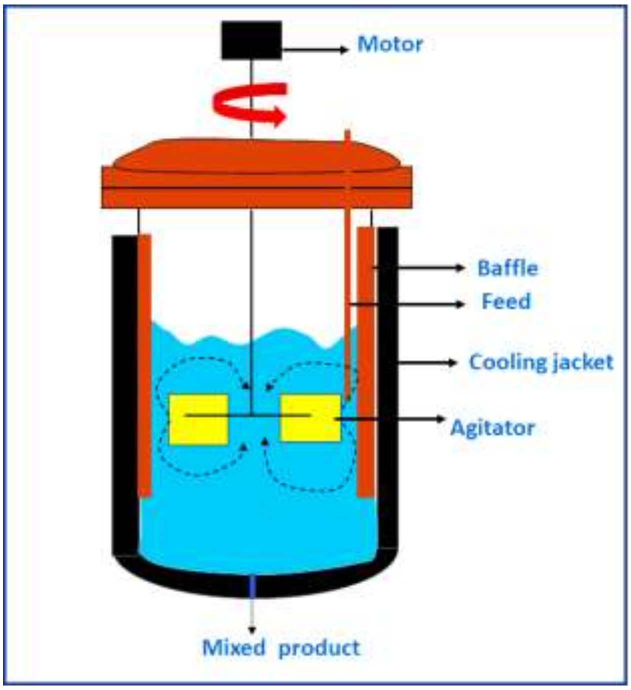

Figure 1 Bio-diesel-mixer

Table 1 Blended biodiesel concertation [11, 23]

Fuel	Blend proportional (%)			
	Palm oil	Sunflower oil	Diesel	Ethanol
100D	-	-	100	-
P5S5D90	5	5	90	-
P5S5D85E5	5	5	85	5
P5S5D85E10	5	5	80	10

For this experimental investigation, four-stroke single-acting cylinder specifications like connecting rod length of 232 mm, stroke length of 110 mm, cylinder bore of 87 mm, injection pressure of 210 bar, maximum power of 4 kW, and water-cooling system were used for this experimental investigation. A Sun Diagnostic fuel analyzer was used to determine the emissions of CO and NOx. A type-K thermocouple was originally used to measure the temperature of the exhaust fuel. Ethanol is added to the B25 mix in amounts ranging from 5% to 10%. The kinematic viscosity, flash point, and density of sunflower oil and palm oil fuel are shown in Table 2. One significant difference between biodiesel and oil diesel is the high oxygen content (between 10 and 11%), which improves burning and execution characteristics. The properties of biofuels are shown in Table 2.

Table 2 Properties of biodiesel and diesel fuels [9]

Types of fuel/Property	Flash point °C	Density kg/m^3	Kinematic viscosity at 40^0C mm^2/s
Diesel fuel	56	850	2.7
Palm oil	286	902	30
Palm oil Bio diesel	170	876	4.8
Sunflower oil	274	918	33.9
Sunflower oil Biodiesel	176	880	4.3

3. Results and discussions

3.1 Brake thermal efficiency

The thermal efficiency of palm/sunflower biodiesel fuels is shown in Figure 2. The mechanical energy is converted from chemical energy. The figure reveals that the BTE is the maximum for neat diesel fuel. As compared to the biodiesel, the 10% addition of ethanol enhanced the thermal efficiency. Palm/sunflower blended biodiesel obtained a minimum thermal efficiency compared to other ethanol blended fuels. When compared to P5S5D90 biodiesel at maximum loaded condition, P5S5D85E10 increased efficiency by 11% and P5S5D85E5 increased efficiency by 5%. Moreover, efficiency increases with increasing load because, as the engine load grows, a lesser amount of power is lost. However, when the percentage of ethanol in the fuel mixes grows, the BTE falls due to the lower calorific value of the gasoline blend. Also, the results revealed that increasing the amount of ethanol in the fuel mixture increased the fuel efficiency. This efficiency improvement by the addition of ethanol is due to the good combustion process taking place, resulting in an oxygenated environment. Similar efficiency results are reported in the previous literatures [23, 24].

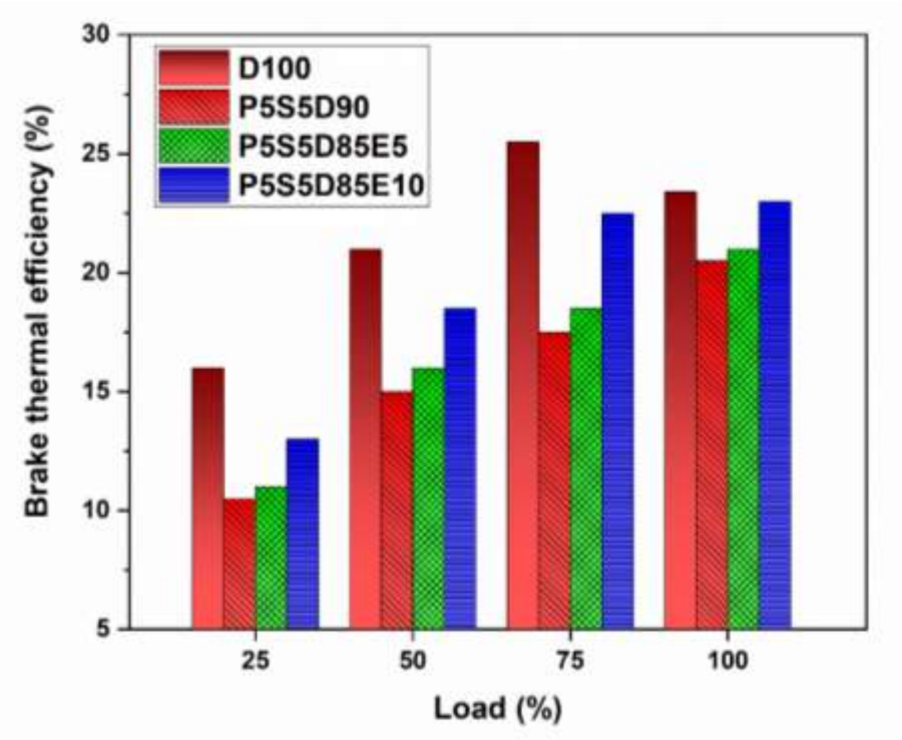

Fig. 2 Brake thermal efficiency of biodiesel at various loading

4.3 Carbon monoxide emissions

Figure 3 depicts the carbon monoxide (CO) emission of diesel and palm/sunflower biodiesel as a function of various loading conditions. The experimental results revealed that the biodiesel fuel reduced carbon monoxide emissions. The palm/sunflower biodiesel blended ethanol 10% fuel (P5S5D85E10) showed a minimum CO emission for all the load conditions. P5S5D85E10 biodiesel emits less CO than P5S5D90 (palm/sunflower oil blended) and P5S5D90 (palm/sunflower/ethanol blended biodiesel). This is due to the ethanal reducing the carbon content in the biodiesel. CO emissions for P5S5D90, P5S5D85E5, and P5S5D85E10 biodiesel were reduced by 33.3%, 42.8%, and 71%, respectively, when compared to neat diesel at maximum load condition. On other hand, increased load conditions increase the air-fuel mixture, resulting in complete combustion. CO emissions for all fuels are reduced as load increases due to the complete combustion that occurs at higher loadings [14]. Kandasamy et al. [24] discovered that adding ethanol reduced carbon content, which resulted in lower CO emissions.

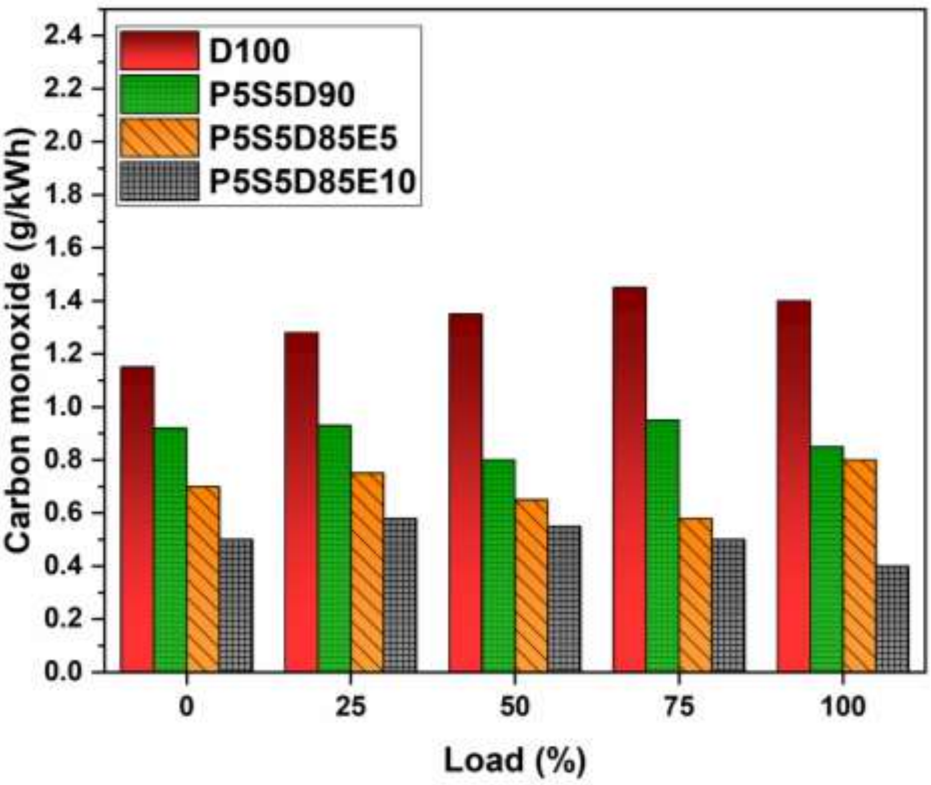

Fig. 3 Carbon monoxide emissions of biodiesel blends

4.4 NO_x emissions

Figure 4 shows the NOx emission level of palm/sunflower biodiesel fuels with varying loads. It can be seen in the plot that a similar trend is shown for CO and NOx emissions. The experimental results revealed that the biodiesel fuel reduced carbon monoxide emissions. The P5S5D85E10 bio diesel showed a minimum NOx emission for all the load conditions. When compared to P5S5D90 and P5S5D85 biodiesels, P5S5D85E10 biodiesel emits less NOx. This is due to ethanal's cooling effect, which reduces NOx emissions. When compared to neat diesel, NOx emissions (maximum load) for P5S5D90, P5S5D85E5, and P5S5D85E10 biodiesel were reduced by 15.3%, 20.2%, and 23.9%, respectively. The higher oxygen content of ethanol blend fuel reduces the NOx emissions. On the other hand, the addition of the loading level increased the combustion temperature, and the resulting NOx emission level has been increased for all biodiesel. When ethanol is added to biodiesel, it reduces NOx emissions when compared to neat diesel, which could be attributed to the cooling effect of ethanol. All of the fuels produce the same results at full load, which could be reported that full load increases heating to evaporate fuel while decreasing ethanol's cooling impact [13, 23].

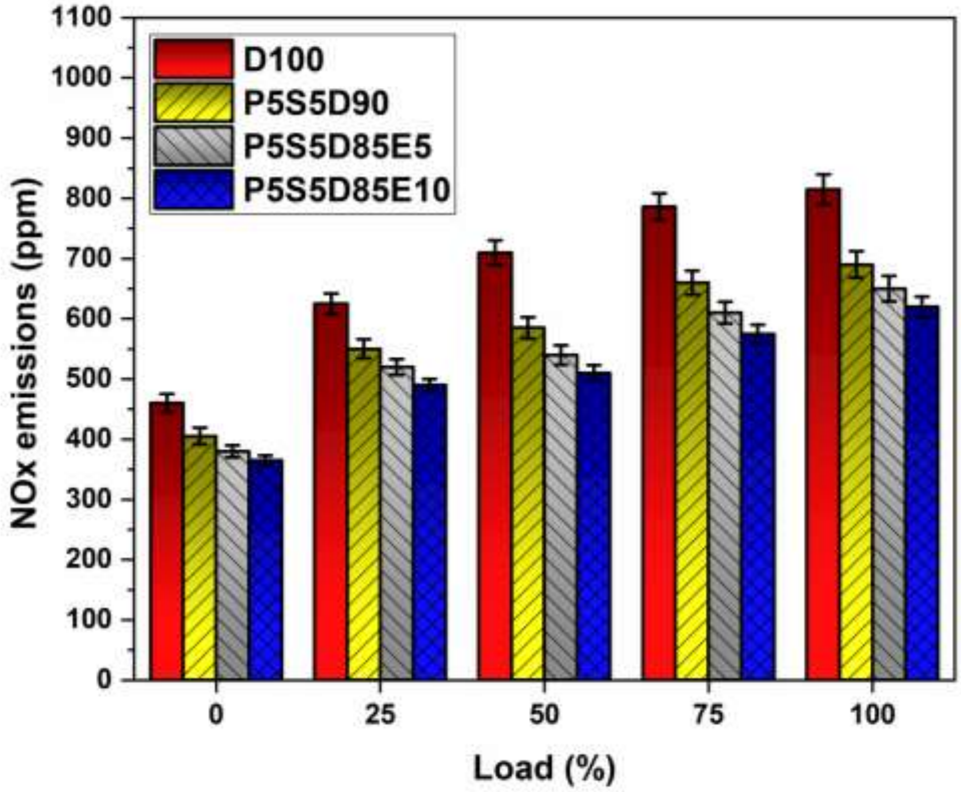

Fig. 4 NOx emissions of biodiesel blends

4.4 Smoke opacity

In Figure 5, the smoke opacity levels of neat diesel and palm/sunflower biodiesel fuels are shown. In general, the level of smoke opacity is determined by the incompleteness of combustion. The figure clearly shows that the ethanol blended bio diesel improved the smoking quality of the fluid gases. The P5S5D85E10 bio diesel showed a low-level smoke opacity for all the load conditions. P5S5D85E10 has a lower smoke opacity than all other fuels due to the addition of ethanol to improve oxygen content, which aids in complete combustion, resulting in a lower smoke opacity. When compared to P5S5D90 and P5S5D85 biodiesels, P5S5D85E10 biodiesel emits less smoke opacity level. When compared to neat diesel, smoke opacity at maximum load condition for P5S5D90, P5S5D85E5, and P5S5D85E10 biodiesel was reduced by 9.09%, 15.15%, and 21.2%. The higher oxygen content of ethanol blend fuel reduces the smoke opacity. On the other hand, the addition of the loading level increased the combustion temperature, and the resulting smoke level has been increased for all biodiesel. Overall, results showed that smoke emissions quality improved with ethanol addition. Similar smoke opacity levels of biodiesel were observed by Vergel et al. [23].

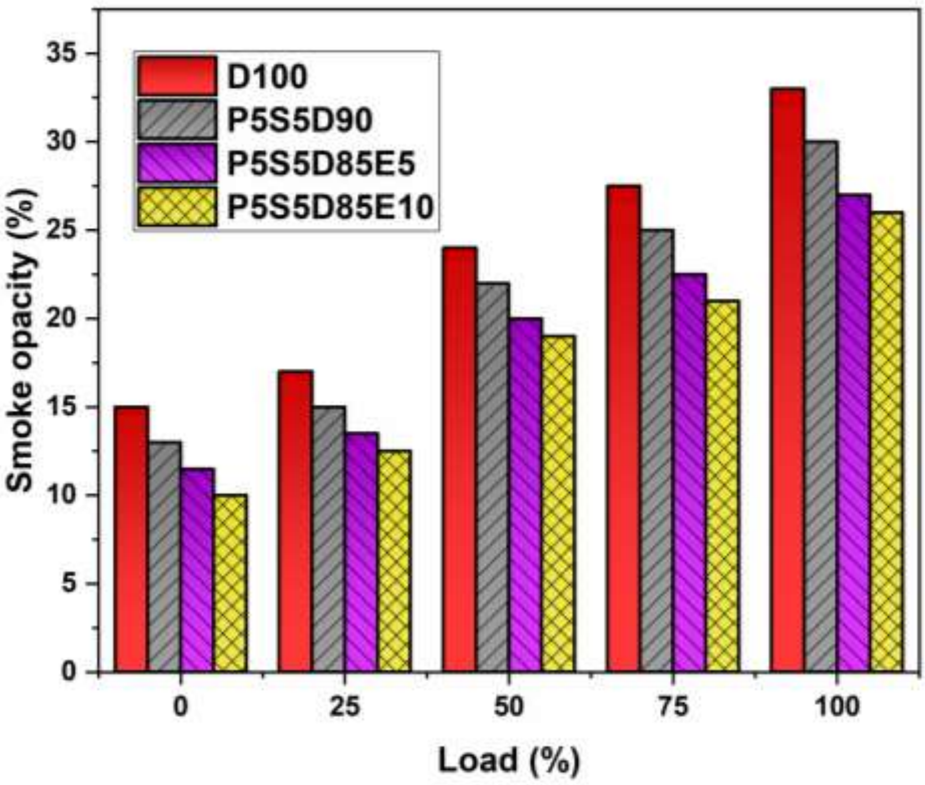

Figure 5 Smoke opacity of biodiesel at various load

Conclusion

The efficiency and emission characteristics of palm/sunflower biodiesel fuels were experimentally studied and following conclusions are summarized:

1. Experiment results showed palm/sunflower biodiesel fuels were significantly affected brake thermal efficiency and emissions. The thermal efficiency was improved by palm/sunflower biodiesel with a 10% ethanol addition. When compared to ethanol blended fuels, palm/sunflower blended biodiesel had the lowest thermal efficiency.
2. The results of the experiments revealed that biodiesel fuel reduced carbon monoxide emissions. The palm/sunflower biodiesel blended ethanol 10% fuel (P5S5D85E10) emitted the least amount of CO under all load conditions. This is due to the ethanal reducing the carbon content in the biodiesel. Similar NOx emissions results were observed for palm/sunflower blended fuels.
3. The higher oxygen content of ethanol blend biofuel reduces the opacity of the smoke. Overall results revealed that the P5S5D85E10 biodiesel showed better results for fuel characteristics such as emission and efficiency.

References

[1] Altarazi, Y.S., Yu, J., Gires, E., Ghafir, M.F.A., Lucas, J. and Yusaf, T., 2022. Effects of biofuel on engines performance and emission characteristics: A review. Energy, 238, p.121910.

[2] Jain, S. and Sharma, M.P., 2010. Prospects of biodiesel from Jatropha in India: a review. Renewable and Sustainable Energy Reviews, 14(2), pp.763-771.

[3] Asif, M. and Muneer, T., 2007. Energy supply, its demand and security issues for developed and emerging economies. Renewable and sustainable energy reviews, 11(7), pp.1388-1413.

[4] Perea-Moreno, M.A., Manzano-Agugliaro, F., Hernandez-Escobedo, Q. and Perea-Moreno, A.J., 2020. Sustainable thermal energy generation at universities by using loquat seeds as biofuel. Sustainability, 12(5), p.2093.

[5] Wang, T., Yu, W., Liu, F., Fang, M., Farooq, M. and Luo, Z., 2016. Enhanced CO2 absorption and desorption by monoethanolamine (MEA)-based nanoparticle suspensions. Industrial & Engineering Chemistry Research, 55(28), pp.7830-7838.

[6] Suresh, M., Jawahar, C.P. and Richard, A., 2018. A review on biodiesel production, combustion, performance, and emission characteristics of non-edible oils in variable compression ratio diesel engine using biodiesel and its blends. Renewable and Sustainable Energy Reviews, 92, pp.38-49.

[7] Farooq, M., Saeed, M.A., Imran, M., Uddin, G.M., Asim, M., Bilal, H., Younas, M.R. and Andresen, J.M., 2019. CO 2 capture through electro-conductive adsorbent using physical adsorption system for sustainable development. *Environmental geochemistry and health*, pp.1-9.

[8] Ogunkunle, O. and Ahmed, N.A., 2020. Exhaust emissions and engine performance analysis of a marine diesel engine fuelledwith Parinari polyandra biodiesel–diesel blends. *Energy Reports*, *6*, pp.2999-3007.

[9] Usman, M., Farooq, M., Naqvi, M., Saleem, M.W., Hussain, J., Naqvi, S.R., Jahangir, S., Jazim Usama, H.M., Idrees, S. and Anukam, A., 2020. Use of gasoline, LPG and LPG-HHO blend in SI engine: A comparative performance for emission control and sustainable environment. *Processes*, *8*(1), p.74.

[10] Agarwal, D., Sinha, S. and Agarwal, A.K., 2006. Experimental investigation of control of NOx emissions in biodiesel-fueled compression ignition engine. *Renewable energy*, *31*(14), pp.2356-2369.

[11] Fattah, I.R., Masjuki, H.H., Kalam, M.A., Mofijur, M. and Abedin, M.J., 2014. Effect of antioxidant on the performance and emission characteristics of a diesel engine fueled with palm biodiesel blends. *Energy Conversion and Management*, *79*, pp.265-272.

[12] Thushari, P.G.I. and Babel, S., 2018. Biodiesel production from waste palm oil using palm empty fruit bunch-derived novel carbon acid catalyst. *Journal of Energy Resources Technology*, *140*(3).

[13] Singh, S.P. and Singh, D., 2010. Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: a review. *Renewable and sustainable energy reviews*, *14*(1), pp.200-216.

[14] Mamat, R., Sani, M.S.M., Sudhakar, K., Kadarohman, A. and Sardjono, R.E., 2019. An overview of Higher alcohol and biodiesel as alternative fuels in engines. *Energy Reports*, *5*, pp.467-479.

[15] Caligiuri, C., Renzi, M., Bietresato, M. and Baratieri, M., 2019. Experimental investigation on the effects of bioethanol addition in diesel-biodiesel blends on emissions and performances of a micro-cogeneration system. *Energy Conversion and Management*, *185*, pp.55-65.

[16] EL_Kassaby, M. and Nemit_allah, M.A., 2013. Studying the effect of compression ratio on an engine fueled with waste oil produced biodiesel/diesel fuel. *Alexandria Engineering Journal*, *52*(1), pp.1-11.

[17] Razzaq, L., Farooq, M., Mujtaba, M.A., Sher, F., Farhan, M., Hassan, M.T., Soudagar, M.E.M., Atabani, A.E., Kalam, M.A. and Imran, M., 2020. Modeling viscosity and density of ethanol-diesel-biodiesel ternary blends for sustainable environment. *Sustainability*, *12*(12), p.5186.

[18] Bhale, P.V., Deshpande, N.V. and Thombre, S.B., 2009. Improving the low temperature properties of biodiesel fuel. *Renewable energy*, *34*(3), pp.794-800.

[19] Zhu, L., Cheung, C.S., Zhang, W.G. and Huang, Z., 2011. Combustion, performance and emission characteristics of a DI diesel engine fueled with ethanol–biodiesel blends. *Fuel*, *90*(5), pp.1743-1750.

[20] Alptekin, E., 2017. Emission, injection and combustion characteristics of biodiesel and oxygenated fuel blends in a common rail diesel engine. *Energy*, *119*, pp.44-52.

[21] Muralidharan, K., Vasudevan, D. and Sheeba, K.N., 2011. Performance, emission and combustion characteristics of biodiesel fuelled variable compression ratio engine. *Energy*, *36*(8), pp.5385-5393.

[22] Patil, V.V. and Patil, R.S., 2018. Investigations on partial addition of n-butanol in sunflower oil methyl ester powered diesel engine. *Journal of Energy Resources Technology*, *140*(1).

[23] Vergel-Ortega, M., Valencia-Ochoa, G. and Duarte-Forero, J., 2021. Experimental study of emissions in single-cylinder diesel engine operating with diesel-biodiesel blends of palm oil-sunflower oil and ethanol. *Case Studies in Thermal Engineering*, *26*, p.101190.

[24] Kandasamy, S.K., Selvaraj, A.S. and Rajagopal, T.K.R., 2019. Experimental investigations of ethanol blended biodiesel fuel on automotive diesel engine performance, emission and durability characteristics. Renewable Energy, 141, pp.411-419.