International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

Reducing Emissions in CI Engines: Antioxidant Influence on Algae Biodiesel Blend

Prabakaran P[1,4], Karthikeyan S[2], Abhilash V[3]

[1]Research Scholar, Department of Mechanical Engineering, SRM Institute of Science and Technology, Vadapalani, Chennai, Tamilnadu, India

[2]Professor, Department of Mechanical Engineering, SRM Institute of Science and Technology, Vadapalani, Chennai, Tamilnadu, India

[3,4]Assistant Professor, Department of Mechanical Engineering, PERI Institute of Technology, Chennai.

Abstract:

This research investigates the impact of incorporating antioxidants into algae biodiesel blend as a fuel for compression ignition engines. The study evaluates the performance and emission parameters of a microalgae biodiesel-diesel blend, including brake thermal efficiency (BTE), unburnt hydrocarbons (UBHC), carbon monoxide (CO), oxides of nitrogen (NOx), and smoke opacity. Experimental tests conducted at varying loads demonstrate that the algae biodiesel blend resulted in reductions of 28% in CO, 15% in UBHC, and 21% in smoke opacity, alongside a 38% increase in NOx emissions with minor fluctuations in BTE. Upon the addition of antioxidants to the blend, NOx emissions decreased by 25%, while CO, UBHC, and smoke emissions increased by 32%, 50%, and 36% respectively. To address these effects, engine tests were carried out with adjustments in injection timing. The combined influence of modified injection timing and antioxidants led to a 20% decrease in CO, UBHC, and smoke opacity, coupled with a 30% increase in NOx emissions at advanced injection timing, and vice versa. A trade-off injection timing of 24.5, 23.5, 24, and 24 CAD was identified to balance NOx emissions with smoke, UBHC, CO, and BTE, aiming to achieve effective NOx control while minimizing compromises on other emission parameters. This study provides valuable insights into optimizing engine performance and emissions characteristics when utilizing algae biodiesel blends with antioxidant enhancements.

Keywords: Algae biodiesel, Antioxidants, Emission reduction, CI engine, Fuel injection timing.

1. Introduction

The escalating global energy demand coupled with growing environmental concerns has spurred extensive research into alternative energy sources that offer sustainability and reduced environmental impact [1]. The widespread use of fossil fuels in internal combustion engines has been a major contributor to environmental issues, prompting the exploration of cleaner and more sustainable fuel options [3]. Biodiesel, a renewable fuel derived from vegetable oils, has emerged as a promising alternative due to its eco-friendly nature and potential to reduce dependence on fossil fuels [4,5]. Researchers have conducted systematic studies on the use of biodiesel in compression ignition (CI) engines, aiming to harness its benefits in terms of sustainability and environmental friendliness [6–9].

Despite the advantages of biodiesel, challenges such as higher nitrogen oxides (NOx) emissions compared to diesel engines have been observed [10–13]. In response, researchers have investigated various strategies to mitigate NOx emissions, including modifications to injection timing, exhaust gas recirculation (EGR), and fuel additives [14]. One promising avenue is the use of antioxidants, which have shown potential in improving the oxidation stability of biodiesel blends [27–29]. Among the antioxidants, butylated hydroxytoluene (BHT) has been identified for its superior stabilizing properties in biodiesel blends [27–29].

In this context, the present study focuses on exploring the effects of antioxidants, specifically BHT, on the performance and emission characteristics of an algae biodiesel blend in a CI engine [T1]. The objective is to reduce NOx emissions while maintaining engine performance and minimizing other emissions. Algae oil, extracted from algae biomass, represents a renewable non-edible oil with high productivity per acre, making it a promising and sustainable feedstock for biodiesel production [T4]. By investigating the combined impact of antioxidants and modified injection timing on engine emissions, this study aims to optimize the use of algae biodiesel blends for enhanced engine efficiency and reduced environmental impact.

2. Experimental Procedure

2.1.Preparation of biodiesel:

The biodiesel derived from algae plants through a transesterification method was used as a fuel in a mixture form (20% biodiesel + 80% diesel). Table 1 illustrates the characteristics of the algae biodiesel mixture (B20) compared to diesel. Butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ), and 2-ethylhexyl nitrate (EHN), Di-Ethyl Amine (DEA), and P-Phenylene Di Amine (PPPD) are potential stabilizers that can be added to the fuel as additives [27–29]. It was noted that the addition of stabilizers can enhance the resistance to oxidation of the biodiesel [27–29]. Studies have shown that artificial stabilizers (BHA, BHT, and TBHQ) exhibit better resistance to oxidation than organic stabilizers [27–29]. Among the artificial stabilizers, butylated hydroxytoluene (BHT) has a higher stabilization capacity in biodiesel blends [27–29]. For this study focused on testing algae biodiesel blends, BHT was selected as a stabilizer, and the experimental fuel was prepared by blending BHT with B20.

2.2 Engine specifications

The experimental setup depicted in Figure 1 showcases the technical specifications of the engine. A 4.4 kW stationary engine linked to an eddy current dynamometer was utilized for the study. The engine details include a Kirloskar TAF1 make, with a bore of 87.5 mm, stroke of 110 mm, and a swept volume of 661 cm3. The compression ratio is 17.5:1, with a rated power of 4.4 kW at 1500 rpm. The engine operates on direct injection, with a standard injection timing of 23 degrees crank angle before top dead center (TDC) and an injection pressure of 210 bar.

International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

Figure 1: CI Engine experimental setup

3. Results and Discussion

In all cases, the lowest COemission is related to the fuels of B20P50, B20P75, and B20P100 ppm, respectively Shown in figure 2.. The highestamount of CO emission is for B20 fuel blends. The results indicated that the CO emission was lowerfor the CeO2 nanoparticles blended fuels compared with the B20 fuel. This is due to the shortenedignition delay effect associated with the CeO2 additives blended emulsion fuels, the degree of air-fuelmixing, and uniform burning, which could have improved in the presence of potential CeO2nanoparticles, leading to complete combustion (Karthikeyan and Prathima, 2016d).

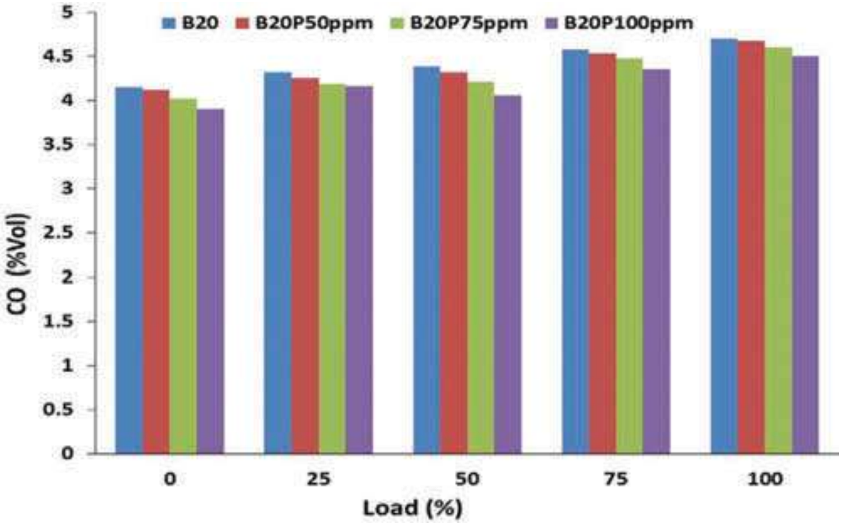

Figure 2:Variation of CO with load.

3.1 CO2 emission

Figure 3 illustrates the amount of CO2 versus engine load for all fuel blends. On comparing the COand CO2 contents, it is observed that CO2 emission increases with increased CeO2 nano additiveblends. It shows the emission of more CO2, which is due to the availability of more oxygen moleculesfor the complete conversion of CO to O2 during combustion. The presence of oxygen reduces theCO freezing duration. Generally, when the emission of CO2 is increased, it means that morecomplete combustion is happening (Karthikeyan et al., 2016e).

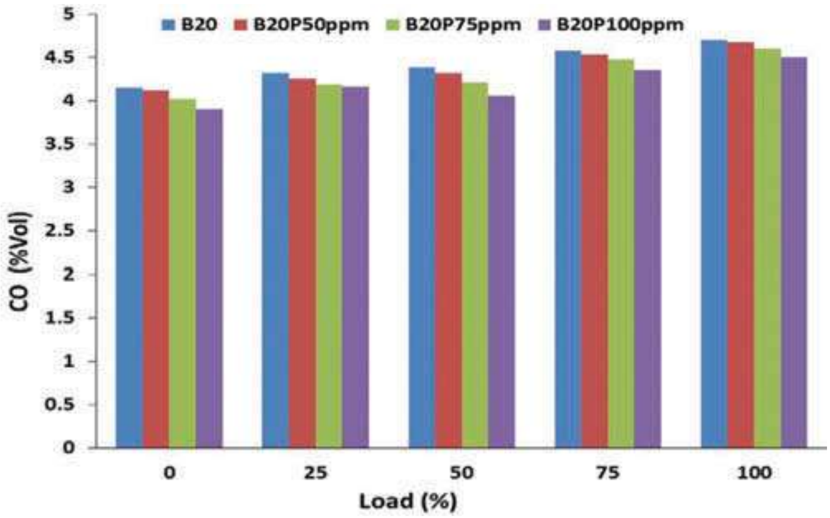

Figure 3. Variation of CO2 with load.

3.2 O2 emission

Figure 4 represents the O2 content according to load for all fuel blends. The lowest O2 content isobserved for fuel blends of B20P50, B20P75, and B20P100 ppm, while these fuels have the highestamount of CO2. The highest amount of O2 is seen for fuel blends of B20; however, these fuels havethe lowest CO2 content. These interpretations indicate that half of the O2 mole combines with CO toform CO2 molecule, and prevents the formation of one mole of CO as a dangerous gas. Theremaining half mole of the O2 is probably associated with NO generation.

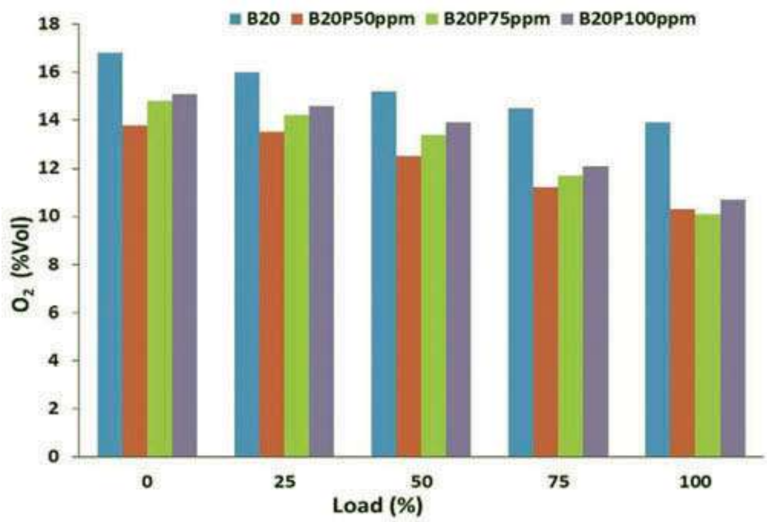

Figure 4. Variation of O2 with load.

3.3 Oxides of nitrogen (NOx)

Figure 6 shows the NO content according to engine load for all fuel blends. According to this figure,it is understood that the NO content is high in the B20P50, B20P75, and B20P100 ppm fuel blends.There is a positive correlation between the NO content. In general, it can be deduced that there is aninverse correlation between the CO and NO values. By increasing CO, the NO decreases and viceversa. As a result, the lowest O2 content belongs to the B20P50, B20P75, and B20P100 ppm fuelblends, which have the lowest CO and highest NO. In many studies, an increase in NOx has beenreported (Karthikeyan and Prathima, 2016g).

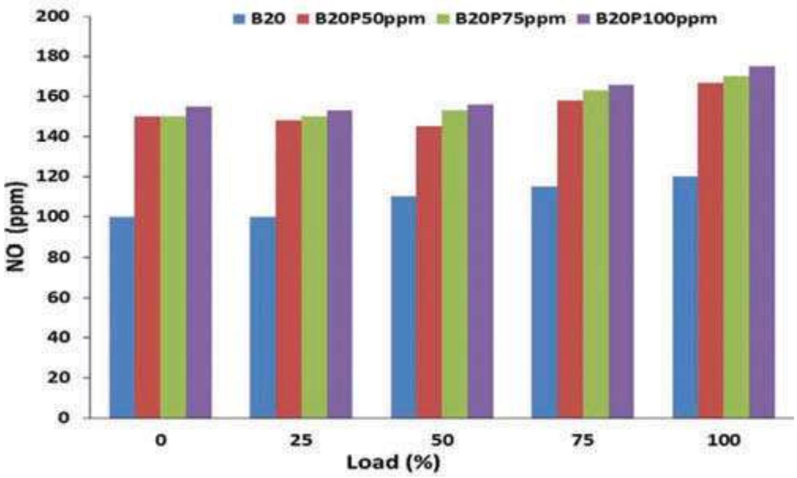

Figure 5. Variation of NO with load.

Conclusion

In this study, the modified fuels by the mixing of CeO2 nano additives biodiesel-diesel in the CIengine and their impact on various engine parameters and exhaust emissions are studied. The CeO2nanoparticles mixed with B20 fuel blends were used to evaluate the exhaust emissions characteristicsof a single-cylinder engine. The CeO2 with dosages of 50, 75, and 100 ppm were applied in fuel.

Reference

1. Karthikeyan, S. 2016. An environmental effect of Vitis vinifera biofuel blends in a marine engine. Energy Sour. Part. A38:3262–3267. doi:10.1080/15567036.2016.1179362.
2. Karthikeyan, S., Elango, A., and Prathima, A. 2015. Environmental effect of Vitis vinifera (grape seed oil) biofuel blends in marine engine. Indian J. Geo-Mar. Sci. 44:886–891.
3. Karthikeyan, S., Elango, A., Silaimani, S. M., and Prathima, A. 2014. Role of Al2O3 nanoadditive in GSO Biodiesel on the working characteristics of a CI engine. Indian J. Chem. Technol. 21:285–289.

4. Karthikeyan, S., and Prathima, A. 2016. Emission analysis diesel fuel using microalgae methylester with Nano-La2O3.EnergySour.Part.A 38:3174–3180. doi:10.1080/15567036.2015.1138000.
5. Karthikeyan, S., and Prathima, A. 2016a. Environmental effect on the impact of ferrofluid on Caulerpa Racemosa Oilmethyl ester from marine macroalgae. Energy Sour. Part. A 38:3242–3248. doi:10.1080/15567036.2016.1143060.
6. Karthikeyan, S., and Prathima, A. 2016b. Environmental impact of an algal biofuel doped with carbon black. Energy Sour.Part.A 38:3214–3220. doi:10.1080/15567036.2015.1138003.
7. Karthikeyan, S., and Prathima, A. 2016c. Environmental effect of CI engine using microalgae methyl ester with dopednano additives. Trans. Res. D - Tr E. 50:385–396. doi:10.1016/j.trd.2016.11.028.
8. Karthikeyan, S., and Prathima, A. 2016d. Environmental effect of CeO2 nano additive on biodiesel. Energy Sour. Part.A 38:3673–3679. doi:10.1080/15567036.2016.1177624.
9. Karthikeyan, S., and Prathima, A. 2016e. Environmental effect of CI engine using microalgae methyl ester with dopednano additives. Trans. Res. D - Tr E. 50:385–396. doi:10.1016/j.trd.2016.11.028.
10. Karthikeyan, S., and Prathima, A. 2016f. Characteristics analysis of carbon nanowires in diesel: Neochlorisoleoabundansalgae oil biodiesel-ethanol blends in a CI engine. Energy Sour. Part. A. 38:3089–3094. doi:10.1080/
11. 15567036.2015.1135210.