

Effect of Antioxidant on the Performance and Emission Characteristics of a Diesel Engine Fueled with Biodiesel Blend

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ABSTRACT: This paper deals with the impact of antioxidant on the performance and emission characteristics of a diesel engine fueled with biodiesel blend. In this paper, 20% of Calophyllum inophyllum biodiesel (CIB20) was used as biodiesel feedstock. The antioxidant Butylated Hydroxy Toluene (BHT) is used at 500ppm, 1000ppm and 1500ppm concentration with CIB20. The exhaust emission and performance of a single cylinder diesel engine were analysed and compared to those of biodiesel blend (CIB20) with different concentration and diesel. The results show that there is no significant negative impact on biodiesel physiochemical properties. While adding antioxidant, it increases the brake thermal efficiency and reduces specific fuel consumption compared to biodiesel blend (CIB20). The effect of antioxidant also reduces the CO and NO_x emission compared to the biodiesel blend (CIB20).

KEYWORDS: CO, NO_x, ppm.

I. INTRODUCTION

Biodiesel is a renewable source of energy mainly produced from vegetable oils, animal fats, waste cooking oil etc. Biodiesel produced from vegetable oils of edible origins can be used as alternative to fossil fuel derived fuels. The higher cost of these edible oils leads to search for alternative origins, such as non-edible oil, waste-free fatty acids, etc., for producing biodiesel. Homogeneous catalysts, such as NaOH or KOH, are most often used to produce biodiesel. Although biodiesel can be used in its pure form, it is usually blended with standard diesel fuel. Blends are indicated by the abbreviation Bxx, where xx is the percentage of biodiesel in the mixture.

Recent studies reveals that up to 20% of biodiesel blend with diesel can be used without any modification to the engine. Some of these studies shows that 20% of biodiesel blend performs better than blends which consist of a different proportion of biodiesel. In this experiment, 20% of Calophyllum inophyllum biodiesel (CIB20) was used as biodiesel feedstock.

Although few studies have shows that synthetic antioxidants are being used in diesel-biodiesel blends, issues related to NO_x emissions are still rises. Generally, phenolic antioxidants like TBHQ, BHT, BHA, etc. are included into biodiesel, in order to prevent the degradation of biodiesel. Although the free radicals are effectively controlled at room temperature, their activity as antioxidants is quickly reduced with increasing temperature.

The calophyllum inophyllum biodiesel (CIB) was prepared by using an alkali catalyzed transesterification process. After the biodiesel is prepared, it is then mixed with different concentration of antioxidants 500ppm, 1000ppm, 1500ppm of BHT (Butylated Hydroxy Toluene) with 20% of biodiesel and is tested in the diesel engine and emission characteristics are carried out. The advantages of biodiesel as a diesel fuel are liquid nature-portability, ready availability, renewability, higher combustion efficiency, lower sulphur and aromatic content, higher cetane number, and higher biodegradability.

The main advantages of biodiesel fueled with antioxidant are increase in the brake thermal efficiency and decrease in the specific fuel consumption. It also reduces the CO and NO_x emission compared to biodiesel blend.

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II. OBJECTIVE

The objectives of this study are to evaluate experimentally the effect of the antioxidant BHT, on the engine performance and emissions of a single-cylinder diesel engine, fuelled by Calophyllum inophyllum biodiesel blends. Although researches are found on biodiesel stability using synthetic antioxidant, still there is lack of enough research and literature on aromatic amine antioxidants and their effect on the overall performance and emission characteristics of the diesel engine.

III. METHODOLOGY

A. Feedstock and antioxidants

The biodiesel was produced from Calophyllum inophyllum oil, purchased from the Coimbatore local market. In this study, Butylated Hydroxy Toluene (BHT) was chosen as test antioxidant with Calophyllum inophyllum. BHT was collected from Prowess chemicals, Ottappalam.

B. Production and preparation of biodiesel blends

Sulphuric acid (H_2SO_4), methanol (CH_3OH) and potassium hydroxide (KOH) were used as reagent for the production of biodiesel. The Calophyllum inophyllum oil has high acid value which causes issues during the separation. So a two-step process (acid-base catalyst) was recommended to change Calophyllum inophyllum oil into biodiesel (Methyl ester). The procedure for producing biodiesel was similar to the method and steps followed by Rizwanul Fattah et al. (2014b) [2].

The Calophyllum inophyllum biodiesel (CIB) is mixed with diesel at 20% by volume, with the use of a magnetic stirrer at 2000 rpm for 30 min and at 400 rpm for 30 min. Thereafter, the physical properties of the biodiesel and its blends were assessed according to the ASTM standards.

C. Experimental setup

A Kirloskar single cylinder constant speed engine was used for experimental investigation. AVL exhaust gas analyser was used for measuring hydrocarbon (HC), Carbon monoxide (CO), and oxides of nitrogen (NO_x) emission. The experimental investigation was taken for zero loading to full loading condition on a single cylinder four stroke compression ignition engine with the following specifications and layout as shown in Fig.1.

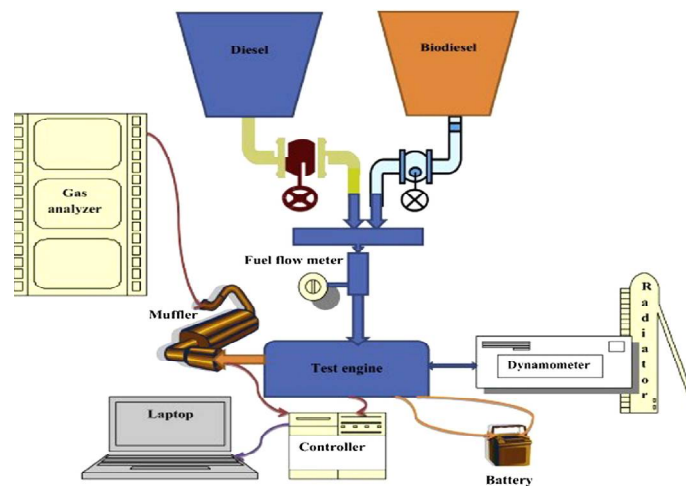


Fig.1 Layout of the experimental setup

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D. Engine test procedure

In this paper, the experimental investigation was carried out by using diesel with different blends, with and without antioxidant (diesel, BHT, BHT+500ppm, BHT+1000ppm, and BHT+1500ppm). All tests are taken under constant engine speed. The eddy current dynamometer was connected with the test engine and a positive displacement type flow meter was used to measure the fuel flow during running the engine. A k-type thermocouple was used for measuring the cooling of water, exhaust gas, engine oil and inlet temperatures. An exhaust gas analyser is used to measure exhaust gas parameters like HC, CO and NOx. The engine was run on diesel for 15 min, in order to allow it to warm up and gain stability, before testing the blends. A similar procedure is used for each of the tested fuel samples. To drain out the fuels into the fuel line, the engine was run on diesel fuel for a few minutes.

IV. EXPERIMENTAL RESULTS

A. Impact of antioxidant addition on brake thermal efficiency

The performance of an engine is indicated by the term efficiency. The term thermal efficiency is used to determine how efficiently the fuel is used in the engine. Brake Thermal Efficiency is the brake power of the engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy. Brake Thermal Efficiency (BTE) is defined as the ratio of energy in the brake power to the input fuel energy.

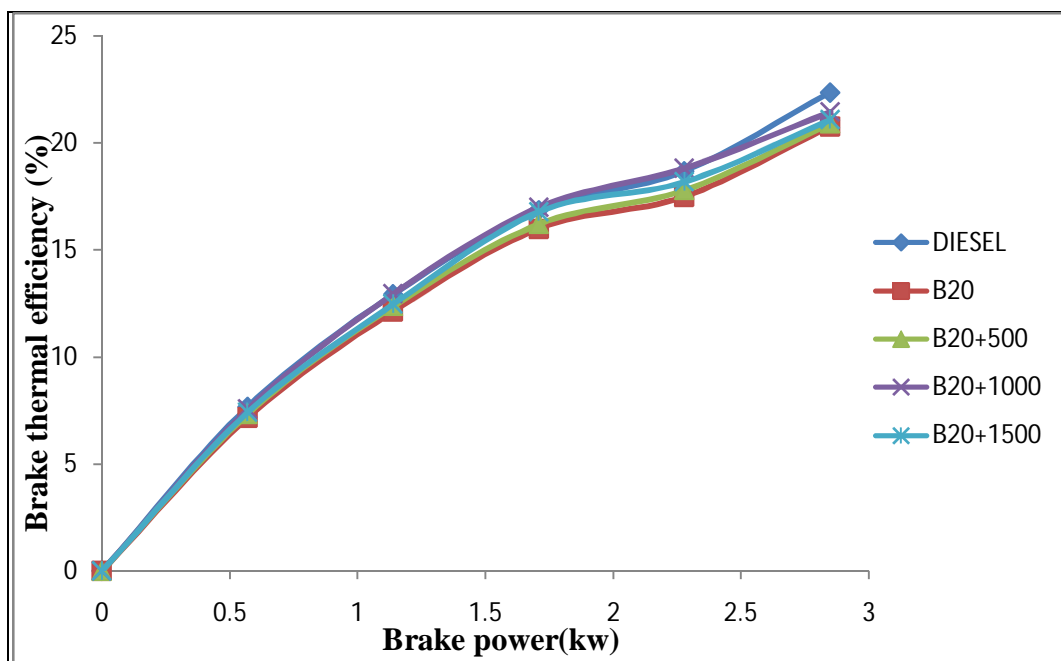


Fig.2 Brake thermal efficiency vs Brake power

The variations in brake thermal efficiency and power output for diesel and biodiesel blend with the addition of antioxidant in 500ppm, 1000ppm and 1500ppm concentration are shown in fig.2. From the plot of BTE, it can be observed that the overall characteristics of BTE follows general trend for both diesel and biodiesel blend. It can be seen that for all the cases, the BTE increases with an increase in the power of the engine.

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Brake thermal efficiency is greater for diesel compared to biodiesel blend B20. While adding antioxidant, we can see the improvement in brake thermal efficiency compared to B20. B20+500ppm exhibit an increment of 0.31%, B20+1000ppm exhibits an increment of 1.33% and B20+1500ppm exhibits an increment of 0.69% BTE than B20. It is found that at half loads, B20+1000 exhibits an increment of 0.14% BTE compared to diesel. This is due to the presence of antioxidant in the biodiesel blend.

B. Impact of antioxidant addition on specific fuel consumption

The fuel consumption characteristic of an engine is generally expressed in terms of specific fuel consumption (SFC) in Kg/KWhr. SFC is an important characteristic when comparing the performance of two engines or comparing the performance of an engine while running on different fuels. The SFC of an engine is defined as the ratio of the total fuel consumption to brake power output of the engine.

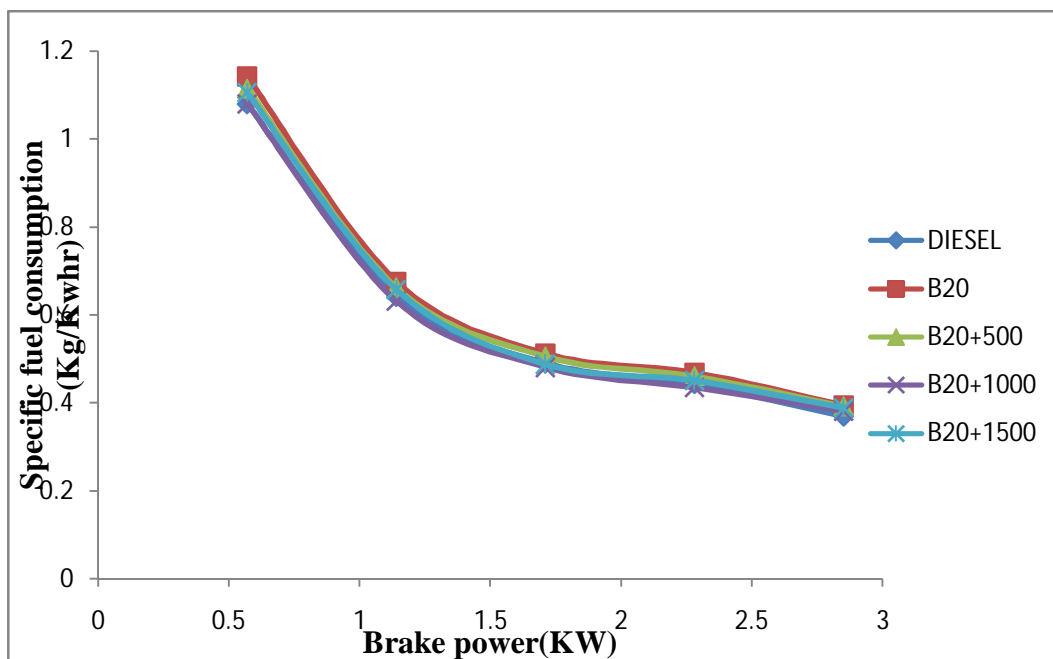


Fig.3 S.F.C. vs Brake power

The Fig. 3 shows the variation of SFC with respect to the power output of the engine at constant speed of 1500 rpm for diesel fuel, B20 and B20 with the addition of antioxidant in 500ppm, 1000ppm and 1500ppm concentration. B20+500ppm exhibit a decrement of 1.72%, B20+1000ppm exhibits a decrement of 7.27% and B20+1500ppm exhibits a decrement of 3.88% than biodiesel blend B20. Addition of antioxidant increases the specific fuel consumption compared to diesel except in B20+1000ppm, which reduces by an amount of 0.02%. It is seen that B20 with 1000ppm blend has lowest SFC compared to other blends. This is due to the presence of antioxidant in the biodiesel blend.

C. Impact of antioxidant addition on carbon monoxide emission

Carbon Monoxide (CO) is a product of incomplete combustion due to insufficient amount of air in the air-fuel mixture or insufficient time in the cycle for the completion of combustion process. These emissions affect the global environmental trends and affects human health by impairing the ability of the blood to bring oxygen to body tissues. Two-thirds of the carbon monoxide emissions were found to come from transportation sources. The complete

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elimination of CO is not possible as there will always be some CO in the exhaust even when the engine is running under very lean mixtures.

The Fig.4 shows the variation of CO emissions with respect to engine load for diesel and biodiesel blend with addition of antioxidant in 500ppm, 1000ppm and 1500ppm concentration. B20+500ppm exhibits a decrement by 0.001%, B20+1000ppm exhibits a decrement by 0.003% and B20+1500ppm exhibits a decrement by 0.007% than B20 in CO emissions. But when compared to diesel, B20+500ppm exhibits a decrement of 0.023%, B20+1000ppm exhibits a decrement of 0.025% and B20+1500ppm exhibits a decrement of 0.029% CO emissions.

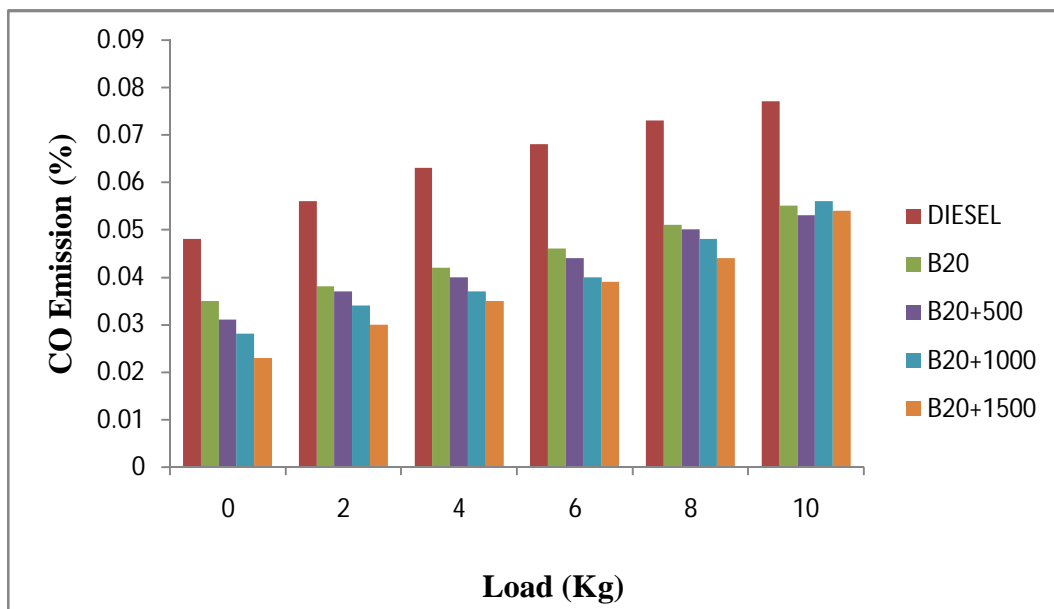


Fig.4 CO Emission vs Load

The CO emission is higher for diesel as compared with other biodiesel blends. From Fig.4, CO emission is least for B20+1500 compared to B20 and diesel. This may be due to complete and stable combustion of biodiesel which contains more oxygen atoms. Since the diesel contains only lesser number of oxygen atoms, incomplete combustion occurs and CO emission increases. But when the oxygen content increases stable combustion occurs and CO emission decreases.

D. Impact of antioxidant addition on Oxides of nitrogen emission

Oxides of nitrogen, which also occur only in the engine exhaust, are a combination of Nitric Oxide (NO) and Nitrogen dioxide (NO₂). NO_x gases are usually produced from the reaction among nitrogen and oxygen during combustion of fuels, such as hydrocarbons, in air; especially at high temperatures, such as occur in car engines. In areas of high motor vehicle traffic, such as in large cities, the nitrogen oxides emitted can be a significant source of air pollution. NO₂ has adverse effects on human health. NO₂ also contributes to the formation of secondary particulate aerosols and tropospheric ozone (O₃) in the atmosphere - both are important air pollutants due to their adverse impacts on human health. N₂ and O₂ react at relatively high temperatures to form NO_x.

The variation of NO_x emissions for diesel and different blends are shown in Fig.5. It is found that NO_x emission is lesser for diesel and greater for B20. B20+500ppm exhibits a decrement of 8%, B20+1000ppm exhibits a decrement of 11% and B20+1500ppm exhibits a decrement of 15% compared to B20. When comparing with B20, it is found that B20+1500ppm have lowest NO_x emission and it is the best blend combination to reduce NO_x emission. B20 has higher NO_x emission due to the presence of oxygen atoms and higher temperature of combustion. When the

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temperature of combustion increases, NO_x emission is also increases. It can be reduced by adding antioxidant with suitable concentration to B20.

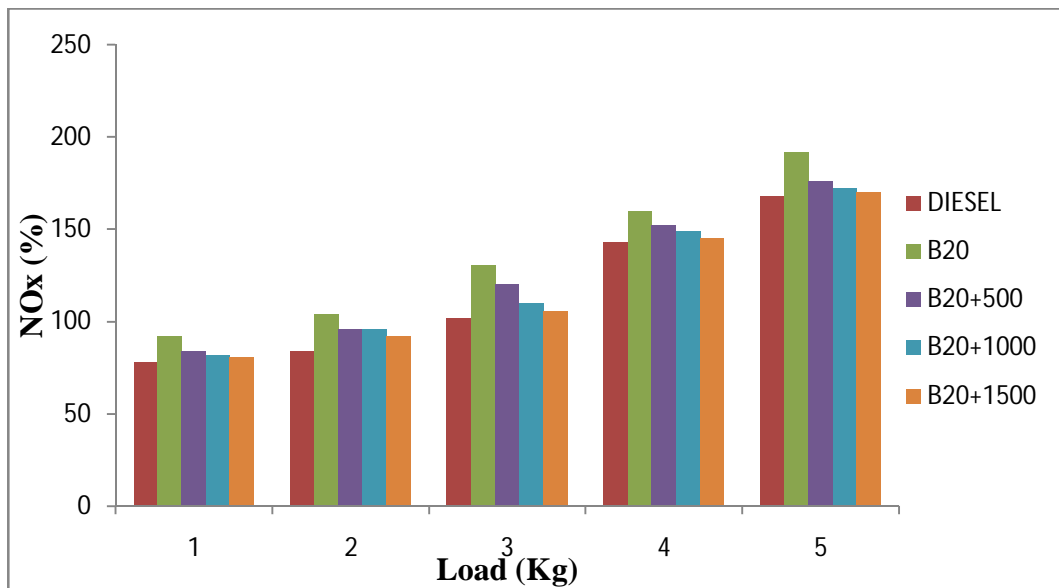


Fig.5 NO_x vs Load

E. Impact of antioxidant addition on Unburnt hydrocarbon emission

Unburnt HC is an important parameter in finding the emission characteristics of a diesel engine. Unburnt HC emission occurs when the fuel molecules in the engine fail to burn completely.

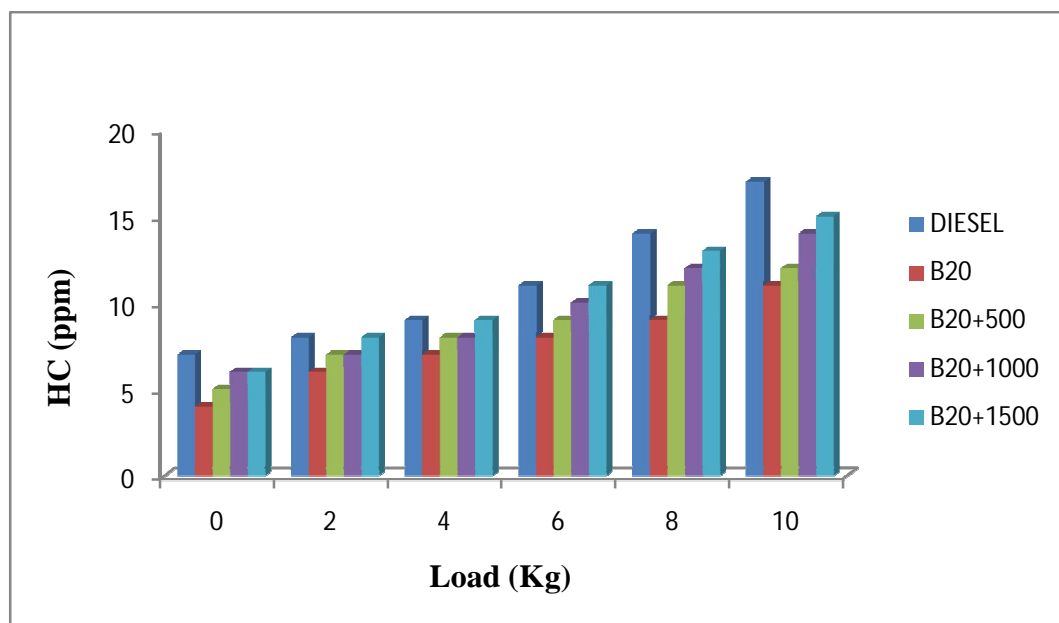


Fig.6 HC vs Load

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The fig.6 compares the HC emission for diesel and biodiesel blend with the addition of antioxidant in 500ppm, 1000ppm and 1500ppm concentration. Hydrocarbon emission is lesser for B20 compared to diesel and other blends. B20 exhibits a decrement of 35.71% HC emission compared to diesel. This is due to the complete and stable combustion of the biodiesel blend, which contains more number of oxygen atoms. But the addition of antioxidant increases the unburnt hydrocarbon emission compared to B20, which is still less than diesel.

V. CONCLUSION

This study aimed the performance and emission characteristics of a diesel engine fueled with biodiesel blend with the addition of antioxidant in different concentrations. Following are the main conclusions drawn from this work.

- Brake thermal efficiency is greater for diesel compared to biodiesel blend B20. While adding antioxidant, there is an improvement in the brake thermal efficiency compared to biodiesel blend B20 due to the presence of antioxidant.
- B20+1000ppm has lower SFC compared to biodiesel blend B20 and diesel except in the case of higher load. This reduction in SFC is due to the presence of antioxidant in the biodiesel blend. At higher loads diesel has lower SFC due to higher ignition characteristics.
- It is observed that CO emission is least for B20+1500ppm compared to B20 and diesel. This may be due to complete and stable combustion of biodiesel which contains more oxygen atoms. Since the diesel contains only lesser number of oxygen atoms, incomplete combustion occurs and CO emission increases. But when the oxygen content increases, stable combustion occurs and CO emission decreases.
- HC emission is lesser for B20 compared to diesel and other blends. B20 exhibits a decrement of 35.71% HC emission compared to diesel. This is due to the complete and stable combustion of the biodiesel blend, which contains more number of oxygen atoms.
- The biodiesel blend B20 has higher NO_x emission due to the presence of oxygen atoms and higher temperature of combustion. It can be reduced by adding antioxidant with suitable concentration to B20.

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