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The Influence of Olive Oil Waste as a Biofuel on the Exhaust Gases of the Internal Combustion Engine

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ABSTRACT
Future options for addressing the depletion of fossil fuels and reducing pollution from internal combustion engines may include biofuel as an alternative fuel. This study aims to experimentally and statistically assess the effect of using diesel-biofuel blends on the emissions of a single-cylinder direct-injection engine. Using recycled olive oil, a chemical Tran's esterification process was used to create biofuel. The experimental results were contrasted with those of a one-dimensional engine model for exhaust emissions and torque, which showed high agreement between test and numerical data. In order to comprehend the factors that affect the engine's reaction to variations in fuel composition, the thermodynamic characteristics of the engine for various blends were also supplied. According to the investigation, a mixture with 20% of the volume fraction of oleic acid methyl ester olive-based biofuel and 80% of the volume fraction of pure diesel can be an effective fuel alternative for cleaner exhaust emissions while offering almost the same performance.

Keywords: olive oil, waste, biofuel, combustion, engine.

INTRODUCTION

Several initiatives have been made in recent years to improve the performance and emissions of internal combustion engines (ICEs) by downsizing (Moussa et al., 2019), turbocharging (Ketata et al., 2020, 2021a, 2021b), and the use of alternative fuels (Alagumalai et al., 2021). The majority of the world's energy needs are met by fossil fuels, which has resulted in significant atmospheric pollution emissions. The primary causes of these facts are the exhaust gas emissions from the burning of fossil fuels, which include carbon dioxide (CO2), nitrogen dioxide (NOx), and sulfur dioxide (SOx) (Bórawski et al., 2019; Narwane et al., 2021; Prabhakar and Elder, 2009; Zhou and Thomson, 2009). Nowadays, it is more necessary than ever to find clean, alternative alternatives to fossil fuels in order to address these environmental issues. Bio-combustible materials are a class of fuels made from organic resources that are both renewable and non-fossil. They are a component of two large families: biofuels and vegetable oils, which are alternatives to diesel fuel, and bioethanol, butane, and bio methanol, which are alternatives to gasoline (Alagumalai et al., 2021). Some benefits of biofuel include biodegradability, renewability, non-toxicity, and accessibility (Millo et al., 2021; Roy et al., 2021). Animal fats and vegetable oils may be converted into biofuel, an environmentally friendly renewable biofuel. It may be utilized to directly feed the engine, which lowers engine pollution emissions (Lin and Lu, 2021; Moyo et al., 2021). Abed et al. (2018) used three mixes of waste olive oil biofuel and regular diesel to conduct an experimental study on the performance of the diesel engine and its exhaust emissions at various engine loads. They observed that the engine's exhaust emissions were enhanced by the carefully thought-out biofuel mixes of used olive oil. However, compared to diesel, the NOx emissions, specific fuel consumption, and thermal efficiency of biofuel and its mixes were greater. As spent oil causes a number of ecological issues, such as the contamination of river water

(Kulkarni and Dalai, 2006), it has a significant potential for usage as biofuel due to its high concentration of triglycerides and free fatty acids. Through extensive experimental and computational research, the current work seeks to determine if Oleic Acid Methyl Ester (OAME), which is derived from old and wasted olive oil, may be utilized as a bio alternative fuel.

MATERIALS AND METHODS

Biofuel characteristics

As shown in Figure 1, the process for making oleic acid methyl ester is conducted. The used oil, made from leftover olive oil, was first weighed using a weigher. Before adding them to the Trans esterification reaction's container, methanol, which has the chemical formula CH3OH, and potassium hydroxide, which has the chemical formula KOH, were combined.

Experimental procedure

The subsequent addition of the methanol and potassium hydroxide combination triggers the Trans esterification process. The transformation of vegetable oil into biofuel is made possible by the Trans esterification process. The reaction temperature, the mole ratio of alcohol to oil, the natures of the alcohol and the catalysis are the key factors affecting reaction efficiency. At a reaction temperature of 60 °C and with basic catalysis

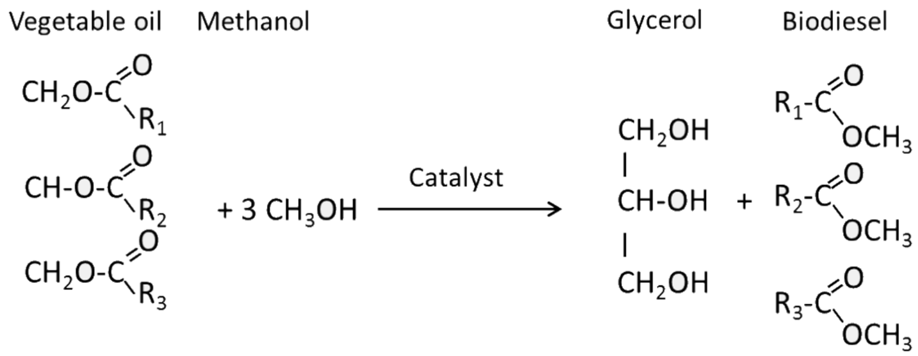
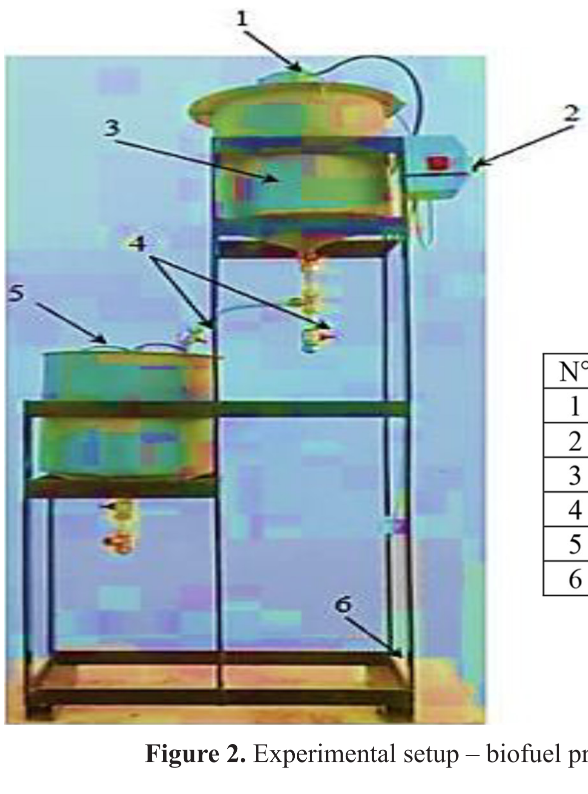


Figure 1. OAME biodiesel production



N°	Designation
1	Agitation system
2	Electric Controller
3	esterification reactor
4	Valves
5	Separation Tank
6	Metal support

Figure 2. Experimental setup – biofuel production process

present, the methanol mole ratio to utilized waste olive oil in this study is 6:1. A three-necked flask reactor with a reflux condenser and a thermometer to gauge the reaction temperature were utilized in the lab for the Trans esterification reaction. Using a paraffin oil bath and a magnetic hot plate stirrer with a temperature controller, the combination of the reaction components stated above was heated to the requisite temperature. In reality, six blends known as B0, B20, B40, B60, B80, and B100 have been created, including various volume fractions of biofuels at 0%, 20%, 40%, 60%, 80%, and 100%. They were combined with only pure diesel fuel.

The laboratory scale is insufficient to produce a significant quantity of biofuel, thus a facility with huge dimensions has been constructed, as illustrated in Figures 2 to produce a high quantity of biofuel. While adhering to the identical lab-scale procedure's procedures. The facility for producing biofuels includes a 10 L esterification reactor with an agitating system and a heating resistance that allows the temperature to reach 100 °C, as well as a 15 L settling tank where the glycerol and crude oleic acid methyl ester are separated. It is investigated how different oleic methyl biofuel blends made from recycled olive oil affect engine performance and emissions analyses. The effect of olive oil on a Lombardini 15L Diesel engine's performance is explored. A comparison of other diesel-methyl ester blends, including B100, B70, B50, B40, and B20, with regular diesel has really been given. Measurement equipment for harmful emissions To identify the primary polluting gases, such as carbon monoxide (CO) and unburned hydrocarbons, a "Techno-test" type chemical analyzer is utilized (HC). In this work, an exhaust gas analyzer is utilized. A Cr/Al thermocouple set to a digital display is used to measure the temperatures of the intake air and exhaust gases. To get a pure phase of the biofuel, the crude oleic acid methyl ester from the separation process was filtered and dehydrated with the addition of calcium chloride (CaCl2). The net biofuel was then put into storage for a final physicochemical analysis before being used as fuel for internal combustion engines.

RESULTS AND DISCUSSION

Carbon monoxide release

Figure 3 shows the cycle-average experimental and numerically anticipated emissions of carbon monoxide (CO), expressed in parts per million (ppm), from the test engine's exhaust for the various fuel mixes under investigation and at various rotational speeds ranging from 800 rpm to 3500 rpm. It has been demonstrated from these findings that the numerical and experimental results closely match each other. As the rotational speed drops from 3500 rpm to 2000 rpm, the CO emission spikes. The CO emission achieves its maximum value at 2000 rpm of the rotational speed indicative of high output torque, and then it gradually lowers as the rotational speed falls to 800 rpm. The findings demonstrated that the addition of biofuel derived from oleic acid methyl ester up to

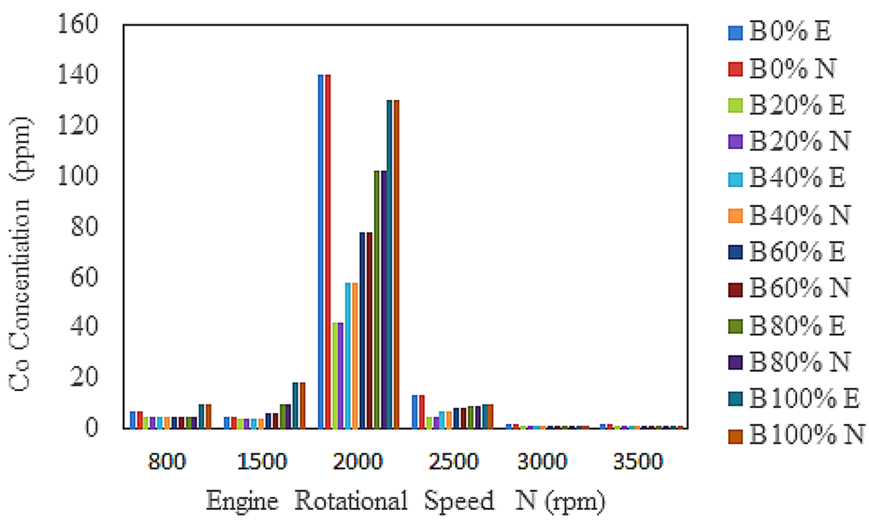


Figure 3. Effect of diesel-OAME blend on cycle average CO emissions

20% of the volume fraction caused a considerable decrease in carbon monoxide emissions, with the B20% providing the lowest emissions. The CO emission rises at biofuel concentrations beyond 20% of the volume portion, but it stays below the level that is seen when the engine is running on pure diesel. For instance, the CO emissions for the B0%, B20%, and B100% instances, respectively, are 142.3 ppm, 41.25 ppm, and 129.31 ppm at a rotating speed of 2000 rpm. However, the findings revealed that at low and high rotational speeds, as opposed to the observation reported at medium rotational speeds ranging from 1500 rpm to 2500 rpm, the CO emission is essentially insensitive to the change in the blend composition (Al-Aseebee et al., 2023). Due to its mixing properties, the B20% blend has produced the least amount of CO emissions. The mixture produces a better air-fuel mixture and more oxygen since the amount of oleic acid, methyl ester biofuel is low. Due to modifications in its mixing qualities and its capacity to produce an appropriate air-fuel combination, the decrease in CO emissions is less evident as biofuel percentage increases in contrast to a B20% blend.

Carbon dioxide release

Carbon dioxide (CO_2) emissions cycle-average experimentally and numerically anticipated under a range of rotational speeds from 800 rpm to 3500 rpm are shown in Figure 4. These findings show that the numerical results closely match experimental findings. In the analyzed range of engine rotational speed, the findings showed minimal CO_2 emissions for all blends containing amounts of biofuel equivalent to the B20%, B40%, B60%, B80%, and B100% instances. The volume fraction of oleic acid methyl ester biofuel appears to have no substantial impact on the CO_2 emissions at the engine exhaust for volume fractions ranging from 20% to 100%. The B20% blend has produced the least amount of CO_2 emissions for all engine rotational speeds, even if the difference in CO_2 concentration in the exhaust gas with the other cases was judged to be small since it did not surpass 1% of difference. For instance, the CO_2 emission is 126717 ppm, 109604 ppm, and 110174 ppm, respectively, for the B0%, B20%, and B100% scenarios. This reduced CO_2 emission can be explained by the biofuel's oxygenated composition, which makes more oxygen accessible for combustion (Al-Aseebee et al., 2022). Since the oleic acid methyl ester biofuel is produced by photosynthesis, the CO2 emissions have a benefit in this situation since they may be seen as a carbon credit.

Unburned hydrocarbons releases

Unburned hydrocarbon emissions are a sign of insufficient fuel combustion, and Figure 5 shows the cycle average anticipated emissions of unburned hydrocarbons (HC) expressed in ppm under a rotational speed range from 800 rpm to 3500 rpm (Heywood, 2018). According to the findings of Figure 9.a, the HC emission increases with increasing rotational speed from

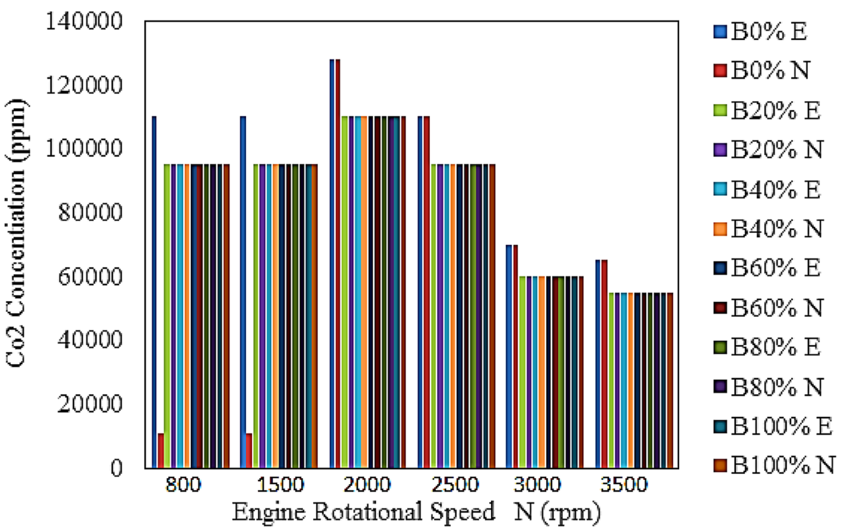


Figure 4. Effect of diesel-OAME blend on cycle average CO_2 emissions

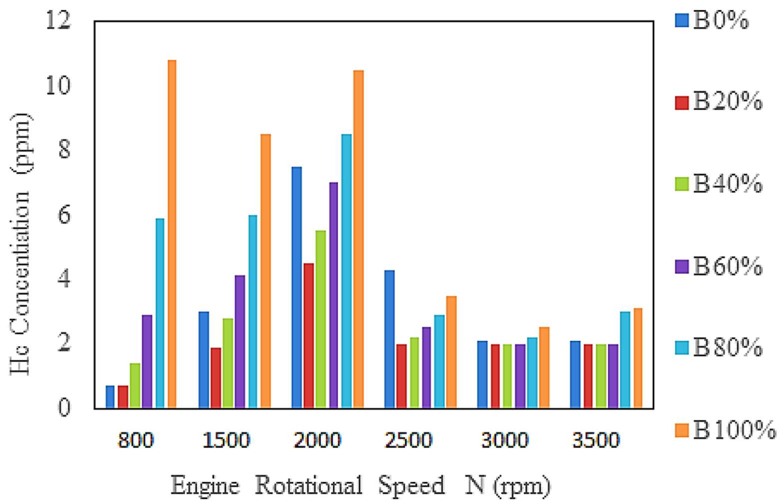


Figure 5. Effect of diesel-OAME blend on cycle average HC emissions

800 rpm to 2000 rpm, where it achieves its highest value. From 2000 rpm to 3500 rpm, rotational speeds rise, and a considerable decrease in HC emission has been seen. The results also demonstrated that the HC emission was highly responsive to the fuel mix. The B20% blends permitted the lowest HC emission among the other tested fuels at all rotational speeds, demonstrating that increasing the quantity of oleic acid methyl ester biofuel in the mix causes a larger HC emission. It is important to keep in mind, nevertheless, that the HC emission from pure diesel fuel is always larger than what was seen in the B20% scenario. For instance, for the B0%, B20%, and B100% situations, respectively, the emission of unburned hydrocarbons is 7.53 ppm, 4.48 ppm, and 10.39 ppm. The B20% blend's low hydrocarbon generation is due to its oxygenated composition, which was already noted when talking about carbon dioxide emissions. The fact that blends with greater oleic acid methyl ester biofuel percentages could not provide the same low hydrocarbon emission be mostly because of their high viscosity, which is detrimental to the injector's ability to function at its best. These findings are come to an agreement with previous study (Al-Aseebee et al., 2023).

Nitrogen oxides releases

The cycle average estimated emissions of nitrogen oxides (NOx) are shown in Figure 6 and are expressed in ppm for a range of

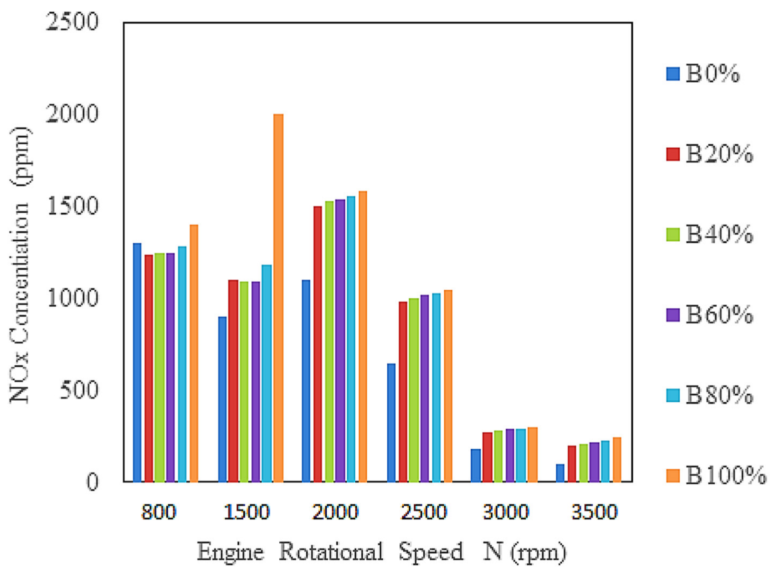


Figure 6. Effect of diesel-OAME blend on cycle average NO_x emissions

rotational speeds between 800 and 3500 rpm. Based on these findings, the engine produces minimal NOx emissions at its exhaust when rotating at an increasing speed. For instance, the NOx emissions from pure diesel fuel are 1324.32 ppm and 106.635 ppm, respectively, at rotational speeds of 800 rpm and 3500 rpm. Additionally, compared to the case of pure diesel, the mixture comprising the oleic acid methyl ester biofuel produces more NOx at the engine exhaust. For instance, when the amount of oleic acid methyl ester biofuel in the mix increases from 20% to 100%, the NOx emission increases by 5.25%. This observation is a result of the fact that when the proportion of oleic acid methyl ester biofuel grows, the fuel's oxygen content rises and a greater amount of NOx is emitted. It is important to note that because the created biofuel contains amines, burning it in the engine cylinder's combustion chamber would undoubtedly release more NOx. Some other possibility is that the biofuel may include trace levels of vitamins with bonded nitrogen that were not entirely eliminated during the biofuel's production. Such bonded nitrogen causes an increase in NOx production as mentioned in former study (Al-Aseebee et al., 2022).

CONCLUSIONS

The biofuel is made of oleic acid methyl ester and was created in a laboratory using a specially designed equipment for the Trans esterification procedure. As a result of the poor biofuel content, the B20% mix generally displayed performance results comparable to those of pure diesel, according to the results. As the proportion of biofuel in the mix rises, an increase in NOx emissions has been seen. The B20% blend had the lowest emissions of unburned hydrocarbons (4.48 ppm) and carbon monoxide (41.25 ppm The B20% blend's low viscosity, which is equivalent to that of pure diesel and necessary for the injector to operate optimally to provide the desired spray characteristics, and its oxygenated nature both contribute to the blend's low HC and CO emissions. According to all of the findings, the blend B20%, which is made up of 20% transesterified used olive oil and 80% pure diesel, can be a reliable alternative fuel since it maintains engine performance while allowing minimal emissions of pollutants.

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