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Research Article

Influence Examine of Visnaga Oil Biodiesel on the Performance and Emission Characteristics of CI Engines

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ABSTRACT

The main reason for global warming and respiratory problems in humans is the influence of emissions from fossil fuel combustion. Levels of these pollutants have increased significantly due to the expansion of vehicle numbers, especially in Iraq, exacerbating the environmental and health impacts. Procedures to mitigate these emissions include modifying engine-part design or utilizing environmentally friendly fuel sources. The aim of this research is to perform an experimental investigation examining the use of a new type of visnaga oil biodiesel on the performance and emissions of a single-cylinder, air cooled, and 4 strokes CI engines. The visnaga oil biodiesel was added to diesel fuel in volumetric ratios of 10%, 20%, 30%, and 40%. The results of the tests show that this type of biodiesel lowers the engine's thermal efficiency while raising the EGT and BSFC. The highest decrease in BTE was 7.63% and the highest increase in BSFC was 15.28%, for biodiesel at 40% in the blend (BF40). Additionally, for the visnaga oil biodiesel, the emissions of carbon monoxide (CO) and unburned hydrocarbons (HC) were decreased, but the emissions of nitrogen oxides (NOx) and carbon dioxide (CO_2) were increased. The greatest reduction in CO and HC emissions was achieved with the use of the BF40 blend, where reductions of 24.7% and 39.5% were recorded respectively, while the NOX and CO_2 emissions increased by 36% and 38.2%, respectively.

1. Introduction

In light of the recent surge in energy demand, attention has been redirected towards devising optimized utilization strategies for finite fossil fuels. Nevertheless, due to the aggravation caused by the climate change problem, it is critical to preserve the environmentally favorable performance of internal combustion (IC) engines. Over eleven million cubic metrics of diesel, gasoline, aviation fuel, and heavy fuel oil are consumed daily [1,2]. The production and combustion of these fuels result in the emission of substantial volumes of greenhouse gases (GHGs), with carbon dioxide (CO_2) being the most prominent. These emissions significantly contribute to the acceleration of global warming [3]. By virtue of their brief carbon life cycle, Biodiesel fuels (BDFs) have long been utilized to mitigate CO_2 emissions [4,5]. Nonetheless, the full

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substitution of fossil fuels with BDFs presents a formidable challenge. The principal obstacle is that BDF derived from edible sources is incompatible with the growing problem of food scarcity. BDFs of the first generation are those derived from edible sources. In the third generation of BDF, microalgae were employed, while non-edible plants such as jatropha were utilized in the second generation [6,7]. Physically and chemically, BDF is inferior to diesel fuel (DF), possessing a lower calorific value and ignitability; a higher pour point and viscosity; and inferior ignition and combustion properties. Numerous research endeavors have been devoted to the discovery of solutions to these challenges. In binary and ternary mixtures, DF is combined with alcohols and BDF to improve its efficacy in internal combustion (IC) engines [8-10]. Kassim et al. [11] examined how using palm oil BDF affected CI engines' efficiency and pollution levels. BDF proportions were added to the fuel, ranging from 5% to 20%. The BSFC and emissions of, CO_2, and NOx were found to have increased. While the BTHE and emissions of CO and HC were decreased. Imran and Saleh [12] examined the effects of Cresson oil BDF on CI engines' performance and emissions. The Cresson oil BDF was blended with diesel fuel at different volumetric ratios. The engine operated smoothly with a fuel injection timing of 23º bTDC and an engine compression ratio of 18. The results show that using BDF in engines reduced BTHE, HRR, ID, and ICP in tests, but increased EGT and BSFC. The NOx and CO_2 emissions increased, while CO, soot, and UHC emissions were reduced. Nair et al. [13] utilized BDF derived from neem oil. They found that blending BDF with DF resulted in a marginal decrease in engine (BP), which was deemed satisfactory considering the advantages over pure diesel, including elevated engine (BP) and reduced HC, CO, and NOx emissions by 8.5%, 23%, and 23%, respectively. Attia et al. [14] investigated the effect of using Castrol oil BDF on engine emissions and performance. The ultrasonic technique was used to prepare castor oil BDF. The final experimental results show that the HC and CO emissions were reduced by 40% and 17%, respectively. Dubey and Gupta [15] investigated how turpentine BDF and jatropha affected the efficiency and pollution levels of CI engines. Operating under full load conditions, the BTHE decreased by 2.9%, while emissions of smoke, HC, CO, and NOx were decreased by 4.72%, 4.56%, 42.5%, and 29.16%, respectively, but the emissions of CO_2 increased by 10.7%. Zheng et al. [16] compared three oxygenated BDFs with minimal reactivity: 2,5-dimethylfura, n-butanol, and ethanol. The findings show that combining BDF and ethanol has the most potential for concurrently lowering NOX and soot emissions. However, the combination of BDF and n-butanol increased BTHE. Can [17] Produced BDF from two manufacturing and fast-food restaurants' waste cooking oil.

The CI engine tested two biodiesel-diesel mixes with 5% and 10% BDF. The experimental study found that mixing cooking oil BDF with DF accelerated injection and combustion. The BDF and DF mixtures increased BSFC and NOx emissions. At high engine loads, BDF reduces CO, HC, and soot emissions. The B20 blend showed a higher increase in engine performance and lower exhaust emissions. Elkelawy et al. [18] tested the influence of using soybean and sunflower oils BDF on engine emissions and performance. According to the researchers, the BDF blends showed significant improvements in both BTHE and BSFC. However, it was found that the NOX emissions were higher than the DF emissions, even though the CO and HC emissions were reduced by 33.8% and 41.18%, respectively.

Li et al. [19] mixed Polyoxymethylene dimethyl ethers with BDF to research the effect of this fuel mixture on the engine's characteristics. Compared to B100, they discovered that incorporating polyoxymethylene dimethyl ethers (PODE) resulted in a shorter ignition delay. This was attributed to the high CN of BP15, comprising 15% PODE and 85% BDF. It was also discovered that BP15 had reduced levels of soot and NOX emissions. Krishna et al. [20] examined how a diesel engine's exhaust emission characteristics changed when fueling the engine with the mixture of Jatropha, tire pyrolysis oil, and spirulina microalgae BDF. The engine had a rated output power of 3.5 kW at 1500 rpm. The practical results show that using 20% mixes reduces smoke, PM, and NOX emissions. At full load, JMETPO20 and SP20 produced somewhat more CO_2 than one another, but their smoke, particulate matter, and NOX emissions were all cut in half. Rajak et al. [21] tested the engine with spirulina microalgae (SMB) BDF blends under varying loads.

The exhaust emissions, cylinder pressures, BTHE, temperature, and maximum rising pressure rates were lower with SMB20. Increased spirulina microalgae mix to 20% at higher load increased fuel consumption by 3.3%, ignition delay by 8.2%, and BTHE by 3.03%. Despite reducing PM, NOX, and smoke emissions by 20.7%,4.9%, and 5.4%, SMB mixes increased CO_2 emissions for all loads. Incorporating SMB lowered BTHE, EGT, and CO_2 emissions. Sakthimurugan and Madhu [22] examined the effects of Scenedesmus obliquus BDF on CI engines characteristics, which was mixed with DF at 20%, 30%, and 40% volume ratios. The test results show that the B20 mix achieved BTHE and the emissions of smoke, HC, and CO comparable to DF. However, the SOBD mix raises CO_2 and NOx emissions. The SOBD has lower (ICP) and (HR) than DF at 100% load. The B20 blend appears to be a good fuel for unmodified combustion engines with low exhaust emissions.

The difference between this research and others was that there were no investigations on the influence of using visnaga oil BDF blends on diesel engines emissions and performance. The main novelty of this research is to determine how a visnaga oil BDF mixture influences the performance and emissions of a single cylinder CI engine, as well as the measuring the important physical and chemical properties. This study is considered the first study in which this type of oil is converted into biofuel and used to operate a diesel engine. This study is comprehensive, as it includes the measurement of important physical and chemical properties. Thus, it is vital to understand how visnaga oil BDF mixtures work in diesel engines and create pollutants.

2. Method for Producing BDF

The preparation of visnaga oil BDF was carried out using a trans-esterification process in several stages, as seen in Figure 1. KOH and pure methanol per liter of visnaga oil were mixed to generate the methoxide at room temperature, which is the initial stage in BDF synthesis. After the visnaga oil was heated, the methoxide was added, and the mixture was stirred. The visnaga oil and methoxide were subjected to a 60°C temperature and mixing speed to complete the chemical reaction. To separate the glycerin from the BDF, the blended fluid was transferred to a separation funnel after mixing for 24 hours. After removing the glycerin from the separation funnel, the BDF was washed with deionized water [23]. After the washing process, the BDF was warmed to 110 ºC to evaporate residual water. Finally, the last thing to do is filter the BDF to eliminate any contaminants [24,25]. The standard Iraqi DF was combined with visnage oil BDF at 10%, 20%, 30%, and 40%. The physical and chemical properties were measured, as shown in Table 1.

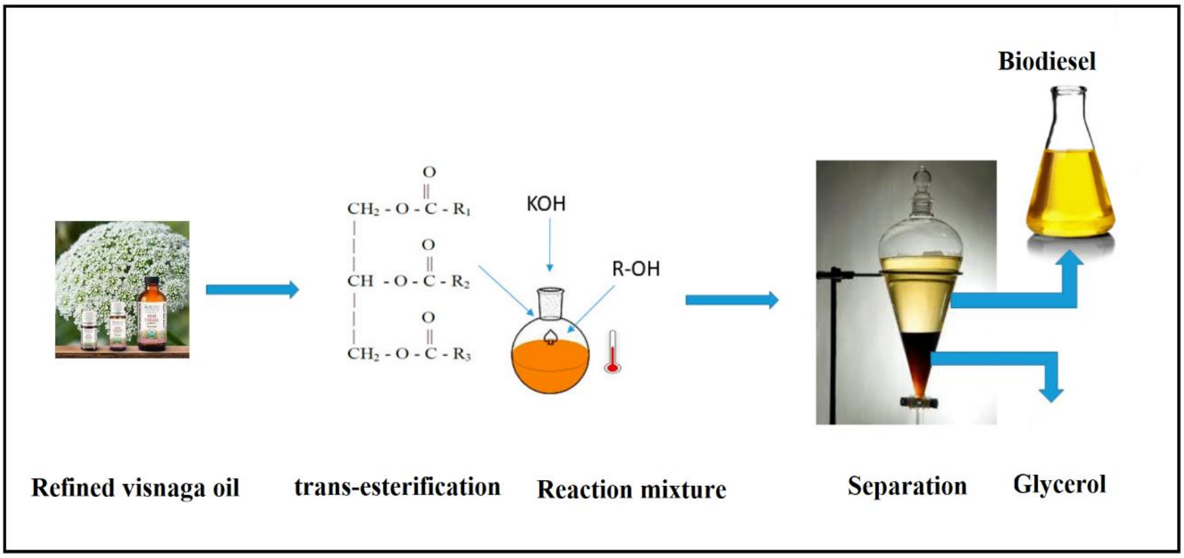

Fig. 1. Preparation stages of Visnaga-oil BDF

Table 1. Chemical and physical properties of the fuels used

Property	Unit	DF	BF10	BF20	BF30	BF40
Density @ 15ºC	kg/m3	831	836.4	848	861	880
Viscosity @ 38.8 ºC	mm2/s	2.51	2.8	3.21	3.9	4.7
Calorific value	MJ/kg	46.5	46	45.3	44.8	43.41
Cetane number	-	46.3	48	51.1	54.1	56.2
Flash point temperature	ºC	62	72	82	93	122

3. Methodology

3.1. Experimental Setup

A test rig was constructed using a 175 cm^3, 4-stroke, single-cylinder, air-cooled diesel engine linked to a swinging dynamometer by a belt to measure BP and torque, as shown in the schematic diagram in Figure 2.

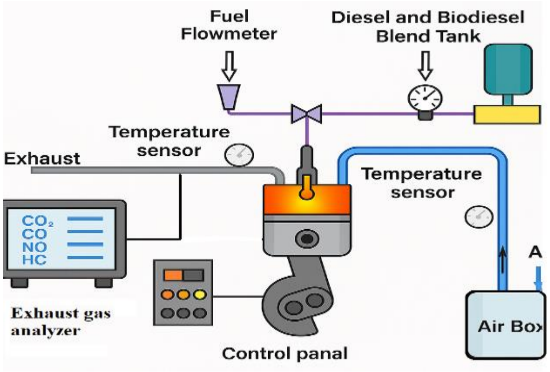

Fig. 2. Combustion system test rig

The control system was used to manage the speed of the dynamometer. A sensor attached to the dynamometer's end shaft was used to measure the engine's speed, while fuel consumption was determined using a graduated cylinder and a timer. The intake air was measured using a special air box. The temperature of exhaust gases was measured by fitting a thermocouple in the exhaust gas port before the engine muffler. The exhaust gas, including NOX, CO, CO_2, and UHC, were measured using an exhaust gas analyzer of type TEXA.

3.2. Analyzing Precision and Measuring Uncertainty

Analyzing the measurement uncertainty and system accuracy is one way to confirm that the experimental results are accurate. There are a number of potential causes of increased uncertainty in testing, such as faulty or improperly calibrated equipment, features of the testing environment, test strategy and plan, and procedures for interpreting and recording results.

The total uncertainty may be thought of as the accumulation of all the uncertainties associated with the study's parameters. It is possible to calculate the overall uncertainty using the method given in [26,27].

Total uncertainty

$$= \sqrt{(angle\ encoder)^2 + (pressure\ transducer)^2 + (thermocouple)^2 + (Smoke\ opacity)^2 + (CO)^2 + (HC)^2 + (O_2)^2 + (CO_2)^2 + (NO_X)^2} \tag{1}$$

$$= \left(\sqrt{(0.2)^2 + (0.11)^2 + (0.23)^2 + (0.21)^2 + (0.25)^2 + (0.22)^2 + (0.22)^2 + (0.21)^2 + (0.7)^2}\right) = \sqrt{0.84} = \pm 0.916\%$$

3.3. Mathematical Model of Engine Performance

The engine performance was calculated using a simple mathematical model based on general engine thermodynamics [28,29]:

- Flow rate of fuel mass:

$$\dot{\mathrm{m}}_{\mathrm{f}} = \frac{V_F}{\mathrm{time}} \times \rho_F \ \frac{\mathrm{kg}}{\mathrm{sec}} \tag{2}$$

- Brake power:

$$bp = \frac{2\pi \times N \times T_b}{60 \times 1000} \ kW \tag{3}$$

- Brake specific fuel consumption:

$$\mathrm{bsfc} = \frac{\dot{\mathrm{m}}_{\mathrm{f}}}{\mathrm{bp}} \times 3600 \ \frac{\mathrm{kg}}{\mathrm{kW.hr}} \tag{4}$$

- Engine air consumption:

$$\dot{m}_{\mathrm{a,act.}} = 2.056 \times 10^{-4} \times \sqrt{\nabla P} \ \frac{\mathrm{kg}}{\mathrm{sec}} \tag{5}$$

- The brake thermal efficiency:

$$\eta_{bth} = \frac{bp}{\dot{m}_f \times \mathrm{L.C.V}} \tag{6}$$

3.4. Approach to Experimentation

The following steps were carried out to complete the experiment:

I. During the testing process, the fuel and air temperatures were determined to be 27°C based on the laboratory temperature.

II. Before each series of tests, the test rig and instrumentation for the engines were put into standby mode.

III. Biofuel samples were then prepared and made available.

IV. Following that, the engine's speed, brake torque, and the pressure difference between the air box and the atmosphere were adjusted, and the fuel consumption for 100 ml of each fuel type was measured.

4. Results and Discussion

The experiments above were carried out to illustrate the effect of BDF derived from visnaga oil on the performance of the CI engine. The BTHE, BSFC, BP, and engine emissions were the primary operational factors assessed during the experimental activity. These characteristics were connected to the proportion of visnaga oil biofuel in the BDF blend. Consequently, a summary of the most important findings is provided in the following context:

4.1. The Effect of BDF on BTHE

Figure 3 shows the relationship between the BTHE of the fuel types tested (DF, BF10, BF20, BF30, and BF40) versus engine speeds. From the figure, the BTHE was higher with the use of DF at all engine speeds compared to all BDF blends. For BDF mixtures, the BTHE decreased with increasing the volumetric fraction of BDF in the fuel blend.

As seen in Figure 3, the maximum decrease in BTHE was 7.63% when using BF40, which included 40% visnaga oil biofuel. The BTHE decreased with an increase in the proportion of BDF in the fuel blend because the flash point temperature, viscosity density, and surface tension of the blend increased, but the fuel heating value decreased, reducing the combustion temperature in the initial stage of combustion, leading to a drop in engine cylinder pressure. Operating the engine with low cylinder pressure led to a decrease in engine BP and BTHE.

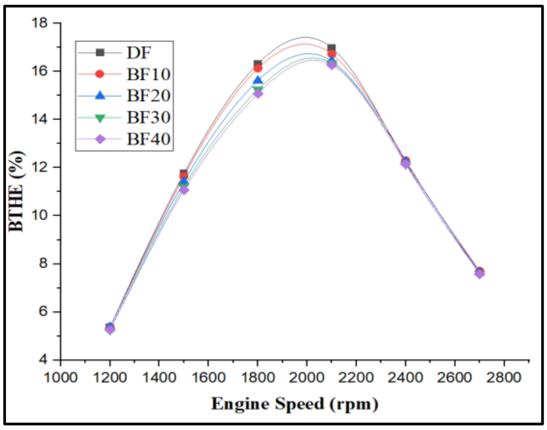

Fig. 3. The relation between engine speed and BTHE for different biodiesel fuel blends

4.2. The Effect of BDF on BSFC

The variation between the BSFC of the fuel types tested versus engine speeds can be illustrated in Figure 4. Compared to all BDF blends, BSFC was observed to be lower with DF at all engine speeds. Meanwhile, the BSFC increased with an increase in the volumetric ratio of BDF in the blend, as shown in Figure 4.

The maximum increase in the BSFC was 15.28% when using BF40 as the engine fuel. The reason for the increase in the BSFC when using biodiesel as engine fuel is attributed to the fact that the BDF blend heating value is lower than that of DF, which requires a greater amount of fuel to achieve the same energy output [29, 30].

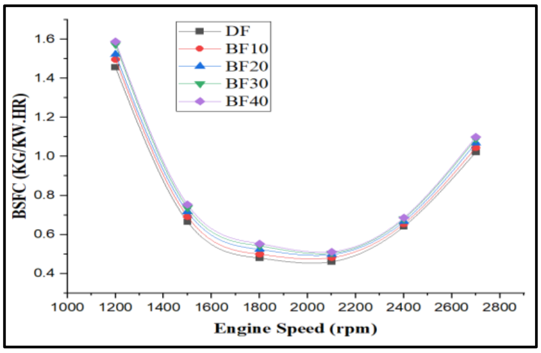

Fig. 4. The relation between engine speed and BSFC for different biodiesel fuel blends

4.3. The Effect of BDF on EGT

Figure 5 shows the relation between the EGT of the fuel types tested (DF, BF10, BF20, BF30, and BF40) versus engine speeds. From this figure, it was noticed that EGT increases with increasing engine speed and BDF concentration in the blend. The reason for the increase in EGT with increased engine speed is due to burning more fuel within the combustion chamber. The EGT also increased with BDF fuel because biofuels, in their molecular structure, contain compounds that burn slowly at the end of the exhaust stroke, and they also contain compounds that burn quickly, which are responsible for increasing the CN number.

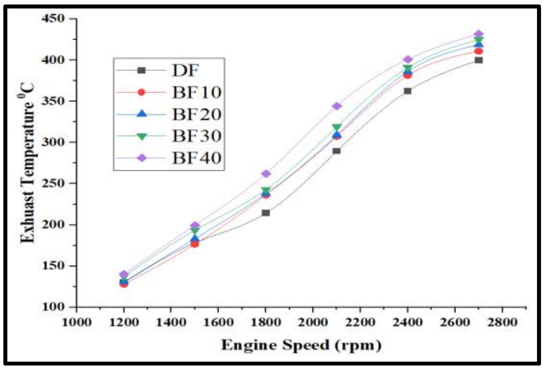

Fig. 5. The relation between engine speed and EGT for different biodiesel fuel blends

4.4. The Effect of BDF on CO Emissions

The variation between the CO emissions of the fuel types tested versus engine speeds can be illustrated in Figure 6. When the volumetric proportion of BDF in fuel blends increases, there is a corresponding drop in CO emissions. Based on the data shown in Figure 6, the highest decrease in CO emissions was 24.7% when using the BF40 blend. The reason for the decrease in CO emissions when using biodiesel fuel as engine fuel is that the BDF contains O_2 as part of its chemical structure, which helps provide the necessary amount of O_2 inside the CC, ensuring CO oxidation and its conversion into CO_2 [30]. In this way, CO emissions are reduced.

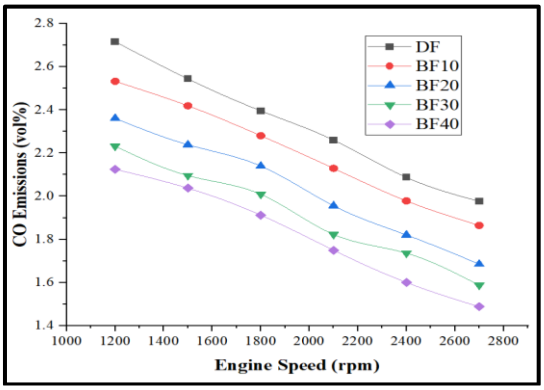

Fig. 6. The relation between engine speed and CO emissions for different biodiesel fuel blends

4.5. The Effect of BDF on HC Emissions

Figure 7 shows the relation between the HC emissions of the fuel types tested versus engine speeds. From this figure, it was demonstrated that increasing the volumetric percentages of visnaga oil BDF reduced HC emissions. The highest decrease was 39.5%, achieved when using the BDF, which include 40% visnaga oil BDF. The reduction in HC emissions as the volumetric percentage of oil in BDF increases can be attributed to the additional O_2 atoms in BDF. Due to the BDF chemical composition, these O_2 atoms are crucial in improving combustion during uncontrolled combustion. The existence of O_2 in the fuel, together with the presence of free oxygen atoms in the surrounding air during the induction stroke, stimulates the spread of the flame inside the combustion chamber, thus facilitating the creation of the flame nucleus [30].

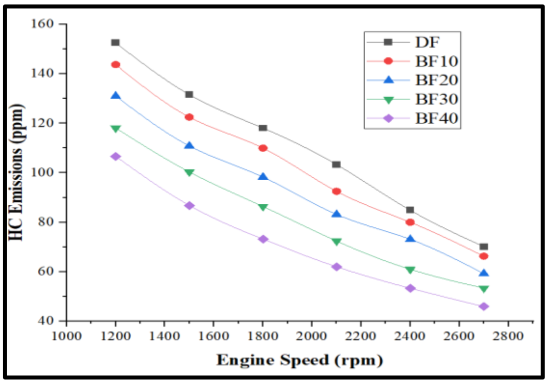

Fig. 7. The relation between engine speed and HC emissions for different biodiesel fuel blends

4.6. The Effect of BDF on NOX Emissions

Figure 8 illustrates the relationship between engine speed and NOX emissions for all tested fuel types. It can be seen from the figure that NOX emissions increase as the volume percentage of BDF in the fuel blend increases. The most significant increase was 36% when using BF40 as the engine fuel. Once more, the escalation in NOX emissions can be attributed to the elevated O_2 concentration in the combustion chamber, which is caused by BDF utilization at high temperatures. This O_2 concentration stimulates the generation of NOX and other combustion byproducts [30].

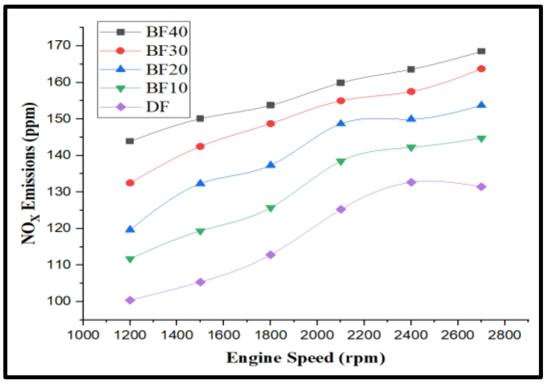

Fig. 8. The relation between engine speed and NOX emissions for different biodiesel fuel blends

4.7. The Effect of BDF on CO_2 Emissions

The variation between the CO_2 emissions of the fuel types tested versus engine speeds can be demonstrated in Figure 9. As the volume percentage of visnaga oil BDF increases, the rate of CO_2 produced as a byproduct of combustion also increases as shown in Figure 9. The maximum increase in CO_2 emission occurs When using BF40, where the highest possible amount of CO_2 was 38.2%. Increasing the amount of O_2 available in the combustion chamber due to both the two-source induction stroke and the BDF explains this rise in combustion chamber emissions. This increase in O_2 availability enables the oxidation of additional CO, ultimately converting it into CO_2 [30].

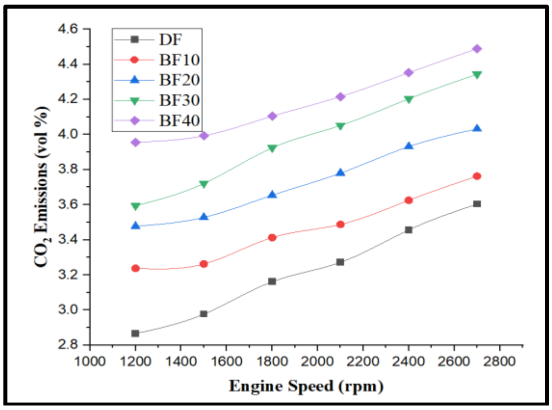

Fig. 9. The relation between engine speed and CO_2 emissions for different biodiesel fuel blends

5. The Social Importance of Using Biodiesel

1. The use of biodiesel reduces emissions of toxic gases, improving air quality and, consequently, the health impacts of the population.

2. The use of biodiesel contributes to reducing dependence on fossil fuels.
3. The use of biodiesel created from waste cooking oil, spent engine oil, or vegetable oil as an alternative fuel indicates a beneficial opportunity to enhance the economy and achieve cost savings through oil recycling. Furthermore, it encourages the cultivation of unused land through efficient use of resources and decreased dependence on fossil fuels.
4. Biodiesel is an environmentally friendly and sustainable option compared to conventional fuels.

6. Conclusions

The following conclusions are supported by the findings that were gathered from trials that used BDF produced by blending visnaga oil BDF with DF:

1- The decrease in the heat value of fuel when visnaga oil BDF are used results in a rise in the BSFC and EGT while BTE decreases.

2- When using BF40, BSFC increased by 15.28%, while BTE decreased by 7.63%.

3- The CO and HC emissions decrease with increases in the percentages of visnaga oil BDF in the fuel blend, whereas the NOX and CO_2 increase.

4- The greatest reduction in CO and HC emissions was achieved with the use of the BF40 blend, with reductions of 24.7% and 39.5%, respectively.

5- At BF40, the NOX and CO_2 emissions increased by 36% and 38.2%, respectively.

Despite the visnaga oil biodiesel is superior in reducing the engine emissions, it is recommended to study the use of new blends by blending visnaga oil biodiesel with methanol or ethanol in different proportions to improve performance.

Nomenclature

BDF	Biodiesel fuel
BP	Brake power, KW
BSFC	Brake-Specific Fuel Consumption kg/ KJ.hr
BTHE	Brake Thermal Efficiency, %
bTDC	Before Top Dead Centre
CI	Compression-Ignition
CO	Carbon Monoxide, vol%
CO_2	Carbon Dioxide, vol%
DF	Diesel Fuel
EGT	Exhaust Gas Temperature, °C
HC	Hydrocarbon, ppm
NOX	Nitrogen Oxides, ppm
O_2	Oxygen

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Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

Authors Contribution Statement

Abdulrahman Shakir Mahmood: Conceptualization; Methodology; Investigation; Formal Analysis; Writing – Original Draft.

Mohammed Kadhim Allawi: Supervision; Project Administration; Validation; Writing – Review & Editing.

Ghanim Mohammed Hachim: Data Curation; Software; Visualization; Resources.

Fouad Alwan Saleh: Investigation; Validation; Formal Analysis; Writing – Review & Editing.

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