Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 9, S. 195-201, 5, 2025
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Araştırma Makalesi

https://as-proceeding.com/index.php/ijanser
ISSN:2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 9, pp. 195-201, 5, 2025
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Research Article

Performance Analysis of Sunflower Oil Biodiesel as an Alternative Fuel in Diesel Engines

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(Received: 13 May 2025, Accepted: 19 May 2025)

(7th International Conference on Applied Engineering and Natural Sciences ICSIS 2025, May 15-16, 2025)

ATIF/REFERENCE: Cesur, İ. (2025). Performance Analysis of Sunflower Oil Biodiesel as an Alternative Fuel in Diesel Engines. *International Journal of Advanced Natural Sciences and Engineering Researches*, 9(5), 194-201.

Abstract **–** In this study, the effects of biodiesel derived from sunflower oil on diesel engine performance were experimentally investigated. Biodiesel blends were prepared at ratios of 10% (BIO10), 20% (BIO20), and 50% (BIO50) with standard diesel fuel and tested in a diesel engine operating within the speed range of 1500–3000 rpm. Experimental evaluations focused on parameters such as effective power, engine torque, specific fuel consumption, and effective efficiency. The results indicated that the BIO10 and BIO20 blends led to noticeable improvements in engine performance parameters, whereas a slight decrease was observed with the BIO50 blend. The best performance was achieved with the BIO20 blend, which provided an average increase of approximately 4% in engine power. In contrast, the BIO50 blend resulted in an approximate 2% reduction in engine power compared to standard diesel. These variations in performance parameters were attributed to the lower heating value of biodiesel compared to diesel fuel, its higher oxygen content, higher cetane number, and improved combustion characteristics. Additionally, the higher viscosity of biodiesel was found to slightly affect spray characteristics and the ignition timing. As a result, it was concluded that sunflower biodiesel can be safely used in diesel engines without any modifications, and performance losses remain minimal at low and medium blend ratios. These findings suggest that biodiesel blends represent a viable alternative for cleaner and more sustainable energy solutions.

Keyswords: Biodiesel, Sunflower Oil, Engine Torque, Fuel Consumption.

I. INTRODUCTION

The global increase in energy demand and the depletion of fossil fuels have made it essential to develop renewable and environmentally friendly energy sources. In this context, biofuels have attracted significant attention in recent years as alternative energy solutions. Biodiesel, a type of biofuel that can be used in diesel engines, is obtained from vegetable oils or animal fats. Sunflower oil is one of the commonly used feedstocks in biodiesel production, preferred particularly due to its low viscosity and favorable combustion properties [1,2]. Sunflower oil biodiesel stands out as a sustainable alternative fuel with the potential to reduce environmental impact and enhance energy independence [3].

Diesel engines are widely used due to their high efficiency and long lifespan, making them one of the most preferred internal combustion engines today. However, the high carbon emissions and environmental effects of diesel fuels have encouraged the search for alternative fuels [4]. Biodiesel offers environmental advantages as an alternative to fossil fuels, thanks to its potential to reduce emissions and its production from renewable sources [5]. Sunflower oil biodiesel, with its high oxygen content, enables cleaner combustion, which results in lower emission levels and reduced particulate matter in engines [6].

The effects of using sunflower oil biodiesel in diesel engines on engine performance are still being investigated. The use of biodiesel can lead to changes in parameters such as engine power, torque, fuel consumption, exhaust emissions, and efficiency [7]. Although biodiesel has a lower heating value compared to diesel fuels, its high cetane number and oxygen content can improve combustion efficiency [8].

When examining literature studies on biodiesel, Cristina Dueso and her colleagues investigated the effects of biodiesel blends containing sunflower methyl ester on engine performance. Blends with 20% and 30% concentrations delivered similar brake power to diesel under full load, while causing a reduction in power under medium load conditions. Although the calorific value of pure sunflower methyl ester was 14.5% lower, brake thermal efficiency increased by 38%, while brake specific fuel consumption decreased by 12.5%. On the other hand, blends containing sunflower methyl ester increased fuel consumption by between 10% and 15% [9]. Bjorn S. Santos et al. evaluated the effects of sunflower methyl ester on engine performance. Blends with 5% and 20% biodiesel caused no significant power loss, while the use of pure biodiesel resulted in a 4.5% decrease in brake power and a 2% reduction in torque. Additionally, 100% biodiesel increased brake specific fuel consumption by 5% to 14%, with this increase reaching up to 17.2% in large displacement engines [10]. In another study conducted by Behçet et al., 20% biodiesel blends derived from fish and chicken fat were tested in a single-cylinder diesel engine. The use of 20% fish oil biodiesel resulted in a 4.33% decrease in brake power and a 3.2% decrease in torque, while the same ratio of chicken oil biodiesel showed a lower performance loss (2.4% in power and 1.9% in torque). These blends also caused a 6.7% increase in fuel consumption [11]. Canakci et al. examined the effects of palm-based biodiesel on engine performance and exhaust emissions. A 20% biodiesel blend reduced brake torque by between 2% and 5%, while pure biodiesel usage caused a torque drop of 8% to 12% due to its low heating value. In both blends, fuel consumption increased by 10% to 25% [12].

The aim of this study is to experimentally investigate the effects of sunflower oil biodiesel on diesel engine performance. The study was conducted at different engine speeds (within the 1500–3000 rpm range) and under full load conditions. It aims to demonstrate the usability of sunflower oil biodiesel in diesel engines and the sustainability advantages it offers. In addition, the study will analyze how the physical properties of biodiesel—such as its high viscosity and spray characteristics—affect engine performance. The results will shed light on the adjustments needed to optimize engine performance with biodiesel and promote its wider adoption as an alternative fuel.

II. METERIAL METHOD

In this study, the biodiesel used was obtained from sunflower oil through the transesterification method. The stages of biodiesel production are presented in Figure 1. The transesterification method used for biodiesel production is summarized below;

- Oil Selection: Any oil source can be used for biodiesel production; however, the most commonly used oils are vegetable oils (such as soybean oil, sunflower oil, canola oil, linseed oil, etc.) and animal fats.
- Alcohol Selection: The most commonly used alcohols are methanol and ethanol. Methanol or ethanol reacts with fatty acids to produce methyl esters or ethyl esters (biodiesel).
- Catalyst: The transesterification reaction is usually accelerated with the help of a catalyst. These catalysts can be either alkaline or acidic.
- Alkaline Catalysts: The most commonly used alkaline catalysts are sodium hydroxide (NaOH) and potassium hydroxide (KOH). Alkaline catalysts allow triglycerides to react more efficiently with methanol or ethanol to produce biodiesel and glycerin.
- Reaction: The oil is mixed with alcohol and the catalyst. This mixture is heated and allowed to react at a specific temperature. At the end of the reaction, biodiesel (methyl or ethyl ester) and glycerin are formed.

- Phase Separation: After the reaction, biodiesel and glycerin are separated. Biodiesel forms the upper phase, while glycerin settles at the bottom. A separating funnel is used for the phase separation process.
- Washing and Purification: The resulting biodiesel must be purified from methanol, water, and other impurities, which are byproducts of the reaction. For this purpose, the biodiesel is washed with distilled water. The washing process is repeated several times, and then the biodiesel is dried under vacuum.

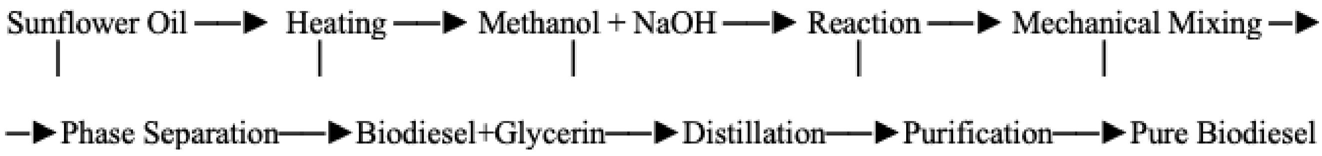

Figure 1. Biodiesel production stages

In the experiments, a single-cylinder, direct injection, naturally aspirated, and water-cooled diesel engine was used. The technical specifications of the engine are detailed in Table 1. The test setup is equipped with precision measuring instruments and data acquisition systems, and its schematic representation is provided in Figure 2.

Table 1. Test Engine Features

Engine type	Diesel engine
Diameter [mm]	85
Stroke[mm]	90
Cylinder number	1
Stroke volume[lt]	0,51
Power - 2700 d/d. HP	9
Injector open pressure, [bar]	175
Injection advance	28
Maximum speed, d/d	3000
Injector type	Direct

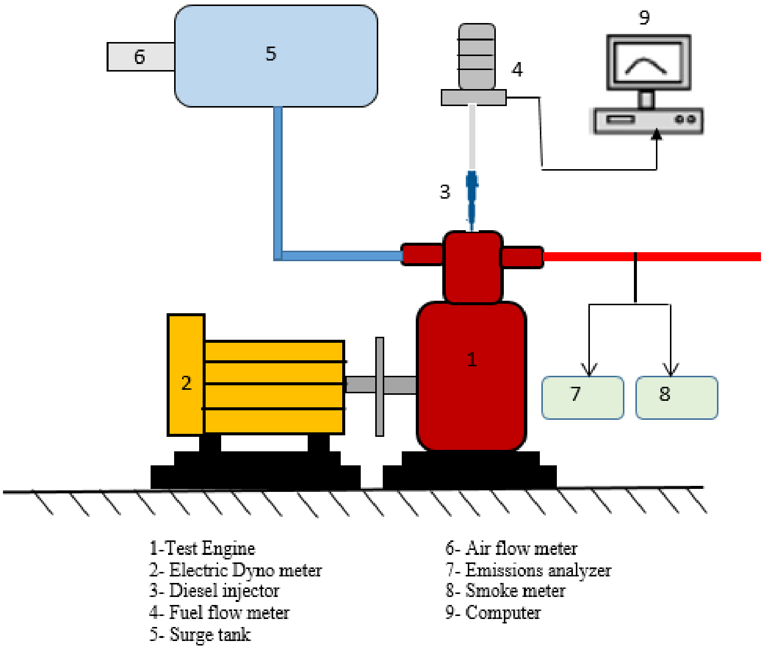

Figure 2. Test Setup

In the experiments, a 20 kW capacity electric DC dynamometer was used to apply a load to the engine. The test engine was connected to the dynamometer via a coupling from the crankshaft output. The engine load was measured using an 'S'-type load cell attached to the dynamometer arm. Diesel fuel consumption was measured in grams using a precision scale with 0.1-gram accuracy and a stopwatch, by repeating the measurement at least three times for each test point over a defined time period. Exhaust gas temperature was recorded using a 'K'-type thermocouple.

III. RESULTS

In this study, the effects of sunflower oil biodiesel on diesel engine performance were examined in detail. Experimental studies were carried out at different engine speeds and under full load conditions, comparing the performance characteristics of standard diesel fuel with various blend ratios of sunflower oil biodiesel. The experimental analyses focused on effective power, torque, specific fuel consumption (SFC), and effective efficiency. The results obtained for each emission parameter were presented through graphs and interpreted in detail.

Figure 3 presents graphs showing the effects of using different sunflower oil biodiesel blend ratios in a diesel engine on engine torque. Upon examining the graph, it is observed that the BIO10 and BIO20 blend fuels improve engine torque, while the BIO50 blend results in a deterioration in torque values. The highest increase in engine torque was achieved with the BIO20 blend fuel. On average, increases of up to 4% across all engine speeds were recorded for the BIO20 blend. The greatest decrease in torque was observed with the BIO50 blend, with an average reduction of 2%.The reason for the increase in torque is that, despite the lower lower heating value (LHV) of biodiesel, its higher cetane number and oxygen content enhance combustion efficiency in biodiesel-powered operation. Furthermore, the higher density of biodiesel compared to diesel fuel results in a greater mass of fuel being delivered to the engine for the same volume pumped, thus increasing the total energy input to the engine. The decrease in torque and effective power observed with the BIO50 blend, compared to the BIO10 and BIO20 fuels, can be attributed to the reduced lower heating value of the blend.

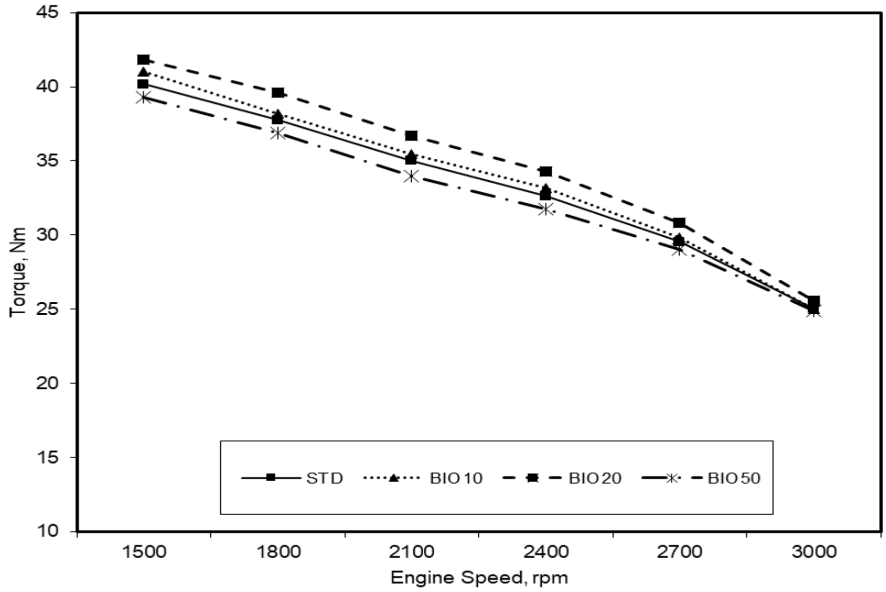

Figure 3. Effect of different ratios of biodiesel blends on engine torque

Figure 4 shows the effects of using different sunflower oil biodiesel blend ratios on the effective power of a diesel engine. Upon examining the graph, it is observed that the use of BIO10 and BIO20 blend fuels results in an improvement in effective power, whereas the BIO50 blend leads to a decline in effective power values. The highest increase in effective power was achieved with the BIO20 blend fuel.

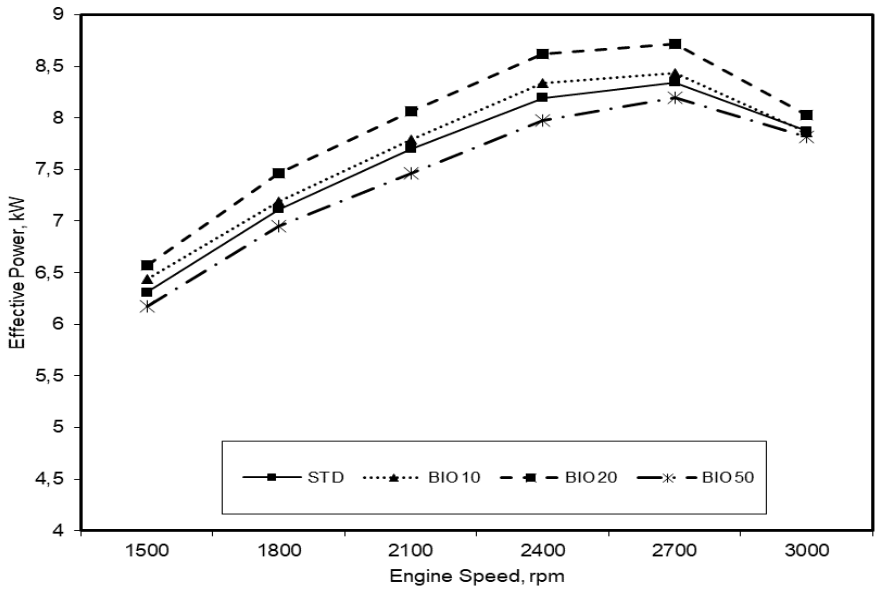

Figure 4. Effect of different ratios of biodiesel blends on effective power

Figure 5 illustrates the variation in specific fuel consumption (SFC) with engine speed for different sunflower oil biodiesel blend ratios. When BIO10 and BIO20 blend fuels are used, the SFC is lower compared to standard diesel fuel. The maximum reduction in SFC across all engine speeds was observed with the BIO20 blend. Compared to the standard value, the maximum average decrease was approximately 2%.The density, viscosity, and lower heating value of the injected fuel affect specific fuel consumption. However, due to the higher oxygen content in the BIO10 and BIO20 fuels, the thermal efficiency of combustion increases, resulting in lower SFC compared to diesel fuel. In contrast, when using the BIO50 blend, an increase in SFC was observed relative to diesel. This increase is due to the lower heating value of biodiesel, which requires more fuel to be consumed to obtain the same amount of energy. As a result, specific fuel consumption is higher than that of diesel. On average, a 2% increase in SFC was recorded with the BIO50 blend.

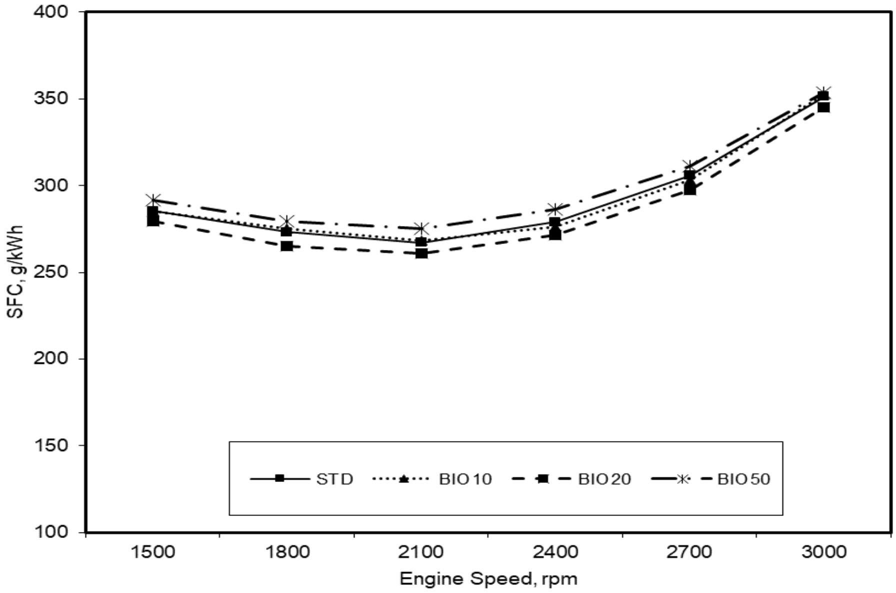

Figure 5. Effect of different ratios of biodiesel blends on specific fuel consumption

Figure 6 shows the effect of different sunflower oil biodiesel blend ratios on effective efficiency as a function of engine speed. An increase in engine effective efficiency was observed with the use of BIO10 and BIO20 fuels, while a decrease was detected with the BIO50 blend. The highest increase in effective efficiency was obtained with the BIO20 blend fuel. Compared to the standard value, the BIO20 blend showed an average increase of approximately 2% in effective efficiency across the tested engine speeds. On the other hand, the BIO50 blend resulted in an average decrease of about 2%.

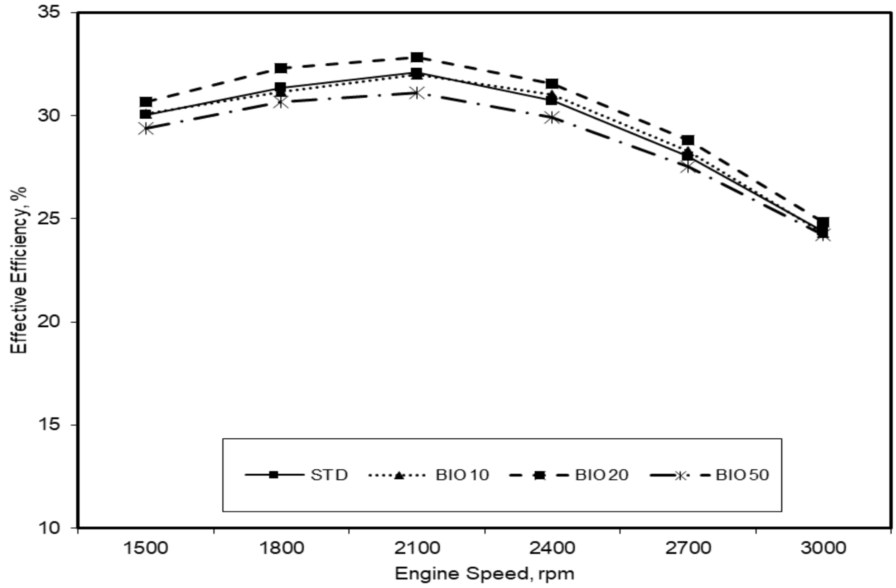

Figure 6. Effect of different ratios of biodiesel blends on effective efficiency

IV. CONCLUSION AND RECOMMENDATIONS

In this study, the effects of sunflower oil biodiesel on diesel engine performance were experimentally investigated. Tests were conducted using different biodiesel blend ratios (10%, 20%, 50%), and parameters such as engine torque, effective power, specific fuel consumption, and effective efficiency were evaluated. According to the experimental results, BIO10 and BIO20 blends had a positive impact on engine performance, while the BIO50 blend caused a certain degree of performance loss.

The best engine performance was achieved with the 20% biodiesel blend (BIO20). With the BIO20 blend, an average increase of approximately 4% in engine power was observed, along with similar improvements in torque and efficiency parameters. These results indicate that biodiesel can work compatibly with diesel fuel at low and medium blend ratios and can enhance engine efficiency. Additionally, it was determined that the oxygen content, high cetane number, and improved combustion characteristics of biodiesel are key factors positively affecting engine performance.

On the other hand, with the 50% biodiesel blend (BIO50), a 2% decrease in engine power and torque was observed. This decline can be attributed to the lower heating value and higher viscosity of biodiesel compared to diesel fuel. Higher viscosity may negatively affect the spray and atomization characteristics of biodiesel, which can reduce combustion efficiency and limit engine performance.

In conclusion, sunflower oil biodiesel can be safely used in diesel engines, especially at low and medium blend ratios (BIO10 and BIO20), with minimal performance losses and potential improvements in engine power. At higher blend ratios, decreases in engine performance were observed. However, considering the environmental benefits offered by such blends, increasing biodiesel usage holds significant potential for reducing emissions and supporting sustainable energy solutions.

The use of sunflower oil biodiesel in diesel engines offers an alternative fuel solution that maintains minimal performance loss and even increases engine power at lower and moderate blend levels (BIO10 and BIO20). However, the use of high biodiesel ratios can have some adverse effects on engine performance. These findings highlight the potential of biodiesel blends as cleaner and more sustainable energy alternatives, while also emphasizing the need for further research and development to optimize engine performance. Future studies should focus on developing engine technologies that support widespread biodiesel use, improving biodiesel production processes, and further reducing environmental impacts.

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