Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

(Research Article)

Check for updates

Experimental investigation of the performance and emission of low-speed diesel engine using various bio diesel blends at variable load conditions: (Part II)

Rashed D Alnazal [1] and M. Abuzaid [2, *]

[1] *Mutah University, Jordan.*

[2] *Faculty of Engineering, Mutah University, Jordan.*

Global Journal of Engineering and Technology Advances, 2023, 15(02), 052–059

Publication history: Received on 23 March 2023; revised on 06 May 2023; accepted on 09 May 2023

Article DOI: https://doi.org/10.30574/gjeta.2023.15.2.0083

Abstract

The purpose of this study is to experimentally investigate the performance and emission of compression ignition engine using biodiesel extracted from waste cooking oils (WCO), such as (falafel frying oil; origin from palm oil , chicken frying oil; origin from soybean oil), and fresh oils such as (soybean oil, olive oil), after produce biodiesel from WCO and fresh oils, will be blending with pure diesel in two percentage are B20 (20% biodiesel from each type, 80% pure diesel), B10 (10% biodiesel from each type , 90% pure diesel). The biodiesel blends were used as an alternative fuel for diesel engine. After that, they were compared to pure diesel B00 (0% biodiesel, 100%pure diesel) at engine variable load from (0-6 kW) at constant speed of (2000 RPM). For engine performance, (Brake power, brake specific fuel consumption, brake thermal efficiency) were analyzed. Also, for emissions, (, exhaust gas temperatures to indicate NOx) were analyzed. The results showed that pure diesel produces higher brake force (BP) than all biodiesel blends. The highest value for BSFC is for B20-F (20% biodiesel from falafel frying oil, 80% pure diesel) is equal (0.243426 gm/kW.s). The highest value for brake thermal efficiency BTE is for B10-S (10% biodiesel from soybeans oil, 90% pure diesel) is equal 27.6%. The B10-S produces the highest value of NOx. In addition, pure diesel produces higher emissions than all biodiesel blends. All biodiesel blends produce higher emissions than pure diesel.

Keywords: Biodiesel; Diesel engine; Waste cooking oil; Performance; Emissions

1. Introduction

As the number of people around the world is increasing rapidly as well as the technological sector is developing constantly; these changes make the matter of energy a top priority. Although many resources of energy are available, fossil fuels still the most useful source in producing energy, and Consumption of this source increases around 2% per year [1]. Fossil fuels can be formed by the natural ways, such as decomposition of dead organisms; this source is divided into (oil, coal, and natural gas). All types of fossil fuel are used in many sectors such as transportation, commerce, industry, and residence.

The gases emitted by the diesel engine have many effects. whereas the Particulate matter (PM) which is one of the most harmful gases on human health, according to the International Agency for Research on Cancer (IARC), the particulate matter is considered as carcinogens under group-I [2]. In addition, carbon dioxide (CO2) and other gases effect on ecosystem, and increase amount of greenhouse gases in the atmosphere, which in turn causes global warming [3]. Whereas the transport sector contribution around 26% of all carbon dioxide emissions in 2000, and road transport which is responsible for about 65% of those emissions [4]. However, these ratios are not fixed and will increase in the future due to excessive use of the transport sector, this will effect on the environment and leads to climate change. According to the International Energy Agency (IEA), the carbon emission from transport sector will increase by 92% till

* Corresponding author: M. Abuzaid

2020, and it is expected that 8.6 billion metric tons carbon dioxide will be emitted to the atmosphere from 2020 - 2035 [5].

Biofuels is derived from biomass. There is more than one type of biofuel, and the most common one is biodiesel. It is the best source among renewable energy sources replace to pure diesel, because they have properties like pure diesel. According to ASTM, biodiesel is defined as “mono alkyl ester of long-chain fatty acids which is derived from vegetable oil” and assigned as (B100). The chemical process, which is used to make biodiesel, is called transesterification. In this process, the triglycerides in vegetable oil is reacted with alcohol like (methanol), with the presence of a catalyst like (Sodium hydroxide; NaOH), resulting two products, First; fatty acid methyl esters (FAME), Second; glycerin (a valuable by-product usually uses in soap and cosmetics) [6].

The heating value is the total energy released as heat when the fuel burns. The calorific value of the fuel is mainly used to measure the energy produced when the fuel is burned, and it is an essential factor that effects on the engine power. a calorific value for biodiesel lower than pure diesel. Thus, when increasing the amount of biodiesel in blends, this will reduce the engine power [7].

Cetane number (CN) is an indication for fuel combustion speed and compression required for ignition. The cetane number in biodiesel depends on the raw materials used to produce it. Changing the cetane number effects on fuel ignition properties; if it is low, it impedes the starting of engine in cold weather and leads to pollution due to weak combustion, but if it is high, this leads to immediate ignition, which reduces fuel efficiency. The cetane number of biodiesels is more than pure diesel due to the long-chain hydrocarbon groups that leads to higher combustion efficiency and better ignition property [8].

A study on the impact of biodiesel blends (B10, B20) that are produced from Jatropha, palm, algae and waste cooking oils (WCO) on engine emissions, such as CO, CO2, NOx, HC, and smoke. The results show decreasing in CO, HC, and smoke for biodiesel blends (B10, B20) produced from (Jatropha, algae and palm) compared to pure diesel fuel. However, an increasing in CO2 for biodiesel blends (B10, B20) produced from (WCO) compared to pure diesel. NOX emissions from all biodiesel blends (B10, B20) is higher than diesel fuel [9].

The major objective of this study was achieved through experimental verification. And to explore the effect of the biodiesel blends on the performance of the diesel engine to reduce the percentage of gases emitted and to compare it with pure diesel. In particular, the experiment is designed to study the following sub-objectives:

- To Utilize waste cooking oils and fresh oils to produce biodiesel fuel and to using as an alternative energy source and to maintain energy security.
- To reduce the pollution of gases and to increase reliance on renewable energy sources in energy production.
- To investigate the effect of biodiesel blends on the performance of the internal combustion engine.
- To analyze the exhaust gases that are produced from biodiesel blends and to compare them with pure diesel

2. Material and methods

In this study, biodiesel is produced from fresh oils and WCO. Fresh oils are (soybean oil, olive oil), and WCO are (falafel frying oil; origin from palm oil, chicken frying oil; origin from soybean oil). The crude oils were obtained from different places: soybean oil from local market, olive oil from local production, falafel frying oil and chicken frying oil from local restaurant. The amount of crude oil used is 10 liters of each type.

2.1. Transesterification Process

The major method of producing biodiesel is transesterification process. This method was used because it is the most effective way to reduce the viscosity of biodiesel, also it has low production cost, and returns good yields of biodiesel [10]. Transesterification process is a chemical reaction between vegetable oils and alcohol such as methanol (CH3OH) with the help of catalysts such as sodium hydroxide (NaOH) to produce biodiesel (also known as FAME) and glycerin as a by-product [11].

2.2. Engine Experiments Setup

After producing biodiesel from (olive oil, soybean oil, falafel frying oil, chicken frying oil), eight blends of biodiesel were prepared with diesel in the following ratios: **B20-S** (20% biodiesel from soybean oil, and 80% fuel Diesel), **B20-O** (20% biodiesel from olive oil, and 80% diesel fuel), **B20-F** (20% biodiesel from falafel frying oil, and 80% diesel fuel), and

B20-C (20% biodiesel from chicken frying oil, and 80% diesel), and **B10-S** (10% biodiesel from soybean oil, and 90% fuel Diesel), **B10-**O (10% biodiesel from olive oil, and 90% diesel fuel), **B10-F** (10% biodiesel from falafel frying oil, and 90% diesel fuel), and **B10-C** (10% biodiesel from chicken frying oil, and 90% diesel), and use it as an alternative fuel for the diesel engine, and compare it with pure diesel B00 (00% biodiesel and 100% diesel), to analyze the impact of biodiesel on the performance and emissions of engine.

3. Results and discussion

The biodiesel blends are divided into two groups, the first group is biodiesel produced from WCO such as (B20-C, B10-C, B20-F, and B10-F). The second group is biodiesel produced from fresh oils such as (B20-O, B10-O, B20-S, and B10-S). We will discuss the effect of each group of biodiesel blends on engine performance such as (brake power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE)), and emissions such as (Exhaust temperature, CO_2, O_2). The discussion will be in two cases. The first case of discussion will be about engine performance and emissions at constant load and variable speed, and the second case of discussion will be about engine performance and emissions at constant speed and variable load. Then, comparing each group with pure diesel to see how biodiesel will effect on the performance and emissions of the diesel engine.

Figures 1 and 2 show the brake power BP as function of load. It is clear from both figures that the brake power BP increases with increasing in load for all biodiesel blends and pure diesel until load 2, after that it begins to decrease. The highest BP in figure 4.3 is for B20-S, which is equal 3.10 kW; the average increase in BP for B20-S compared to pure diesel is about 10%. In addition, the highest value of BP in figure 4.4 is for B20-F, which is equal 3.27 kW. The average increase in BP for B20-F compared to pure diesel is about 4%. The reason behind higher BP of these blends (B20-S, B20-F) is increase in fuel consumption with increased load.

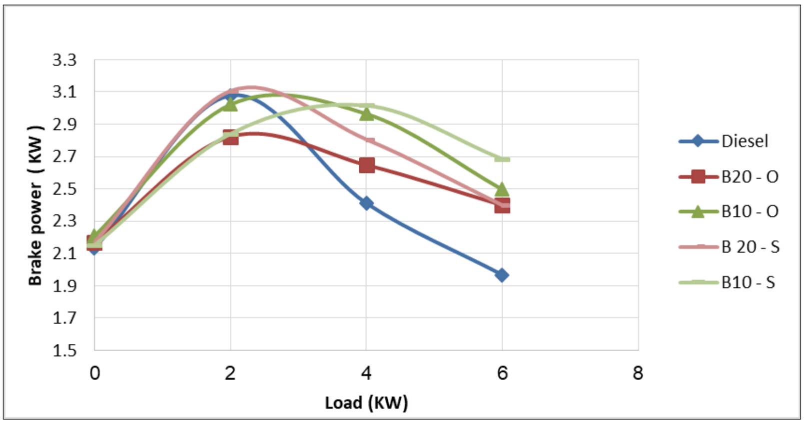

Figure 1 Brake power resulting from using (Diesel, B20-O, B10-O, B20-S, B10-S) as a function of variable load

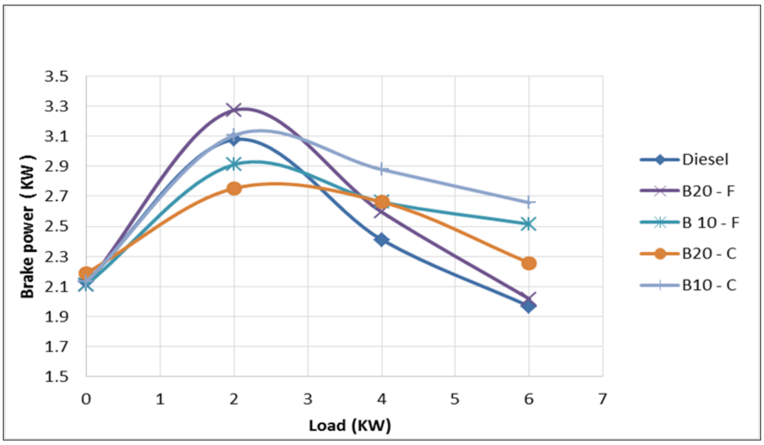

Figure 2 Brake power resulting from using (Diesel, B20-F, B10-F, B20-C, B10-C) as a function of variable Load

Figures 3 and 4 show the BSFC as a function of load. The BSFC is the ratio of mass fuel consumption to the brake power; it is a measure of the capability of the engine in converting fuel to brake power. It is desirable to have lower BSFC meaning that the engine uses less fuel to produce the same amount of power. In both figures, the BSFC of pure diesel and all biodiesel blends increases until load two after that, it decreases and begins to increase slightly. The highest value of BSFC in figure 4.7 for B20-S is equal (0.235 gm/kW. s), the average increasing in BSFC for B20-S compared to BSFC for pure diesel is about 5.5 %. In addition, the highest value of BSFC in figure 4.8 for B20-F is equal (0.243 gm/kW. s), average increasing in BSFC for B20-F compared to BSFC for pure diesel is about 11.6 %. Because they both contain the highest fuel consumption

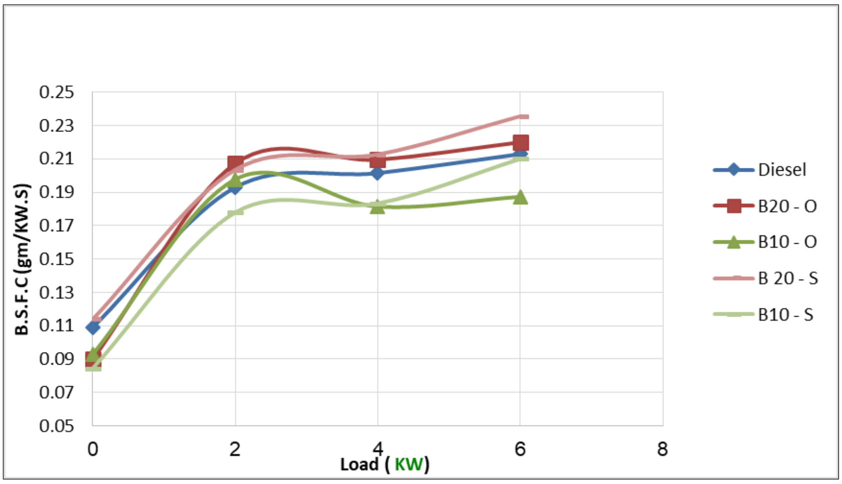

Figure 3 Brake specific fuel consumption (B.S.F.C) resulting from using (Diesel, B20-O, B10-O, B20-S, B10-S) as a function of variable load

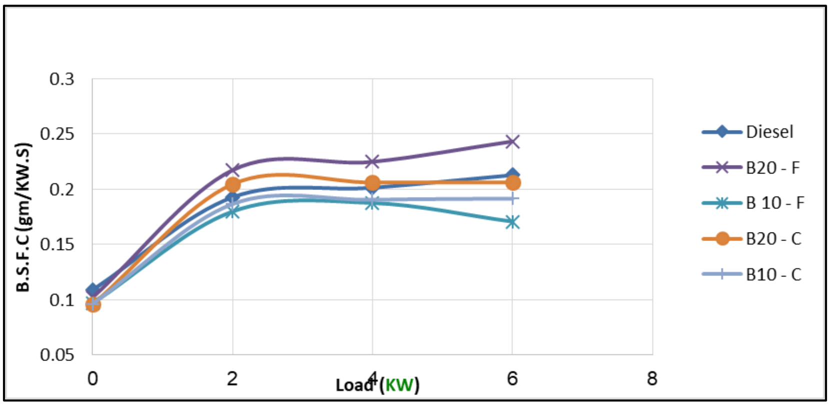

Figure 4 Brake specific fuel consumption (B.S.F.C) resulting from using (Diesel, B20-F, B10-F, B20-C, B10-C) as a function of variable load

Figures 5 and 6 show the Brake thermal efficiency (BTE) as a function of load. It is clear from the figures that the BTE decreases with increasing in engine load until load 2. After that, it slowly decreases with increasing in load. Because of insufficient, air which causes incomplete combustion of fuel. Consequently, the BTE decreases. The highest BTE in figure 4.11 is for B10-S is equal 27.6%. The average increasing in BTE for B10-S compared to BTE for pure diesel is about 17.6 %. In addition, the highest BTE in figure 4.12 is for B20-C is equal 24.6%. The average increasing in BTE for B20-C compared to BTE for pure diesel is about 6.8 %. The reason for the increase in BTE of biodiesel blends is the higher oxygen content, which leads to more complete combustion and higher thermal energy production in the engine.

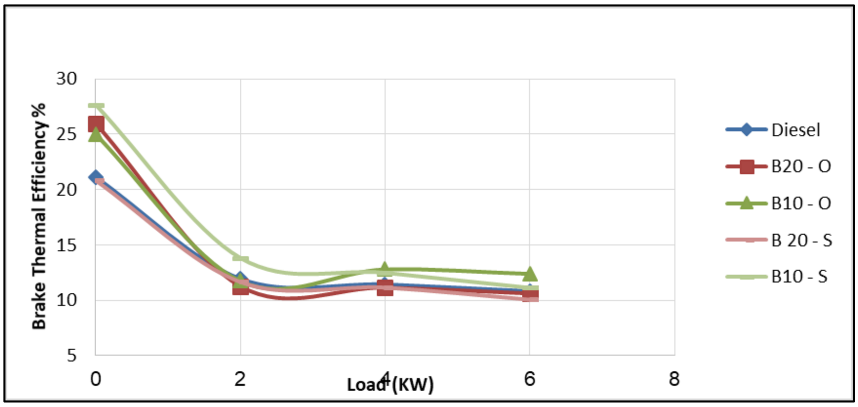

Figure 5 Brake Thermal Efficiency resulting from using (Diesel, B20-O, B10-O, B20-S, B10-S) as a function of variable load

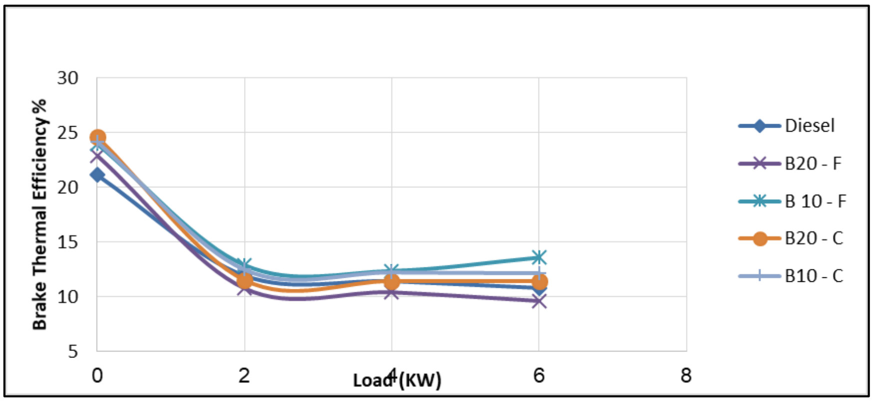

Figure 6 Brake Thermal Efficiency (BTE) resulting from using (Diesel, B20-F, B10-F, B20-C, B10-C) as a function of variable load

Figures 7 and 8 show the exhaust gas temperature as a function of load. It is clear in both figures the exhaust gas temperature increases with increasing load for all tested fuels. The exhaust temperature is an important parameter in the analysis of exhaust gases, especially NOx. The higher the exhaust temperature is, the higher the emissions of NOx will be. The highest exhaust temperature in figure 4.15 is for B10-F, also; the highest exhaust temperature in figure 4.16 is for B10-S. When using the biodiesel blends and changing engine load, the exhaust temperature increases. Thus, biodiesel blends produce NOx more than pure diesel. This is because biodiesel contains some amount of oxygen molecules in the ester form, which enhances the combustion process.

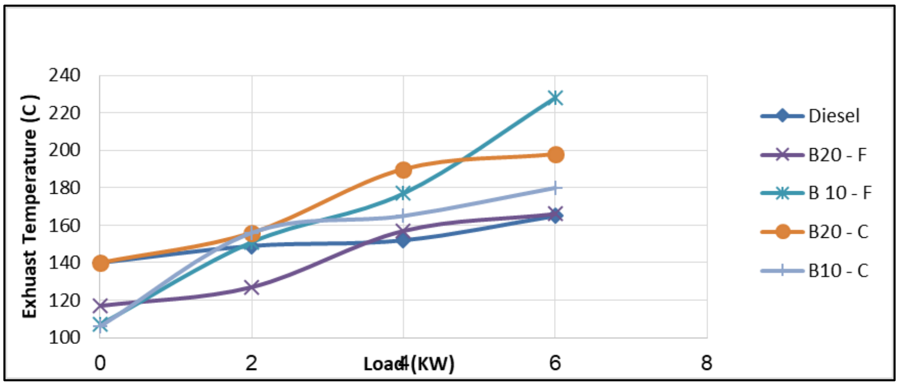

Figure 7 Exhaust Temperature resulting from using (Diesel, B20-F, B10-F, B20-C, B10-C) as a function of variable load

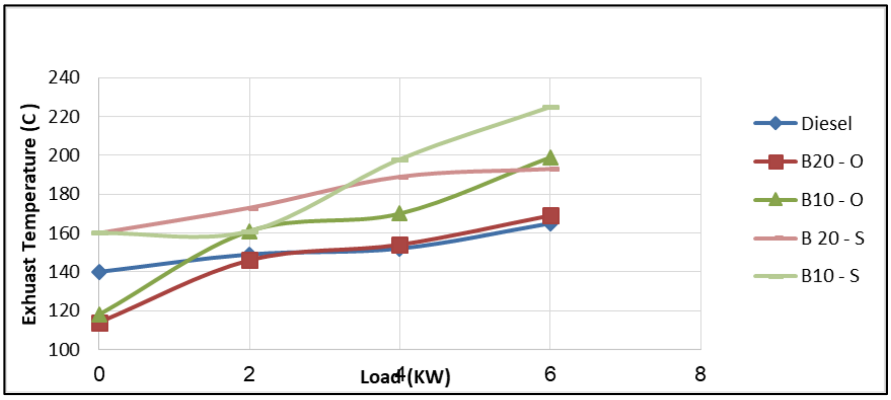

Figure 8 Exhaust Temperature resulting from using (Diesel, B20-O, B10-O, B20-S,B10-S) as a function of variable load

Figure 9 and 10 show carbon dioxide CO_2 emission as a function of load. It is clear from both figures that CO_2 emissions increase with an increasing in engine load. The reason behind such increasing is the increasing in fuel consumption associated with the increasing in load. In both figures, the amount of carbon dioxide emitted from biodiesel is lower compared to that of pure diesel. An increasing for carbon dioxide emitted in the exhaust gases is an indication of the complete combustion of the fuel.

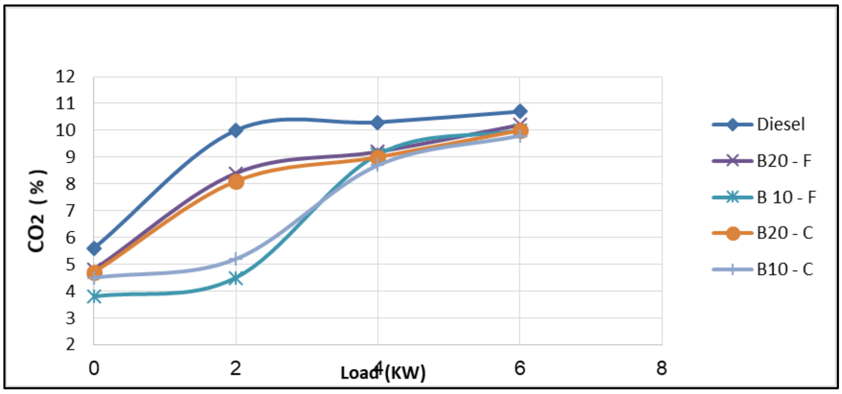

Figure 9 Effect biodiesel blends such as (Diesel, B20-F, B10-F, B20-C, B10-C) on carbon dioxide (%) at variable load

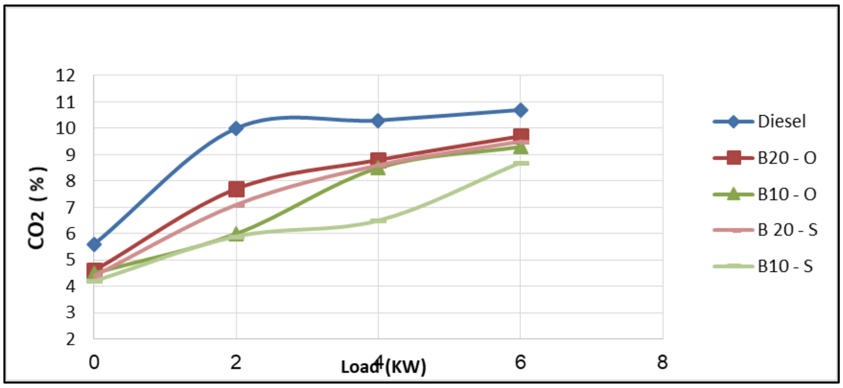

Figure 10 Effect biodiesel blends such as (Diesel, B20-O, B10-O, B20-S, and B10-S) on carbon dioxide (percentage) at variable load

Figures 11 and 12 show the effect of biodiesel blends on oxygen emissions level (percentage) with changing in engine load. It is clear from both figures the O_2emissions decrease with an increasing in engine load. The results indicate that the oxygen level at starting process is high. Whereas, when the load is increased, the oxygen level decreases. Due to the increasing in fuel consumption and the increasing in the combustion ratio. In both figures, the proportion of O_2emitted from all biodiesel blends was higher than that of pure diesel. The reason is that oxygen is founded within the alkyl ester structure of biodiesel as double bonded carbonyl oxygen and single carboxylic oxygen (w11percentage by weight).

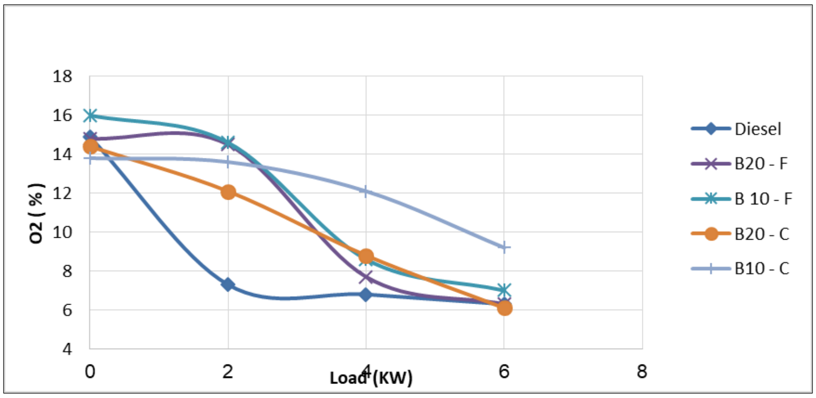

Figure 11 Effect biodiesel blends such as (Diesel, B20-F, B10-F, B20-C, and B10-C) on Oxygen level (percentage) at variable load

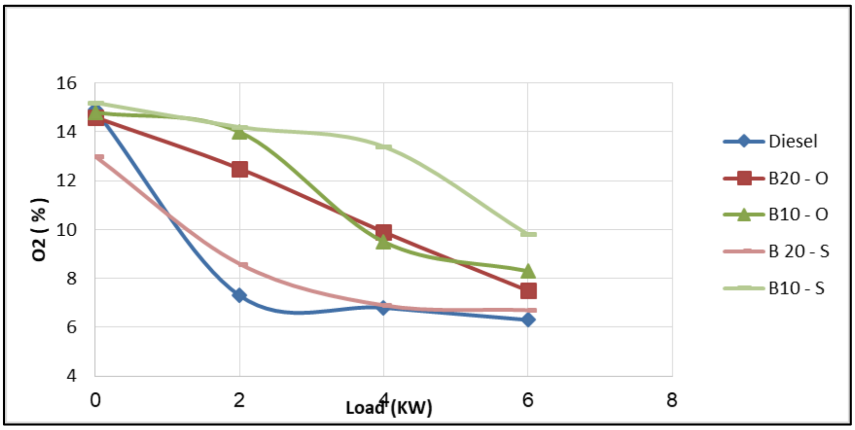

Figure 12 Effect biodiesel blends such as (Diesel, B20-O, B10-O, B20-S, and B10-S) on Oxygen level (percentage) at variable load

4. Conclusion

The experimental results of this study lead to the following conclusions:

- The biodiesel blends can be used as an alternative fuel for compression ignition engine without modification on it.
- The highest value of BP is for B20-F, which is equal 3.27 kW; the average increase in BP for B20-F compared to pure diesel is about 4%.
- The highest value of BSFC for biodiesel that produce from WCO is B20-F is equal (0.243 gm/wk.'s), the average increasing in BSFC for B20-F compared to BSFC for pure diesel is about 11.6%.
- The biodiesel produces BTE higher than pure diesel.
- The highest value of BTE for B10-S is equal 27.6%, the average increasing in BTE for B10-S compared to BTE for pure diesel is about 17.6%.
- Reducing the proportion of biodiesel in the blends contributes to the increasing in brake thermal efficiency.
- All biodiesel blends produce less carbon dioxide than pure diesel.
- All biodiesel blends produce higher oxygen than pure diesel; the reason is that oxygen is found within the alkyl ester structure of biodiesel as double bonded carbonyl oxygen and single carboxylic oxygen (w11percentage by weight).

- After experimental investigate from biodiesel blends, the best biodiesel from all biodiesel blends is B10-S, because it has lowest BSFC and highest BTE compared to pure diesel Also, It is less harmful to the environment compared to other types.

Recommendations

- Experiments should be done to enhance the performance and emissions of diesel engines by using biodiesel produced from WCO.
- It is recommended to use nano- catalyst to improve biodiesel properties to investigate its effect on engine performance and emission.

Compliance with ethical standards

Acknowledgments

The authors would like to thank Al-Balqa Applied University for permitting the experiments to be executed at the laboratories of the Mechanical Department – Faculty of Engineering.

Disclosure of conflict of interest

All authors declare that they have no conflict of interest.

References

[1] Foster, E., Contestabile, M., Blazquez, J., Manzano, B., Workman, M., & Shah, N. (2017). The unstudied barriers to widespread renewable energy deployment: Fossil fuel price responses. Energy Policy, 103, 258-264.

[2] Rahman, M. (2015). Influences of biodiesel chemical compositions and physical properties on engine exhaust particle emissions (Doctoral dissertation, Queensland University of Technology).

[3] Hasan, M. M. and Rahman, M. M. (2017) 'Performance and emission characteristics of biodiesel–diesel blend and environmental and economic impacts of biodiesel production: A review', Renewable and Sustainable Energy Reviews. Elsevier Ltd, 74(October 2014), pp. 938–948 .

[4] Turkensteen, M. (2017) 'The accuracy of carbon emission and fuel consumption computations in green vehicle routing', European Journal of Operational Research. Elsevier B.V., 262(2), pp. 647–659.

[5] Othman, M. F., Adam, A., Najafi, G., & Mamat, R. (2017). Green fuel as alternative fuel for diesel engine: A review. Renewable and Sustainable Energy Reviews, 80, 694-709.

[6] Singh, D., Sharma, D., Soni, S. L., Sharma, S., & Kumari, D. (2019). Chemical compositions, properties, and standards for different generation biodiesels: A review. Fuel, 253, 60-71.

[7] Sarkan, B., Stopka, O., Gnap, J., & Caban, J. (2017). Investigation of exhaust emissions of vehicles with the spark ignition engine within emission control. Procedia Engineering, 187, pp. 775-782.

[8] How, H. G., Masjuki, H. H., Kalam, M. A., & Teoh, Y. H. (2018). Influence of injection timing and split injection strategies on performance, emissions, and combustion characteristics of diesel engine fueled with biodiesel-blended fuels. Fuel, 213, pp. 106-114.

[9] Sidhu, M. S. (2018). Effect of glycerin and water emulsion of diesel-biodiesel blends on engine performance and emissions with EGR (Doctoral dissertation).

[10] Shirneshan, A. (2013) 'HC, CO, CO2 and NOx Emission Evaluation of a Diesel Engine Fueled with Waste Frying Oil Methyl Ester', Procedia - Social and Behavioral Sciences. Elsevier B.V., 75(x), pp. 292–297.

[11] Abed, K. A., Gad, M. S., El Morsi, A. K., Sayed, M. M., & Elyazeed, S. A. (2019). Effect of biodiesel fuels on diesel engine emissions. Egyptian journal of petroleum, 28(2), 183-188.