Evaluating the impact of using various biodiesel blends on the performance of diesel engine at variable load conditions

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Abstract. Recently, researchers use various types of alternative fuels, for diesel engines. Previous studies, reveals that biodiesel with renewable origin, is the most promising alternative fuel, with less impact on the environment. The objective of this paper, is to determine experimentally, the impact of using different biodiesel blends, extracted from Sun flower, Palm, and Corn oils, on the performance on diesel engine. The engine was operated at variable load and fixed speed. The following main parameters were determined: Torque, Brake power, Brake Specific Fuel Consumption (BSFC), Brake thermal efficiency, Fuel consumption, and Exhaust temperature. Results show that when all the biodiesels were used as a fuel to the engine, the engine has lower BSFC and exhaust temperature, and higher brake thermal efficiency, than when using pure diesel as fuel for the engine. This implies that using the biodiesel blends is more economically than using pure diesel as a fuel for the engine. In addition, it was concluded that using all these blends produces less NOx emissions.

1. Introduction
The transportation sectors usually used a large quantity of crude oil products. The fuel usage in Jordan increases dramatically, with the increase in population. In addition, the prices of crude oil keep increasing. The major resource of fuel for many vehicles is diesel. One way to decrease the diesel fuel consumption is using renewable fuel. For CI engines bio diesel is the most suitable alternative fuel. It produces less harmful emissions, with no sulfur content.

Bio diesel is One of the main sources of renewable energy. Many researchers studied the use of bio diesel derived from animal fats and vegetable oils, in CI engines. Recently, Numerous studies has been performed to use bio diesel blends instead of diesel, to evaluate its effect on the performance of CI engines [1-4]. Puravi and Meiyanathan [5] performed tests on diesel engines using 100% bio diesel alone, he concluded that brake power and thermal efficiency increased significantly. Bhatt et. al. [6] studied the suitability of mahua oil as alternative fuel for CI engines. They reported that muhau could be easily substituted up to 20% in the diesel without any significant differences in the performance of CI engines.

Puravi and Meiyanathan [7] studied the performance of diesel engines using bio diesel blends, by varying the load and speed. The results shows that with 100% biodiesel blend alone, the brake power, and brake thermal efficiency were significantly increased. Kasundra and Gohi [8] compared different performance parameters of CI engine with different vegetable oils as a fuel.

Nadir et. al. [9] studied the effect of using propanol, n-butanol, and 1-pentanol in waste oil methyl ester (B100) on engine performance and exhaust emissions on a diesel engine running at different...
loads (0, 3, 6, and 9 KW) with a fixed engine speed (1800 rpm). They concluded that the addition of propane n-butanol, and 1-pentanolto B100 had the effect of increasing brake specific fuel consumption and exhaust gases.

Anbumani and Singh [10] investigated the use of vegetable oils as bio fuel for CI engines. Their study have revealed that among the different vegetable oils, sunflower blend at 15% by volume with diesel fuel exhibited best combustion and performance in terms of total fuel consumption, specific fuel consumption, brake thermal efficiency and cylinder peak pressure.

The objective of this study is to evaluate the impact of using different blends of bio diesel derived from: corn, sun flower, and palm oils, on the performance of diesel engine at variable load and constant speed.

2. Experimental apparatus and procedure
A single cylinder diesel engine, four stroke, direct injection, with compression ratio of 17:1, was used in the experiments. The dynamometer maximum speed is 67 rev./sec., with five different engine loads (0, 0.25, 0.5, 0.75, 1.0).

The production of bio diesel blends vegetable oil (Palm, or corn, or Sunflower) was prepared, using sodium hydroxide as alkaline catalyst. The following chemical properties of the blends: calorific value, cetane number, and density were determined.

The engine was started with diesel fuel, and until the engine reached the operating temperature. Then the engine operated using blends of bio diesel with diesel in proportion (20% bio diesel from vegetable oil, and 80% pure diesel).

The following parameters were recorded: instantaneous speed (rpm), fuel consumption, Torque, Exhaust temperature, at variable engine load and fixed engine speed conditions.

3. Analysis
The following formulas were used to determine the value of various parameter in this study:

\[
\text{Brake torque (T_b)} = \text{Force} \times \text{radius (N.m)}
\]

\[
\text{Brake power (B_p)} = \left(2 \times \pi \times N \times T_b\right) / (6000)
\]

where N is r.p.m.

\[
\text{Brake thermal efficiency (}\eta_{\text{th}}\text{)= }B_p / (\text{mass flow rate of fuel } \times \text{ calorific value of the fuel)}
\]

\[
\text{Bake mean effective pressure (B.M.E.P.)} = (6000 \times B_p) / (L \times A \times n)
\]

where L is the stroke, A is the cross sectional area of the piston, and n = N/2.

\[
\text{Brake specific fuel consumption (B.S.F.C)} = \text{mass flow rate of fuel} / \text{Brake power}
\]

4. Results and discussion
From the collected data during each experiment, torque, mean effective pressure, brake power, fuel consumption, brake specific fuel consumption, brake thermal efficiency, and exhaust temperature, were analyzed, and were plotted versus engine load, to evaluate the performance of the engine as a function of the engine load. The following results were obtained:

The results for the performance of the engine as a function of engine load keeping engine speed constant, the collected data during each set of experiments. The following parameters were determined: torque, mean effective pressure, brake power, fuel consumption, brake specific fuel consumption, brake thermal efficiency. and were plotted versus engine load (min. load, 1/4 load, 1/2 load, 3/4 load, and full load). The results are as follows:

Figure 1 shows, the torque as a function of load. In general the torque increase as the engine load increases. This is because as the load increases, more fresh charge enter the cylinder, producing larger force exerted on top of the piston, thus more torque produced. Pure diesel has the highest values. This is because diesel has the highest calorific value, when combustion occurs, produce large amount of thermal energy, which result in producing very high torque.
Figure 1. Torque as a function of engine load.

Figure 2 shows, the brake mean effective pressure as a function of engine load. As explained before it is a function of engine torque. As expected the BMEP increase as the engine load increases, similar to the variation of torque. It is clear that pure diesel has the highest values. Because it has the highest calorific value, as explained before for the torque parameter.

Figure 2. Brake mean effective pressure as a function of engine load.

Figure 3 shows, the fuel consumption rate as a function of engine load. Generally the fuel consumption increase as the engine load. This is because the amount of fuel required is higher. The values of all bio diesels are lower than pure diesel. This is Because of their lower calorific values compared to pure diesel.
Figure 3. Fuel consumption as a function of engine load.

Figure 4 shows, the brake power as a function of engine load. It is clear that when load increases brake power also increases. The brake power is a function of torque and engine speed. As shown before the torque increases with the engine load, and the speed remains constant. Hence as the engine load increases the brake power increases. The values for pure diesel is the highest. This is because the fuel consumption rate, and is its calorific value is the highest.

![Figure 4. Brake power as a function of engine load.](image)

Figure 5 shows, the brake specific fuel consumption as a function of engine load. This parameter is very important parameter, it shows the capability of the engine to convert the fuel to brake power, which reflects how good the engine performance is. It is clear that with increase in engine load, the BSFC decreases. One possible explanation for this could be due to an increase in brake power with load, as compared with fuel consumption. In addition, once the load reached at full load, the time taken for combustion was decreased, caused incomplete combustion. The values of BSFC of all bio diesels are lower than pure diesel. This shows that using the bio diesel blends is more economically than using pure diesel.

![Figure 5. Brake specific fuel consumption as a function of engine load.](image)
Figure 6 shows brake thermal efficiency as a function of engine load. The brake thermal efficiency is defined as the ratio of brake power to the thermal energy produced from the combustion of the fuel supplied during the same interval of time. It is clear, that the brake thermal efficiency increases to about half load, and then decreases. One possible explanation for this could be due to an increase in brake power with load, as compared with fuel consumption. In addition, once the load reached at full load, the time taken for complete combustion was decreased. The values of brake thermal efficiency of all bio diesels are higher than pure diesel. This shows that using the bio diesel blends is more economically than using pure diesel.

Figure 6. Brake thermal efficiency as a function of engine load.

Figure 7 shows, the exhaust temperature as a function of engine load. In general the exhaust temperature increases along with the increase in engine load for all fuels. The increase in exhaust temperature with load is obvious from the fact that more fuel is required to take additional load, which is resulting in producing more thermal energy. Hence increasing the temperature of the products of combustion inside the cylinder.

Figure 7. Exhaust temperature as a function of engine load.

5. Conclusions
In this study, a comparison of the performance for a compression ignition engine, using pure diesel and bio diesels fuel blends. Results shows that the use of bio diesel blends can be used in compression
ignition engine with no modifications, and can replace pure diesel fuel. The engine consumes less fuel for corn and sunflower bio diesels than pure diesel. It was concluded that all bio diesel blends have lower BSFC and higher brake thermal efficiency than pure diesel. This implies that using the bio diesel blends is more economically than using pure diesel. In addition, All bio diesels blends produces less NOx emissions than pure diesel.

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