Enhanced The Performance of Diesel Fuel Blended With Palm Kernel Oil For Diesel Engine

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Abstract

This study focus on enhancing the Iraqi diesel fuel with palm kernel biodiesel. Palm kernel biodiesel was prepared by transesterification process using methanol and sodium hydroxide (NaOH) as catalyst. The performance evaluation and emissions of inline four cylinders, four strokes, direct injection diesel engine. The engine operated with palm kernel biodiesel (100% biodiesel) and its blends with diesel fuel for the ratios (20% palm kernel biodiesel with 80% diesel) and (50% palm kernel biodiesel with 50% diesel) and compared with pure diesel fuel (100% diesel).The tests carried out at constant speed of (1500 rpm) with variable loads (5, 10, 15, 20 and 25). The results show reduction in BSFC when using B20 and B50 blend ratio. The maximum reduction was at B20 by about (8.28%) compared to diesel fuel. The same blend gives higher thermal efficiency by about (12.11%). The increasing biodiesel blend ratio led to reduce the exhaust gas emissions for CO_2, and SO_2 were (47.51%), and (97.20%) respectively. However, NO_x emissions showed at B100 increased by 7.10% with the increasing of biodiesel blend ratio.

Keywords: palm kernel oil; engine performance; emission.

1. Introduction

The growth and development of a nation is heavily dependent on energy. From cars to cell phones, from health to pleasure, from air condition to heating, from exploring space to communication, energy plays an important role in our lives. Post industrial revolution, new technologies have been developed to help make life easier and better. Energy has played a great role in helping us perform various activities like farming, computing, manufacturing, construction, and health and social services. Each of the 7 billion people on this planet use energy to make their lives richer, more productive, healthier and safer. There are many energy players tapping into this market with an objective of bridging the gap between demand and supply. With the standard of living of people increasing and our lives becoming increasingly dependent on energy, it is estimated that we will see about a 35% increase in energy consumption over the next 5 years until 2019 (Exxon Mobile 2014) .

Biodiesel is increasingly gaining importance and interests as an alternative fuel for diesel. It is made from vegetable oils or animal fats through a chemical process called transesterification. This involves a chemical reaction with methanol using sodium or potassium hydroxide as a catalyst (Mendow et al. 2012),(Lam et al. 2010),(Demirbas 2008).

There has been a tremendous amount of research done around the world to find a way to decrease the harmful emissions produced by engines using both Diesel and gasoline. Most of these are associated with the fuel oil properties and the local climatic and geographical conditions (Rao and Gopalkrishnan 1991). The fuel injection, combustion and atomization characteristics of vegetable oils are very different than those of diesel fuel. The high viscosity of vegetable oils interferes with the injection process in the engine resulting in poor and improper atomization. Poor and improper mixing of fuel oils with air in the engine leads to improper combustion, lower power output and high emissions often leading to deposit formations in the combustion chamber, piston head and injectors. The combination of high viscosity associated with vegetable oils and their low viscosity causes poor cold stat of the engine and misfires. Over a long period of operations, vegetable oils start gumming, chocking of injectors and valve sticking which can result in engine breakdowns (Srivastava and Prasad 2000),(Haldar et al. 2009). In

(Babulal et al. 2015) investigated the engine performance and emissions of single cylinder, four stroke, DI diesel engine.

The engine fuelled with three types of fuels. They are diesel fuel, pongamia biodiesel B100 and blend of (B40). The results shows that BSFC in B100 and B40 is about (26%, 8%) higher than diesel fuel. At full load condition, BTE for

B40 is nearly equal to that of diesel fuel. NOx emission increased by (2 %, 10%) for B40 and B100 respectively when compared to diesel fuel, CO emission decreased by about (20% and 60 %) for B40 and B100 respectively. The results conclude that biodiesel mixture of B40 is the best substitute for diesel fuel. In (Maki and Prabhakaran 2012) , investigated performance and exhaust emission by using palm biodiesel on multi cylinder , four stroke, DI diesel engine , the blended ratio that take it in this study was (B20, B40, B60, B80, B100) . The results show that the palm biodiesel is suitable for using in diesel engine as alternative fuel, hydrocarbon emissions in terms of (CO, CO2, HC) are reduced, SO2 also reduced while NOx emission increased, bsfc was increased and there is slight decrease in thermal efficiency. In (Palash et al. 2014) , evaluated the performance and emission characteristics of four-cylinder diesel engine using Jatropha biodiesel blends (B5, B10, B15 and B20) with and without the addition of antioxidant. For each tested fuel, the engine performance and emissions measured at engine speeds (1000–4000 rpm) with interval of (500 rpm) under the full throttle condition. The results shows that biodiesel blends without the addition of antioxidant increases NOx emission with the increasing of blend ratio by (6.16%, 8.38%, 10.24% and 11.32%) for B5, B10, B15 and B20 respectively. But when using antioxidant additive was reduced and with a slight penalty in terms of engine power and BSFC as well as CO and HC emissions. When compared to diesel combustion, the emissions of HC and CO with the addition of the antioxidant additive found to be nearly the same or lower. By the addition of 0.15% antioxidant additive in B5, B10, B15 and B20, the reduction in NOx emissions were 8.03%, 3.503%, 13.65% and 16.54% respectively, compared to biodiesel blends without the additive.

As of today, we have come a long way to understand the formation of biodiesel. It has in fact opened the door and new avenues to the direct use of vegetable oils as straight palm kernel oil (PKO). This paper will study the effects of introducing palm kernel oil to Diesel fuel for a number of different volumes by ratio. In addition, evaluate the characteristics of emissions in blended Diesel-Palm kernel oil. These emission characteristics include the parts per million (ppm) of different gases produced by the engine. Such gases include Carbon Dioxide (CO2), Carbon Monoxide (CO), Nitrous Oxide (NOx), Hydrocarbons (HC), and Oxygen (O2). In this study, the results for NOx and O2 are not included or discussed.

2. Related Work

Alternative fuels' greatest contender to the beast of fossil fuels is that of Bio-Diesel. Using Bio-Diesel instead of traditional Diesel requires no real significant changes to a compression engine that runs off of Diesel fuel. This is important because Diesel powered engines are very popular in European countries, accounting for roughly 50% of all vehicles according to a Popular Mechanics article.

2.1 Diesel Fuel

Diesel fuel is, in some circles, considered to be the most widely used fossil fuel today, being used all over the globe to produce power for users. Applications for Diesel fuel powered systems such as various modes of transportation, especially automobiles, and generators to create electricity, are used every day. According to studies done Diesel fuel powered engines found in automobiles are increasing in popularity dramatically. This is due to a number of factors including engine life, power, an extremely high fuel efficiency, and relatively low Carbon Monoxide emissions, which, when compared to its counterpart, being gasoline used in a Spark Ignition Engine is a reason why its use has increased over the years. In a study done, it was found that the percentages of Diesel engines used in European countries has grown from 10% to 50% in a period of approximately 26 years.

In order to create Diesel fuel, crude oil is obtained and is separated into specific hydrocarbons such as paraffins, naphtenes, aromatics, and olefins. Because Diesel fuel is composed of hydrocarbons it reacts to and combusts with air under pressure, which is necessary to power an engine.

2.2 Bio-Diesel Fuel

Bio-Diesel fuels are one of the most commonly known types of renewable fuels that are used as an alternative to Diesel fuel in Compression Ignition engines. The reason for this is because the production process of creating Bio-Diesel fuel is simple and affordable to most. For instance, using vegetable oil or used cooking oil one can create useable Bio-Diesel fuel. It was seen that the Bio-Diesel fuel tested had a reduction of both Carbon Monoxide and Hydrocarbon emissions, however there was an increase of both Nitrous Oxide and Carbon Dioxide emissions. This all can be seen in the results section of this study, with the exception of Nitrous Oxide results.

3. Material and method

The biodiesel prepared from palm kernel oil (PKO) by transesterification process using methanol and sodium hydroxide (NaOH) as catalyst. Figure 1, show overall system in which, Methanol was mixed with NaOH until it completely dissolved, the PKO was preheated to the steady temperature of (55°C), and the sodium methoxide added to preheated oil and stirred together using magnetic stirrer for (2 hr) at the same temperature. Figure 2, shows the three biodiesel preparation steps; first step the mixture was poured into separating funnel, the mixture settled for (12 hr), in order to obtain two layers; the top layer of biodiesel and the bottom of glycerol, Second step washing, purifications steps take place, and third step drying at temperature of (120°C) for (20 min). The physical properties of diesel and biodiesel are shown in Table 1.

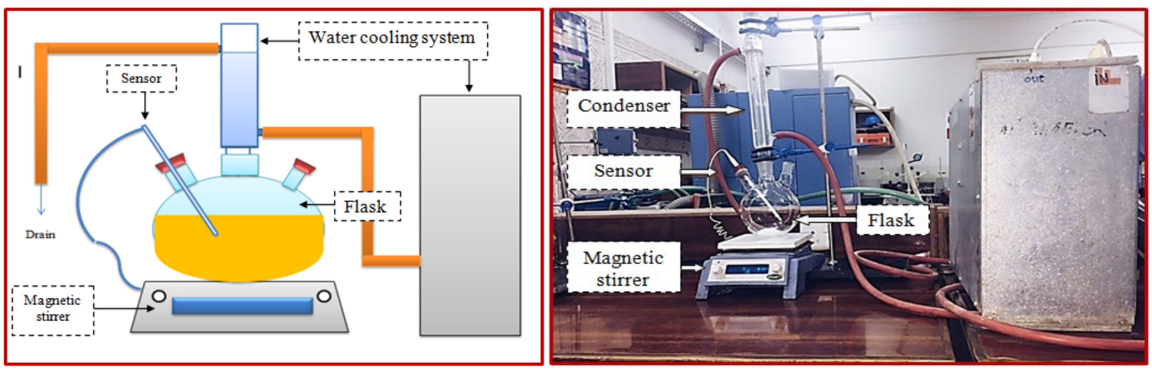

Figure 1. Biodiesel preparation system

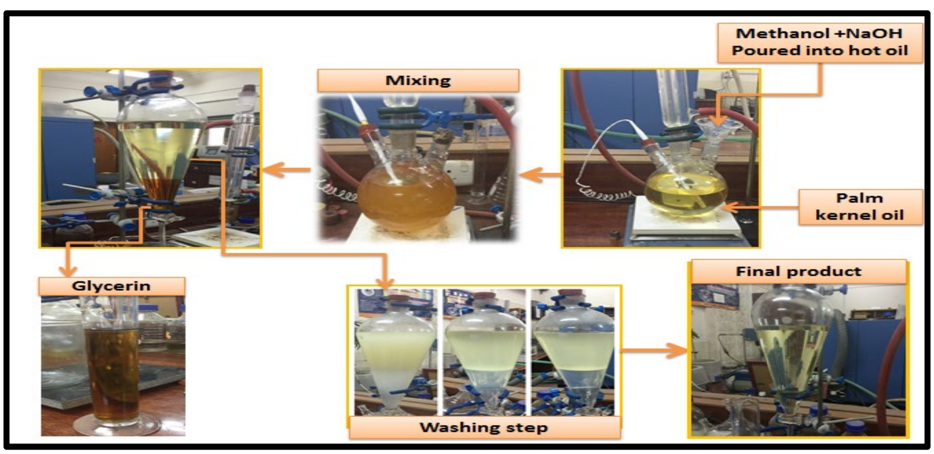

Figure 2. Biodiesel preparation steps

Table 1. Physical properties of diesel, biodiesel fuel

Test	method	units	Gas oil	biodiesel
Density	ASTM D-4052	kg/m^3	0.82948	0.88574

Sp.Gr @ 15.6°C	ASTM D-4052		0.8303	0.8866
Viscosity @40°C	ASTM-D445	mm^2/s	3.5363	4.3068
Flash point	ASTM –D92	°C	71	138
Pour point	ASTM –D97	°C	-12	-11
Sulfur content	ASTM –D7039	ppm	6354	2.6
Calorific value	ASTM –D240	Cal/g	10907.682	9004.0149
Cetane No.	ASTM –D716-16		51.2	50.5

4. Experimental setup

3.1 Experimental apparatuses

In this study four cylinders, four stroke, water cooled direct injection diesel engine used, the engine coupled with hydraulic dynamometer to measure the engine torque. Table 2, lists the engine specifications information such as types, model, combustion type and compression ratio. Figure 3, shows the schematic diagram of the engine including inline four cylinders, four strokes, direct injection diesel engine.

Table 2. specification of diesel engine

Engine model	Fiat , TD 313 , Diesel engine rig
Engine type	Four cylinder , Four stroke
Combustion type	Direct Injection, natural aspirated water cooled
Valve per cylinder	Two
Stroke	110 mm
Bore	100 mm
Compression ratio	17.667
Displacement	3.666 Lit.

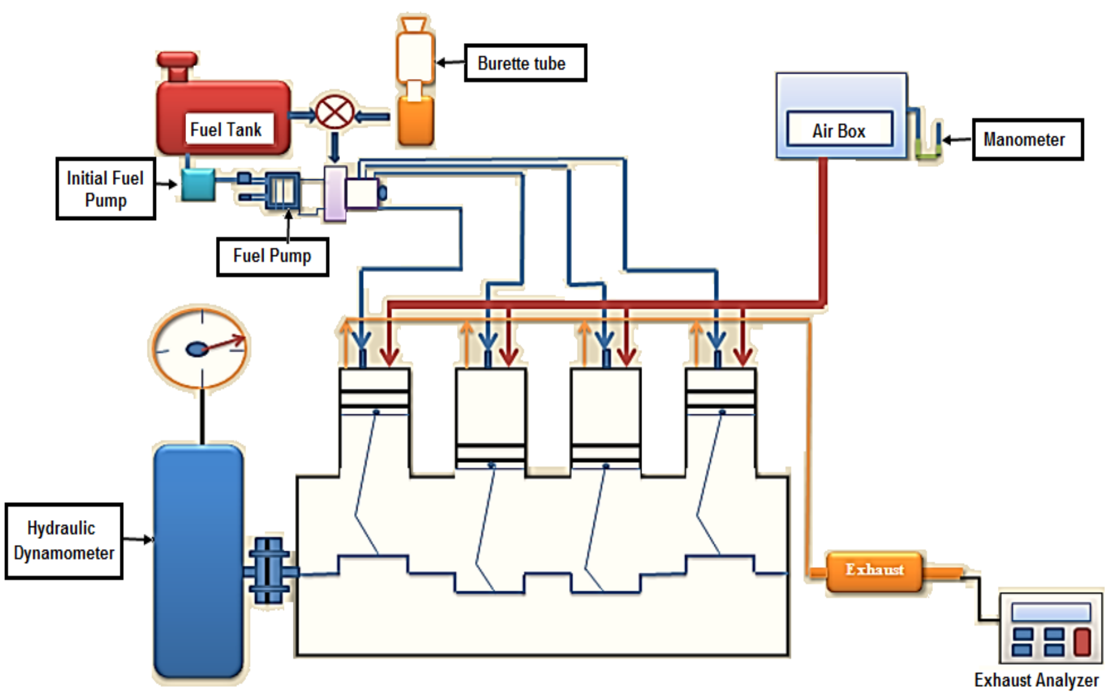

Figure 3. Schematic diagram of the diesel engine

3.2 Testing Procedure

First, diesel fuel analyzed using Gas chromatography/ mass spectrometry (GC/MS) in order to found its compounds, total Carbon atoms (773). Then biodiesel prepared and measured its physical properties also analyzed it by(GC/MS)analyzer, the total carbon atom found to be (276) ,then mixed with diesel fuel for the ratios (B20, B50 and B100) using mechanical stirrer. After that this samples tested in the engine and calculated the fuel consumption ($\dot{m}_f$), air consumption ($\dot{m}_a$), brake specific fuel consumption (bsfc), thermal efficiency (η_{th}) and emission measurements. The tests were done at constant speed (1500 rpm) with variable loads (5, 10, 15, 20 and 25 kg).

5. Results and discussion

The relation between brake torque and brake specific fuel consumption when using diesel, biodiesel and its blends with diesel fuel, are shown in Figure 4. The blends (B20, B50) shows reduction in bsfc by (8.28%, 2.88%) respectively. In spite of the cetane number and amount of calorific value are slight lower than diesel fuel, but the higher oxygen content of biodiesel improve the brake power and compensate the loss of heating value, in case of B100 the cetane number and the calorific value are much lower than the diesel fuel and the blends, this lead to higher bsfc by (16.18%) compared to diesel fuel, the Eq.(2) used for bsfc calculation (Maki and Prabhakaran 2012).

$$bsfc = (\dot{m}f \,/\, bp) * 3600 \,(kg/kw.hr) \quad (1)$$

The relation between brake torques versus brake thermal efficiency (η_{th}) and the effect of biodiesel percentage in diesel fuel compared with the pure diesel fuel on the brake thermal efficiency are shown in Figure (5). As can be seen from the equation (2) that the thermal efficiency proportional directly with (bp) and inversely with ($\dot{m}_f$) and calorific value (LHV) (Maki and Prabhakaran 2012).

$$\eta th\,\% = bp/(\dot{m}f) * (LHV) \quad (2)$$

So that the thermal efficiency increases with increasing of torque in all percentages of blends, the blend of B20 gives the best thermal efficiency of about (12.11%) more than the efficiency of pure diesel fuel followed by B50 of about (11.18%) but B100 was decreased by (1.83%), as well as the thermal efficiency was increased due to the lubricity of biodiesel compared to pure diesel fuel.

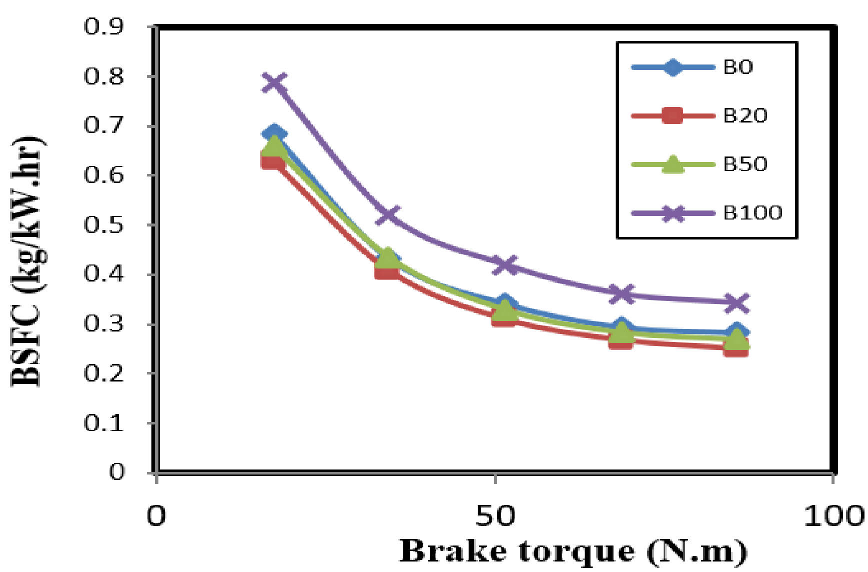

Figure 4. The relation between brake torque and brake specific fuel consumption at speed 1500 rpm

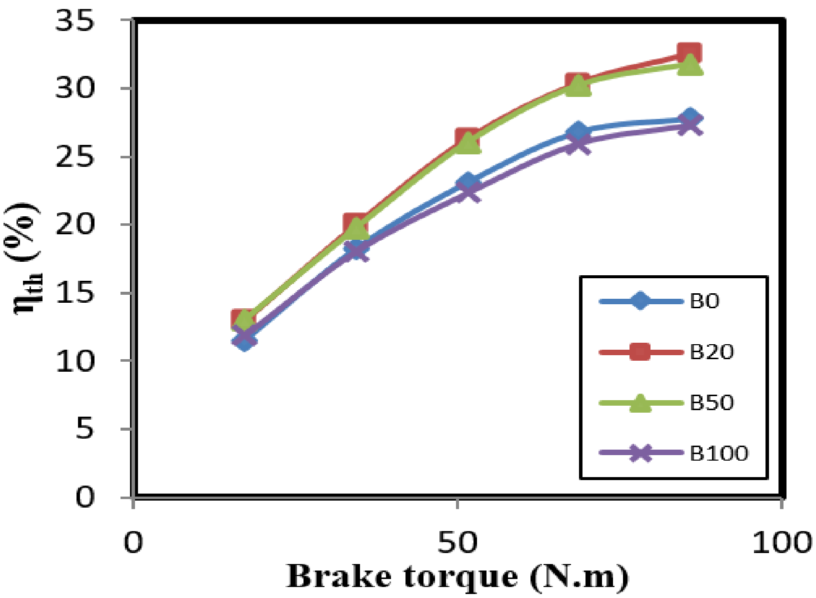

Figure 5. The relation between brake torque and brake thermal efficiency at speed 1500 rpm

Figure 6, show the conducted that (SO_2) increases with increasing of load in all types of fuel due to increasing of temperature followed by oxidation of sulfur compounds, there is a significant decrease in SO_2 emission with the increase of biodiesel ratio with the diesel fuel reaches to max reduction in B100 by (97.20 %), this reduction of SO_2 is due to the fact this biodiesel is free of sulfur compounds on the contrary with diesel fuel. Figure 7, it can observe that with the increasing of torque, CO_2 increases for the diesel fuel and biodiesel blends due to increasing of temperature, but there is reduction of CO_2 by increasing of biodiesel percentage. And the maximum reduction in CO_2 emission was at B100 by (47.51%). This due to lower carbon content of biodiesel is compared with diesel fuel

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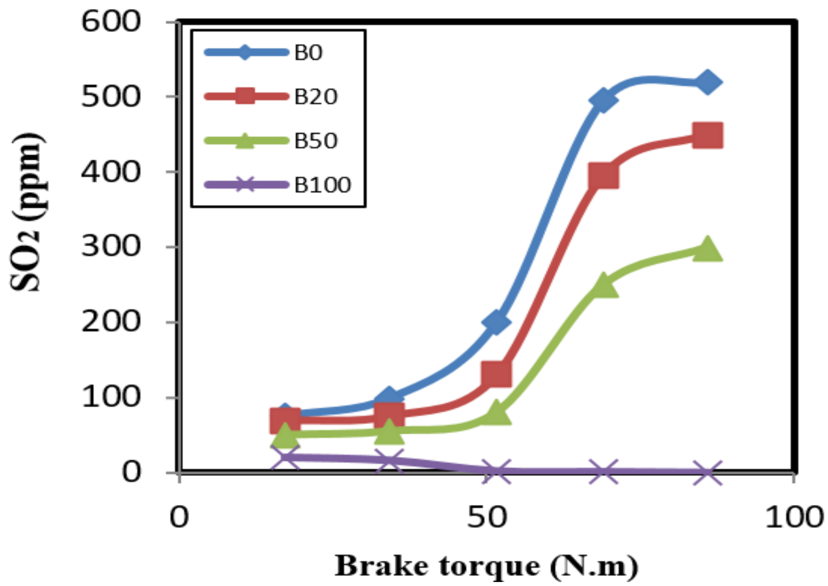

Figure 6. The relation between brake torque and SO_2 emission at speed 1500 rpm

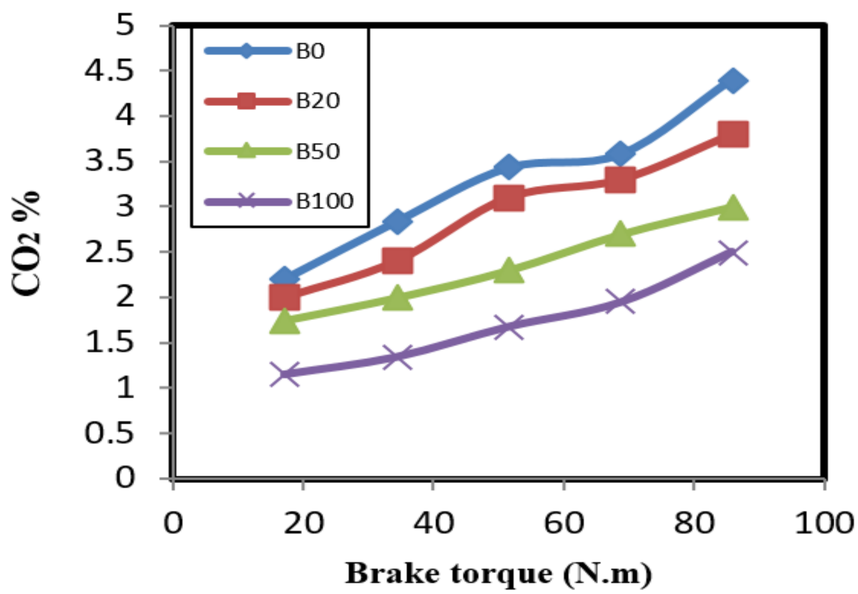

Figure 7. The relation between brake torque and CO_2 emission at speed 1500 rpm

Figure 8, shows the effect of increasing the torque on NO_x emission. It is clear that there is an increase of NO_x with the increasing of torque for diesel fuel and biodiesel blends due to the increasing of temperature, and also there is a slight increase in NO_x emission with the increasing of blends percentage. The main reason that form NO_x emission is the higher oxygen content of biodiesel that combined with nitrogen from air and form the nitrogen oxides. The maximum increasing was in B100 of about (7.1%).

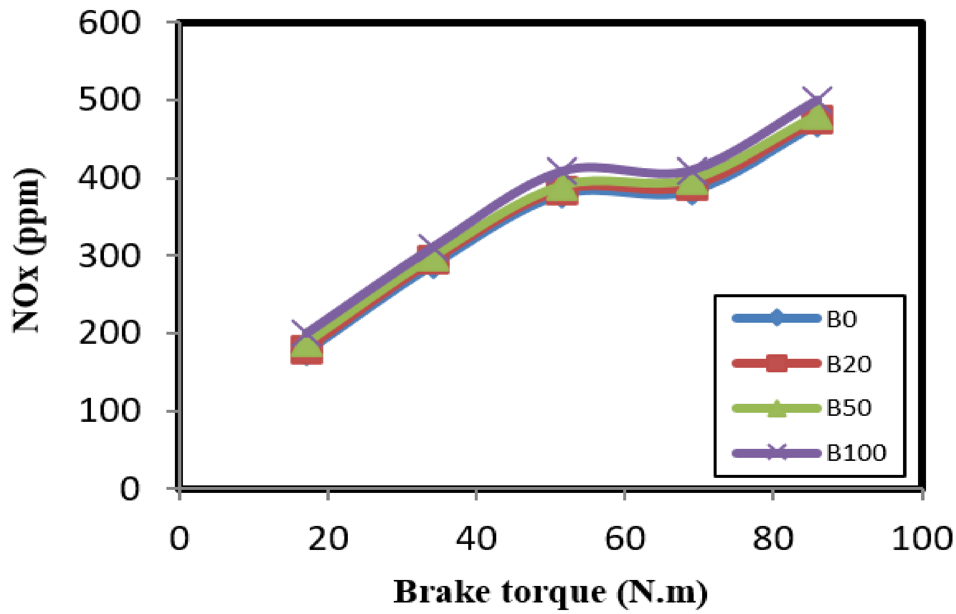

Figure 8. The relation between brake torque and NOx emission at speed 1500 rpm

6. Conclusions

This paper prepared biodiesel from palm kernel oil for diesel engine as alternative fuel without any engine modifications. The reduction in brake specific fuel consumption for biodiesel blends about (8.28%) for blend B20 and (2.88%) for blend B50, but increased at B100 by about (16.18%) compared with biodiesel. The thermal efficiency of blend B20 is higher than diesel by about (12.11%) followed by B50 by about (11.18%), but in B100 thermal efficiency is reduced by about (1.83%). There is significant reduction of exhaust gas emissions in (CO_2 and SO_2) with the increasing of all biodiesel percentages as compared to the diesel fuel. Maximum reduction of these gasses emissions was found at B100 by (47.51%), and (97.20%) respectively. The NOx emission shows slight increase with the increasing of biodiesel blend ratio. The maximum increasing found at B100 by about (7.10%). The results show the possibility of the use of palm kernel biodiesel blends with diesel fuel which improves engine performance by reduces the amount of brake specific fuel consumption and reduces the amount of toxic emissions. The palm kernel biodiesel considered environmentally friendly fuel and improve the impact on human health and the environment.

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