Experimental Investigation on Performance and Emission Characteristics of a Diesel Engine Fuelled with Linseed Biodiesel Blends

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Abstracts: The core object of this study is to examine the suitability of linseeds for biodiesel production. Engine performance and emissions at different proportions of linseed-diesel blends were investigated. Linseed biodiesel was produced through transesterification process and mixed with petro-diesel fuel (D100) at volumetric ratios of 5% (LB5), 10% (LB10), and 15% (LB15). The properties of linseed biodiesel and its blends were measured according to ASTM standards and compared with petro-diesel as a threshold for comparison. The results showed that fuel properties of produced biodiesel are within ASTM permissible limits. Engine test shows lower specific fuel consumption (SFC) for LB5 blend compared to LB10 and LB15 with slightly higher value compared to that of D100. The higher brake thermal efficiency (BTE) was observed for LB15 among the other investigated fuel samples. The heat dissipation rate in all linseed blends was found to have been less than that of D100. Carbon monoxide (CO), carbon dioxide (CO2) and hydrocarbons (HC) emissions of linseed blends are mostly lower in comparison with D100's. Among all blends, LB5 was found more suitable alternative fuel for diesel engines and can be blended with petro diesel without engine modifications. It can be concluded that cultivation and production of linseed in Iraq is very promising, therefore, it is recommended that proper exploitation and use of linseed for energy production may be encouraged through pertinent agencies of Iraq.

Keywords: Linseed Biodiesel, Transesterification, Engine, Performance, Emission.

1. INTRODUCTION

The rapidly increasing global consumption of liquid fossil fuels suggests that oil reserves may soon be depleted oil supply shortages may occur by 2020–2030 [1]. This presents a dual challenge to humanity to sustain global economic and technological development without compromising resources for future generations [2]. Fuel emissions are also a significant health risk, inducing, for example, an estimated 600,000 premature deaths in European Union countries in 2010 alone and a corresponding morbidity of $1.575 trillion [3].The global energy consumption has duplicated during the recent three decades. Fossil fuels are dominant in the global energy mix, as they represent over 80% of the total energy supplies in the world today [4]. According to the World Trade Organization, in 2010, the fuel market was responsible for a 15.8% share of the total trade in merchandising and primary products. Most are due to diesel fuel that is essential for transportation and heavy-duty engines [5].

Carbon dioxide is the main gas that contributes to global warming and is mainly emitted from the combustion of fossil fuels, According to the current data and due to the increase in carbon dioxide emissions, it will become more expensive and difficult to control global warming in the near future [6].The measured carbon dioxide concentration according to measurements made by the Mauna Loa Observatory, Hawaii, in 2018 is 409 ppm while the suggested top safety concentration is 350 ppm [7]. A number of air pollutants are emitted at the same time in addition to carbon dioxide emissions, such as nitrogen oxides (NOx) and sulfur dioxide (SO2), which generate harmful effects on the environment and public health that the extraction, transportation and processing of fuels Fossil lead to water and air pollution [8].

Energy that mainly depends on natural sources such as solar energy, wind energy, biomass, geothermal energy, hydropower, and tidal energy is called renewable energy. Currently, renewable resources are the source of about 24% of global electricity generation. Among these renewable energies, biomass represents a promising source of energy for biofuel production that may replace fossil fuels in various sectors, especially in the transportation sector, where most of the renewable energies are utilized to supply fully or partially the requirements of electric energy and heating. In the future, it will be heavily relied on sustainable energy sources, primarily biomass, equivalent to (3271) million tons of oil by 2040 [9]. The term biomass refers to all biological materials derived from living or recently living plants (such as algae and agricultural crops) and their waste [10]. Biofuels are produced by biological, chemical or thermochemical processing of biomass such as biodiesel, bio-oil, biogas, bioethanol and biomethane [11]. Biofuels are renewable resources and have the ability to degrade [7]. Biodiesel fuel is considered a promising alternative fuel through which global warming may be reduced. Biodiesel is the best potential future energy source in the transportation sector. Less carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides and smoke. Combustion of linseed diesel biodiesel leads to a significant reduction in total unburned hydrocarbons (HCs) and aromatic hydro carbons (PAHs) , also has a significant reduction in particulates Depending on the engine family and the following test procedures [12]., we can evaluate and improve diesel engine performance and emissions. By checking the characteristics related to engine performance and emissions, the benefits and technical challenges of biodiesel as a diesel engine fuel are revealed. Biodiesel and diesel fuel share similar properties [13].

Biodiesel can be made from locally produced and renewable oilseed crops. Biodiesel is less hazardous if transported and stored than mineral diesel. Because it is biodegradable and has a high flash point, so it is safe to handle and transport, unlike mineral diesel fuel. Using biodiesel fuel alone or mixing it in certain proportions with mineral diesel fuel [14]. Among all non-edible feed stocks, linseed is recognized to be one of the most suitable sources for biodiesel production as it is an oil seed bearing plant [15]. Linseed oil is a non-edible vegetable oil and is considered as a potential alternative fuel for compression ignition engines. It is a sulfur free, non-aromatic, nontoxic, and oxygenated oil, It is an annual herbaceous plant that is cultivated in 59 countries for its fiber in addition to its oil [16]. Linseed contains 35-45% oil by weight and is rich in unsaturated compounds [17].

This study aimed to produce linseed biodiesel using indigenous linseed seeds and to examine the performance of a diesel engine by using its different blends with petro diesel and exhaust emission rates. The study includes physcio-chemical properties of produced biodiesel, such as density, flash point, kinematic viscosity, cetane number, pour point, and calorific value. The performance parameters, like brake thermal efficiency (BTE), fuel consumption, and heat carried by coolant were evaluated at varying loads. Regarding exhaust gas emission, Carbon monoxide (CO), carbon dioxide (CO2), hydrocarbons (HC) and nitrogen oxides (NOx) were also analyzed. The objective of this study was to draw attention to the synthesis of linseed biodiesel, which is an excellent alternate of petroleum diesel.

2. MATERIALS AND METHODS

The experimental work produced biodiesel using refined linseed oil as raw material. It also investigated the performance and emission characteristics of linseed methyl ester using different blends and compared them with petro diesel. The linseeds were purchased from the local markets of Tikrit, Iraq. The linseed oil can be obtained by different methods like solvent extraction, enzymatic extraction and screw press method. The screw press method is preferable as it gives more yields and so it was adopted [18, 19]. The crude linseed oil was extracted with the help of the screw press mechanical expeller of the Biofuel At first, the linseed seeds were cleaned in order to avoid the impurities, foreign particles and adhered agrochemical sprays remaining on the outer seed’s surface. The extracted oil was collected in air sealed glass bottles which were already sterilized, washed with double distilled water and oven dried. Oil’s free fatty acid level was reduced through single esterification.

2.1. Transesterification Process

Linseed biodiesel was produced. In this process, 500 ml of linseed crude oil was heated at 100°C for 15 minutes to remove moisture content. Then, potassium methylate was prepared by mixing 5.25gram potassium hydroxide (KOH) with 120 ml methanol. After that, heated 500ml of linseed oil was filled in the reactor vessel and then the mixture of potassium methylate was added through charging hole and allowed for 45 minutes by keeping reaction temperature at 50°C and set stirrer speed 800 rpm. After the transesterification process, crude linseed biodiesel was shifted to a separating funnel in order to separate crude glycerin. Finally, water washing was carried out by using hot water at 200 ml/liter to remove the catalyst unreacted reagents. Four times washing was done till required pH value was achieved as prepared sample is shown in Figure 1.

Figure 1. Transesterification process

2.2. Blend Preparation, Engine Performance and Exhaust Emissions

The blends of varying ratio of linseed biodiesel and petro- diesel were prepared at room temperature in Biofuel Laboratory. The linseed biodiesel was blended with petro diesel at volumetric ratios of 5% (LB5), 10% (LB10) and 15% (LB15) as shown in Figure 1. The different blends of linseed biodiesel were tested on a slow speed diesel engine, (Marshall, Model FM-II). The specifications are mentioned in Table 1 [*22*].

Table 1. Diesel Engine Specifications

Parameter	Specifications
Engine Type	**Field Marshall, Model FM-II, 1 cylinder, 4 stroke, compression ignition, Diesel fuel, Water cooled engine**
Bore	**0.1143 m**
Stroke	**0.1397 m**
Engine capacity	**1.432×10^{-3} m^3**
Compression ratio	**17**
Rated power	**5.9 kW @ 850 rpm**
Dynamometer	**AC generator**
Power transmission	**V-belt**
Air flow measuring	**Air box MS fabricated with orifice meter and manometer (orifice dia. 35 mm)**
Fuel tank	**Capacity 15 lit with glass fuel metering column**
Calorimeter	**Type pipe in pipe**
Temp. sensor	**Type RTD, PT100 and thermocouple**
Fuel flow measuring	**Glass fuel metering (volumetric based)**
Rotameter	**Engine cooling 100-1000 LPH, calorimeter 25-250 LPH**

The engine comprises of several systems such as lubricating system, fuel supply system, water cooling system and several sensors which are attached with measuring devices in an integrated manner [18]. The load on the engine increased gradually from zero to the maximum of 1kW. The increase of load on the engine decreases the rpm of the engine. The power output (torque) was measured by an eddy current electric dynamometer. Fuel consumption was measured on volumetric basis [20, 21]. Performance parameters like torque, brake specific fuel consumption (BSFC), lubrication oil temperature, water inlet and outlet temperatures, suction and exhaust pressures, exhaust temperature and thermal efficiency were examined. Moreover, Exhaust Gas Analysing Unit were used for the analysis of various flue gas emissions like carbon monoxide (CO), carbon dioxide (CO2), hydrocarbon (HC) and oxygen (O2).

3. RESULTS AND DISCUSSION

3.1. Fuel Properties and Engine Performance

The results of the properties of the different blends of produced linseed biodiesel are shown in Table 2. The produced biodiesel was found to have lower viscosity and density, higher cetane number and flash point. In blend LB5, maximum cetane number was found to be 45.7, whereas, in LB10 it was 43.2 which is more than the ASTM Standard. Flash point was discovered to be more in LB10 and LB15 than petro diesel. Sulfur was found less in all blends than that in 100% diesel. The calorific values were within permissible limits. Generally, all fuel properties of LB5 blend were found better in term of less kinematic viscosity, higher cetane number, even elevated calorific values. L B5 was found to be more suitable feasible blend compared to LB10 and LB15. All blend samples were found better than petro diesel. The results were found similar to the ones reported in [22-23].

Table 2. Fuel Properties of Linseed Biodiesel and Blends

Quality Parameters	Allowable limits	Diesel 100%	LB 100%	LB 5 %	LB 10%	LB 15%
Density at 15ºC kg/Lit	0.88	0.8235	0.8965	0.8445	0.8489	0.8501
Kinematic Viscosity at 40ºC (mm^2 / SEC)	1.9–6.0	2.8	4	3.23	3.41	3.62
Sulfur %wt	0.05 max	0.719	0.0012	0.561	0.442	0.362
Flash point º C	130 min	71	210	75	80	85
Total Acid Number mgKOH/gm	0.80 max	0.066	0.3355	0.082	0.134	0.183
Pour point ºC	-15 to +5	-18	0	-14.5	-13	-11
Cetane number	47 mini	47	37	47.5	45.5	42.3
Calorific value MJ/kg	37.5 - 42.80	43	40	39.6	39.3	38.8

Engine performance or brake power output was examined by load variation. The variation in specific fuel consumption (SFC) versus brake power for different fuel blends is shown in Figure 2. In general, at 0.7 kW power, SFC was found maximum, and it decreased with the increase of brake power. However, SFC in LB5 blend found less as compared to LB10 and LB15. At the maximum brake power D100 performed well with respect to specific fuel consumption (SFC).

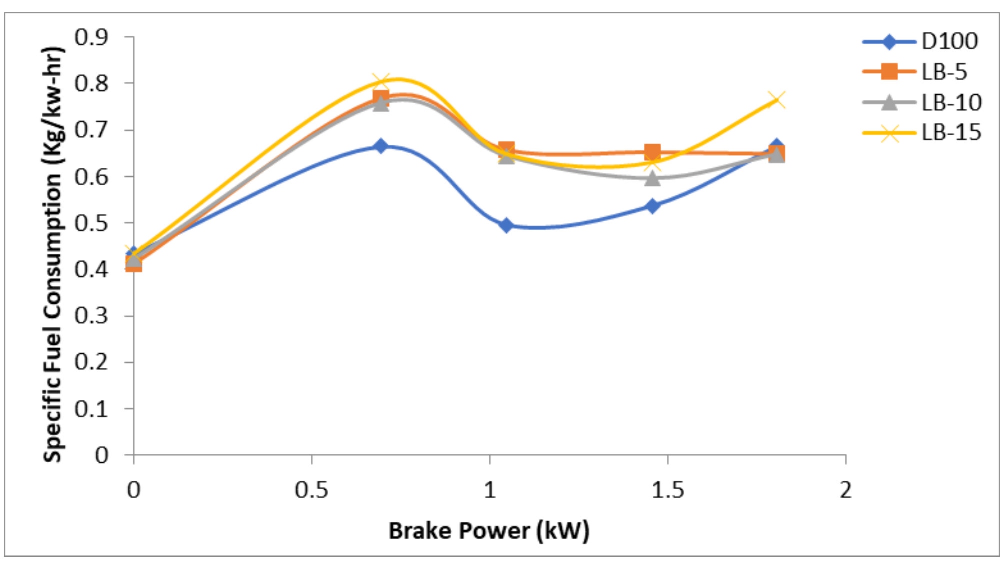

Figure 2. Brake power versus brake specific fuel consumption.

Figure 3 shows the deviation of BTE versus brake power output for the different blends of linseed biodiesel. BTE was found to increase with increase of brake power. LB5, LB10 and LB15 blends could be practically applied in Internal Combustion (IC) engine due to its higher thermal efficiency.

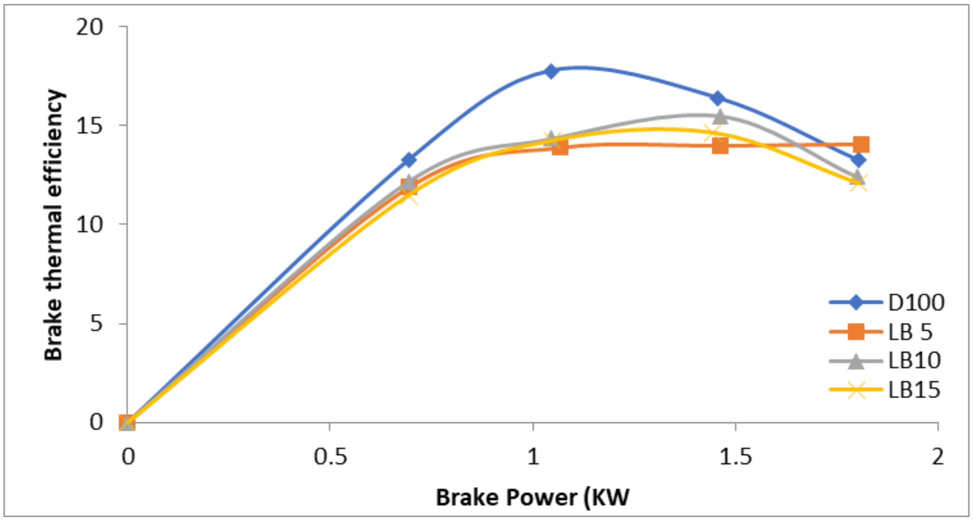

Figure.3. Brake power versus brake thermal efficiency for the test fuels

3.2. Exhaust Emissions

Figure 4 shows the exhaust emissions Carbon monoxide (CO) by load. In this study exhaust emissions of biodiesel blends were compared with diesel's. Among vehicular fuels, petro-diesel produces slightly larger quantities of particulate matters, which consists of carbonaceous material [15]. As a result, by the use of alternate biofuels the environmental impacts can be reduced. Carbon monoxide (CO) is a formation mixture of temperature and unburned flue gases, which when combined controls the rate of fuel decomposition and oxidation [17]. The minimum CO was found in the 5% blend of LB at no load, 25% and 50% load condition with 170, 190 and 210 ppm respectively. All carbon separation chemistries provide a lower CO chemistry compared to petroleum diesel. The LB15 mixture produced lower emissions than LB5 and LB10 at 0, 50 and 75 loads and increased significantly at 25 and 100 loads. [17–18]. It was found that the percentage of Carbon monoxide (CO) emission increases with the percentage of molecular fuel decomposition in the case of full loading, but it is less than that of gasoline.

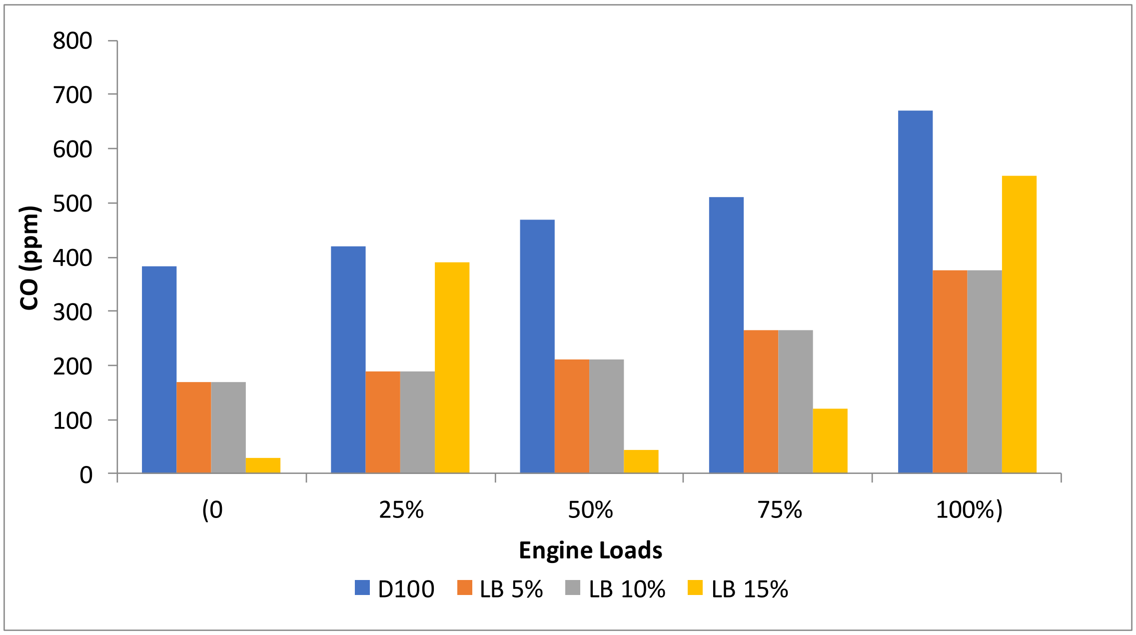

Figure. 4. Comparison of exhaust Carbon monoxide (CO) (ppm) with loads

Figure 5 shows the All biodiesel blends provide lesser carbon dioxide (CO2) emissions compared to petro diesel. LB15 blend gave slightly lower emission than LB5 and LB10. Similar results were also reported in [17-18]. The percentage of carbon dioxide (CO2) emission was found increasing with the increase of biodiesel ratios at full load condition but remained lower than that of petro diesel.

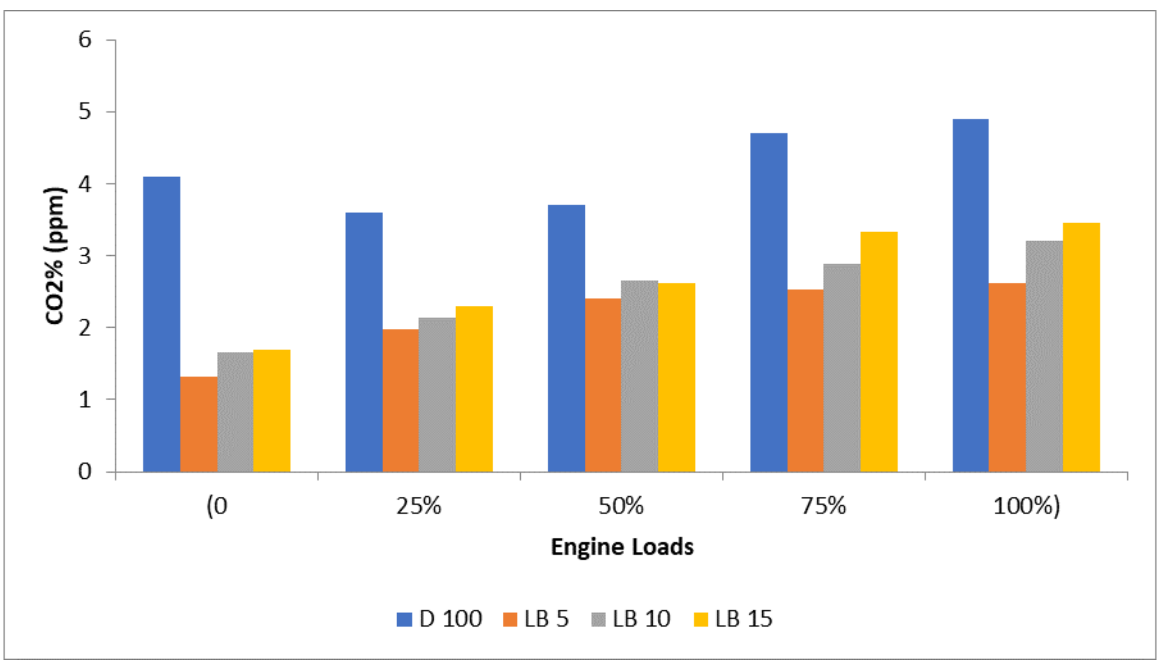

Figure. 5. Comparison of exhaust carbon dioxide (CO_2) (ppm) with loads

Figure 6 shows the nitrogen oxide levels (NOx) is an exhaust emission of diesel engines. It could create health hazards, when it is inhaled. [21]. The nitrogen oxide (NOx) emissions of all blends were found lower than that of petro diesel. Among all blends, LB5 blend emission was much lower than the ones of LB10 and LB15.but at load This reveals that the linseed biodiesel is feasible using blend forms for nitrogen oxide (NOx) reduction.

Similarly, other pollutant results, like NO2, NO and CO2 remained lower than that of 100% diesel. But the level of NOx emission of D100 was decreased dramatically at 75 % load 60 ppm and later on at 100% load was decreased more as 27 ppm, Whereas nitrogen oxide (NOx) emission of LB15 at 75 % and 100% decreased dramatically 42 ppm and 18 ppm respectively. It was concluded that at higher load nitrogen oxide (NOx) emission became lower.

Similarly, the results for other pollutants, such as HC, remained lower than the results for diesel by 100%, while the O2 was higher in all biodiesel blends Similarly, the results for other pollutants, such as HC, remained lower than the results for diesel by 100%, while the O2 was higher in all biodiesel blends.

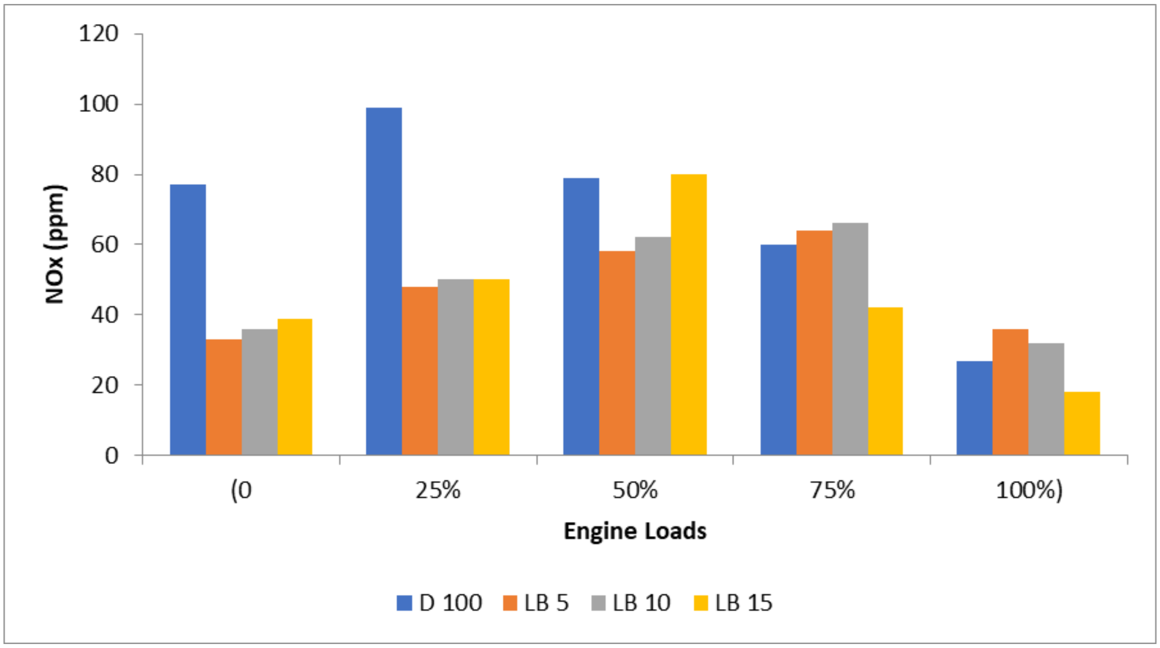

Figure. 6. Comparison of exhaust nitrogen oxide (NOx) (ppm) with loads

CONCLUSIONS

Linseed biodiesel has been produced through the esterification process using native linseeds. The produced biodiesel was blended with petroleum diesel fuel (D100) in different volume ratios of 5% (LB5), 10% (LB10), and 15% (LB15). The fuel properties of the biodiesel produced were found to be within the allowable limits of ASTM. The specific fuel consumption of the LB5 blend was found to be lower than that of the LB10 and LB15. The minimum Carbon monoxide (CO) was found in the 5% blend of PB at no load. All carbon separation chemistries provide a lower Carbon monoxide (CO) chemistry compared to petroleum diesel. The carbon dioxide (CO2), nitrogen oxide (NOx) emissions from linseed blends were found to be lower when compared to petroleum diesel fuels. All blends, LB5, LB10, and LB15 have been found to be a more suitable alternative fuel for diesel engines and can be blended with petroleum diesel without engine modifications. Through the results of emissions obtained by adding L B 5, which shows a clear decrease in greenhouse gas emissions, and this greatly improves the environment and has a large economic return. It was also noted that the cultivation and production of linseed in Iraq is very promising, so it is recommended to encourage the relevant agencies in Iraq and Tunisia to make appropriate utilization and use of linseed for energy production.

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