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Experimental Study on the Production of Karanja Oil Methyl Ester and Its Effect on Diesel Engine

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ABSTRACT: Fast depletion of fossil fuel resources forces the extensive research on the alternative fuels. Vegetable oils edible or non edible can be a better substitute for the petroleum diesel. Karanja, a non edible oil can be a potential source to replace the diesel fuel. To investigate the feasibility of Karanja oil as an alternative diesel fuel, its biodiesel was prepared through the transesterification process. The Biodiesel was then subjected to performance and emission tests in order to assess its actual performance, when used as a diesel engine fuel. The data generated for the 20, 50 and 100 percent blended biodiesel were compared with base line data generated for neat diesel fuel. Result showed that the Biodiesel and its blend showed lower thermal efficiency. Emission of Carbon monoxide, unburned Hydrocarbon and smoke was found to be reduced where as oxides of nitrogen was higher with biodiesel and its blends.

Keywords: alternate Diesel fuel; Biodiesel; Karanja oil methyl ester; performance and emission

1. Introduction

Diesel engines are widely used as power sources in medium and heavy duty applications because of their lower fuel consumption and lower emissions of carbon monoxide (CO) and unburned hydrocarbons (HC) compared with gasoline engines **[1,2]**. Dr. Rudolf Diesel first developed the Diesel engine in 1895 with the intention of operating on different fuels, including vegetable oil. Diesel exhibited his very first engine at the World Exhibition in Paris in 1900 using peanut oil as fuel.

The rapid development of the petroleum industry caused the price of petroleum fuel decrease and therefore the development of the vegetable oil as fuel was also decreased. World War II and the oil crises of the 1970’s saw brief interest in using vegetable oils to fuel diesel engines.

The growing popularity of renewable fuels is based on increasing concerns about environmental protection and shortage of crude supply. Several different vegetable oils have been investigated for their suitability as an alternate fuel. These vegetable oils are those that occupy vast areas in the country of testing. Therefore, soybean oil is a primary interest source in the United States while many European countries are concentrating on rapeseed oil **[3]**, and countries with tropical climates prefer to utilize coconut oil or palm oil **[4]**. Other vegetable oils, including sunflower, safflower, Jatropha, mahua, neem, Karanja, etc. have also been investigated. Furthermore, other sources of biodiesels studied include animal fats and used cooking oils.

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The use of raw vegetable oils in engines without any modification results in poor performance and leads to wear of engine components **[5]**. The problems faced with raw vegetable oils as fuels are poor atomization due to their high viscosity, severe engine deposits, injector coking, and piston ring sticking and incomplete combustion leading to higher smoke density **[6,7,8]**. In order to reduce the viscosity, a transesterification process is used to produce esters of vegetable oils. The process of transesterification removes glycerin from the oil and replaces it with radicals from the alcohol used for the conversion process. This process decreases the viscosity of the oil **[9]**. These esters are promising alternate fuels for compression ignition engines and are called biodiesel. It is non toxic and biodegradable, means it dissipates quickly after a spill. It does not ignite easily as conventional diesel fuel because of its high flashpoint and low volatility. This makes biodiesel safer fuel to handle.

In the present investigation, biodiesel prepared from Karanja oil was used for the study. The oil is widely available in India. Furthermore the use of non-edible vegetable oils like Karanja oil is of importance because of the great need for edible oil as food. The main objective of this experimental study is to determine the performance and exhaust emission parameter while using Karanja oil methyl ester as a fuel in a DI diesel engine. The results for KOME (Karanja oil methyl ester) were compared with those for diesel fuel.

Karanja is believed to be originated in India and distributed throughout the country from the Ravi river eastward in the hills of south India up to elevation of about 1200 metres and in the Himalayas up to about 610 metres. It is widely grown from tropical dry to sub tropical dry forest life zones. It is a widely adaptable tree that grows under the wide range of temperature from 50°C to 500°C and average rainfall of 600 to 2500 mm **[10]**. The annual production potential of Karanja is 70000 metric tonnes **[11]**.

2. Experimental setup and methodology

2.1 Production of Biodiesel from Karanja Oil

The Karanja oil was heated to about 60°C in a reactor shown in Figure 1 with a capacity of about 10L. 40% Methanol (99.9% pure) and 0.75% potassium hydroxide was mixed separately to dissolve and added to the heated 10L Karanja oil in the reactor. After the mixture was stirred for around 1.3 hours at a fixed temperature of about 60°C, it was allowed to separate layers of glycerol and ester. Once the heavy black glycerol layer was settled down, the methyl ester layer formed at the upper part of the reactor. Glycerol followed by KOME separated from the bottom part of the reactor through a valve. The yield of KOME was approximately 88 percent. After that, a gentle washing process was carried out to remove some un-reacted remainder of methanol and catalyst using heated distilled water which if not removed can react and damage storing and fuel carrying parts.

Fig.1. Biodiesel Reactor

During washing ester present react with water and can form soap. Figure 2 shows the product of rigorous washing by using higher percentage of water and Figure 3 shows the product of gentle washing by using lesser percentage of water. Two to three gentle washing was required to remove un-reacted remainder but it may leads to loss of esters. After washing two distinct layer formed with bottom layer having water and impurities settled down and removed. The upper layer is of biodiesel.

A heating process at about 60°C was applied for removing water contained in the esterified Karanja oil and finally, left to cool down. Figure 4 shows the two samples showing difference between the washed sample and washed and dried sample.

In this study reaction time from 30 min to 2 hours, catalyst percentage from 0.5% to 2%, methanol percentage from 20% to 40% have also investigated and found that 0.75% catalyst 40% methanol and 1.3 hours time gives maximum yield of ester.

The experimental setup shows in Figure 5 consists of a four cylinders, four stroke, naturally aspirated diesel engine, an engine test bed with hydraulic dynamometer. The specifications of the test engine are given in Table 1.

Table 1
Test Engine Specification

Make	Force Motors
Cylinder Number and type	Four, Four stroke
Bore(mm)	78
Stroke(mm)	95
Compression Ratio	18.65:1
Rated Power (H.P.)	27
Rated speed	2200 rpm

The test bed contains instruments for measuring various parameters such as engine load, air flow by anemometer, gas temperatures by K type thermocouples. The fuel consumption was determined by weighing the fuel on an electronic scale. For the analysis of the exhaust, Eurotron green line gas analyzer and AVL 437 smoke meter was used. The CO and HC were measured by the principle of NDIR and NOx by electrochemical sensors. The fuel properties are tested and given in Table 2.

3. Results and Discussion

Experiments were conducted at the constant speed of 2000 rpm by varying loads. Initially neat diesel was tested to prepare the baseline data, and then the blends of 20 percent (B20), 50 percent (B50) and 100 percent (B100) Karanja oil methyl ester with diesel were tested.

3.1 Brake specific fuel consumption

Figure 6 shows the variation of Brake specific fuel consumption (BSFC) with BMEP of the tested fuels. The brake specific fuel consumption was decreased with increase in load. The values of BSFC of the KOME and its blends were found slightly higher than neat diesel under all range of engine loads. The B20, B50 and B100 reported 6.4, 15 and 28 percent average increased fuel consumption than the neat diesel fuel. The reason of higher BSFC of KOME and its blend was due to lower calorific value and hence higher amount of fuel was required to produce the same amount of energy. Some researcher reported the similar trend **[12-15]**. Different trend was also reported by some researchers **[16-17]**.

Fig.2. Product of Rigorous washing

Fig.3. Product of gentle washing

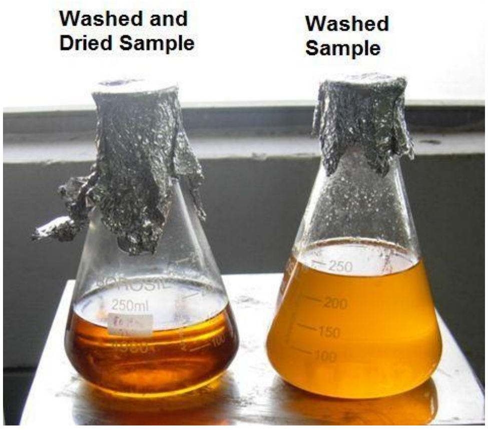

Fig.4. Difference of drying

Fig.5. Engine Setup

Table 2
Fuel Properties of Diesel and KOME

Properties	Test Method	Diesel	KOME
Kinematic viscosity @ 40^{0}c, cSt	D445	2.4	5.5
Density@15^{0}c, kg/m^3	D1298	822.4	891.8
Flash Point, ^{0}C	D93	67	136
Net Calorific Value, MJ/kg	D240	42.7	37.58
Water and sediments % volume	D2709	0.01	0.02
Sulphur, %wt	D4294	0.28	Nil

3.2 Brake specific Energy consumption

The Figure 7 shows the variation of BSEC with BMEP. The Brake specific fuel consumption (BSFC) is not a reliable criterion for comparing two fuels of different calorific value. Hence brake specific energy consumption (BSEC) is more reliable for this purpose, which takes into account the calorific value of fuel. The values of BSEC were decreased with the increase in load. The possible reason could be the reduction in losses at higher loads. BSEC of KOME and its blends were found higher than diesel fuel. B20, B50 and B100 KOME showed an average 5.56, 8.92 and 12.4 percent higher energy consumption. The increase in the energy consumption of Biodiesel and its blends could be the higher viscosity, density and lower volatility resulted in higher amount of fuel injected than the diesel fuel, which affects the formation of mixture and leads to more dominating diffusion combustion phase. Some researchers have reported the different trends of BSEC with increasing load **[18,19]**.

3.3 Brake thermal efficiency

Thermal efficiency is the ratio of power output to the energy of injected fuel. Energy of the injected fuel is the product of mass flow rate of fuel and calorific value, which is referred as brake specific energy consumption and hence BTE is indicating the inverse of BSEC. Figure 8 is representing the variation of brake thermal efficiency (BTE) with BMEP. The values of BTE were increased with increasing load in all cases. This was due to reduction in heat losses at higher load. The BTE of neat KOME and its blends showed lower brake thermal efficiency compared to diesel fuel. The B20, B50 and B100 KOME showed average 5.26, 8.16 and 11.03 percent reduction in BTE respectively. This reduction can be attributed to the lower calorific value which

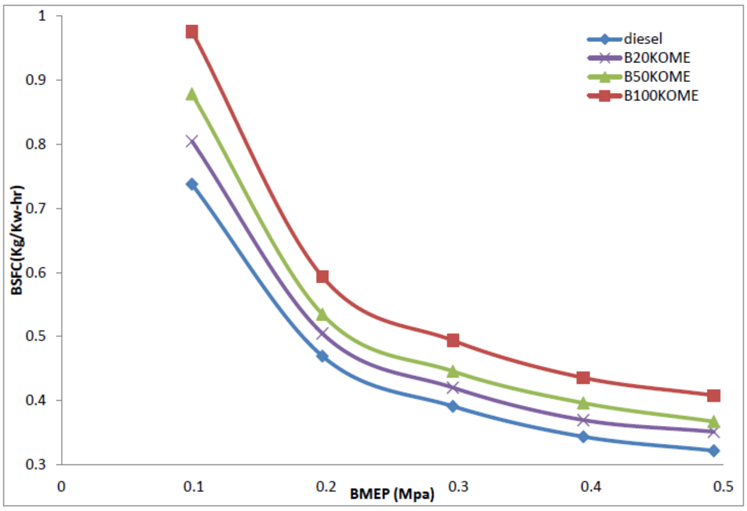

Fig.6. Variation of BSFC with BMEP

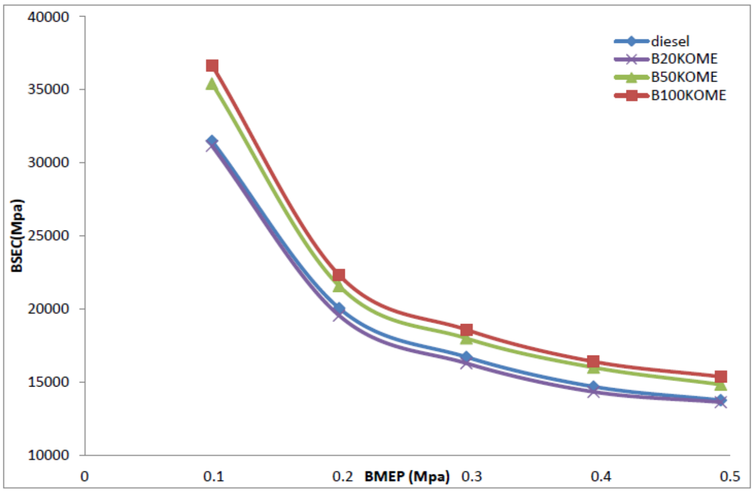

Fig.7. Variation of BSEC with BMEP

leads to increase in the specific fuel consumption. The increase in fuel consumption requires the increase of volume and duration of fuel injection. Since the fuel was injected at fixed injection timing more fuel was injected during the expansion stroke and leads to more diffusion combustion. Some of the researchers have found no significant change in thermal efficiency while using diesel, biodiesel and the different blends **[3]**, some have reported increased efficiency with all the blends of biodiesel**[11,21]**.

3.4 Exhaust gas temperature

The Figure 9 shows the variation of Exhaust gas temperature with the BMEP. Increasing the load showed increase in the exhaust gas temperature. This is due to the higher amount of fuel injected at higher load. KOME and its blends showed higher exhaust gas temperature than the diesel fuel. The 20, 50 and 100 percent KOME blend showed average 3.75, 9.30 and 15.19 percent increased temperature compare to average diesel temperature. This can be due to the higher amount of fuel injected during combustion which indicates the higher heat loss in the form of exhaust gas temperature.

3.5 CO Emissions

The Figure 10 shows the variation of Carbon monoxide (CO) with the BMEP. It was observed that the increasing the load decreases CO emission this trend was different from most of the other researchers **[13,15,16,22,23]**, but similar trend was observed by few **[24,25]**. The maximum and minimum value of CO emission for the neat diesel was 433, 174 ppm and that of neat KOME was 340 and 143 ppm respectively. The diesel fuel showed highest CO emission and the KOME blends showed reduction in CO emission.

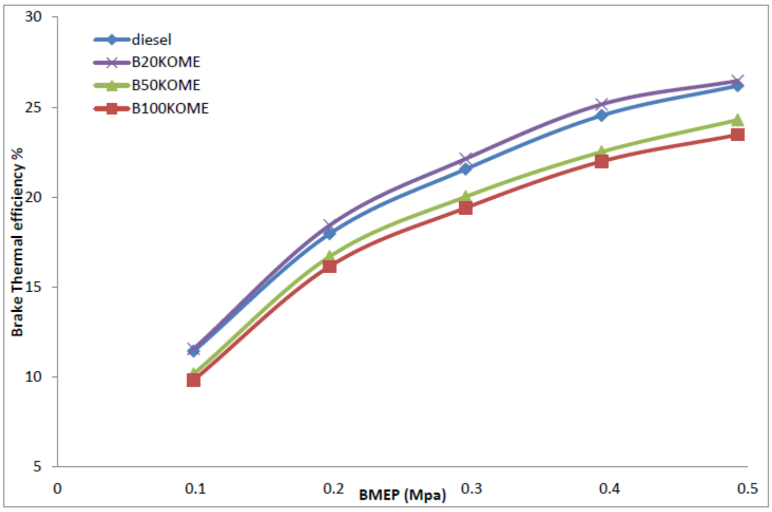

Fig.8. Variation of Brake Thermal efficiency with BMEP

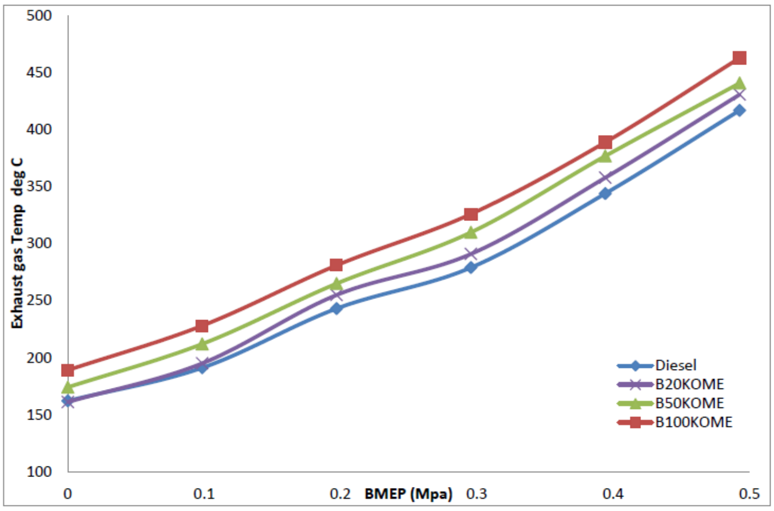

Fig.9. Variation of Exhaust gas temp with BMEP

The 20, 50 and 100 percent blend showed 6.46, 11.13 and 14.54 percent average reduction compared to neat diesel fuel. The reduction in the CO emission may be attributed to the conversion of the CO into CO_2 by taking the oxygen present in the KOME molecules. The CO emission also depends upon the Carbon to hydrogen ratio and the cylinder temperature. In case of KOME biodiesel fuel carbon to hydrogen ratio is comparatively lower and the cylinder temperature is higher than diesel fuel which results in lower formation of carbon monoxide. Similar finding was reported by **[13-15,23]**.

3.6 HC Emissions

The Figure 11 shows the variation of Hydrocarbon emission (HC) with the BMEP. It was observed that the increasing the load increases HC emission and the blending of KOME with diesel fuel decreases the hydrocarbon emission. Diesel fuel showed highest HC emission where as B100 showed lowest. The 20, 50 and 100 percent blend showed average reduction of 4.87, 10.47 and 14.88 percent respectively compared to diesel fuel. The reduction in HC emission is the indicative of cleaner combustion which could be due to the presence of oxygen in the KOME with high combustion temperature make the HC oxidation easier. Similar finding was reported by **[14,15,23]**.

3.7 Nitrogen Oxide Emissions

The Figure 12 shows the variation of Nitrogen oxides (NOx) emission with the BMEP. NOx emission increased with the engine load. The diesel fuel showed lowest NOx emission and the blending with KOME showed increased NOx emission. Comparatively higher NOx emission was observed at higher load.

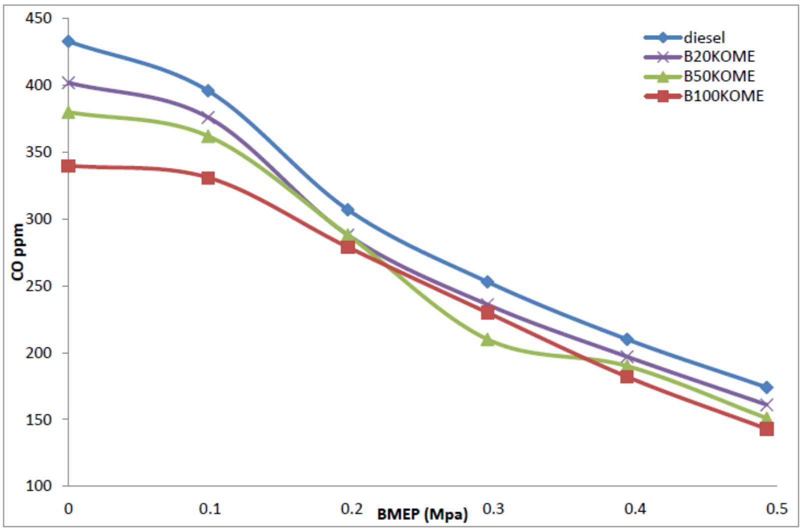

Fig.10. Variation of Carbon monoxide emissions with BMEP

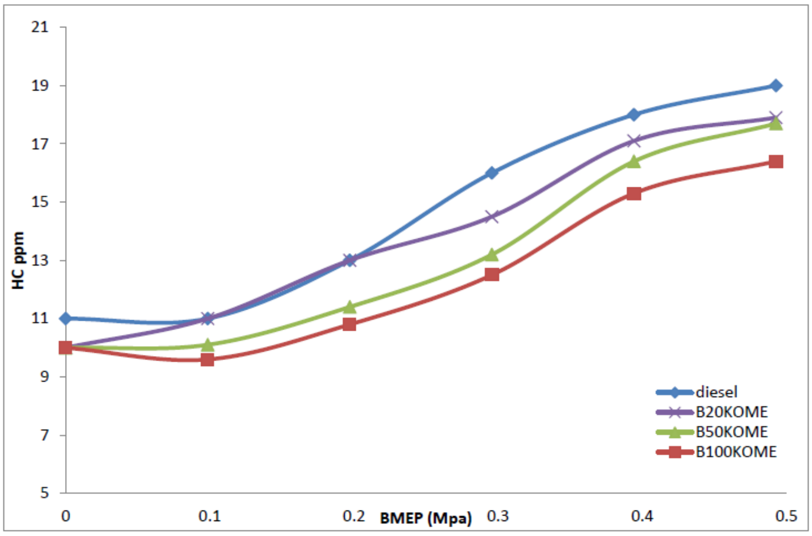

Fig.11. Variation of Hydrocarbon emissions with BMEP

The neat KOME showed highest NOx emission of 847 ppm and where as neat diesel showed 715 ppm at the BMEP of 0.5 MPa. The 20, 50 and 100 percent blend showed an average of 3.42, 11.12 and 18.11 percent increase NOx compared to diesel fuel. The increase in the NOx emission may be attributed to injection advance due to physical properties of biodiesel (viscosity, density, compressibility, sound velocity). The Injection of biodiesel results in quicker pressure rise produced by the pump due to the higher bulk modulus, quick propagation towards the injectors due to its higher sound velocity, and less leakage in the pump due to its higher viscosity leading to an increase in the injection line pressure. Thus needle opens at an earlier point than the diesel fuel. The advance start of injection leads to higher ignition delay this leads to higher pressure and temperature peaks. Higher temperature peaks leads to increased NOx formation **[20,26,27]**.

3.8 Smoke Emissions

Smoke opacity, considered as the indicator of dry soot emission and particulate matter emission, which have soot as their main components. The Figure 13 shows the variation of Smoke emission with the BMEP. It was observed that the increasing the load increases smoke emission. The blending of KOME with diesel fuel decreases the smoke emission. No significant changes in smoke was observed at lower load, however higher load showed highest of 23.6 percent reduction in smoke with neat KOME. The 20, 50 and 100 percent blend showed average reduction of 6.6, 7.17 and 11.76 percent respectively compared to diesel fuel. The possible reason of smoke reduction could be attributed to the presence of fuel bound oxygen, even in the regions of combustion chamber with fuel rich diffusion flame.

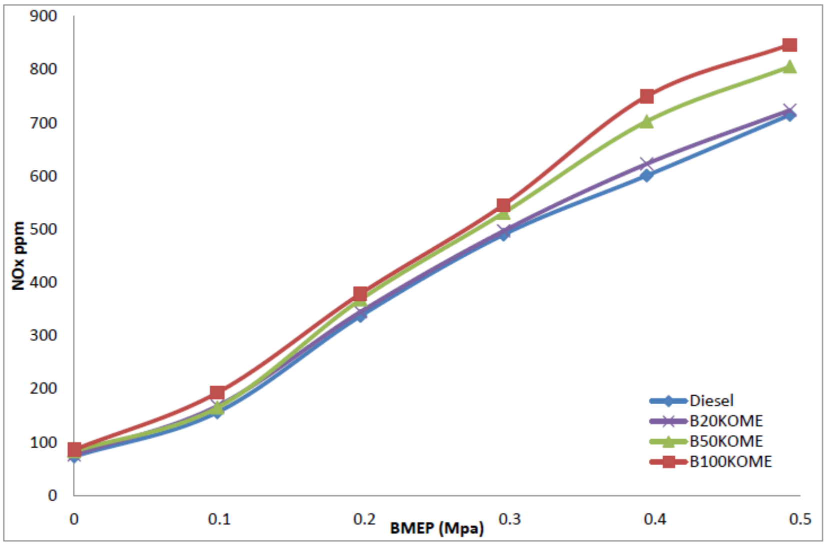

Fig.12. Variation of NOx Emissions with BMEP

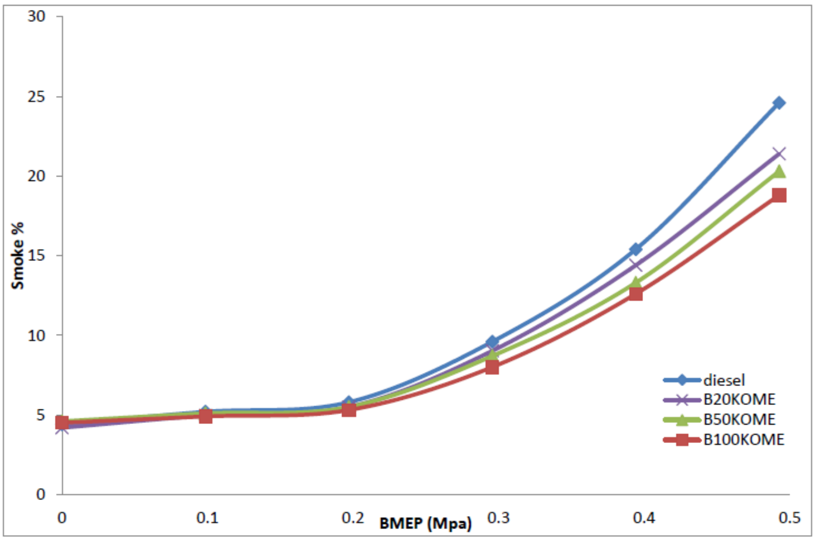

Fig.13. Variation of Smoke emissions with BMEP

Some of the studies suggested this reduction due to absence of the aromatics which considered as soot precursors in the biodiesel **[28,29]**. The combustion advance caused by biodiesel fuel properties increases the residence time of soot particles at elevated temperature promotes oxidation **[27]**.

4. Conclusion

In this study, biodiesel was prepared in our laboratory from Karanja oil. The KOME and its blends were compared with diesel fuel. Based on the experimental study, the main result of performance and emission parameters are summarized as follows.

- The KOME showed higher fuel consumption and higher energy consumption than diesel fuel.
- The thermal efficiency of Biodiesel and its blends was lower than the diesel fuel.
- The emission of KOME and its blends showed reduction in carbon monoxide, Hydrocarbon and smoke emissions where as NOx emission was found higher compared to diesel.
- The 20 percent blend of KOME showed higher average reduction in CO, HC, and Smoke in comparison to average increase in NOx

So it can be concluded from the above mentioned findings that the Karanja oil methyl ester (KOME) and its blends can be used as an alternative fuel in diesel engine without any significant modification in the engine.

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