Preparation and Application of Karanja Bio-diesel and it's Blends in a Twin Cylinder Diesel Engine

Chandrakanta Nayak[1*], Saroj kumar Achrya[2] and Ranjan kumar Swain[3]

[1,2]*Department of Mechanical Engineering, SOA University, Bhubaneswar-751030, Odisha, India*

[3]*Department of mechanical engineering I.G.I.T. Saranga, Dhenkanal, Odisha*

[1]*E-mail: chandra_kec@rediffmail.com;* [2]*E-mail: saroj.achrya76@gmail.com;* [3]*E-mail: ranjanigit@yahoo.com*

Abstract: Biodiesel are becoming popular as alternative eco-friendly fuel now days. The petroleum product requirement is going on increasing day by day in India with limited resources in the oil pool. Crisis of petroleum fuel and import of fossil fuel is giving a high impact on the economy and development. Besides the economy and development, fossil fuel also leads to a major problem like global warming and climatic change. The emission of harmful gasses like CO, NOx, $CO_{2,}$ and smoke density causes acid rain, health hazard and also global warming. The high oil price, environmental concern and supply instability put many researchers to go for alternative fuel i.e. biodiesel. Biodiesel is part of the solution which reduced many of the problems. The objectives of this study are performance analysis of biodiesel blends from karanja oil which is known as Karanja oil methyl ester (KOME). Engine tests have been carried out in a water cooled four stroke diesel engine and experimental investigation have been carried out to examine performance and emission of different blends of KOME. The study reveals that the emission parameters are better for biodiesel blends fuel compared to diesel. Whereas, brake thermal efficiency and brake specific fuel consumption parameters are inferior compared to diesel.

Keywords: Biodiesel, twin cylinder, blend, performance, emission

1. INTRODUCTION

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources such as plant oils, animal fats, used cooking oil and even from algae. Biodiesel contains no petroleum, but can be blended at any level with petroleum diesel to create a biodiesel blend. Biodiesel blends can be used in compression ignition engines with little or no modifications. Among the vegetable oils edible and non-edible oils are used to produce biodiesel. The use of edible is a great concern with food materials. So it is justified to use non edible for the production of biodiesel. Non edible trees can grow in inhospitable condition of heat, low water, rocky and sandy soils. So non-edible oil plants like karanja, jatropha, mahua, neem will be the best choice for the source of biodiesel production. The use of Karanja biodiesel in conventional diesel engines when used alone or with blends with petroleum diesel substantially reduces exhaust emission such as the overall life cycle of carbon dioxide (CO2), particulate matter (PM), carbon monoxide (CO), sulfur oxides (SOx) and unburned hydrocarbons(HC) with reducing the green house emission also. Regarding the power is same to that of diesel engine. The specific fuel consumption is more or less the same. The brake thermal efficiency is slightly on higher side. The aim of the present study is to experimentally investigate the effect of different blends of KOME on the performance of diesel engine. The results were compared with petroleum diesel.

In recent years several researches have been made to use vegetable oil,animal fats as a source of renewable energy known as bio diesel that can be used as fuel in CI engines. Vegetable oils are the most promising alternative fuels for CI engines as they are renewable, biodegradable, non toxic,environmental friendly, a lower emission profile compared to diesel fuel and most of the situation where conventional petroleum diesel is used. Even though "diesel" is part of its name there is no petroleum or other fossil fuels in bio diesel. It is 100% vegetable oil based, that can be blended at any level with petroleum diesel to create a bio diesel blend or can be used in its pure form. Non edible vegetable oils are the most significant to use as a fuel compared to edible vegetable oils as it has a tremendous demand for using as a food and also the high expense for production. Therefore many researchers are experimenting on non edible vegetable oils.

In India the feasibility of producing bio diesel as diesel substitute can be significantly thought as there is a large junk of degraded forest land, unutilized public land, and fallow lands of farmers, even rural areas that will be beneficial for overall economic growth. There are many tree species that bear seeds rich in non edible vegetable oils. Some of the promising tree species are Pongamia pinnata (karanja), Meliazadirachta (neem), Jatropha curcas (Ratanjyot) etc. But most surprisingly as pertheir potential only a maximum of 6% is used. Major problems encountered with vegetable oil as bio diesel used in CI engine are its low volatility and high viscosity due to long chain structure. Thecommon problems faced are excessive pumping power, improper combustion and poor atomization of fuel particles. The conversion of the vegetable oil as a CI engine fuel can be done any of the four methods; pyrolysis, micro emulsification, dilution/ blending and transesterification.

Number of research papers and studies has been conducted on the use of karanja biodiesel blend as a substitute of fuel and effect of changes in parameters like injection pressure, injection timing, fuel quantity, fuel spray pattern etc. Number of reviews has been taken below to complete the present study.

Nagarhalli M. V. *et al.*, [1] have tested KOME and found that HC emission decrease by 12.8% for B20 and 3% for B40 at full load. NOx decreased by 39% for B20 and 20% for B40 at full load. BSEC increased by 7% for B20 and 1.9 % for B40 at full load. A B40 blend has been recommended by the author.

H. Raheman and A. G. Phadatare *et al.*, [2] Emissions and Performance of Diesel Engine from Blends of Karaja Oil Methyl Ester(KOME) and Diesel have used for test. They found the average BSFC was 3% lower than diesel in case of B20 and B40. Maximum BTE was found to be 26.79% for B20 which is 12% higher than diesel. They concluded that B40 could replace diesel.

Nitin Shrivastava *et al.*,[3] made the experiment on JOME and KOME indicated that the emission of both showed reduction in CO, HC and smoke emission where as NOx emission was found higher compared to diesel.

Ramchandra S. Jahagidar *et al* [4] carried experiment on KOME found that for KOME the brake power of the engine was almost same for all the loads. For BTE of KOME were improved by 3.8%. Volumetric efficiency also improved. They concluded that B40 & B60 will have the optimum performance.

Meher *et al.* (5) studied the transesterification of Pongamia pinnata oil by means of methanol to study the feasibility of methanolysis process by using potassium hydroxide catalysts. The yield of biodiesel obtained was >97 per cent by using oil/ methanol molar ratio 12:1, potassium hydroxide as catalyst, at 65oC and stirring at 360 rpm in 3 h. The biodiesel was characterized by TLC and HPLC analysis to determine the fatty acid methyl esters, mono-, di- and triglycerides and glycerol. The properties like viscosity, flash point, cloud point, and pour point have been determined for accessing the fuel quality of karanja based biodiesel.

Krawcyzk (1996) (6) - Biodiesel, an alternative diesel fuel, is made from renewable biological sources such as vegetable oils and animal fats. It is biodegradable and non-toxic. It also has low emission profiles and so is environmentally beneficial.

A.S. Ramadhas *et al.* [7] conducted the Experimental analysis of the engine with various types of biodiesel and their blends, require much effort and time. In the present investigation, biodiesel is produced using unrefined rubber seed oil. The performance tests are carried out on a C.I. engine using biodiesel and its blends with diesel (B20 and B100) as fuel. The effects of relative air-fuel ratio and compression ratio on the engine performance for different fuels are also analyzed using this model. The comparisons of theoretical and experimental results are presented.

A. S. Ramadhas *et al.* [8] used the pure rubber seed oil, diesel and biodiesel as fuel in compression ignition engine. The performance and emission characteristics of the engine were analyzed. The lower blends of biodiesel increased the brake thermal efficiency and reduced the fuel consumption. The exhaust gas emissions were reduced with the increase in biodiesel concentration. The experimental results proved that the use of biodiesel (produced from unrefined rubber seed oil) in compression ignition engines is a viable alternative to diesel.

V. S. Hariharan *et al.* [9] conducted the performance of the cottonseed oil fuelled engine in comparison with diesel fuelled engine. It could be run without any difficulty by using cottonseed oil either in esterified form or in refined form. These blends of cottonseed oil could be recommended for present diesel engines without any modification. Heat loss in the engine was reduced by the usage of cottonseed oil. It was because exhaust gas temperatures were lower, when compared to those of diesel. Hence brake thermalefficiency of cottonseed oil was high. Thus the above investigations suggested that esterified vegetable oil can be effectively employed in emergency as a suitable alternative fuel in place of existing diesel.

B. Premanand *et al.* [10] the experiments were conducted on a single cylinder diesel engine. The performance, smoke emissions and combustion parameters of diesel, 100% bio-diesel, 30% and 50% blends are calculated. Performance was increased in lower blends with reduced fuel consumption, but NOx was much higher for diesel and blends, and lower for 100% bio-diesel. Particulate matter was higher for neat diesel and lower for 100% bio-diesels.

N. Usta, [11] conducted an experimental study on the performance and exhaust emissions of a turbocharged indirect injection diesel engine fuelled with tobacco seed oil methyl ester, which was performed at full and partial loads. The results showed that the addition of tobacco seed oil methyl ester to diesel fuel reduced CO and SO2 emissions while causing slightly higher NOx emissions. Meanwhile, it was found that the power and the efficiency increased slightly with the addition of tobacco seed oil methyl ester.

H. Raheman *et al.* [12] Used diesel, Bio-diesel mixed with diesel used in diesel engine for the investigation of combustion and emission parameters. It was observed that biodiesel blends with diesel showed lower CO, Smoke and increase NOx Emissions. NOx emission is to be reduced slightly whenever EGR was applied.

2. METHODS OF BIODIESEL PRODUCTION AND ITS BLENDS

2.1. Collection of Crude Karanja Oil

The crude karanja oil is collected from North Odisha which is a clear, viscous and dark brown in colour. After collection, then it is filter with a nylon mesh cloth filter.

2.1.1. Degumming of Karanja Oil

The method of removal of phosphorus from crude karanja oil is known as degumming. A fixed quantity of refined crude oil (1250 ml for each run) was taken in a flask and 1% v/v phosphoric acid was mixed with it. The oil is stirred continuously for one hour at a temperature of 65^{o}C. Then it is allowed to settle down for two hours and then purified karanja oil was collected from the upper layer.

2.2. Estrification of Karanja Oil

In this process same quantity of degummed karanja oil was taken in a biodiesel processor along with 22% v/v methanol and1% v/v ratio sulphuric acid. The mixture is then stirred for period of one hour at a temperature of 65^{o}C. This process is further repeated for purification of karanja oil.

2.3. Transestrification of Karanja Oil

In this process an equal amount of acid esterified Karanja oil i.e. 1250 ml was taken in transestrification unit which consists of round bottom flask of 2.0 liter capacity unit with a separation valve at bottom and an electrical stirrer at the top of the flask. A reagent mixture was prepared with anhydrous methanol (22% v/v) and base catalyst KOH (0.5% v/v). The regent mixture was supplied in to the transesterification unit to get mixed with the acid esterified Karanja oil. The total mixture was then continuously stirred at a constant speed below a temperature of 65^{o}C (i.e. the boiling point of methanol) for about 1.5-2.0 hours. Then the stirring and heating was stopped and the mixture was allowed to settle down for about 24 hours. After settling, glycerol which is dark in colour was obtained in the lower layer and separated through separating valve. The upper layer which is Karanja methyl ester was collected separately. Then water washing of methyl ester was performed 2-3 times to remove extra esters and KOH. It was then heated above 65°C to remove additional methanol to obtained pure Karanja biodiesel.

2.4. Preparation of Biodiesel Blends

The Karanja biodiesel was then blended with fossil diesel (FD) in various concentrations to get biodiesel blends. These blends were used in the engine test. In the present work, the blends used are B10, B20 and B30. B10 blend is prepared by mixing 10% Karanja biodiesel and 90% diesel by weight basis followed by the preparation of other two blends.

2.5. Determination of Fuel Properties

After production of biodiesel and its blends some of the important properties of the fuel were carried out before use in diesel engine. Fuel properties like density, kinematic viscosity, acid value, free fatty acid (FFA), flash point, fire point, cloud point, pour point and calorific value etc were estimated using various ASTM methods. The estimated fuel properties of different test fuels are given in Table 1.

Table 1
Properties of Test Fuels

Properties	*Diesel*	*Karanja oil*	*Karanja biodiesel*	*B10*	*B20*	*ASTM Methods*
Density at 25°C(Kg/m^3)	825	925	885	827	831	D 1298
Kinematic viscosityat 40°C (cSt.)	2.76	28.69	5.12	2.92	3.88	D 445
Acid value (mg KOH/g)	-	30.76	1.13	-	-	D 664
FFA (mg KOH/g)	-	15.4	0.56	-	-	D 664
Calorific value (MJ/kg)	42.5	34.7	37.5	42	41.5	D 240
Cetane number	47	32.33	56.65	52.4	53	D 613
Flash point (°C)	73	219	161	79	81	D 93
Fire point (°C)	103	235	189	102	109	D 93
Cloud point(°C)	-10	9	5	-	-	D 2500
Pour point(°C)	-19	3	-2	-	-	D 97

3. TEST PROCEDURE AND METHODOLOGY

The experimental setup consists of a twin cylinder 4-stroke diesel engine with electrical generator and bulb loading devices supplied by Prakash Diesels Pvt. Ltd. Agra, a downdraft type biomass gasifier, gas cooler, gas filter supplied by Ankur Scientific Energy Technology Pvt. Ltd., Baroda. The photograph of experimental setup is shown in figure 1. The detailed specifications of the engine are given in Table 2. The engine was always operated at its rated speed of 1500 rpm, injection timing of 23° before top dead centre (BTDC) and injection pressure of 220 bars. The test is carried out under single mode operation of diesel, B10 and B20 under different load conditions. The performance and emission studies were observed at the above case of operation. The AVL make 5-gas analyzer (model no. AVL Digas 444) and smoke meter (model no. AVL 437 C) with accuracy ±1% is used to measure exhaust gas emission parameters. A mechanical type thermocouple is used to measure exhaust gas temperature.

Table 2
Engine Specifications

Make	*Prakash Diesel Pvt. Ltd. Agra*
Rated horse power	14 Hp
No of cylinder	Two
No of stroke	4-stroke
Rpm	1500
Compression ratio	16.:1
Bore diameter	114 mm
Stroke length	110 mm
Injection pressure	220 bar
Injection timing	23° BTDC
Alternator	10.3 kW, directly coupled to engine15 KVA, 21 amp, 3-phase, 415 volt

Figure 1: Photograph of Experimental Setup

4. RESULT AND DISCUSSION

The experiment is conducted by using the above engine to analyze the performance, and emission characteristics of different blends of KOME were compared with fossil diesel.

4.1. Brake Thermal Efficiency

The variation of brake thermal efficiency with load for different fuel blends are shown in fig.2. In all the cases brake thermal efficiency is increased with increased in load. The maximum efficiency obtained in this experiment was 28.75% (diesel), 24.58% (B10) and25% (B20). But considering the viscosity B20 is the better option and this value is comparable with the maximum brake thermal efficiency for diesel. From figure, it is found that brake thermal efficiency is increases for all fuels with increase in load conditions due to better combustion & high cylinder temperature. Brake thermal efficiency of diesel is more than biodiesel due to higher calorific value.

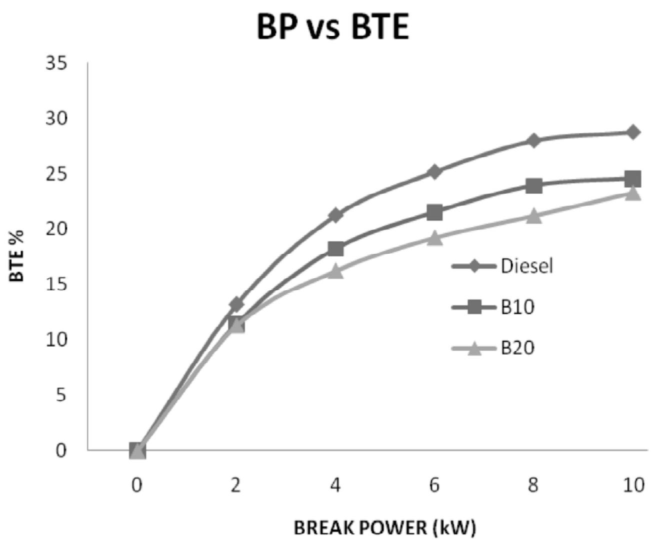


Figure 2

4.2. Brake Specific Fuel Consumption (BSFC)

The variation of BSFC at different load is shown in figure 3. For all cases BSFC reduces with increase in load. But at full load this value increases for all fuels. The increase in the BSFC for different blends compared to diesel. This may be due to increase in biodiesel percentage ensuring lower calorific value of fuel. Another reason for the increase in BSFC in biodiesel in comparison to petro diesel may be due to a change in the combustion timing caused by the biodiesel's higher cetane number as well as injection timing. At 8 kW load BSFC reduces a minimum of 0.37 kg/kWh for B20 fuel and at highest load it is 0.43 kg/kWh.

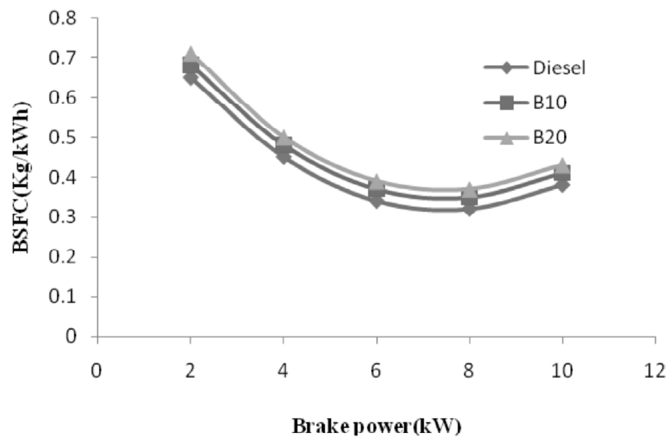
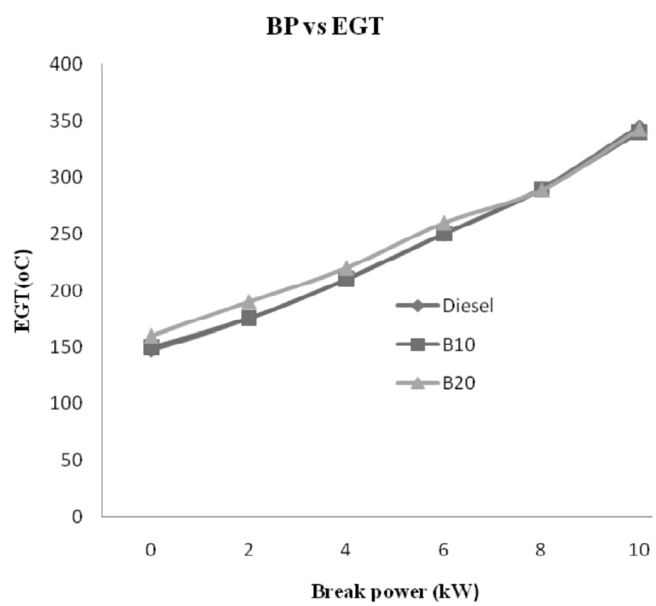


Figure 3

4.3. Exhaust Gas Temperature

The exhaust temperature variation profiles for different test fuels under different loads are shown in fig. 4. With increase in load on the engine the exhaust gas temperature increases for all fuels, however, for biodiesel blends the gas temperature is lower than that of the diesel fuel at highest load, where at low & higher load operation it is observed to be greater than that of the diesel fuel. This is due to higher energy released after combustion as result of higher viscosity of blended fuels.



Figue 4

4.4. CO emission

The variation of CO produced with diesel and blends are presented in fig. 5. The amount of CO produced, whether for a B10 or a B20 is much less

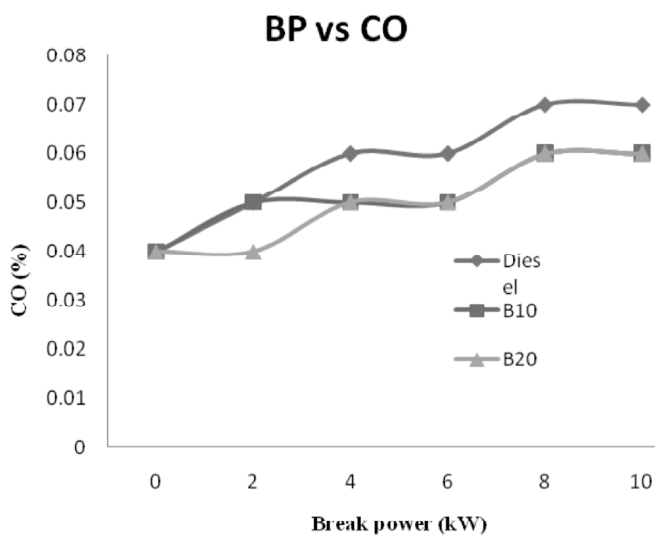


Figure 5

than the CO produced from the diesel that indicates the complete combustion of the biodiesel which being an oxygenated fuel. For B20 blend the maximum and minimum CO produced is 0.06 % and 0.04 %, which is much less than, mentioned in EURO – IV Norms. It is an indication of the complete combustion of biodiesel being an oxygenated fuel. At full load CO emission is more due to rich mixture of fue

4.5. NO_x Emission

The variation of NO_X at different engine load is presented in fig. 6. The cetane numbers of the

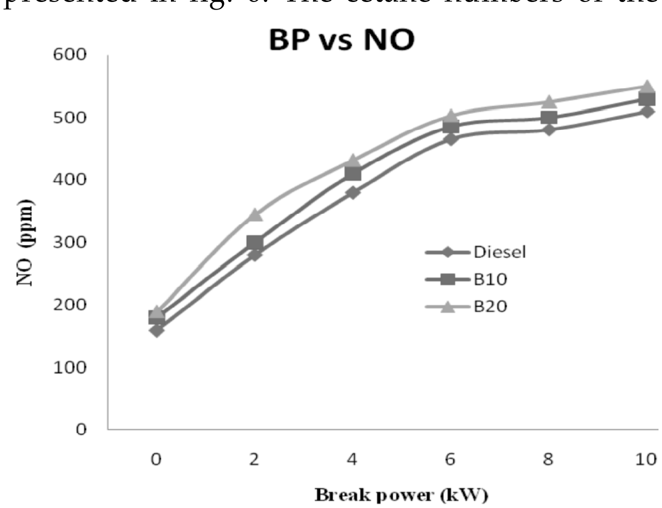


Figure 6

biodiesel are generally higher than that of diesel fuel which associated with higher NOx emission. The other reason may be due to presence of oxygen bonding in biodiesel, so better combustion hence NO_x emission is more for blend fuels. The injection timing advancement associated with these effects could be partially responsible for the increase in NO_X emissions. For B20 blend the maximum and minimum NO_X produced which is much less than, mentioned in EURO – IV Norms. NOx emission is increased due to higher energy input and more combustion temp with increases in load for all types of fuel.

4.6. Hydrocarbon (HC) Emission

The variations of un-burnt hydrocarbon at different engine loads for all fuels are shown in fig. 7. The shorter ignition delay associated with biodiesel,

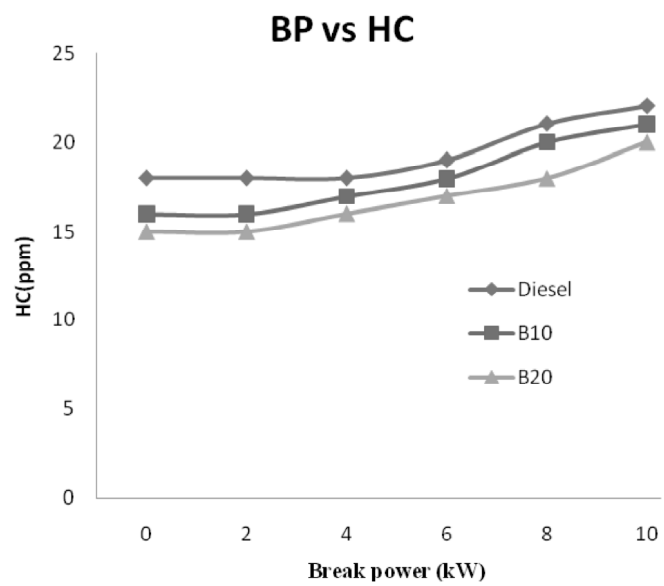


Figure 7

higher cetane number could also reduce the emission of HC in compare to diesel. For B20 the maximum and minimum HC produced is which is around same as that is mentioned in EURO – IV Norms. At higher loads the emission of HC is more due to rich mixture with incomplete combustion of fuel.

4.7. CO_2 emission

The variation of CO_2 produced at different engine load is presented in fig. 8. For B20 blend the percentage of CO_2 emission increases due to

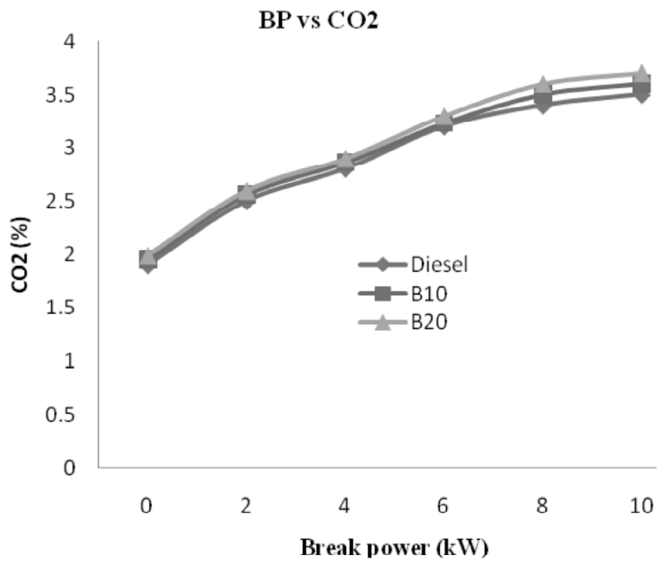


Figure 8

incomplete combustion of the fuel compare to diesel. But it has no bad effect on atmosphere on the net life cycle basis because the carbon in biodiesel emission is recycled by biodiesel plant. The CO_2 emission increases for all fuels with increase in load due richness of mixture

4.8. Opacity

From the figure 9, it is observed that smoke opacity emitted with biodiesel as fuel was lesser than diesel fuel. This is due to diesel is fully hydrocarbon fuel so smoke emission is more but biodiesel is oxygen bonding fuel, higher cetane number hence better combustion. With increase in load the smoke emission is more due to absence of fresh air.

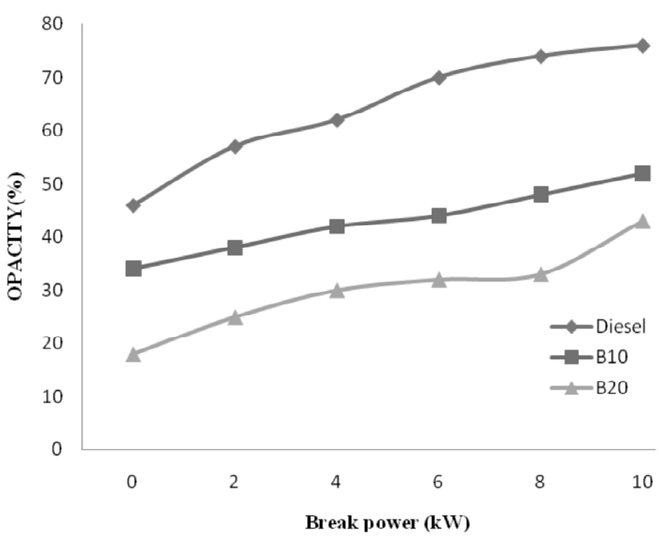


Figure 9

5. CONCLUSION

By transesterification method karanja crude oil was converted to KOME. Major of the fuel properties were tested. Performance and emission tests were conducted by using a four stroke diesel engine. Respective graphs were plotted and results were analyzed and compared with diesel. The major conclusions were drawn based on the tests.

- Lower calorific value indicates more oil consumption.
- The specific gravity, Kinematic viscosity of B20 and B10 blends is much closer to diesel.
- BSFC reduces with increase in load but at full load increases.
- BTE shows better result for diesel.
- Incomplete combustion of KOME is much lower than diesel which was indicated in smoke opacity curve.
- Exhaust gas temp is higher compare to diesel.
- CO_2 & NO_x emissions are found to be more for KOME blends while HC,CO and smoke emissions are lowered as compared to diesel.

From the above observation it can be concluded that besides considering the economy part blends of B20 and B10 of Karanja biodiesel can be considered as a sustainable fuel. It can be used as an environment friendly alternative fuel without major engine modification.

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