INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH
S. Mohite et al., Vol.6, No.2, 2016

Experimental Studies on Use of Karanja Biodiesel as Blend in a Compression Ignition Engine

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Received: 17.12.2016 Accepted:23.02.2016

Abstract- Ecological system is being affected adversely by the use of diesel engines which causes harmful emissions. Alternative sources are being found to sort out this problem. Biodiesel is one of the alternative source. Nowadays, there is a focus on the non-edible oils to use it as biodiesel because of its capability to be available on waste lands. Karanja is one of the non-edible oil, which may be preferred to be used as biodiesel because of its certain advantages on diesel engine comparatively. This experimental study was aimed to find out performance characteristics and smoke emission with 10%, 20% and 30% biodiesel blend with diesel at varying loads (brake power) of 0.5 to 3.5 kW at a constant speed of 1500 rpm. Brake thermal efficiency, brake specific energy consumption, exhaust gas temperature, mechanical efficiency, volumetric efficiency, air fuel ratio and smoke opacity of biodiesel blended fuel were evaluated and compared with diesel and it has been found satisfactory. Brake thermal efficiency of 20% biodiesel blend fuel was found to be slightly higher than that of diesel with reduced smoke emissions. Brake thermal efficiency of B20 and diesel was found to be 29.04% and 29% respectively at 3.5 kW brake power. On the basis of experimental study, the B20 Karanja biodiesel blend is found more useful among all tested fuels in terms of brake thermal efficiency. Smoke opacity was also found to be reduced with Karanja biodiesel blends. Hence Karanja biodiesel is proved to be an environmentally friendly alternative to diesel.

Keywords Biodiesel, Blends, Karanja, Brake Thermal Efficiency, Smoke Emissions.

1. Introduction

In the world, 80% of primary energy is consumed by fossil fuel and out of which, 58% is consumed by the transport sector. There was a 23 % increase in the consumption of diesel while the increase in the consumption of other petroleum products was 7% from 2000 to 2008 according to reports of International Energy Agency [1]. Ecological system is being affected adversely by the use of diesel engines which causes harmful emissions. Alternative sources are being found to sort out this problem. Biodiesel is one of the alternative source. Biodiesel has calorific value, cetane number and flash point which are comparable with diesel [2].Biodiesel is an ester of vegetable oil. Ester is obtained by transesterification process which reduces the viscosity of vegetable oil with the conversion of triglyceride into ester. Biodiesel is safe to handle due to its high flash point and low volatility. Biodiesel may be used as a substitute for diesel due to its similar combustion behaviour and performance [3]. Transesterification process decreases the viscosity of vegetable oils causing biodiesel to be easily miscible with diesel in any ratio of blends. Biodiesel has density, viscosity and calorific value which is nearer to that of diesel [4]. Biodiesel is renewable, energy efficient, non-toxic, biodegradable and can be used suitably for sensitive environments. At present, Edible oil contributes to the 95% of biodiesel production, which means the conversion of food into fuel leading to food starvation problem. So non-edible feedstocks are being focused in the biodiesel production to get rid of food starvation problem [5].

Jatropha curcas, Pongamia pinnata, Sterculia foetida, Madhuca indica, Calophyllum inophyllum, Azadirachta indica, Rice bran, Terminalia bellerica roxb, Croton mega locarpus, Cerbera odollam, Hevea brasiliensis, Eruca sativa, Melia azedarach and microalgae are the non-edible oilseed crops which are available in the world [6]. Various types of feedstocks are used for biodiesel production, according to the suitability of climatic and agricultural conditions in the world. Jatropha and Karanja, are popular biodiesel feedstocks in South Asia. But Karanja is more useful in long term biodiesel production in comparison to jatropha [7]. Feedstock and its cost are the major factor for the selection of a vegetable oil for the production of biodiesel. The potential feedstock for biodiesel production is Karanja with 200 million tons output capacity per annum [8]. Karanja trees are found in ample quantities in south east Asia and it can be easily grown in barren lands. Endurance test for 250 hours was conducted using B20 Karanja biodiesel blend and textural condition of cylinder liner’s surface condition was found to be in good condition [9].

Karanja biodiesel was produced from Karanja oil by transesterification and viscosity, density and calorific value were found to be 5.72 cSt, 885 kg/m^3 and 37,425 kJ/kg, whereas the viscosity, density and calorific value of Karanja oil were 69.6cSt, 911 kg/m^3 and 38,416kJ/kg. It was also observed that 24.87 % was the maximum value of brake thermal efficiency with Karanja biodiesel whereas diesel has brake thermal efficiency of 30.59% at maximum power output [10]. An experiment was conducted for 10%, 20% and 30% cotton seed biodiesel blends with diesel and it was found that the brake thermal efficiency of B20 and diesel was 29.6% and 30.2% respectively at rated power. They concluded that B20 showed almost the same performance as that of diesel with reduced emissions significantly [11]. BSFC of lower Karanja biodiesel blends was found to be comparable to that of diesel, but its value increased with the use of higher blends of biodiesel. It was also found that smoke opacity of Karanja biodiesel blends was lower than that of diesel [7]. It was found that the BSEC increased with proportions of biodiesel blends. Increased in BSEC for Karanja biodiesel blends of 20%, 50% and 100% were found to be 2.68%,5.84% and 13.31% higher than that of diesel at 2200 rpm respectively [12]. Increased in EGT was observed with the increase in the proportions of biodiesel in the blended fuel as well with the increase in engine load. It was also found that B10, B20 and diesel have mean EGT values of 308^{0}C, 310^{0}C and 296^{0}C respectively [13].

2. Materials and Methods

2.1. Experimental Setup

The experiment was conducted on a single cylinder, four stroke, water cooled, direct injection diesel engine to evaluate performance & smoke emission characteristics. Eddy current dynamometer was connected to the engine for loading. The specifications of compression ignition engine are given in Table 1. A Stand- alone panel box which consists of the air box, dual fuel tank for fuel test, manometer, fuel measuring unit, transmitters for air & fuel flow measurements, process indicator and engine indicator was used in this experiment. Cooling water and calorimeter water flow was measured by Rotameters. Software “Engine soft LV” was used for online engine performance evaluation.

Table 1. Specification of Compression Ignition Engine

Make	Kirloskar
Number of Cylinder	One
Type	Four Stroke
Constant Speed	1500 rpm
Rated power	3.5 kW
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	18:1
Capacity	661 cc
Cooling arrangement	Water cooled

2.2. Experimental Test Procedure

The engine performance characteristics were recorded with the use of ‘Engine Soft’ software.Various performance characteristics were measured by running the diesel engine with fuels at a compression ratio of 18 and varying the load (brake power) from 0.5 kW to 3.5 kW at constant speed of 1500 rpm. The AVL Smoke meter was used to measure smoke opacity. Karanja biodiesel was produced in the laboratory and then its blends of 10%, 20% and 30% (volume basis) with diesel fuel were prepared in the Laboratory. The calorific values, densities and viscosities of diesel and biodiesel blended fuel were measured and it is shown in Table 2.

Table 2. Important Physical Properties of test fuels

S.N	Test fuels	Density Kg / m^3	Viscosity cSt	Calorific Value MJ/kg
1	Diesel	856	3.01	42.5
2	B 10	830.2	3.2	42
3	B 20	835.6	3.28	41.5
4	B 30	841.3	3.37	41

3. Results and Discussion

The test fuel used in this experimental study were diesel and 10%, 20% and 30% Karanja biodiesel blends. Experiments were conducted by varying the loads (brake power) at a constant speed of 1500 rpm. The measured performance characteristics and smoke emission are discussed below:-

3.1. Brake Thermal Efficiency

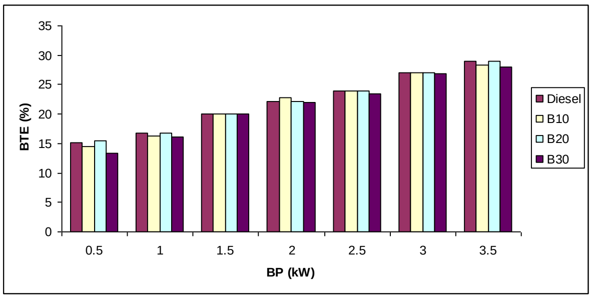

Fig.1. Brake thermal efficiency vs brake power

BTE of B20 was found to be 29.04 % maximum followed by 29% for diesel, 28.3% for B10 and minimum 27.92% for B30 at 3.5 kW brake power. In all cases, maximum decreases in BTE with respect to diesel up to 11.84 % are observed between diesel and B30 at lower load (0.5 kW brake power). Biodiesel blends are characterized by ample oxygen availability for better combustion and higher viscosity. B20 has slightly more BTE than that of diesel. Combustion process takes place in a better way due to the presence of more oxygen and lubricity increases due to higher viscosity. Biodiesel has 66% better performance in terms of lubrication than diesel. An increase of 30% in lubricity is possible with 1% addition of biodiesel in the fuel. These two factors probably increase the BTE of B20. B10 has lower BTE at lower and higher loads than that of diesel, which may be due to the lesser amount of oxygen content than other biodiesel blends comparatively but it increases at the middle loads i.e. at 2 and 2.5kW brake power as compared to diesel. This may be attributed due to more increase in lubricity at middle loads. B30 biodiesel blend has lower BTE at all loads and this may be due to higher viscosity, inappropriate spray and inappropriate combustion which surpass the lubricity benefits. This agrees with [14-15]. BTE of different fuels is shown in the bar chart (Fig.1).

3. 2.Brake Specific Fuel Consumption

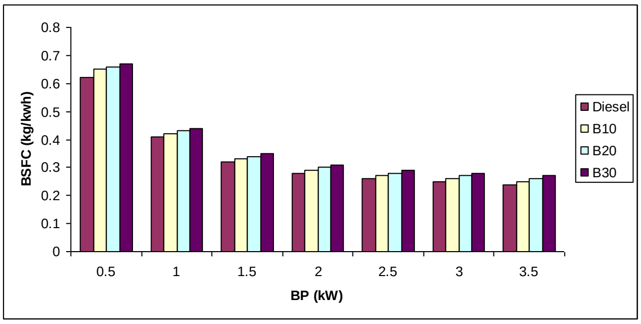

Fig.2. Brake specific fuel consumption vs brake power

It is observed that BSFC decreases with increase in load for all fuels. Biodiesel blends have higher BSFC than diesel due to its higher density and lower calorific value. Density, viscosity and calorific value are the main factors on which BSFC depends. Higher density of biodiesel causes more mass of fuel injection as compared to diesel for the same conditions and settings of fuel injection pump. This results in higher consumption of biodiesel blends causing higher BSFC. BSFC of biodiesel blends increases to maintain the same brake power output in view for the compensation of its lower heating value as compared to diesel. This agrees with [16-17]. BSFC of different fuels is shown in the bar chart (Fig.2).

3.3 Brake Specific Energy Consumption

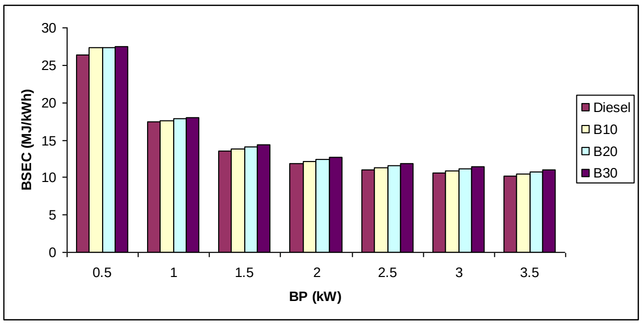

Fig.3. Brake specific energy consumption vs brake power

While using biodiesel blends, BSEC is considered trustworthy because it takes into account the calorific value of fuels as compared to BSFC. It is observed that the BSEC decreases with increase in load due to decrease in brake specific fuel consumption at higher loads for operating the engine. It is also observed that there is increased in BSEC correspondingly with the increase in the biodiesel proportion in blended fuel. This may be attributed as BSEC depends on BSFC directly as it is a product of calorific value and brake specific fuel consumption. This is observed that there is a maximum increase of 8.52 % between B30 and diesel while considering all blended fuel. This may be attributed due to lower heating value, lower volatility and higher density of biodiesel. This agrees with [18]. BSEC of different fuels is shown in the bar chart (Fig.3).

3. 4. Exhaust Gas Temperature

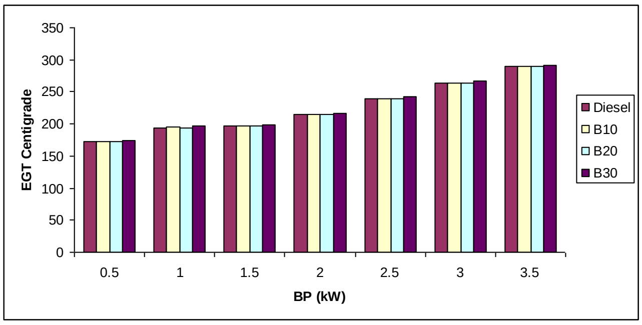

Fig.4. Exhaust gas temperature vs brake power

EGT increases with increase in load for all fuels due to the requirement of more generation for power resulting in more demand of fuel. Flame temperature with biodiesel is greater than that for diesel at a particular load in spite of the lower calorific value of biodiesel as compared to diesel, which causes an increase in EGT with an increase in compositions of biodiesel in blended fuel. But B20 has slightly lower EGT than other fuels, which is due to its higher brake thermal efficiency, which implies an effective utilization of heat energy. This agrees with [19-22]. Higher BTE surpasses the flame temperature factor also. EGT of different fuels is shown in the bar chart (Fig.4).

3. 5. Mechanical Efficiency

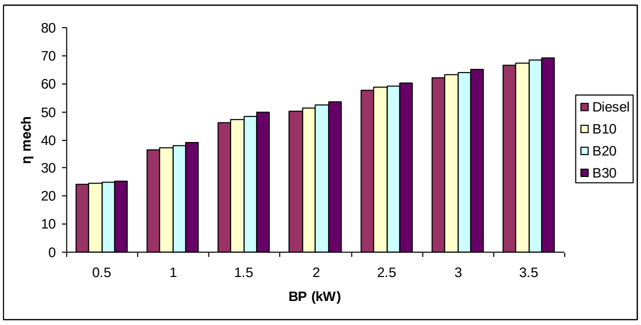

Fig.5. Mechanical efficiency vs brake power

Mechanical efficiency is defined as the ratio of brake power to the sum of brake power and friction power. Lubricity reduces friction power, causing an increase in mechanical efficiency when brake power is same. The biodiesel proportion of the blended fuel affects the Mechanical efficiency of diesel engine and mechanical efficiency increases with the proportions of biodiesel in blended fuel. It is also observed that B30 has a higher mechanical efficiency due to its better lubricity quality among all fuels. Mechanical efficiency increases with the increase in load for all fuels. This agrees with [23]. Mechanical efficiency of different fuels is shown in the bar chart (Fig.5).

3.6. Volumetric Efficiency

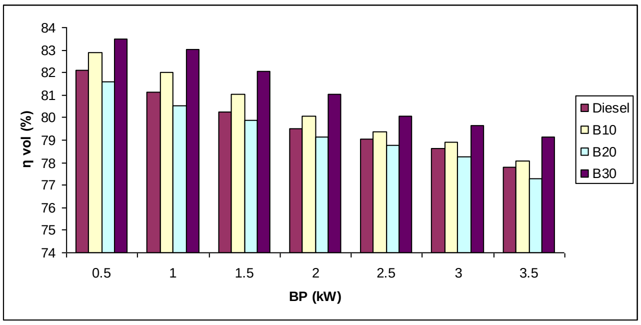

Fig.6. Volumetric efficiency vs brake power

The ratio of the actual consumption of theoretical consumption of air is called Volumetric Efficiency in a diesel engine. Volumetric efficiency is closely associated with exhaust gas temperature. Higher exhaust gas temperature results in the rise of retained gas temperature, which causes the increase in temperature of incoming fresh air. This agrees with [23]. The actual consumption of air is inversely proportional to the density of air. At higher temperature, the density of the air will be low. Since the EGT of B30 is highest among all fuels, it results in bringing down air density low and subsequently, volumetric efficiency of B30 is higher. Volumetric efficiency is also found to be decreased with increase in brake power. This may be attributed due to decrease in air fuel ratio with an increase in brake power [15]. Volumetric efficiency of different fuels is shown in the bar chart (Fig.6).

3.7. Air Fuel Ratio

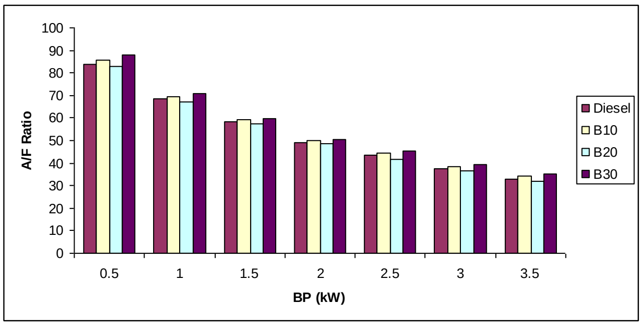

Fig.7. Air-fuel ratio vs brake power

Air fuel ratio is defined as the ratio of the air mass flow rate to fuel mass flow rate. It is observed that the air fuel ratio decreases with increase in loads. It is shown in Fig. 7. This may be attributed due to increase in fuel requirement with increase in load. This agrees with [15].

3.8. Smoke Opacity

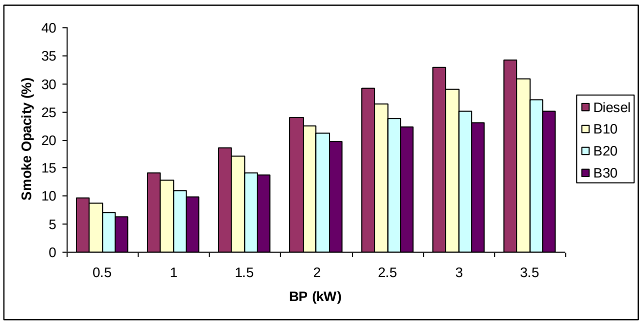

Fig.8. Smoke opacity vs brake power

It is observed that smoke opacity increase with increase in load due to fuel consumption increment. It is shown in Fig. 8. Smoke opacity decreases due to the presence of oxygen in biodiesel as compared to diesel. Biodiesel has also lowered carbon to hydrogen ratio and lack of aromatic compounds as compared to diesel. The higher amount of oxygen presence and lower amount of carbon reduces the smoke formation tendency which results in decrease in smoke opacity. On the other hand, high sulfur content causes an increase in smoke opacity of diesel. This agrees with [24-26].

4. Conclusion

The major conclusions are given below:-

- BTE of B20 was found to be 29.04 % maximum followed by 29% for diesel, 28.3% for B10 and minimum 27.92% for B30 at 3.5 kW brake power.
- BSEC increased up to 8.52 % between B30 and diesel while considering all blended fuel at 3.5 kW brake power.
- EGT of B20 was found to be slightly lower than other tested fuels.
- B30 was found to have a higher mechanical efficiency among all tested fuels. The mechanical efficiency of diesel, B10, B20 and B30 was found to be 66.73%, 67.27%, 68.28% and 69.32% respectively at 3.5 kW brake power.
- Volumetric efficiency of B30 was the highest among all tested fuels. Volumetric efficiency of diesel, B10, B20 and B30 was found to be 77.81%, 78.06%, 77.3% and 79.13% respectively at 3.5 kW brake power.
- Smoke opacity decreased by 26.31%, while using B30 biodiesel blend in comparison to diesel at 3.5 kW brake power.
- On the basis of experimental study, B20 Karanja biodiesel blend is found more useful among all tested fuels in terms of brake thermal efficiency. Smoke opacity was also found to be reduced with Karanja biodiesel blends. Hence Karanja biodiesel is proved to be an environmentally friendly alternative to diesel.

Nomenclature

B10: Karanja biodiesel blends of 10% with Diesel (by volume)

B20: Karanja biodiesel blends of 20% with Diesel (by volume)

B30: Karanja biodiesel blends of 30% with Diesel (by volume)

BTE: Brake Thermal Efficiency

BSFC: Brake Specific Fuel Consumption

BSEC: Brake Specific Energy Consumption

EGT: Exhaust Gas Temperature

A/F Ratio: Air Fuel Ratio

η_{mech} : Mechanical Efficiency

η_{vol} : Volumetric Efficiency

Acknowledgement

The authors are thankful to Delhi Technological University for supporting the facilities and analytical equipment and also, Dr. Amit Pal for his help and cooperation during the experimentation.

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