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Studies on performance and emission characteristics of diesel engine fueled with diesel and bitter apricot kernel oil biodiesel blends

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Abstract

Vegetable oils are produced from numerous oil seeds crops. While all vegetable oils have high energy content, most require some processing to assure safe use in internal combustion engines. Some of these oils already have been evaluated as substitutes for diesel fuels. In the present research work Bitter Apricot kernel oil was employed as a feedstock for the production of biodiesel. The physico-chemical properties of the Bitter Apricot kernel oil methyl ester were investigated as per ASTM D6751. From the series of engine testing, it is concluded that the brake thermal efficiency (BTE) with biodiesel blend was little lower than that of diesel. Brake specific energy consumption (BSEC} is slightly higher for Bitter apricot kernel oil methyl ester blends than neat diesel. For biodiesel blends, CO emission was lower than diesel fuel as B20 reduced CO emissions by 18.75%. Approximately 11% increase in NO_x emission was observed with 20% biodiesel blend. It is observed that HC emissions tend to decrease for biodiesel-based fuels and Smoke opacity was found lower for biodiesel blends in comparison to diesel fuel.

Keywords- Biodiesel; Transesterification; Bitter Apricot Kernel oil; Methyl esters; Performance and Emission testing; Diesel engine

Introduction

Vegetable oils were used as fuel for diesel engines to some extent since the invention of the compression ignition engine by Rudolf Diesel in the late 1800`s. During the early stages of the diesel engine, strong interest was shown in the use of vegetable oils as fuel but this interest declined in the late 1950’s after the supply of petroleum products become abundant (knothe 2005). During the early 1970’s, oil shock, however, caused a renewed interest in vegetable oil fuels. This interest evolved after it became apparent that the world’s petroleum reserves were declining. At present, in order to replace a part of petroleum-based diesel usage, the use of vegetable oils derived biodiesel has been starting in many countries. Vegetable oils are renewable energy source and significant environmental benefit can be derived from the combustion of vegetable oil-based biodiesel rather than petroleum-based diesel fuels. Mostly, biodiesel is prepared from oils like soybean, rapeseed, sunflower, safflower, etc. throughout the world (Lang et al., 2001). These oils are essentially edible in nature. When biodiesel is produced from refined edible oils, feedstock cost contributes more than 88% to the cost of biodiesel (Micheal et al., 2005). Few attempts have been made for producing biodiesel with non-edible oils like karanja and jatropha, especially in India (Kaul et al., 2003). However, there remain a number of other tree-based oilseeds with an estimated annual production potential of more than 20 Mt (Kaul et al., 2003). These oils have great potential to make biodiesel for supplementing other conventional sources.

Therefore, following mentioned objectives are formulated for the present research work.

- Production of biodiesel from Bitter Apricot Kernel oil.
- Determination of important Physico-chemical properties of produced biodiesel.
- Conducting exhaustive experiments on the diesel engine test rig to evaluate performance and emission characteristics of biodiesel-diesel blends and comparison with baseline data of diesel fuel.

Materials and methods

In the present work Bitter Apricot kernel oil (FFA <2%) is used for Biodiesel production. As the oil has low Free Fatty Acid (FFA), so it is suitable for biodiesel production through direct transesterification reaction.

Transesterification of Bitter Apricot kernel oil

Transesterification has been done to produce biodiesel. Transesterification is also known as alcoholysis. A mixture of bitter apricot kernel oil and methanol mixed with potassium hydroxide (used as catalyst) are heated and maintained at 60ºC, while the solution is continuously stirred with the help of magnetic stirrer. Catalyst concentration, 1% (% wt. / wt. of oil) and molar ratio of, 6:1 (alcohol: oil) is used. Time taken in transesterification reaction is s to 60 minutes. When the reaction is over, product is poured into separating funnel. Two distinct layers are formed; the lower layer is of glycerin and the upper layer of ester. The glycerol formed is removed by density separation. The upper layer (ester) is separated out, washed with mild water and then heated to 110ºC to remove any moisture present in the biodiesel. This process increases the volatility and decreases the viscosity of the oil, making it similar to the diesel fuel in these characteristics.

Bitter Apricot kernel oil biodiesel properties

The measured physico-chemical properties of bitter apricot kernel oil biodiesel are shown in **Table 1**.

Table1: Properties of bitter apricot kernel oil-based biodiesel

Property	ASTM Method	Value
Acid Number (mg KOH/gm)	D 664	0.10
Density @ 15°C (gm/cm^3)	D 1298	0.88
Kinematic Viscosity @ 40°C (cSt)	D 445	4.32
Calorific Value (MJ/kg)		39.5
Flash Point (°C)	D 93	115
Ester Content (%)	EN 14103	95

Diesel engine test rig

A Kirloskar made, single cylinder, water cooled, direct injection diesel engine is selected for the present research work, which is primarily used for agricultural activities and household electricity generation. Specifications of Diesel engine are shown in **Table 2**.

Table 2: Specifications of the diesel engine

Make	Kirloskar
Model	TV 1
Rated Brake Power (kW)	5.2 kW @ 1500 rpm
Rated Speed (rpm)	1500
Number of Cylinder	One
Bore x Stroke (mm)	87.5 x 110
Displacement volume (cc)	661
Compression Ratio	17.5:1
Cooling System	Water Cooled
Fuel Injection	23° before TDC

Results and Discussions

The first part deals with the results of various tests conducted for physico-chemical characterization of biodiesel and diesel fuel. The second part discusses the results of performance and emission analysis on diesel engine.

Evaluation of physico-chemical properties

Table 3 shows the Physico-Chemical properties of fuels used in engine. All the fuels, namely neat diesel and diesel- bitter apricot kernel oil biodiesel blends were analyzed for several physical, chemical properties. Density and viscosity of biodiesel- diesel blends were found to be higher than those of diesel fuel. Blending of biodiesel derived from bitter apricot kernel oil in diesel reduces calorific value of the blend due to lower heating value of biodiesel.

Table 3: Physio-chemical properties of fuel used

Sample	Density (g/cm^3)	Kinematic viscosity (cSt)	Cal. Val. (MJ/kg)	Flash Point (°C)
Diesel	0.85	2.95	42	65.5
B 10	0.855	3.087	41.75	70.5
B 20	0.857	3.224	41.5	75.5
B 30	0.86	3.361	41.25	80.5
B 50	0.865	3.635	40.75	90.5

Performance Characteristics

The performance characteristics of the test engine on neat diesel and biodiesel- diesel blends are summarized below: -

Brake Thermal Efficiency

The variation of brake thermal efficiency with respect to engine load for different test fuels is shown in **Figure 1**. In all the cases, brake thermal efficiency has the tendency to increase with increase in applied load reaching a maximum somewhere at 80 per cent load and then decreases. The peak

brake thermal efficiency in case of diesel, B10, B20, B30 and B50 are 34.1%, 33.6%, 33%, 32.4% and 31% respectively. It can be seen that brake thermal efficiency with biodiesel blend was little lower than neat diesel fuel (Chauhan et al., 2013; Chauhan et al., 2012; Canakci et al., 2009).

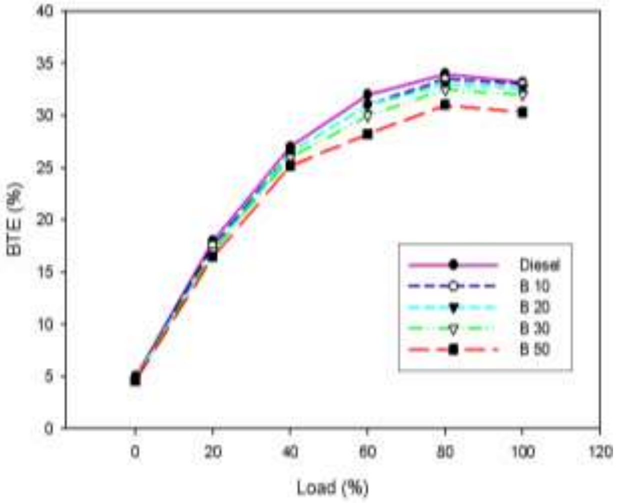

Figure 1. BTE vs. Engine load

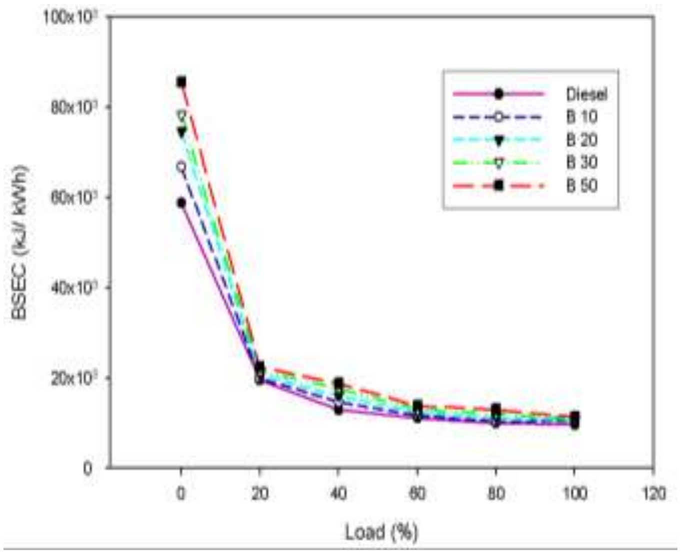

Figure 2. BSFC vs. Engine load

Brake Specific Energy consumption

Brake specific energy consumption (BSEC) is an ideal parameter for comparing engine performance of fuels having different calorific values and densities. The variation of BSEC with engine load for different test fuels is shown in **Figure 2**. It is observed that for all the fuels, the BSEC decreases with increase in load. This is due to higher percentage increase in brake power with load as compared to increase in the fuel consumption. For biodiesel and its blend, the BSEC is slightly higher than diesel fuel. This is due to lower calorific value with increase in biodiesel percentage in the blends (Baiju et al., 2009).

Exhaust temperature

Figure 3 shows the variation of exhaust gas temperature with engine load for diesel and biodiesel- diesel blends. The results show that the exhaust gas temperature increases with the increase in load for all the test fuels.

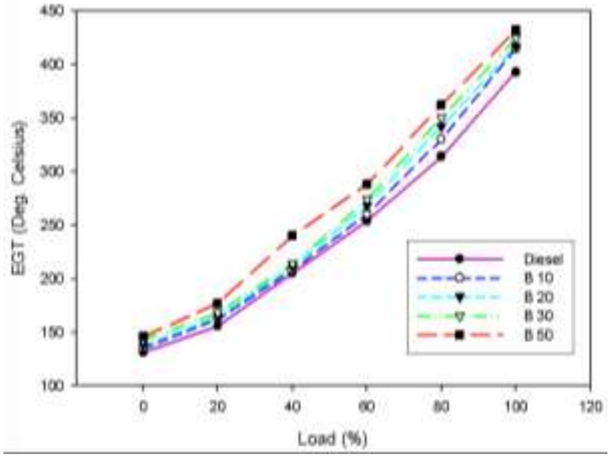

Figure 3. Exhaust gas temperature vs. Engine load

The amount of fuel injected increases with the engine load in order to maintain the power output and hence the heat release and the exhaust gas temperature rise with increase in load. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. At all loads, diesel was found to have the lowest temperature and the temperature for the different blends showed the upward trend with increasing concentration of biodiesel in the blends (Chauhan et al., 2013; Chauhan et al., 2012)

Emission Characteristics

The emissions characteristics of the test engine on neat diesel and biodiesel- diesel blends are summarized in this section.

CO Emissions

Figure 4 shows the CO emissions of the diesel fuel and blends of biodiesel. CO is an intermediate combustion product and is formed mainly due to incomplete combustion of fuel.

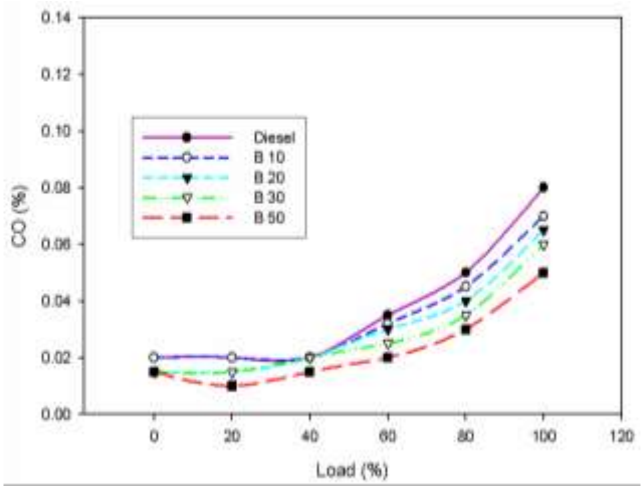

Figure 4. CO emission vs. Engine load

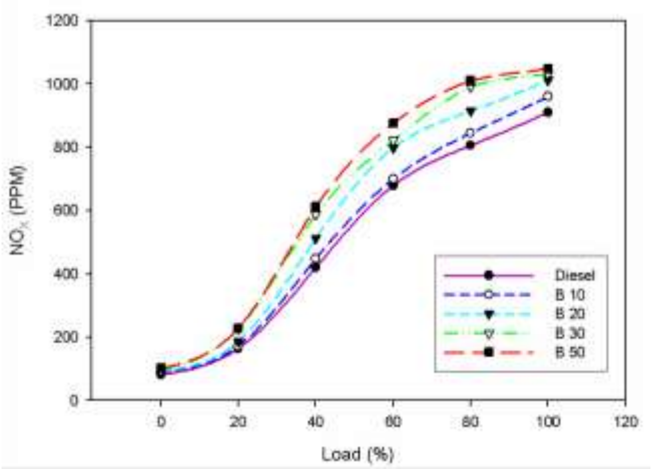

Figure 5. NOX emission vs. Engine load

NOX Emissions

Indicated in **Figure 5**. Naturally NO$_x$ emission increases with the increase in load. It is well known that nitrogen is an inert gas, but it remains inert up to a certain temperature (1100 °C) and above this level, it does not remain inert and participate in chemical reaction. At the end of combustion, gas temperature inside cylinder arises around 1500 °C. At this temperature, oxidation of nitrogen takes places in presence of oxygen inside the cylinder. So, with increasing load more fuel burns which lead to higher combustion temperature thus higher NO$_x$ formation takes place. NO$_x$ level was higher for biodiesel blends than diesel fuel at the same load. This can be explained due to the presence of extra oxygen in the molecules of biodiesel blends. This additional oxygen was responsible for higher NO$_x$ emission (Chauhan et al., 2013; Chauhan et al., 2012; Canakci et al., 2009; Rakopoulos et al., 2008). Around 11% increase in NO$_x$ emission was observed with 20% biodiesel blend at full load.

HC Emissions

Figure 6 depicts the variation of HC emissions for different fuels with load. It can be seen that hydrocarbon emissions tend to increase for all fuels with increasing load. This is because of less oxygen available for the reaction when more fuel is injected into the engine cylinder at high engine load which makes the fuel mixture to become very rich at certain points in combustion chamber. As a result, proper combustion does not take place at those points and fuel goes off in the exhaust as hydrocarbons. It can also be seen that with increasing amount of biodiesel in blends, HC emissions tend to decrease and are lower compared to diesel fuel. This is due to inbuilt oxygen content in biodiesel which is responsible for more complete combustion (Labeckas et al., 2013; kruczynski et al., 2013; Selvam et al., 2012).

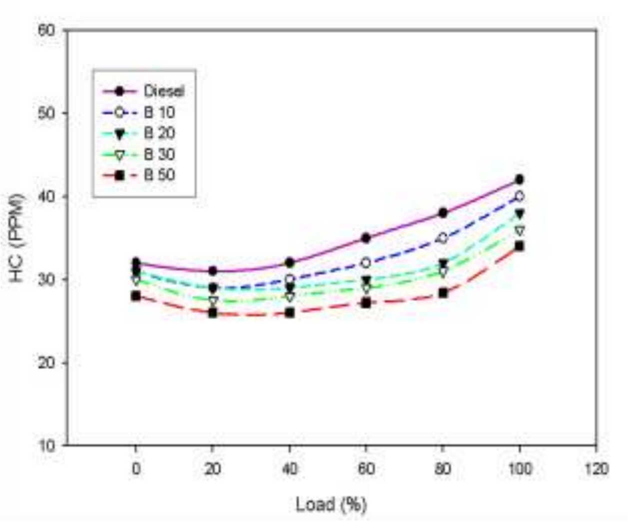

Figure 6: HC vs. engine load

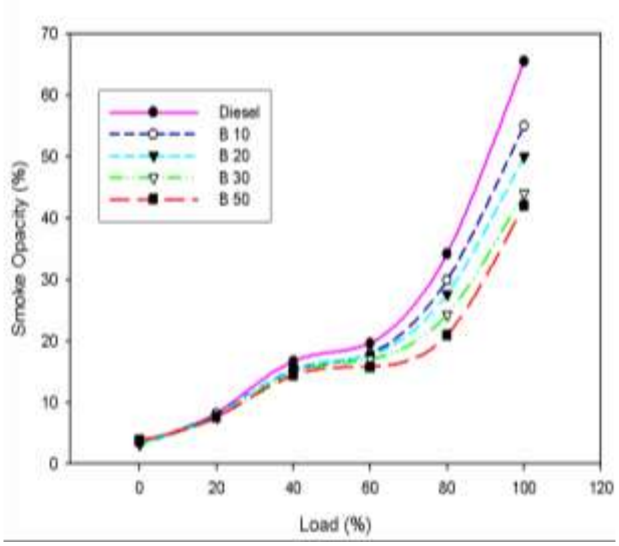

Figure 7: Smoke opacity vs. engine load

Smoke opacity

The variation of smoke opacity with engine load for diesel fuel and biodiesel blends is shown in **Figure 7.** It can be seen that smoke is high mainly at high power outputs for all the fuels. High loads imply that more fuel is injected into the combustion chamber and hence incomplete combustion of fuel is enhanced. Reduction of smoke emissions for different biodiesel-based fuels in comparison to diesel fuel has been achieved for all load conditions (Aggarwal et al., 2007).

Conclusions

The bitter apricot kernel oil was taken as a feedstock in the present research work mainly to evaluate the potential suitability of bitter apricot kernel oil for conversion into biodiesel and subsequent engine application. From the series of exhaustive experiments, the following conclusions can be derived.

- The brake thermal efficiency with biodiesel blend was little lower than that of diesel. The slight reduction of brake thermal efficiency with increase of biodiesel content in blends can be attributed to lower heating value, high viscosity.
- The BSEC decreases with increase in load. For B5, B10, B20, B30 and B50 the BSEC is slightly higher than neat diesel.
- The exhaust gas temperature increases with the increase in load for all the test fuels. At all loads, diesel was found to have the lowest temperature and the temperature for the different blends showed the upward trend with increasing concentration of biodiesel in the blends.
- CO emission is found to increase with increase in load for all test fuels. For biodiesel blends, CO emission was lower than diesel fuel as B 20 reduced CO emissions by 18.75% at full load.
- The NO_x level was higher for biodiesel blends than conventional diesel fuel. Approximately 11% increase in NO_x emission was observed with 20% biodiesel blend at full load.
- It is observed that HC emissions tend to decrease for biodiesel-based fuels. It was also seen that as concentration of biodiesel in biodiesel- diesel blends increase, a downward trend in HC emission is observed.
- Smoke opacity was found lower for biodiesel blends in comparison to diesel fuel.

It can be concluded from the research work that B20 blend can be successfully used in Diesel engine without sacrificing much performance and improve emissions.

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