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## RESEARCH ARTICLE

# PERFORMANCE OF *BOMBAX PENTANDRUM* AND *CASSIA SIAMEA* BIODIESEL AS AN ALTERNATIVE FUEL FOR DIESEL ENGINE

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**ABSTRACT**

Biodiesel has established itself as a precisely sufficient alternative fuel for diesel engines. Generators are vital equipment of industry and have a wide usage area in agriculture. Furthermore engine performance and emissions of electric generators gain importance due to their indoor applications. The objective of this study was to investigate the performance and smoke results of *Bombax pentandrum* and *Cassia siamea* biodiesel utilization in diesel engine. The smoke opacity test was conducted using 20% blends of biodiesel with Single cylinder, four stroke, air cooled, indirect injection diesel engine, and generator performance tests were performed using 10% blends in a 7.5 KVA (6KW) electrical generator. Consecutive tests on Diesel fuel, B20 and B10 blends of *Bombax pentandrum* and *Cassia siamea* methyl ester were conducted, and the results were compared with each other. When compared to Diesel fuel, both utilizations showed improved results on engine performance and emissions. According to the result obtained, *Bombax pentandrum* and *Cassia siamea* seed oil originated biodiesel can be utilized as a blend component during generator applications in rural areas and indoor applications.



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## INTRODUCTION

India currently imports about 72% of its petroleum requirements, which costs more on foreign exchange. With growing demand on the use of fossil fuels, stronger intimidation to clean environment is being posed as burning of fossil fuels is associated with emissions like CO2, CO, SOx, NOx and particulate matter (Kalbande et al., 2007). The harmful exhaust emissions from the engines and uncertainties in supply of petroleum products have together created an interest to search for suitable alternative fuels. Vegetable oils and their esters have the prospective to be considered as an appropriate alternative fuel as their properties are similar to that of diesel and their use in diesel engine reduces the harmful exhaust emission, particularly HC and CO, sulfates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons and PM as compared to diesel (Demirbas, 2005; Cherng and Lin, 2007). There are several non-edible oilseed species such as karanja, jatropha, neem, silk cotton, Jojoba, Kusum, Mahua etc that could be utilized as a feedstock in biodiesel production (Srivastava & Prasad, 2000). In the present study, silk cotton (*Bombax pentandrum*) and yellow cassia (*Cassia siamea*) seed oil are used as a feedstock for production of biodiesel and the biodiesel blends were then tested for operating electric generator for power generation. Silk cotton seeds have relatively high oil content (brownish yellow) which is about 25-30% by weight and is reported almost identical to cotton seed oil and is said to be used for soap making and as a lubricant (Salimon and Kadir, 2005). Yellow cassia seeds are relatively thin and ovate and yield greenish non-edible oil which is about 16-18% by weight (Daulatabad *et al*., 1988).

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## MATERIALS AND METHODS

Silk cotton (*Bombax pentandrum*) and yellow cassia (*Cassia siamea*) seeds were collected from the local area and oil was extracted from the seeds by both solvent and mechanical method. The percentage of seed oil extracted by solvent method from *Bombax pentandrum* was 26.84 and the percentage of oilcake obtained was 73.16. The percent yield of *Cassia siamea* seed oil was 14.57% and the oilcake obtained was 85.43%. The percentage of oil pressed mechanically from the above samples was found to be 20.78; 11.30 and that of oilcake was 78.5; 88.1 respectively. Biodiesel feed stocks are classified by the amount of free fatty acid they contain. A Free Fatty Acid (FFA) is one that has separated from the triglyceride and determines the stability of the vegetable oil used for transesterification and biodiesel yield. The FFA level

of the above oil samples was found to be 4.26% and 1.95% respectively. In order to avoid the problem of saponification and obtain high yield of methyl esters, the acid and alkali catalyzed transesterification (two stage) method was used for the isolation of biodiesel from *Bombax pentandrum* and *Cassia siamea*. Oil sample was poured in to a round bottomed flask equipped with a reflux condenser and heated to the reaction temperature. 1% (v/v) H2SO4 in methanol (8% v/v) was added to the flask. After the reaction, the mixture was allowed to settle in a separating funnel over night. Sodium methoxide was prepared by mixing methanol and required amount of NaOH. The base catalyst requirement for seed oil of *Bombax pentandrum* was 6.5g/l of oil w/v and 6.0 g/l for *Cassia siamea* seed oil. The methanol to oil molar ratio was 6:1. The reaction was allowed to proceed until completion. The lower glycerol layer was drawn off. The reaction time depended on the type of feedstock used. Bio-diesel was then purified by washing gently with water. The percentage conversion of oil to biodiesel and recovery of glycerin in seed oil of *Bombax pentandrum* was 92.3 and 5.5 by volume and 81.96 and 5.29 by weight respectively. In case of *Cassia siamea*, percent conversion of oil to biodiesel was 91.1% by volume and 85% by weight. The percentage of glycerin recovered was 7.2 and 7.76 by volume and weight respectively.

The specified blends of bio-diesel produced from the above feedstock with petroleum diesel were used to investigate the performance and smoke results in diesel engine. The smoke opacity test was conducted using 20% blends of biodiesel with Single cylinder, four stroke, air cooled, indirect injection diesel engine, and generator performance tests were performed using 10% blends in a 7.5 KVA (6KW) electrical generator.

**Determination of the Efficiency of Electricity Generator**

10 % blends of biodiesel (by volume) prepared from the feedstock; *Bombax pentandrum* and *Cassia siamea* were used to test the efficiency of an electrical generator connected to a 2 hp motor. Experimental setup was made to measure fuel consumption per unit time and output current generated for each fuel blend. The efficiency of the generator was determined as the ratio of energy output to the energy input for each fuel blends as follows,

$$\text{Efficiency} = \frac{\text{Energy output (KWh)}}{\text{Energy input (KWh)}} \times 100\%$$

Energy output was considered as the load given to 7.5 KVA generator. The electrical generator was run on constant three phase loading condition of 4500 watt (4.5 KW) on each biodiesel blend. Energy input was measured in terms of energy consumed per hour for the production of specific power. The calorific values of fuel blends were determined as detailed by Demirbas (1998) and presented as KJ/Kg. The overall efficiency of the biodiesel blends were compared with the petroleum diesel. The specification of the electrical generator used for the experimental study is given as.

**Specification of Electricity Generator**

Rating: 7.5 KVA (6KW)
Voltage: 230 / 415 Volt
Rated current: 9.8
Frequency: 50 HZ

**Determination of Smoke Density**

The biodiesel prepared from seed oils of *Bombax pentandrum* and *Cassia siamea,* were blended with diesel fuel and tested for smoke emission by free acceleration test at vehicular pollution control centre. The B20 blends of the samples were prepared by mixing 200 ml of biodiesel with 800 ml diesel fuel. A 20% blend of biodiesel isolated from *Bombax pentandrum* and *Cassia siamea,* seed oil was used for smoke test along with diesel fuel as standard. The biodiesel blends were tested in a Bajaj Mini door vehicle and the technical specification of the diesel engine used is given below.

**Specification of Diesel Engine**

- Engine type Single cylinder, four stroke, air cooled, indirect injection
- Displacement395 cc
- Compression ratio17.6:1
- Maximum output7.2 BHP at 2800-3000 rpm
- Maximum torque18.17 NM @ 2200 rpm
- Fuel efficiency36 km/litre
- Maximum speed 50 km/ hr
- Fuel tank capacity10 litres

A standard Hartridge smoke meter (0.1% resolution) was used to determine the smoke opacity. The smoke meter used in the present study was Netel smoke meter. Free acceleration test was performed with the smoke meter which indicated the full range of smoke opacity during the accelerating and decelerating cycle. The engine oil level was checked at first to ascertain between the minimum and maximum marks on the dipstick. The exhaust system was checked to ensure that there was no leakage. The cut off speed to be governed was verified by gradual acceleration of the engine to the maximum where it got stabilized. After reaching the normal operating temperature, the engine was accelerated as rapidly as possible from idle speed to the position where the throttle was fully open until the maximum governor speed was reached and held for 1-4 seconds. Then the throttle was released to allow the engine to return to the idle speed. The engine was allowed to remain idle for not more than 5 to 45 seconds. 4- 6 trials were performed to complete the smoke emission test (Road Control Regulations, 2010). The smoke density was recorded in the standard Hartridge smoke meter which works on light absorption technique. Light extinction coefficient K is used as the measure of smoke density per meter.

$K = (-1/L) \ln (1-N/100)$

where, K - Smoke density ($m^{-1}$)
L - Optical length of the smoke measurement (m) and
N - Smoke opacity (%).

For each acceleration at a given speed, smoke density was recorded along with oil temperature and the results were recorded.

## RESULTS AND DISCUSSION

In the present study, the overall efficiency of the generator was rated to be 50% and 59% for B10 blends of *Bombax pentandrum* and *Cassia siamea* methyl ester. The efficiency of the generator was found to be 38% when run on petro diesel.

**Table 1. Performance of Electricity Generator using B10 Blends of Biodiesel**

| Name of Sample | Calorific Value*(KJ/Kg) | Energy Consumption/unit time | | Overall Efficiency % |
|---|---|---|---|---|
| | | g/hr | KW h | |
| *Bombax pentandrum* | 42982.2 | 760.03 | 9.08 | 50 |
| *Cassia siamea* | 38493.18 | 716.57 | 7.67 | 59 |
| Petro diesel | 43100.00 | 998.40 | 11.96 | 38 |

**Table 2. Smoke Density - Free Acceleration Test Result for Diesel Fuel**

| Trial Number | Maximum rpm | Light Absorption Co-efficient (K Value) | Test limit max |
|---|---|---|---|
| 1 | 2240 | 2.2 | K value-2.45 (65 HSU) |
| 2 | 2104 | 1.8 | |
| 3 | 2215 | 2.2 | |
| 4 | 2137 | 2.4 | |
| 5 | 2174 | 2.5 | |
| K Avg | | 2.22 | |
| HSU | | 61.17 | |

**Table 3. Smoke Density - Free Acceleration Test Result for Biodiesel Blend (B20) of *Bombax pentandrum***

| Trial Number | Maximum rpm | Light Absorption Co-efficient (K Value) | Test limit max |
|---|---|---|---|
| 1 | 2174 | 1.1 | K value-2.45 (65 HSU) |
| 2 | 2186 | 0.9 | |
| 3 | 2263 | 1.2 | |
| 4 | 2041 | 0.8 | |
| 5 | 2301 | 1.3 | |
| K Avg | | 1.06 | |
| HSU | | 35.67 | |

**Table 4. Smoke Density - Free Acceleration Test Result for Biodiesel Blend (B20) of *Cassia siamea***

| Trial Number | Maximum rpm | Light Absorption Co-efficient (K Value) | Test limit max |
|---|---|---|---|
| 1 | 2254 | 1.4 | K value-2.45 (65 HSU) |
| 2 | 1986 | 0.7 | |
| 3 | 2165 | 1.3 | |
| 4 | 2196 | 1.09 | |
| 5 | 2210 | 1.2 | |
| K Avg | | 1.13 | |
| HSU | | 37.69 | |

Fuel consumption was found higher when run on petro diesel followed by *Bombax pentandrum* and *Cassia siamea*. The performance of generator was rated higher in case of *Cassia siamea* followed by *Bombax pentandrum* and petro diesel (Table 1). The overall efficiency of electricity generator on biodiesel blends was 12 to 21% higher with reference to the generator operating purely on petro diesel. The increase in overall efficiency was due to the less energy input to the engine as compared to the diesel energy input. Although the calorific values of biodiesel blends were found to be less than the diesel fuel, improved fuel efficiency may be attributed to the complete combustion of fuel in the engine. Since biodiesel is an oxygenated fuel and it contains 10-11% oxygen which improves combustion in the engine (Abdullah *et al*., 2007). The results clearly indicate that the biodiesel blends of the above samples can be recommended for powering diesel generators. Similar results have been reported on karanja (Kalbande *et al*., 2007), waste cooking oil biodiesel (Hamasaki *et al*., 2001; Meng *et al*., 2008), palm biodiesel and blends (Almeida *et al*., 2002), biodiesel from leather industry pre fleshings (Ozgunay *et al*., 2007). Similar study on performance of diesel engine on coconut based hybrid fuel (Singh *et al.,* 2010) has also been reported.

**Smoke Emission in Diesel Fuel during Maximum Rpm Condition**

The result revealed during idle condition of the engine fuelled with diesel was noted. During free acceleration condition, the maximum rpm level was chosen randomly and it ranged from 2104 to 2240 rpm. The oil temperature varied from 71 -75 ºC. The smoke emitted in this condition was found to range between 1.8 and 2.5 with the average of 2.22 K value with a HSU of 61.17 (Table 2).

**Free Acceleration Test Result for B20 Blend of *Bombax pentandrum* Biodiesel during Maximum Rpm Condition**

The maximum rpm ranged from 2041 to 2301 rpm. The smoke emitted during each rpm level was recorded in the smoke meter and it ranged from 0.8 to 1.3K with the mean value of 1.06K. The HSU value was 35.67 (Table 3).

**Free Acceleration Test Result for B20 Blend of *Cassia siamea* Biodiesel during Maximum Rpm Condition**

The free acceleration test result for biodiesel blend of *Cassia siamea* gave a mean K value of 1.13 and the rpm ranged from

1986 to 2254. The Light Absorption Co-efficient recorded was from 0.7 to 1.4 and the Hartridge unit was 37.69 (Table 4). The use of biodiesel in engines is reliable as it reduces the particulate matter emissions due to the presence of oxygen content in them (Graboski and McCormick, 1998; Graboski *et al*., 2003; Lapuerta *et al*., 2008). The density of smoke has been reported to reduce sharply by biodiesel fuels (Graboski and Mc.Cormick, 1998; Lapuerta *et al*., 2008). It has been reported that that the smoke number for biodiesel was lower than that of diesel (Scholl and Sorenson, 1988). Guo *et al*., (2002) have reported that the smoke opacity of biodiesel from recycled waste showed 83% reduction of smoke opacity. Similarly studies on mahua and rape seed methyl ester showed a 70 - 75% reduction in smoke density (Puhan *et al*., 2005; Lebedvas *et al*., 2006). Several experimental investigations have been carried out by researchers around the world to evaluate the engine performance of different biodiesel blends. B20 is the popular blend used in various studies because it represents a good balance of cost, emission, cold weather performance, materials compatibility and solvency. Nabi *et al.,* (2008) reported a reduction in smoke density of 34% in diesel engine run on B50 neem ethyl ester. B20 and B50 are considered the optimum fuel blends in terms of emissions (Lin *et al*., 2007). In the present study, the light absorption co-efficient or the K values for the above said methyl ester blends showed a reduction in smoke density from petro diesel ranging from 27.9% to 52.2% which are lower than the limit prescribed for diesel (70% HSU equivalent to 2.8K) proving that B20 blends of the above samples of biodiesel can be recommended as fuel in diesel engines.

**Conclusion**

The efficiency test and smoke density test revealed the reliability and less polluting nature of the biodiesel blends used in the study. Therefore, it may be concluded that the fatty acid methyl esters prepared from the feedstock like *Bombax pentandrum* and *Cassia siamea* can be considered as an alternative to diesel and used as a blend component during generator applications in rural areas and indoor applications.

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