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Performance Characteristics of Blended Rice Bran Biodiesel In a Diesel Engine

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ABSTRACT: *Rice bran is a by-product of the rice milling process and contains 10–25% oil depending on rice variety, milling procedure, and other agro-climatic factors. To supplement the dwindling fossil fuel reservoirs and reduce environmental pollution, there is need to investigate rice bran oil for use as a bio-diesel. Rice bran was sourced from small scale rice millers in Mwea, Kirinyaga County, chemically processed to biodiesel which was used then used in a diesel engine to determine its performance. The engine performance was studied using a single cylinder four stroke engine and EA10 Dynamometer using diesel as a control and biodiesel blends of 5:95, 10:90, 15:95,20:80, 25:75, and 30:70 biodiesel to diesel respectively. It was observed that the engine speed decreased with increase in load for all the fuels. Brake power increased with increase in the percentage of biodiesel in the blend. The average brake power for B5 was 2.636KW while that of B30 was 2.682KW. The average BSFC increased by 47% when using biodiesel B100. However this reduced to 13.2% when using a blended ratio of 5:95. Thermal efficiency was the same for biodiesel, diesel and blends meaning the engine was converting the chemical energy to mechanical energy with the same efficiency for all the fuel types. This study revealed that bio-diesel from rice processing gave similar characteristics as diesel and that it is readily available and can thus be used as a fossil fuel subsidy. It will go a long way in poverty reduction in line with the millennium development goals.*

I. INTRODUCTION

Energy from renewable sources accounts for the bulk of the primary materials upon which future development strategies are directed. Bio-diesel has attracted a great deal of interest during the past decade as a renewable, biodegradable, reduced toxicity and eco-friendly clean fuel which can be used in a diesel engine without engine modification (Kinast, 2003). Rudolf Diesel, the inventor of the engine that bears his name, used vegetable oil as fuel for his engine as early as 1895 (Wright and Purday, 1950). Tests with vegetable oil based fuels in diesel engine indicated that their performance is comparable to that of conventional diesel fuel and they are currently rated among the energy fuels considered as the most promising substitute for the highly priced and diminishing fossil fuels. Since diesel engine is optimized for diesel fuel, a fuel with properties closer to those of diesel is desired to avoid engine modifications. Therefore, modifying vegetable oils through chemical reaction with alcohol (transesterification) to produce the methyl or ethyl esters (biodiesel) is essential for successful long term engine operation (Encinar, 2005). Rice bran oil, though classified as minor oil, is a potential source of biodiesel due to the availability of millions of tonnes of rice bran from the rice milling process worldwide. According to the International Rice Institute, world rice production in 2007 was approximately 645 million tonnes. Most rice varieties are composed of roughly 20% hull, 11% bran, and 69% starchy endosperm (Gupta *et al*, 2007). Thus 1Kg of harvested rice produces approximately 0.11Kg (110g) of rice bran. Rice bran is the thin shell that immediately surrounds the rice kernel. It is removed during the milling/polishing process as the oil in it quickly becomes rancid thus reducing the shelf life of rice (Mondal, 2008). It contains approximately 10 - 25% extractable oil depending on the degree of milling, rice variety, and other agro-climatic factors (Umer *et al*., 2009). Thus considering average of 20% extractable oil, 1Kg of harvested rice can produce approximately 22g of oil. In Kenya, total rice production for the same period was 53,115 tonnes out of which 51,458 tonnes were from Pishori grown in Mwea Irrigation Scheme (CBS, 2008).

II. MATERIALS AND EXPERIMENTAL SETUP

2.1 Experimental Setup

A 10hp, 3000rpm single cylinder four stroke diesel engine coupled to a dynamometer EA10 was used. Brake power, torque, brake specific fuel consumption and brake thermal efficiency were determined at different loads for diesel as a control, bio-diesel and its blends. For the next test, the throttle was set to give a speed of 2500 rev/min at a light load. The load was adjusted to give a reading of 1Kg on the dynamometer dial. When conditions were steady, the following data was recorded; speed, load, the time taken to consume 10ml of fuel and the ambient temperature. The load was adjusted to give a reading of 2, 3, 4, 5, 6, 7, 8, and 8.5Kg recording the data for all fuel samples tested.

2.2 Determination of Engine Brake Power The brake power developed by the engine at various speeds was determined using the following equation

$$\text{Brake Power}\left(\text{b.p.}\right) = \frac{WN}{K}\ \text{Watts} \qquad (1.1)$$

Where
W = Effective Load on Torque arm (N)
N = Engine running speed (rpm)
K = Dynamometer EA-10C constant given as 3000
Thus

$$\text{Brake Power (B.P.)} = \frac{WN}{3000}\ \text{Watts} \qquad (1.2)$$

2.3 Determination of Engine Torque
Torque applied to the engine was given as
Torque (N-m) =0 .239W (1.3)
Where W is the load and 0.239 is the length of the torque arm for the EA-10C dynamometer

2.4 Determination of Brake Specific Fuel Consumption
The amount of fuel required, in kilograms, to develop a brake power of 1 kilowatt for a period of one hour at a given load was determined using the equation

$$BSFC = \frac{R}{p}\ (\text{Kg/KWh})\ldots(1.4)$$

Where
R = rate of fuel consumption in g/s
P = Engine power in Watts given by $P = \omega\ \tau$
Where
τ = Engine Torque (Nm)
ω = Engine speed (rad/sec)

2.5 Determination of Thermal Efficiency
The ratio of work done per second to the heat energy supplied from the fuel per second was determined using equation

$$\eta = \frac{\text{Brakepower (W)} \times 3600}{\text{FuelConsumed(Kg/hr)} \times \text{(J/Kg)}}$$

III. RESULTS AND DISCUSSION

3.1 Effect of Increasing Load on Speed

The engine speed decreased linearly with increase with load from 2502 rpm at 1Kg load to 2413 at 7Kg load for diesel, biodiesel and blends. Further increase in load beyond this point led to a drastic reduction in engine speed to 2115rpm at 7.5kg load indicating the engine had exceeded its maximum loading capacity as shown in Figure 1.1

3.2 Effects of Biodiesel and Blends on Engine Brake Power

Brake power increased linearly with increased load for all the fuel samples up to 7Kg as brake power is directly proportional to load and speed as shown in Figure 1.2. The average brake power for diesel was 2.628KW while that of biodiesel was 2.682KW an increase of 2.1%. It was observed that the engine brake power increased with the biodiesel content in the blend with B5 having an average of 2.636KW an increase of 0.3% compared to diesel and B30 having an average of 2.648KW an increase of 0.76% compared to that of diesel.

3.3 Effects of Biodiesel and blends on engine torque

The engine torque increased linearly with increase in load. With increased torque, the engine speed reduced. Further increase in torque beyond the maximum load of 7Kg, slowed the engine to a stop.

3.4 Effects of Diesel and Biodiesel on the engine BSFC

The variation of brake specific fuel consumption with brake power is shown on figure 1.3. BSFC reduced with increase in load, the average BSFC being 0.485Kg/KWhr and 0.712Kg/KWhr for diesel and biodiesel respectively, an increase of 46.9%. The low heating value, higher density and higher viscosity of biodiesel resulted in higher mass injection for the same volume at the same injection pressure and thus the increased BSFC.

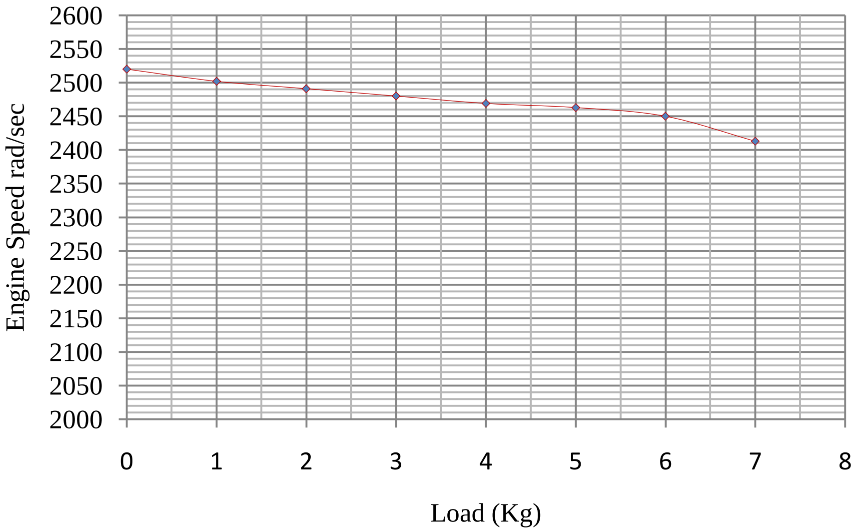

Fig 1.1 Variation of Engine Speed with Load

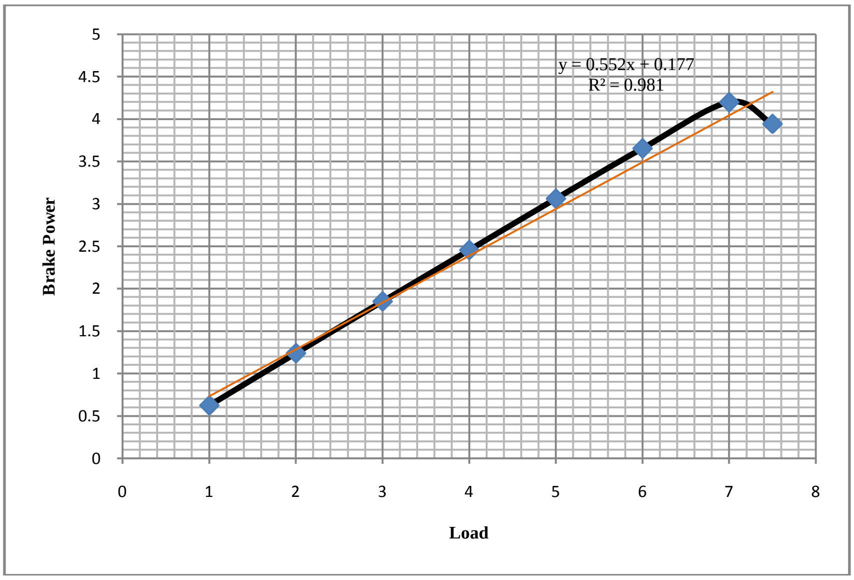

Fig 1.2 Variation of Brake Power with Load

Table 1.1 BSFC of Diesel, Biodiesel, and Blends for Different Engine Load

Load\Fuel	BSFC							
	D100	B5	B10	B15	B20	B25	B30	B100
1	1.135	1.206	1.232	1.258	1.286	1.316	1.346	1.378
2	0.593	0.727	0.745	0.765	0.786	0.808	0.831	0.855
3	0.423	0.433	0.512	0.526	0.541	0.556	0.573	0.649
4	0.367	0.396	0.407	0.419	0.431	0.444	0.458	0.564
5	0.318	0.326	0.336	0.346	0.356	0.392	0.420	0.535
6	0.308	0.317	0.328	0.340	0.352	0.365	0.379	0.448
7	0.277	0.286	0.296	0.306	0.318	0.330	0.343	0.357
7.5	0.457	0.702	0.761	0.830	0.913	1.014	1.141	0.913

Table 1.2 Thermal Efficiency of Diesel, Biodiesel, and Blends for Different Engine Load

Load	Thermal Efficiency							
	B0	B5	B10	B15	B20	B25	B30	B100
1	8.398	8.398	8.400	8.368	8.348	8.468	8.348	8.388
2	16.077	16.101	16.101	16.077	15.977	16.045	15.977	16.047
3	22.000	22.495	22.505	22.507	22.327	22.207	22.327	22.497
4	25.968	25.968	25.968	26.000	26.111	26.000	25.711	25.968
5	29.962	29.902	29.912	29.952	29.952	29.952	29.992	29.952
6	30.922	30.92	30.924	30.932	30.9322	30.932	30.952	30.922
7	34.420	34.424	34.424	34.420	34.420	34.331	33.982	34.420
7.5	20.854	20.864	20.974	20.864	20.964	21.086	21.064	20.854

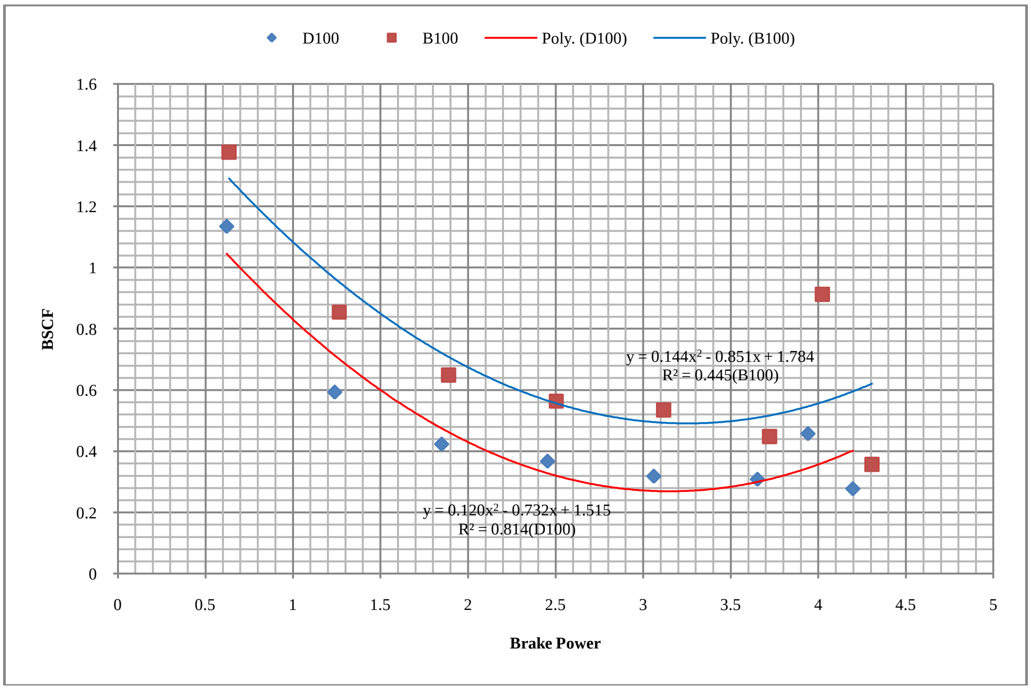

Fig 1.3 Variation of BSFC with Brake power for D100 and B100

3.5 Effects of Biodiesel Blends on Engine BSFC

Blending the biodiesel with diesel was done volumetrically to obtain the following ratios of 5:95, 10:90, 15:85, 20:80, 25:75 and 30:70 biodiesel to diesel. Comparison of the engine when running on biodiesel, diesel and their blends is shown in Figure 1.4. It was observed that the BSFC of diesel, biodiesel and their blends maintained a similar trend, with BSFC reducing with increase in brake power for all the fuels. The BSFC of the fuel samples was also found to increase with increase in the proportion of biodiesel content in the blend. The high energy value, low density and lower viscous properties of diesel fuel resulted in the engine generating the lowest average BSFC of 0.485Kg/KWh while running on diesel. the average BSFC of blend B5 was 0.549Kg/KWhr, which amounted to 13.2% increase in BSFC compared to diesel as shown in Figure 1.4. This was the best fuel in terms of engine performance and the results comparable to those obtained by Xue *et al.*, 2010 who studied the effect of biodiesel and blends on engine performance and emissions. They found the BSFC of three methyl esters to vary between 2.68% to 15.31%. As the load was increased, BSFC of biodiesel decreased and this was attributed to the increase in brake power with load as BSFC is inversely proportional to the brake power. Variation of BSFC of biodiesel and diesel with brake power is shown in Figure 1.5. Therefore, rice bran oil biodiesel was found to be more economically viable when blended with diesel than when used on its own to run the engine in terms of BSFC.

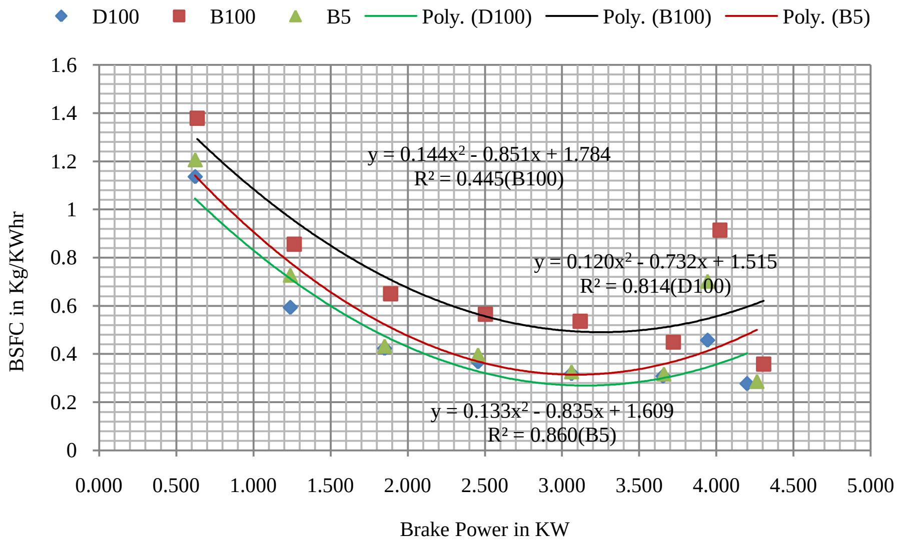

Fig 1.4 Variation of BSFC with Brake power for D100, B100, and B5

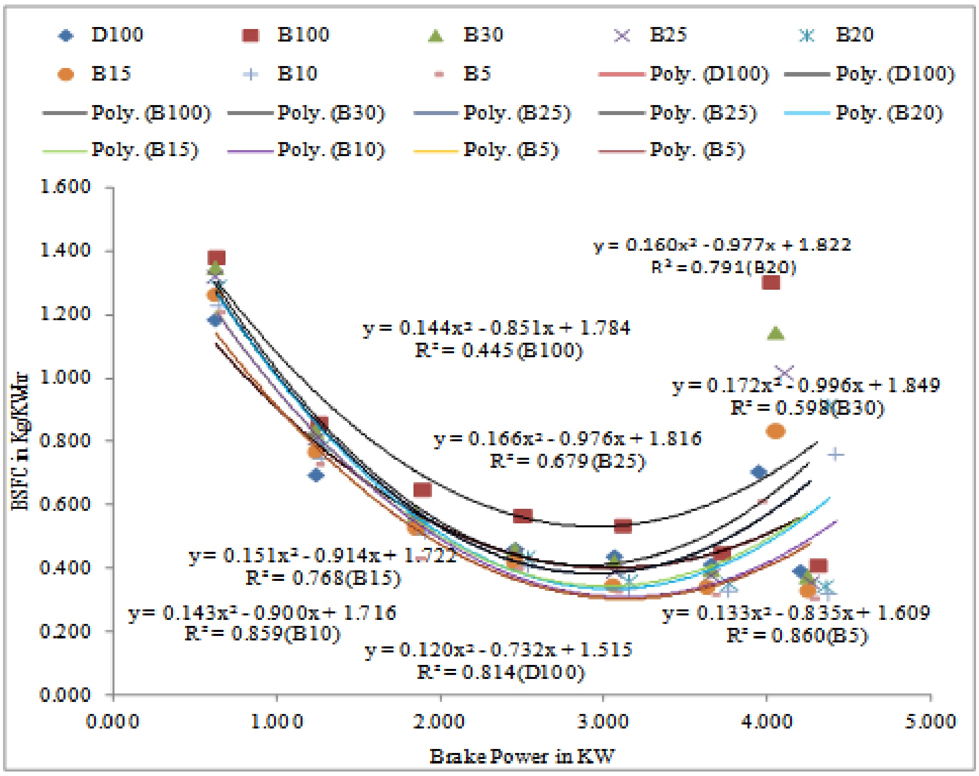

Fig 1.5 Variation of BSFC with brake power for diesel, biodiesel, and blends.

3.6 Effects of biodiesel on Thermal Efficiency

The brake thermal efficiency of the engine increased with increase in brake power. When operating on diesel and biodiesel the brake thermal efficiency was almost the same as shown in Figure 1.6. It was also noted that the Brake thermal efficiency of all the blends followed the same trend as that of diesel and biodiesel respectively as shown in Figure 1.7. This was because brake power is the actual brake work per cycle divided by the amount of fuel chemical energy as indicated by the fuel's lower heating value. This means that the engine converted the chemical energy of the fuel to mechanical energy with the same efficiency for all the fuels used in the test. The results obtained in this study are comparable to those reported by Xue *et al.* (2010) who studied the effect of biodiesel on engine performances and emissions and found the thermal efficiency of biodiesel, diesel and their blends to be equal.

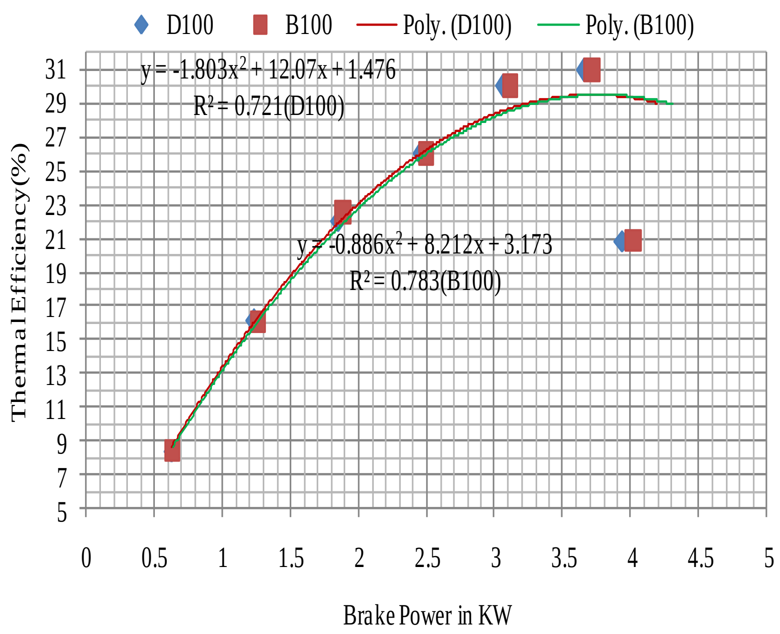

Fig 1.6 Variation of thermal efficiency with Brake power for D100 and B100

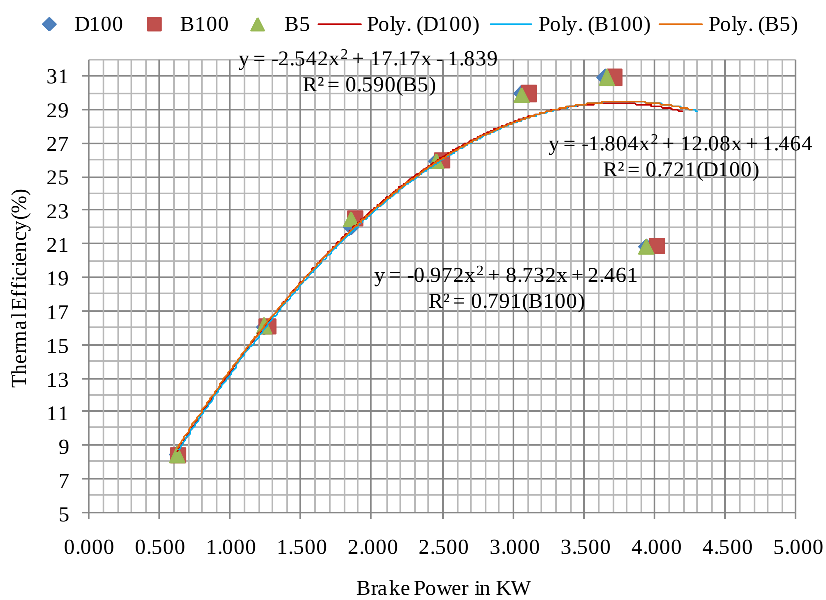

Fig 1.7 Variation of thermal efficiency with Brake power for D100, B100 and B5

IV. CONCLUSION

Although there have been inconsistent trends for biodiesel engine performance and emissions due to varied differences which include; testing engine, operating conditions, source of biodiesel, reference diesel, measurement techniques and measuring instruments, the following general conclusions could be drawn according to analysis related literature in this work:

(1) The fuel characterization showed that the biodiesel properties were within the recommended standard fuel range for use in a diesel engine.

(2) BSFC increased by 47% when using biodiesel due to low heating value, high density and viscosity of biodiesel. However this increase was reduced to 13.2% by blending biodiesel with diesel at the ratio of 5:95. The lesser the biodiesel, the more the BSFC improved. Based on this, the blended ratio of 5:95 biodiesel to diesel was found to be better than the other blends in terms of brake specific fuel consumption and engine power.

(3) The brake thermal efficiency of diesel, biodiesel and blends was the same indicating that the engine converted the chemical energy of the fuel to mechanical energy with the same efficiency

(4) Fuel blend with a small portion of biodiesel, was technically feasible as fuel in CI engine.

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