



P-ISSN: 2349-8528

E-ISSN: 2321-4902

IJCS 2020; 8(1): 383-388

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Received: 25-11-2019

Accepted: 27-12-2019

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## Performance studies of compression ignition engine by using jatropha methyl ester (Biodiesel) from non-edible and waste vegetable oil

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DOI: <https://doi.org/10.22271/chemi.2020.v8.i1e.8276>

**Abstract**

The results of the performance of a compression ignition engine (direct injected, 4-stroke 2-cylinder engine) by using jatropha methyl ester from non-edible vegetable oil (*Jatropha Curcas*) and its blends with diesel fuel have been presented in this paper. *Jatropha* fruits are available plentifully in the state of Odisha, but these are wasted here and there as these are non-edible and are not used for any useful purpose till now. Short-term engine (3.73 kW, water cooled) performance tests were conducted using six different blends of jatropha methyl ester oil with diesel fuel from 10% to 100% by volume [Jatropha methyl ester-diesel (10:90), jatropha methyl ester-diesel (20:80) jatropha methyl ester-diesel (30:70), jatropha methyl ester-diesel (40:60), jatropha methyl ester-diesel (50:50), jatropha methyl ester-diesel (100:0)] The engine performance parameters studied were power output, fuel consumption, brake specific fuel consumption (BSFC) and brake thermal efficiency (BThE) by using the above mentioned blend fuels. Brake power measured by use of Jatropha methyl ester was found to be slightly lower than diesel. Fuel consumption measured by use of Jatropha methyl ester was found to be higher than the diesel. Therefore, jatropha methyl ester can be used as a diesel fuel replacement with little sacrifice in brake thermal efficiency.

**Keywords:** Vegetable oil fuel, alternative fuel, jatropha methyl ester (biodiesel), diesel blend, and diesel engine performance

**Introduction**

The fossil fuels, especially the petroleum oil are depleting at a faster rate year after year and are bound to be exhausted in near future from their limited stock. Therefore, petroleum oil is always under threat due to instability in supply and escalations in cost. This has led to a growing concern for the sustainability of petroleum oil throughout the world and more so in the petroleum importing country like India. The oil prices have increased alarmingly and so also the oil import bill that has touched more than Rs. 120, 000 crores in India for the year 2009-10 (Sharma and Singh, 2011) [8]. The oil consumption is also increasing at an alarming rate and it might create a major crisis if its substitutes are not evolved.

Among the alternate fuels for the petroleum fuel, vegetable oil esters (biodiesel) have gained good promise and suitability for their use in compression ignition engine (Srivastava and Prasad, 2000, Verma and Gupta, 2000, McDonnell *et al.*, 2000, Lang *et al.*, 2001, Bhatt and Mathur, 2002, Pathak, 2004) [9, 11, 6, 5, 3, 7]. Biodiesel is a non-toxic, biodegradable and renewable in nature. Further advantages over petro-diesel include higher cetane number, no sulphur emission, low aromatics, low volatility and the presence of oxygen atom in the fuel molecule. According to the report entitled "compressive analysis of biodiesel impacts on exhaust emissions" published by Environmental Protection Agency, US (2002), biodiesel fuel burns up to 70% cleaner with 93% lower total HC, 50% lower CO and 45% lower particulate matter in comparison with conventional diesel fuel (Chhina *et al.*, 2005) [4].

The vegetable oil esters from edible oils may not be the right option for their substitution in diesel engine due to the lack of self-sufficiency of edible oil production in India. Hence attention has been diverted to test the suitability of non-edible vegetable oils for diesel engine (Bhatt, 1987) [1]. With the abundance of forest and tree-borne non-edible oils available in India, not much attempt has been made to use the esters of these non-edible oils as the alternative fuels for diesel engine. *Jatropha curcas* L. (Ratanjot) is one of the forest based

tree-borne non-edible oils with large production potential in India. This non-edible fruits are wasted here and there and are not used for any useful purpose. Therefore, an attempt is made in this paper to study the feasibility of jatropha methyl ester and its blends with diesel fuel for a compression ignition engine.

### Experiment and Test Procedure

Tests were conducted at the Department of Farm Machinery and Power, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha. A 2-cylinder, four stroke, direct injected diesel engine was selected for the test. Tests were done on a laboratory test bench which consisted of a hydraulic dynamometer, a water tank, exhaust gas temperature measuring system and engine mounting elements as shown in Fig.1. Jatropha methyl ester from non-edible *Jatropha curcas* L. (Ratanjot) was selected for the study. Esterification of jatropha oil is composed of heating of oil, addition of KOH and methyl alcohol, stirring of mixture, separation of glycerol, washing with distilled water and heating for removal of water. Jatropha oil was esterified using a small esterification system developed in the laboratory of Farm Machinery and Power Department, O.U.A.T., Bhubaneswar. The fuel properties of jatropha oil, jatropha methyl ester and diesel have been presented in Table 1. The basic composition of any vegetable oil is triglyceride, which is ester of three fatty acids and one glycerol. Blends of jatropha methyl ester with diesel fuel were prepared on volume basis. The ester was mixed with the diesel in the proportion of 10, 20, 30, 40, 50, and 100 % on volume basis. For example, B0 indicates blend jatropha methyl ester (0%) and diesel (100 %), B20 (Jatropha methyl ester 20% and diesel 80%), B40 (Jatropha methyl ester 40% and diesel 60%), B60 (Jatropha methyl ester 60% and diesel 40%) and B100 (Jatropha methyl ester 100% and diesel 0 %) on volume basis. An electrical heating unit was used to heat the fuel and its blends to the desired temperature. Constant speed short-term performances tests were conducted to compare the suitability of the blend fuels with diesel fuel.

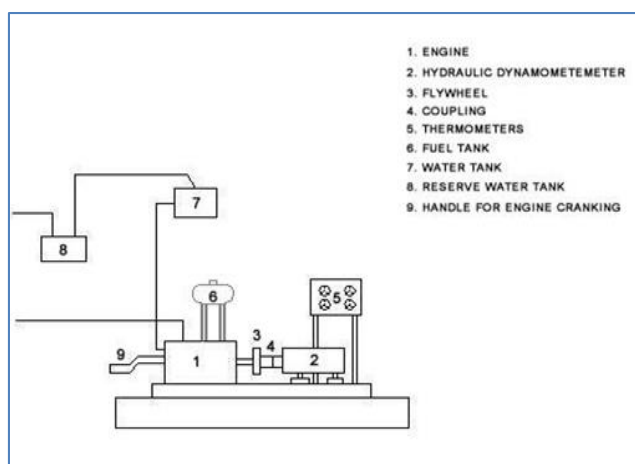


Fig. 1: Schematic layout of experimental set up

*Jatropha curcas* L. (Ratanjot) considered as a wild oilseed plant of the tropics is now being credited as a most promising biofuel crop very much ideally suited for growing in the waste lands of the country. This potential biodiesel crop can be a

major economic activity providing income and employment opportunities to the rural communities. *Jatropha curcas* L. plants grow on poor degraded soils and are able to ensure a reasonable production of seeds with very little inputs. It is not grazed by animals and is highly pest and disease resistant. Time taken for nut yield is between 2 and 5 years based on soil and rainfall conditions. Yield varies from 0.5 to 12 t/ha/year based on soil and rainfall condition. An average seed production of about 5 tones per hectare per year can be expected under optimum condition. A yield of 0.75 to 2 tones of biodiesel could be expected per hectare per year from fifth year onwards (Fiodle and Eder, 1997). *Jatropha curcas* L. is a large shrub or tree native to the American tropics but commonly found and utilized throughout most of the tropical and subtropical regions of the world. Several properties of the plant, including its hardness, rapid growth, and easy propagation and wide ranging usefulness have resulted in its spread far beyond its original destination. The jatropha oil is odourless and colourless when fresh but becomes yellow on standing. The oil content of jatropha seed ranges from 30 to 50 percent by weight and the kernel itself ranges from 45 to 60 percent. The fatty acid composition of jatropha classifies it as a linoleic or oleic acid type, which are unsaturated fatty acids. From the properties of this oil it is envisaged that the oil would be suitable as fuel oil. But jatropha oil has high viscosity compared to diesel. The high viscosity of curcas oil may contribute to the formation of carbon deposits in the engines, incomplete fuel combustion and may result in reducing the life of an engine.

The baseline test was conducted using diesel fuel alone for its comparison with the performance of alternative fuel blends. Technical specifications of the test engine are mentioned in Table 2 (Yadav, G.V. 2006) [10]. The following parameters were selected for the study: engine speed, 1500 r/min; fuel temperature, 30 °C, 50 °C and 70 °C; injection pressure, 180 kg/cm<sup>2</sup> and 245 kg/cm<sup>2</sup>. The engine was started and run till it attained the speed little higher than 1500 rpm. Then the speed was adjusted exactly to 1500 rpm by adjusting the fuel control lever. The load on the engine was gradually applied with the help of a spring balance (100 g x 20 kg). The speed for all the observations was kept constant at 1500 r/min. For the stabilization of measuring parameters at each load change and at the start of each test a time period of 10 minutes and 20 minutes was respectively allowed. Three readings were taken for each set of observations at minimum of three load settings to get a reasonable value. One set of observations consists of measurements relating to (i) net weight on the torque arm, (ii) time for 50 cc of fuel consumption, (iii) reading for the exhaust temperature, (iv) coolant temperature, (v) fuel temperature and fuel injection pressure. The ambient air temperature and barometric pressure were also recorded. From the recorded set of observations, the following parameters were calculated to predict and compare the engine performance such as (i) brake power output, Kw, (ii) brake specific fuel consumption (BSFC) kg/Kw-h, (iii) brake thermal efficiency (BThE) % and (iv) exhaust gas temperature (ExGT) °C. These performance parameters were compared for all fuel blends at three-fuel temperatures and two-injection pressures. The engine test was done according to BIS: 5994-11 (Anon, 1979).

**Table 1:** Fuel properties of jatropha oil, jatropha methyl ester and diesel

Fuel	Kinematic Viscosity at 38 °C (CS)	Density at 21 °C (gm/ml)	Flash point (°C)	Pour point (°C)	Heating value (MJ/kg)
Jatropha oil	49.3	0.92	256	-14	40.3
Jatropha methyl ester	8.16	0.89	170	-2	40.7
Diesel	5.67	0.84	74	-4.83	47.4

**Table 2:** Technical specifications of the test engine

Type	CI-10, 4-stroke vertical Compression Ignition Engine
No. of cylinders	Two
Compression ration	16.5:1
Bore	80 mm
Stroke	110 mm
Clearance volume	700 cm <sup>3</sup>
Maximum speed	1500 rpm
Power	7.4 Kw at 1500 rpm
Type of cooling	Water
Injection timing	27 <sup>o</sup> BTDC
Starting	By hand
Injector opening pressure	180 kg/cm <sup>2</sup>

## Results and Discussion

This section discusses the results of the short-term engine performance tests using jatropha methyl ester oil and their blends with diesel and pure diesel as a reference fuel. The performance of a 3.73 kW, constant speed diesel engine was evaluated on the selected fuel blends as described in Table. 3 and Figure 2 and compared with diesel.

### Brake power

The brake power, speed of the engine when operating on diesel and the blends of jatropha methyl ester with diesel prepared in 10:90, 20:80, 30:70, 40:60, 50:50, and 100:0 ratio

at no load, 20, 40, 60, 80, 100 and 110 percent brake load are shown in Table 3a. It is evident from the Table 3a that at rated load (100 percent load), condition, the engine developed brake power of 3.74 kW at 1506 rpm on diesel. The rated power of the engine as specified by manufacturer is 3.73 kW at 1500 rpm. At an over load condition i.e. at 110 percent load, the engine on diesel developed 4.11 kW and the corresponding engine speed was 1500 rpm. The results indicate that engine was able to develop its rated power (3.73 kW) on all blends and engine speed remained close to its rated speed of 1500 rpm.

**Table 3a:** Brake Power Developed by Engine on Selected Fuel Types

Brake load (%)	Diesel		JME 10		JME 20		JME 30		JME 40		JME 50		JME 100	
	ES	BP	ES	BP	ES	BP	ES	BP	ES	BP	ES	BP	ES	BP
No Load	1560	0	1546	0	1544	0	1545	0	1548	0	1573	0	1555	0
20	1574	0.79	1530	0.76	1523	0.76	1516	0.76	1526	0.76	1555	0.79	1530	0.77
40	1560	1.56	1522	1.52	1511	1.51	1511	1.51	1519	1.52	1533	1.55	1514	1.51
60	1522	2.27	1516	2.26	1515	2.27	1511	2.26	1513	2.26	1517	2.27	1515	2.27
80	1515	3.03	1508	3.01	1513	3.02	1508	3.00	1509	3.01	1511	3.01	1506	3.00
100	1506	3.74	1503	3.74	1499	3.73	1502	3.74	1502	3.74	1497	3.73	1495	3.72
110	1500	4.11	1495	4.09	1494	4.09	1493	4.08	1495	4.10	1490	4.08	1490	4.08

ES: Engine Speed (rpm), BP: Brake Power (kW)

### Fuel consumption

The observed fuel consumption (l/h) of the engine on diesel and jatropha methyl ester with diesel blends is shown in Table 3b. It is observed from the table that the fuel consumption of the engine gradually increased with increase in brake load. The fuel consumption of the engine when developing rated power of 3.73 kW on diesel was 1.161 l/h. It was observed that fuel consumption of the engine at rated load condition

when it developed its rated power was 1.173, 1.175, 1.178, 1.180, 1.239 and 1.353 l/h on 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0 jatropha methyl-ester with diesel blends respectively. These results revealed that engine consumed 1.0, 1.2, 1.4, 1.6, 6.7 and 16.5 percent more fuel on the blends having 10, 20, 30, 40, 50 and 100 percent jatropha methyl ester respectively when developing its rated power (3.73 kW).

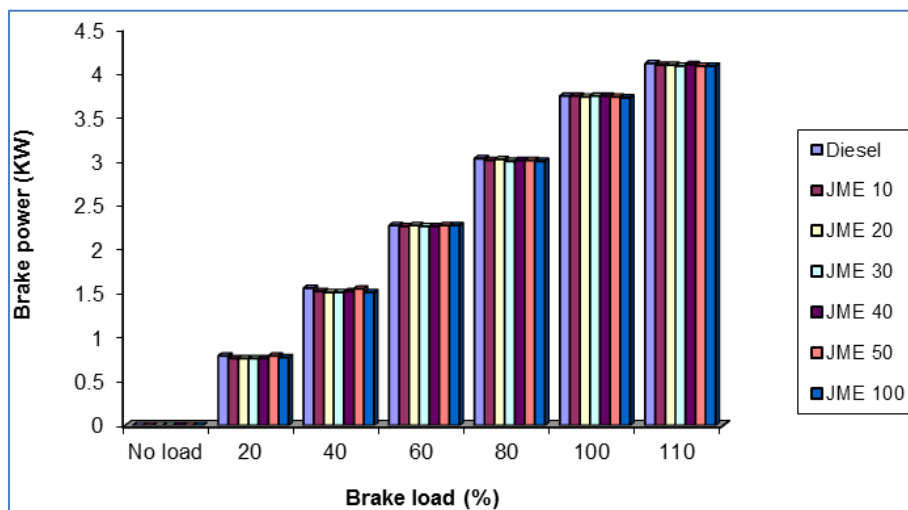


Fig. 2a: Brake power developed by the Engine on selected fuel types during fuel consumption test

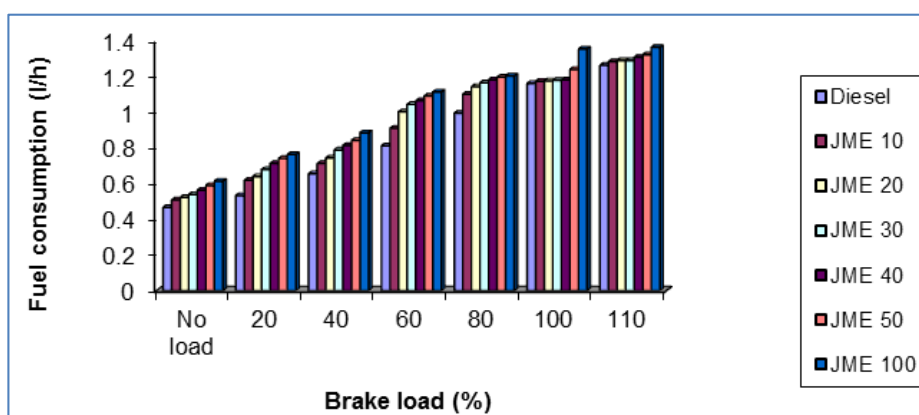


Fig. 2b: Fuel consumption of the Engine on selected fuel types during fuel consumption test

Table 3b: Fuel Consumption (l/hr) of the Engine on Selected Fuel Types

	No load	20	40	60	80	100	110
Diesel	0.466	0.533	0.655	0.811	0.994	1.161	1.262
JME 10	0.508	0.619	0.712	0.909	1.100	1.173	1.283
JME 20	0.522	0.639	0.743	1.002	1.143	1.175	1.289
JME 30	0.539	0.678	0.788	1.043	1.164	1.178	1.289
JME 40	0.563	0.712	0.813	1.064	1.181	1.180	1.307
JME 50	0.589	0.740	0.842	1.090	1.196	1.239	1.321
JME 100	0.613	0.763	0.884	1.113	1.203	1.353	1.363

**Brake specific fuel consumption**

Table 3c. shows the brake specific fuel consumption (BSFC) of the engine on various fuel types at different load conditions. The brake specific fuel consumption of engine when developing rated power on diesel was found to be 0.261 kg/kW-h. The BSFC of the engine on jatropha methyl-ester

with diesel blends mixed in 10:90, 20:80, 30:70, 40:60 50:50 and 100:0 proportion was found as 0.265, 0.267, 0.269, 0.270, 0.286 and 0.321 kg/kW-h respectively. The highest brake specific fuel consumption at rated load was observed when the engine was operating on 100 percent jatropha methyl-ester.

Table 3c: Brake Specific Fuel Consumption of the Engine on Selected Fuel

	No load	20	40	60	80	100	110
Diesel	0	0.566	0.352	0.300	0.275	0.261	0.258
JME 10	0	0.687	0.395	0.338	0.309	0.265	0.265
JME 20	0	0.713	0.417	0.374	0.321	0.267	0.267
JME 30	0	0.761	0.445	0.394	0.331	0.269	0.270
JME 40	0	0.802	0.458	0.403	0.336	0.270	0.273
JME 50	0	0.805	0.467	0.412	0.341	0.286	0.278
JME 100	0	0.874	0.516	0.432	0.354	0.321	0.295

**Brake thermal efficiency**

The brake thermal efficiency of the engine on selected fuel types is shown in Table 3d. The brake thermal efficiency of

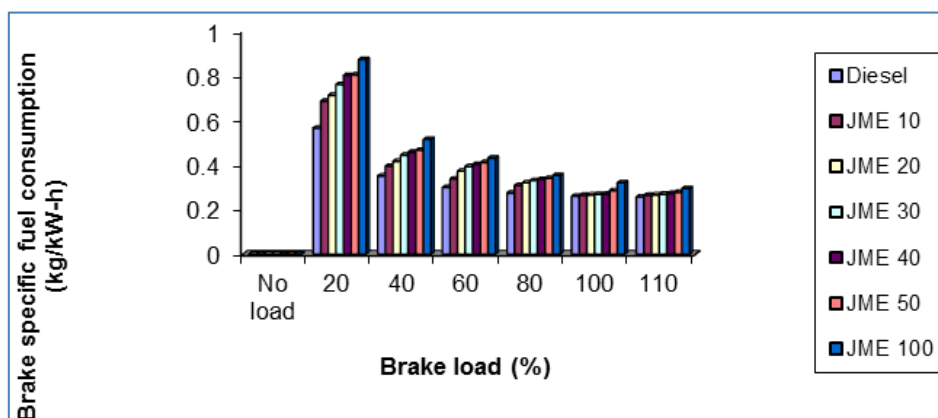
the engine on diesel when developing rated power of 3.73 kW i.e. at rated brake load was observed to be 28.31 percent. The comparison of observed brake thermal efficiency indicates

that when the engine developed its rated power, it was 28.19, 28.30, 28.49, 28.72, 27.40 and 25.92 percent on jatropha methyl-ester with diesel blends having 10:90, 20:80, 30:70, 40:60 50:50 and 100:0 proportion respectively. The highest

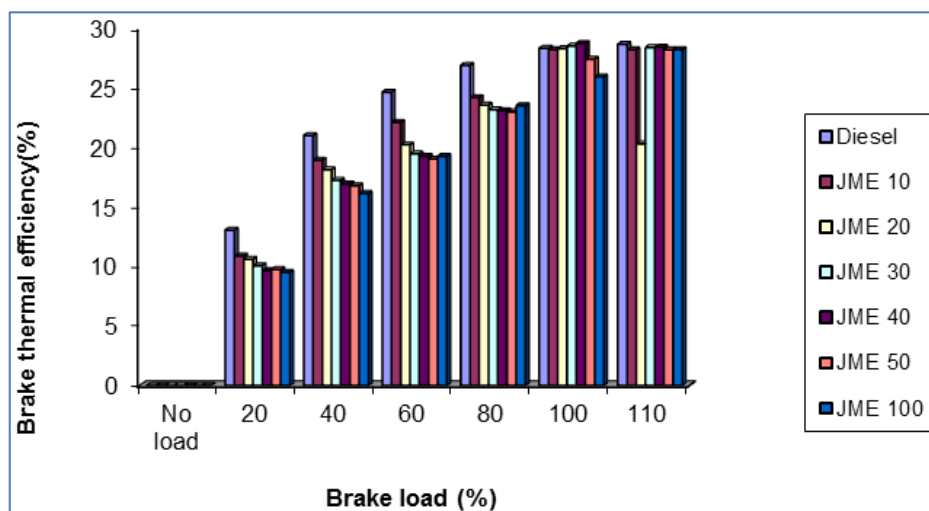
brake thermal efficiency (28.72 percent) at the rated power was observed on the blend having 40 percent jatropha methyl ester and 60 percent diesel and was found to be the lowest (25.92 percent) on the 100% of jatropha methyl-ester.

**Table 3d:** Brake Thermal Efficiency of the Engine on Selected Fuel

	No load	20	40	60	80	100	110
Diesel	0	13.05	20.99	24.63	26.87	28.31	28.64
JME 10	0	10.87	18.91	22.10	24.18	28.19	28.19
JME 20	0	10.60	18.12	20.21	23.54	28.30	20.30
JME 30	0	10.07	17.22	19.45	23.15	28.49	28.38
JME 40	0	9.67	16.93	19.24	23.08	28.72	28.40
JME 50	0	9.74	16.78	19.02	22.98	27.40	28.19
JME 100	0	9.52	16.12	19.26	23.50	25.92	28.20



**Fig. 2c:** Brake specific fuel consumption of the engine on selected fuel types during fuel consumption test



**Fig. 2d:** Brake thermal efficiency of the engine on selected fuel types during fuel consumption test

## Conclusions

From the results of the experimental investigation, the following conclusions are drawn:

- The engine was found to develop its rated power (3.73 kW) at 100 percent load (rated load) on diesel at 1510 rpm.
- The engine was able to develop power similar to diesel on jatropha methyl ester with diesel blends mixed in 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0 proportions at every selected brake load conditions.
- The hourly fuel consumption of the engine was found to increase with the increase in level of jatropha methyl ester in the blends. The fuel consumption of the engine when developing its rated power was found to be the lowest on 10:90 blends (1.173 l/h) and for the similar

condition it was highest (1.352 l/h) on 100:0 blend. The fuel consumption of jatropha methyl ester with diesel blends having 10 percent jatropha methyl ester found to be close to diesel fuel.

- The brake specific fuel consumption of the engine when developing its rated power was found as 0.261 kg/kW-h on diesel. For the similar conditions, the BSFC of the jatropha methyl ester with diesel blend mixed in 10:90 ratios was found close to diesel. The highest brake specific fuel consumption at rated load was observed when the engine was operating on the blend containing 100 percent jatropha methyl ester. The BSFC of the engine was found maximum at 20 percent brake load on all fuel types and it gradually decreased with increase in load.

- (v) The brake thermal efficiency of the engine on diesel when developing rated power of 3.73 kW was observed as 28.31 percent. The highest brake thermal efficiency (28.72 percent) at the rated power was observed on the blend having 40 percent jatropha methyl ester and 60 percent diesel and was found lowest (25.92 percent) on the blend containing 100 percent jatropha methyl ester.

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