Use of Jatropha Oil Methyl Ester and Its Blends as an Alternative Fuel in Diesel Engine

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Biomass derived vegetable oils are quite promising alternative fuels for agricultural diesel engines. Use of vegetable oils in diesel engines leads to slightly inferior performance and higher smoke emissions due to their high viscosity. The performance of vegetable oils can be improved by modifying them through the transesterification process. In the present work, the performance of single cylinder water-cooled diesel engine using methyl-ester of Jatropha oil as fuel was evaluated for its performance and exhaust emissions. The fuel properties of biodiesel such as kinematic viscosity, calorific value, flash point, carbon residue and specific gravity were found. Results indicated that B25 has closer performance to diesel and B100 has lower brake thermal efficiency, mainly due to its high viscosity compared to diesel. The brake thermal efficiency for biodiesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions and there was no difference between the biodiesel and its blended fuels efficiencies. For Jatropha biodiesel and its blended fuels, the exhaust gas temperature increased with increase in power and amount of biodiesel. But, diesel blends showed reasonable efficiency, lower smoke, CO2, CO and HC.

***Keywords**: Jatropha oil, bio-fuels, transesterification, performance and emission characteristics*

Introduction

Majority of the world's energy needs are supplied through petrochemical sources, coal and natural gases, with the exception of hydroelectricity and nuclear energy; of all, these sources are finite and at current usage rates will be consumed shortly. Diesel fuels have an essential function in the industrial economy of developing countries and are used for transport of industrial and agricultural goods, operation of diesel tractor and pump sets in agricultural sector. Economic growth is always accompanied by commensurate increase in the transport. The high energy demand in the industrialized world as well as in the domestic sector and pollution problems caused due to the widespread use of fossil fuels make it increasingly necessary to develop the renewable energy sources of limitless duration and smaller environmental impact than the traditional one. This has stimulated recent interest in alternative sources for petroleum based fuels.

Diesel engines are the most efficient prime movers. From the point of view of protecting global environment and concerns for long-term energy security, it becomes necessary to develop alternative fuels with properties comparable to petroleum based fuels. Unlike the rest of the world, India's demand for diesel fuels is roughly six times that of gasoline, hence seeking alternative to mineral diesel is a natural choice (Barnwal, 2005) (Vijaya Raju *et alii*, 2000). The rapid depletion of petroleum reserves and the rising oil prices have led to the search for alternative fuels. Non edible oils are promising fuels for agricultural applications. Vegetable oils have properties comparable to diesel and can be used to run CI engines with little or no modifications (Altõn, 1998).

An alternative fuel must be technically feasible, economically competitive, environmentally acceptable, and readily available. One possible alternative to fossil fuel is the use of oils of plant origin like vegetable oils and tree borne oil seeds. This alternative diesel fuel can be termed as biodiesel. This fuel is biodegradable and non-toxic and has low emission profiles as compared to petroleum diesel. Usage of biodiesel will allow a balance to be sought between agriculture, economic development and the environment.

Of the various alternate fuels under consideration, biodiesel, derived from vegetable oils, is the most promising alternative fuel to diesel due to the following reasons:

1. Biodiesel can be used in the existing engine without any modifications.
2. Biodiesel is made entirely from vegetable sources; it does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
3. Biodiesel is an oxygenated fuel; emissions of carbon monoxide and soot tend to reduce.
4. Unlike fossil fuels, the use of biodiesel does not contribute to global warming as CO_2 emitted is once again absorbed by the plants grown for vegetable oil/biodiesel production. Thus CO_2 balance is maintained.
5. The occupational safety and health administration classifies biodiesel as a non-flammable liquid.
6. The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel.
7. Biodiesel is produced from renewable vegetable oils/animal fats and hence improves the fuel or energy security and economy independence.

A lot of research work has been carried out to use vegetable oil both in its neat form and modified form (Forson *et alii*, 2004) (Pramanik, 2003) (Agarwal *et alii*, 2007) (Patil and Singh, 1991) (Vijaya Raju *et alii*, 2000) (Ishii and Takeuchi, 1987). Studies have shown that the usage of vegetable oils in neat form is possible but not preferable. The high viscosity of vegetable oils and the low volatility affects the atomization and spray pattern of fuel, leading to

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incomplete combustion and severe carbon deposits, injector choking and piston ring sticking. The methods used to reduce the viscosity are

- Blending with diesel
- Emulsification
- Pyrolysis
- Transesterification

Among these, the transesterification is the commonly used commercial process to produce clean and environmental friendly fuel (Forson *et alii*, 2004) (Agarwal *et alii*, 2007). However, this adds extra cost of processing, because of the transesterification reaction involving chemical and process heat inputs.

Jatropha Curcas

It is non-edible oil being singled out for large-scale for plantation on wastelands. Jatropha curcas plant can thrive under adverse conditions. It is a drought-resistant, perennial plant, living up to fifty years and has capability to grow on marginal soils. It requires very little irrigation and grows in all types of soils (from coastline to hill slopes). The production of Jatropha seeds is about 0.8 kg per square meter per year. The oil content of Jatropha seed ranges from 30% to 40% by weight and the kernel itself ranges from 45% to 60%. Fresh Jatropha oil is slow-drying, odorless and colorless oil, but it turns yellow after aging (Sarin and Sharma, 2007).

The only limitation of this crop is that the seeds are toxic and the press cake cannot be used as animal folder. The press cake can only be used as organic manure. The fact that Jatropha oil cannot be used for nutritional purposes without detoxification makes its use as energy/fuel source very attractive. In Madagascar, Cape Verde and Benin, Jatropha oil was used as mineral diesel substitute during the Second World War. Forson *et alii* (2004) used Jatropha oil and diesel blends in CI engines and found its performance and emissions characteristics similar to that of mineral diesel at low concentration of Jatropha oil in blends. Pramanik (2003) tried to reduce viscosity of Jatropha oil by heating it and also blending it with mineral diesel.

The present research is aimed at exploring technical feasibility of Jatropha oil in direct injection compression ignition engine without any substantial hardware modifications.

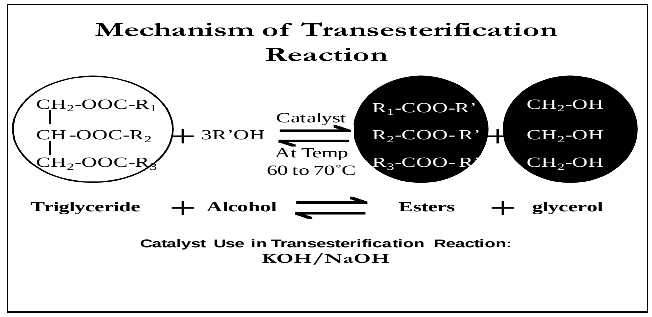
Present Work

In this work the methyl ester of Jatropha oil was investigated for its performance as a diesel engine fuel. Fuel properties of mineral diesel, Jatropha biodiesel and Jatropha oil were evaluated.

Three blends were obtained by mixing diesel and esterified Jatropha in the following proportions by volume: 75% diesel + 25% esterified Jatropha, 50% diesel + 50% esterified Jatropha and 25% diesel + 75% esterified Jatropha. Performance parameters like brake thermal efficiency, specific fuel consumption, brake power were determined. Exhaust emissions like CO_2, CO, NO_X and smoke have been evaluated. For comparison purposes experiments were also carried out on 100% esterified Jatropha and diesel fuel.

Transesterification Process

The conversion of Jatropha oil into its methyl ester can be accomplished by the transesterification process. Transesterification involves reaction of the triglycerides of Jatropha oil with methyl alcohol in the presence of a catalyst Sodium Hydroxide (NaOH) to produce glycerol and fatty acid ester.



The production of biodiesel by transesterification of the oil generally occurs using the following steps:

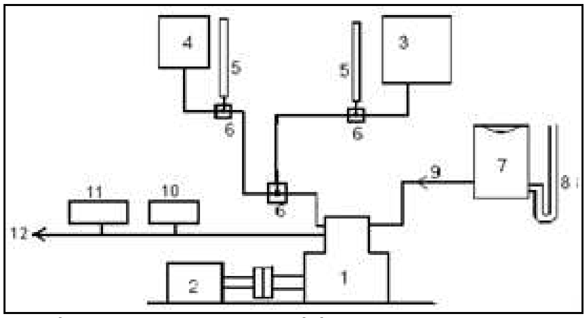
1. *Mixing of alcohol and catalyst.* For this process, a specified amount of 450 ml methanol and 10 gr Sodium Hydroxide (NaOH) was mixed in a round bottom flask.
2. *Reaction.* The alcohol/catalyst mix is then charged into a closed reaction vessel and 1000 ml Jatropha oil is added. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters.
3. *Separation of glycerin and biodiesel.* Once the reaction is complete, two major products exist: glycerin and biodiesel. The quantity of produced glycerin varies according the oil used, the process used, the amount of excess alcohol used. Both the glycerin and biodiesel products have a substantial amount of the excess alcohol that was used in the reaction. The reacted mixture is sometimes neutralized at this step if needed.
4. *Alcohol Removal.*
5. *Glycerin Neutralization.* The glycerin by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerin. In some cases the salt formed during this phase is recovered for use as fertilizer. In most cases the salt is left in the glycerin.
6. *Methyl Ester Wash*. The most important aspects of biodiesel production to ensure trouble free operation in diesel engines are complete reaction, removal of glycerin, removal of catalyst, removal of alcohol and absence of free fatty acids.

Experimental Setup

The engine used for this experimental investigation was a single cylinder 4-stroke naturally aspirated water cooled diesel engine having 5 BHP as rated power at 1500 rpm. The engine was coupled to a brake drum dynamometer to measure the output. Fuel flow rates were timed with calibrated burette. Exhaust gas analysis was performed using a multi gas exhaust analyzer. The pressure crank angle diagram was obtained with help of a piezo electric pressure transducer. A Bosch smoke pump attached to the exhaust pipe was used for measuring smoke levels. The total experimental set up is shown in Fig 1.

Experimental Procedure

Experiments were initially carried out on the engine using diesel as the fuel in order to provide base line data (ISI, 1980). The cooling water temperature at the outlet was maintained at 70^{o}C. The engine was stabilized before taking all measurements. Subsequently experiments were repeated with methyl ester of Jatropha oil for comparison. In all cases, the pressure and crank angle diagram were recorded and processed to get combustion parameters.



1. Engine
2. Brake drum dynamometer
3. Fuel tank (biodiesel)
4. Diesel tank
5. Burettes
6. Three way valve
7. Air box
8. Manometer
9. Air flow direction
10. Exhaust analyzer
11. Smoke meter
12. Exhaust flow

The technical specifications of diesel engine are given below.
Manufacturer: Kirloskar engines Ltd, Pune, India
No of cylinders: One
No. of strokes: Four
Bore & Stroke: 80 & 110 mm
Capacity: 3.68 kW
BHP of engine: 5
Speed: 1500 rpm
Mode of injection: DI
Cooling system: water

Figure 1. Experimental setup.

Results and Discussion

The fuels (mineral diesel, Jatropha biodiesel and Jatropha oil) were analyzed for several physical, chemical and thermal properties and results are shown in Table 1. The observations and calculated data are presented in Tables 2, 3, 4, 5, 6, 7, 8, 9, and 10, where:

F.C = Fuel consumption
S.F.C = Specific fuel consumption
B.P = Brake power
B.Th = Brake thermal efficiency
A/F = Air Fuel ratio.

Density, cloud point and pour point of Jatropha oil was found higher than diesel. Higher cloud and pour point reflect unsuitability of Jatropha oil as diesel fuel in cold climatic conditions. The flash and fire points of Jatropha oil was quite high compared to diesel. Hence, Jatropha oil is extremely safe to handle (Harrington, 1986) (Patil and Singh, 1991). Higher carbon residue from Jatropha oil may possibly lead to higher carbon deposits in combustion chamber of the engine. Low sulphur content in Jatropha oil results in lower SO_X emissions. Presence of oxygen in fuel improves combustion properties and emissions but reduces the calorific value of the fuel (Altõn, 1998) (Yamane *et alii*, 2001). Jatropha oil has approximately 90% calorific value compared to diesel. Nitrogen content of the fuel also affects the NO_X emissions.

Table 1. Fuel properties of mineral diesel, Jatropha biodiesel, Jatropha oil.

Sl no	Property	mineral diesel	Jatropha biodiesel	Jatropha oil
1.	Density (kg/m^3)	840±1.732	879	917±1
2.	Kinematic viscosity at 40 ^{o}C (cSt)	2.44±0.27	4.84	35.98±1.3
3.	Pour point (^{o}C)	6±1	3±1	4±1
4.	Flash point (^{o}C)	71±3	191	229±4
5.	Conradson Carbon residue (%,w/w)	0.1±0.0	0.01	0.8±0.1
6.	Ash content (%, w/w)	0.01±0.0	0.013	0.03±0.0
7.	Calorific value (MJ/kg)	45.343	38.5	39.071
8.	Sulphur (%, w/w)	0.25	<0.001	0
9.	Cetane No.	48-56	51-52	23-41
10.	Carbon (%, w/w)	86.83	77.1	76.11
11.	Hydrogen (%, w/w)	12.72	11.81	10.52
12.	Oxygen (%, w/w)	1.19	10.97	11.06

Table 2. 100% Diesel.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F ratio	Exhaust gas temp. (^{o}C)
1	0	2.5	135	0.416	-	0	0	56.4	190
2	2	2.5	98	0.573	1.154	0.496	7.45	40.9	260
3	4	2.5	85	0.661	0.670	0.992	12.83	35.5	270
4	6	2.5	75	0.750	0.503	1.488	17.1	31.3	290
5	8	2.5	68	0.826	0.416	1.984	20.65	28.4	320
6	10	2.5	61	0.921	0.372	2.480	23.15	25.5	345
7	12	2.5	60	0.936	0.314	2.977	27.35	25.06	365
8	14	2.5	58	0.968	0.279	3.473	30.85	24.2	380

Table 3. 75% Diesel + 25% Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F Ratio	Exhaust gas temp. (^oC)
1	0	2.6	154	0.413	-	0	0	58	180
2	2	2.6	148	0.455	0.917	0.496	9.5	52.7	190
3	4	2.6	130	0.490	0.493	0.992	17.65	49	198
4	6	2.6	120	0.531	0.356	1.488	24.45	45.2	205
5	8	2.6	111	0.574	0.289	1.984	30.12	42.2	220
6	10	2.6	88	0.724	0.291	2.480	29.9	33.14	245
7	12	2.6	75	0.849	0.285	2.977	30.53	28.25	275
8	14	2.6	60	1.06	0.305	3.473	28.5	22.6	325

Table 4. 50% Diesel + 50% Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F ratio	Exhaust gas temp (^oC)
1	0	2.6	158	0.382	-	0	0	62.73	185
2	2	2.6	139	0.434	0.875	0.496	10.1	55.2	190
3	4	2.6	126	0.479	0.482	0.992	18.3	50.0	200
4	6	2.6	117	0.515	0.346	1.488	25.4	46.5	210
5	8	2.6	113	0.534	0.269	1.984	32.84	44.9	215
6	10	2.6	92	0.655	0.264	2.480	33.43	36.53	240
7	12	2.6	65	0.928	0.312	2.977	28.35	25.81	300
8	14	2.6	60	1.005	0.289	3.473	35.53	23.52	340

Table 5. 25% Diesel + 75% Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F ratio	Exhaust gas temp (^oC)
1	0	2.6	147	0.460	-	0	0	52.0	180
2	2	2.6	128	0.529	1.066	0.496	8.52	45.3	190
3	4	2.6	116	0.583	0.590	0.992	15.4	41.0	200
4	6	2.6	104	0.651	0.437	1.488	20.8	36.8	210
5	8	2.6	99	0.684	0.344	1.984	26.36	35.0	220
6	10	2.6	90	0.752	0.303	2.480	29.95	31.8	230
7	12	2.6	82	0.825	0.277	2.977	32.76	29.0	235
8	14	2.6	73	0.927	0.267	3.473	34.0	25.8	250

Table 6. 100% Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F ratio	Exhaust gas temp. (^oC)
1	0	2.6	128	0.523	-	0	0	45.26	160
2	2	2.6	126	0.533	1.071	0.496	8.0	45.1	170
3	4	2.6	109	0.614	0.619	0.992	13.84	38.97	180
4	6	2.6	104	0.644	0.432	1.488	19.84	37.2	194
5	8	2.6	95	0.705	0.355	1.984	24.14	33.95	202
6	10	2.6	69	0.97	0.392	2.480	21.92	24.97	215
7	12	2.6	53	1.263	0.424	2.977	20.2	18.95	230
8	14	2.6	49	0.37	0.3945	3.473	21.73	17.5	250

Table 7. Esterified Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	Bth (%)	A/F ratio	Exhaust gas temp (^oC)
1	0	2.6	128	0.523	-	0	0	45.76	185
2	2	2.6	126	0.531	1.071	0.496	8.0	45.10	190
3	4	2.6	109	0.614	0.619	0.992	13.84	39.00	200
4	6	2.6	104	0.644	0.432	1.488	19.84	37.20	210
5	8	2.6	95	0.705	0.355	1.984	24.84	33.95	225
6	10	2.6	69	0.970	0.391	2.480	21.92	24.70	270
7	12	2.6	53	1.263	0.424	2.977	20.2	19.0	320
8	14	2.6	49	1.370	0.395	3.473	21.73	17.50	360

Table 8. 75% Diesel + 25% Esterified Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F ratio	Exhaust gas temp (°C)
1	0	2.6	160	0.368	-	0	0	65.1	180
2	2	2.6	142	0414	0.835	0.496	10.3	57.76	190
3	4	2.6	127	0464	0.467	0.992	18.4	51.65	200
4	6	2.6	117	0.503	0.338	1.488	25.44	47.6	210
5	8	2.6	110	0.535	0.270	1.984	31.86	44.74	219
6	10	2.6	103	0.571	0.230	2.480	37.3	41.9	224
7	12	2.6	74	0.795	0.267	2.977	32.2	30.1	263
8	14	2.6	60	0.981	0.283	3.473	30.4	24.4	272

Table 9. 50% Diesel + 50% Esterified Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F ratio	Exhaust gas temp (°C)
1	0	2.6	153	0.402	-	0	0	59.51	175
2	2	2.6	134	0.459	0.926	0.496	9.3	52.10	190
3	4	2.6	122	0.505	0.509	0.992	16.9	47.40	200
4	6	2.6	114	0.540	0.362	1.488	23.7	44.30	205
5	8	2.6	106	0.58	0.293	1.984	29.32	41.20	220
6	10	2.6	93	0.662	0.270	2.480	31.8	36.20	240
7	12	2.6	88	0.700	0235	2.977	36.53	34.20	250
8	14	2.6	84	0.733	0.210	3.473	40.9	32.70	260

Table 10. 25% Diesel + 75% Esterified Jatropha oil.

Sl no	Load (kgf)	Manometer reading (cm)	Time taken for 20cc of F.C (sec)	F.C (kg/hr)	S.F.C (kg/kWhr)	B.P (kW)	B.Th (%)	A/F ratio	Exhaust gas temp. (°C)
1	0	2.6	151	0.426	-	0	0	56.25	174
2	2	2.6	128	0.502	1.012	0.496	8.5	47.7	185
3	4	2.6	117	0.550	0.223	0.992	15.5	43.6	195
4	6	2.6	110	0.584	0.392	1.488	21.9	4.10	205
5	8	2.6	102	0.630	0.317	1.984	27.0	38.0	220
6	10	2.6	92	0.699	0.282	2.480	30.5	34.3	230
7	12	2.6	84	0.765	0.257	2.977	33.4	31.3	250
8	14	2.6	78	0.824	0.237	3.473	36.2	29.1	255

Higher viscosity is a major problem in using vegetable oil as fuel for diesel engines. In the present investigation, viscosity was reduced by transesterification process. Viscosity of Jatropha biodiesel is 4.84 cSt at 40°C. It is observed that viscosity of Jatropha oil decreases remarkably with increasing temperature and it becomes close to diesel at temperature above 90°C.

The performance, combustion parameters and exhaust emissions of the engine with diesel and methyl ester of Jatropha oil are presented and discussed below. Observations and calculations are given in the following tables.

In Fig. 2, it indicates that specific fuel consumption is lower than the diesel for various proportions of Jatropha oil with diesel at constant operated conditions. This is due to complete combustion, as addition oxygen is available from fuel itself. Similarly for various blends of esterified Jatropha oil with diesel at constant operating conditions specific fuel consumption is lower when compared to diesel.

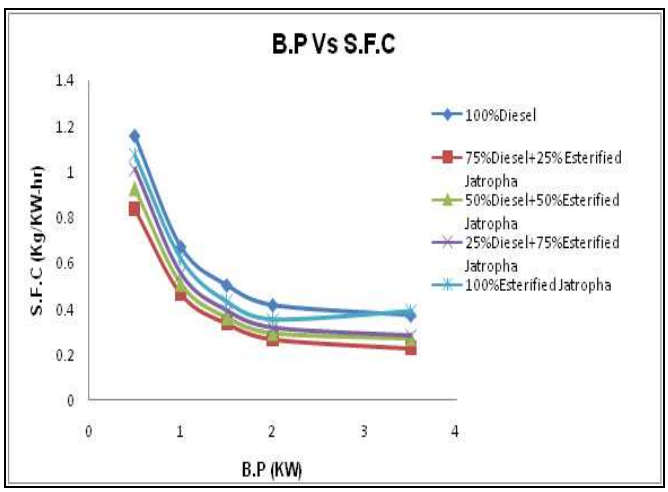


Figure 2. Variation of brake power with specific fuel consumption.

In Fig. 3, brake thermal efficiency is higher for both esterified and non-esterified blends with diesel as compared to neat diesel operation. The fuel which has lowest brake thermal efficiency, is the diesel when compared to without any of the blends with diesel.

In Fig. 4, it indicates that esterified Jatropha oil and its blends, which have calorific value higher than non-esterified, but lower than the diesel. Their exhaust temperature is comparatively higher than the non-esterified and lower than the diesel.

In Fig. 5, it indicates that specific fuel consumption is lower for esterified Jatropha, and Jatropha oil is lower than diesel at lower loads.

In Fig. 6, it indicates that brake thermal efficiency is higher for esterified Jatropha and Jatropha oil compared to diesel at lower loads.

In Fig. 7, it is observed that the exhaust gas temperature for esterified Jatropha and Jatropha oil is lower than diesel at all loads.

The carbon dioxide emission from the diesel engine with different blends is shown in Fig. 8. The CO_2 increased with increase in load conditions for diesel and for biodiesel blended fuels. The Jatropha biodiesel followed the same trend of CO_2 emission, which was higher than in case of diesel. The CO_2 in the exhaust gas was the same for Jatropha biodiesel blended fuels and Jatropha biodiesel.

The CO emission from the diesel fuel with biodiesel blended fuels and biodiesel is shown in Fig. 9. The CO reduction by biodiesel was 17.5, 17, 16, 14 and 14 per cent at 1, 1.5, 2, 2.5 and 3.5 kW load conditions. With diesel fuel mode the lowest CO was recorded as 520 ppm at 2 kW load and as load increased to 3.5 kW, CO also increased to 898 ppm. Similar results were obtained for biodiesel blended fuels and Jatropha biodiesel with lower emission than diesel fuel. The amount of CO emission was lower in case of biodiesel blended fuels and biodiesel than diesel because of the fact that biodiesel contained 11 per cent oxygen molecules. This may lead to complete combustion and reduction of CO emission in biodiesel fuelled engine.

Figure 10 shows the variation of NOx with respect to brake power. At higher power output conditions, due to higher peak and exhaust temperatures the NOx values are relatively higher compared to low power output conditions. A slight increase in NOx is observed for blends of esterified Jatropha Diesel compared to diesel. The reason may be due to late burning of blends of MEJ-diesel during expansion (Forgiel and Varde, 1981). The reason for increase in NOx with respect to esterified Jatropha diesel may be due to sustained and prolonged duration of combustion associated with reduction in combustion temperature.

Figure 11 represents the variation of smoke with respect to brake power. Smoke increases with increase in brake power. Smoke emission was lesser for blends of esterifies Jatropha diesel compared to diesel. This may be due to late burning in the expansion and exhaust (Forgiel and Varde, 1981).

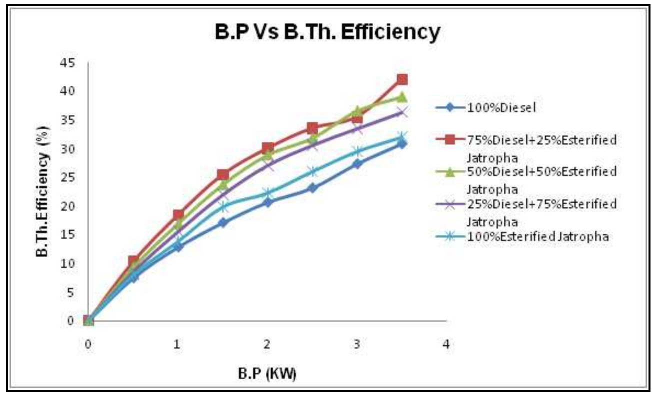


Figure 3. Variation of brake power with brake thermal efficiency.

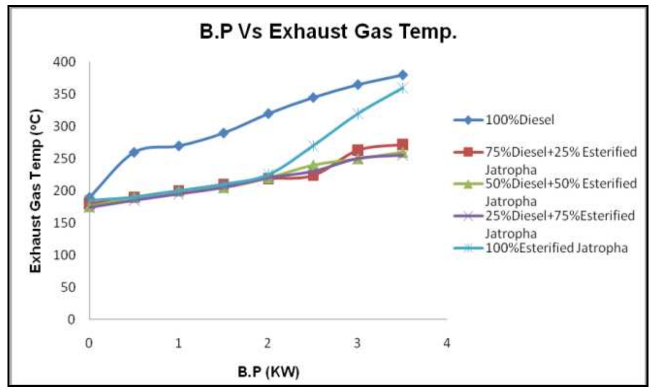


Figure 4. Variation of brake power with exhaust gas temperature.

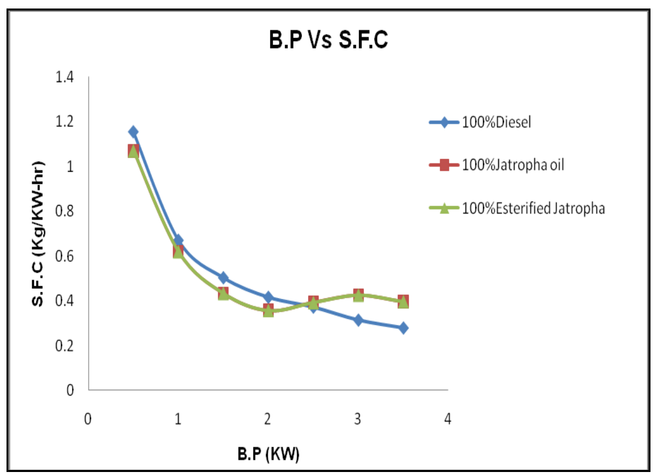


Figure 5. Variation of brake power with specific fuel consumption.

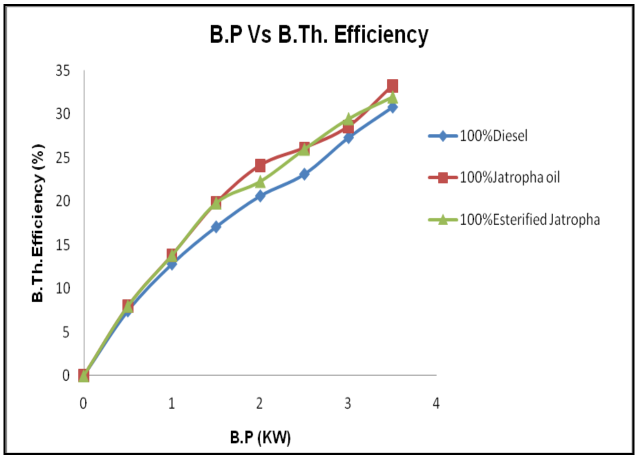


Figure 6. Variation of brake power with brake thermal efficiency.

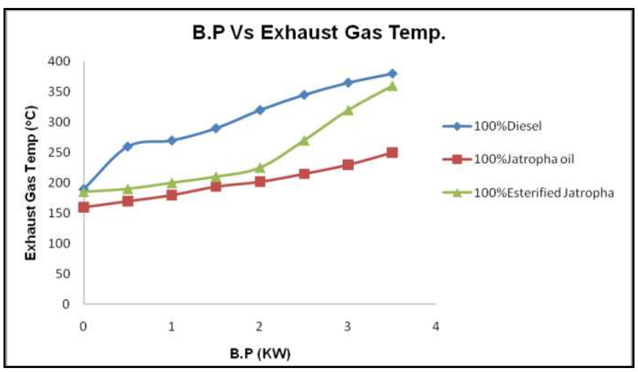


Figure 7. Variation of brake power with exhaust gas temperature.

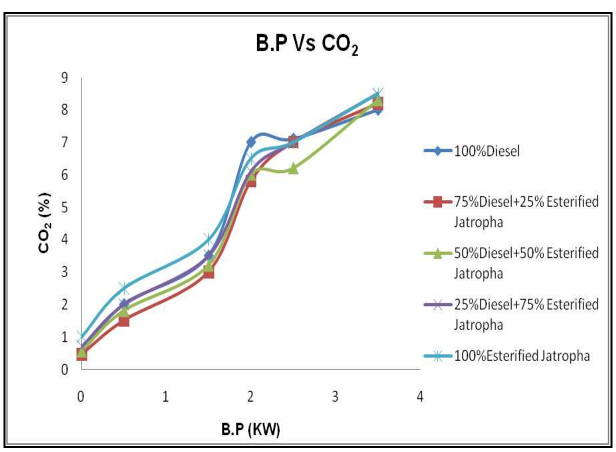


Figure 8. Variation of brake power with CO_2.

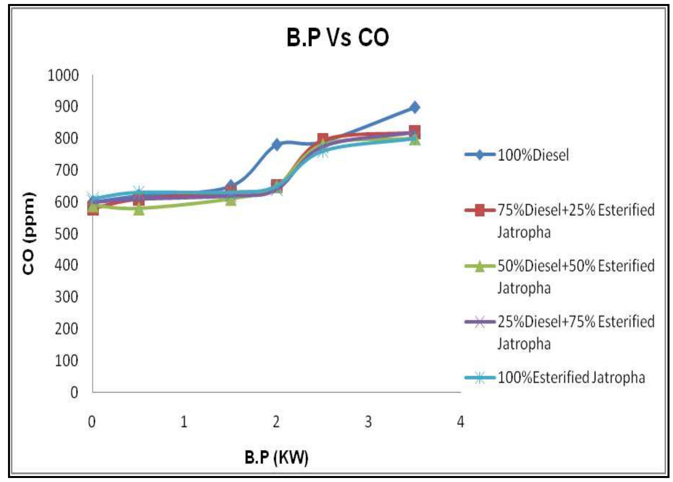


Figure 9. Variation of brake power with CO.

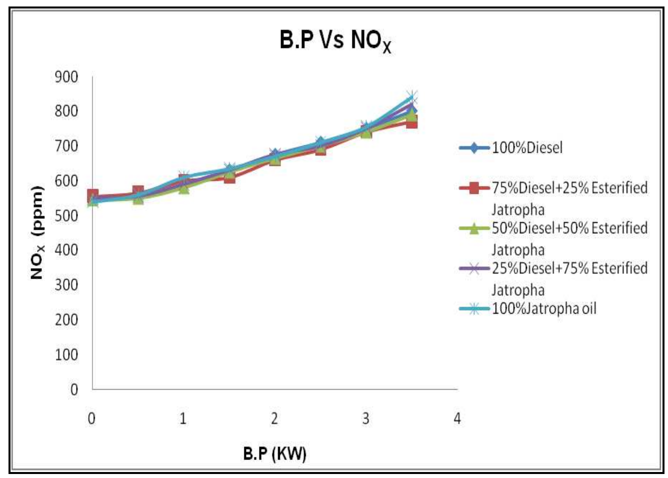


Figure 10. Variation of brake power with NOx.

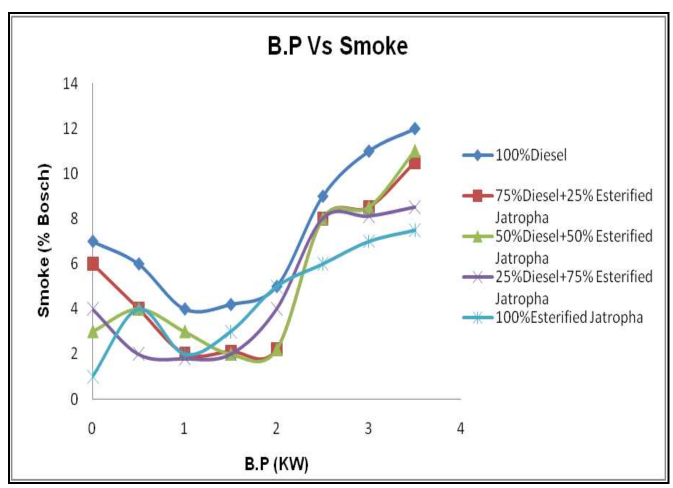


Figure 11. Variation of brake power with smoke.

Conclusions

A single cylinder compression ignition engine was operated successfully using methyl ester of Jatropha oil as the soul fuel. The following conclusions are made based on the experimental results.

- Engine works smoothly on methyl ester of Jatropha oil with performance comparable to diesel operation.
- Methyl ester of Jatropha oil results in a slightly increased thermal efficiency as compared to that of diesel.
- The exhaust gas temperature is decreased with the methyl ester of Jatropha oil as compared to diesel.
- CO_2 emission is low with the methyl ester of Jatropha oil.
- CO emission is low at higher loads when compared with the methyl ester of Jatropha oil.
- NO_X emission is slightly increased with methyl ester of Jatropha oil compared to diesel.
- There is significant difference in smoke emissions when the methyl ester of Jatropha oil is used.

This methyl ester of Jatropha oil along with diesel may reduce the environmental impacts of transportation, the dependency on crude oil imports, and may offer business possibilities to agricultural enterprises for periods of excess agricultural production. On the whole, it is concluded that the methyl ester of Jatropha oil will be a good alternative fuel for diesel engine for agricultural applications.

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