To Save the Diesel Fuel and Environment Pollution by using Jatropha Oil

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Abstract— The aim of present study is to analyze the performance and emission characteristics of C.I. engine using a suitable bio diesel as a fuel. The bio diesel selected to conduct this experimental investigation is Jatropha biodiesel. The performance of single cylinder water-cooled diesel engine and methyl-ester of Jatropha oil as the fuel is 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 are discussed. Results indicated that B25 have closer performance to diesel and B100 had lower brake thermal efficiency mainly due to its high viscosity compared to diesel. The brake thermal efficiency for Bio diesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions and there are 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. However, its diesel blends showed reasonable efficiencies, lower smoke, CO_2 and CO. Methyl ester of Jatropha offers fuel conservation as well as reduce pollution. The emission constituents are carbon monoxide (CO), unburnt hydrocarbons (HC), oxides of nitrogen (NO_X), carbon dioxide (CO_2).

Key words: Performance, Emissions, Blend Fuels, Efficiency, Pollution

I. NOMENCLATURE

A. Symbols

A: Area
D: Engine cylinder diameter
L: Engine cylinder stroke
m_a: Air mass flow rate
m_f: Diesel fuel mass flow rate
N: Speed

II. INTRODUCTION

World's energy consumption has only increased continuously since decades except for a brief period like the oil crisis in 1970's in which the growth slowed down. Energy consumption has increased by more than 5% in 2012, after a slight decrease in 2010. This strong increase is the result of two converging trends. On one hand, industrialized countries, which experienced sharp decreases in energy demand in 2010, recovered firmly in 2012. Oil, gas, coal, and electricity markets followed the same trend. On the other hand, China and India, which showed no signs of slowing down in 2010, continued their intense demand for all forms of energy.

In 2008, the energy supply by fossil fuels was nearly 81% of the total world's energy demand. This constitutes 33.5% by oil, 26.8% by coal and 20.8% by gas. The renewable energy sources like hydropower, solar power, wind power, geothermal power and biofuels contributed to about 13% of the world's energy supply and nuclear power contributed to 5.8%. The facts show that oil is the most popular energy fuel. Since their exploration, the petroleum fuels continued as a major conventional energy source. On the other hand, they are limited in reserves and highly concentrated in certain parts of the globe. Those countries not having these resources are facing energy / foreign exchange crisis due to heavy import bill on crude petroleum. Increased extraction and consumption of fossil fuels have led to a fast depletion in the underground-based petroleum derived fuels. These factors have contributed to a sharp increase in petroleum prices. Also, the petroleum fuels are currently the dominant global source of CO_2 emissions, Greenhouse gases & global warming. Their combustion is posing a stronger threat to clean environment. The global warming emissions are the most serious environmental problem. Therefore many nations have signed the UN agreement to prevent a dangerous imbalance in the climate system.

A. Jatropha Oil

Jatropha curcas is commonly found in most of the tropical and subtropical regions of the world. The oil content of jatropha seed ranges from 30 to 35 % by weight. The fatty acid composition of jatropha oil [8] consists of myristic, palmitic, stearic, arachidic, oleic and linoleic acids. After extraction of oil from seed the detoxification of the seed cake is necessary so that the seed cake can be used as cattle feed. Economic development in India has led to huge increases in energy demand, which in-turn has encouraged development of the Jatropha cultivation and Biodiesel production system.

B. Biodiesel Processing From Vegetable Oil

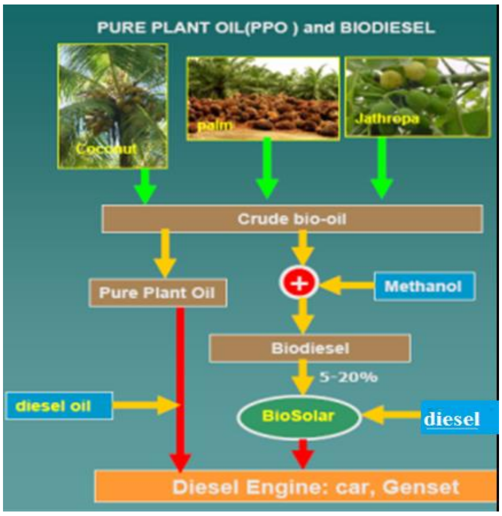


Fig. 1: Schematic diagram for producing bio diesel

Biodiesel can be produced by esterification followed by trans esterification. The oils and fats are filtered and pre-processed to remove water and contaminants. If, free fatty acids are present, they can be removed or transformed into biodiesel using special pretreatment technologies. The pre-treated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium methoxide). The oil molecules (triglycerides) are broken apart and reformed into esters and glycerol, which are then separated from each other and purified. The edible oils like soybean, sunflower, mustard, palm, cotton seeds, whose acid values are less than 3.0 are transesterified with methanol in the presence of sodium methoxide as catalyst. Nonedible oil like, Mahua, karanja and jatropha oils having acid values more than 3.0 are undergoes esterification followed by transesterification. The methyl esters produced by these methods are analyzed to ascertain their suitability as diesel fuels.

C. Selection of Catalyst

Transesterification is a chemical reaction that aims at substituting the glycerol of the glycerides with three molecules of mono alcohols such as methanol thus leading to three molecules of methyl ester of vegetable oil [10] **.** The viscosity of esterified oil is lower than the oil. However, higher ratio of alcohol to oil is generally employed to obtain biodiesel of low viscosity and high conversion [11]. Alkali-catalyzed transesterification is very fast compared to acid catalyzed [12-13**].** Methanol and ethanol is widely used in the transesterification because of low cost [14**]**. The alkali hydrolysis of the oil must have acid value <1 and moisture content of <0.5%. The acid catalyst is the choice for transesterification when low-grade vegetable oil used as raw material because it contains high free fatty acid (FFA) and moisture. Acid catalyst such as sulphuric acid (H_2SO4) is used for esterification process.

D. Jatropha Biodiesel

Jatropha curcas is nonedible oil being singled out for large scale for plantation on wastelands. J. 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 0.8kg 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 et al., 2007). In Madagascar, Cape Verde and Benin, Jatropha oil was used as mineral diesel substitute during the Second World War. Forson et al. (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. Additives are abundantly manufactured and mixed with IC engine fuels to meet the proper performance of fuel in engine. Additives act like catalyst so that they aid combustion, control emission, control fuel quality during distribution and storage and reduce refiners operating cost. Now in India MFA’s are sold in retail market for better mileage of the vehicles and keeping the engine components clean, for better performance and to decrease pollution. For a long time industry has been using various types of chemical additives, which are corrosive, toxic and non ecofriendly. Use of multi functional additives for diesel will lead better fuel conservation and emission control takes place. Awareness of multi functional additives marketing and there use to be given to the automobile owner’s especially fleet owners and huge genets users (Ramana & Raghunadham, 2004). Tests were conducted with two commercially available bio additives and results confirmed that pollution can be controlled by reducing CO and HC emissions and conserving fuel by high thermal efficiency (Raghunadham & Deshpande, 2004). Ethylene glycol mono alkyl ethers as oxygenated fuel additives had taken and studied for performance parameters such as brake specific fuel consumption, brake thermal efficiency and emission levels. Significant reduction in particulate emission is observed with fuel additives (Suresh Shetty et al., 2007). The present research is aimed at exploring technical feasibility of Jatropha oil in direct injection compression ignition engine without any substantial hardware modifications. 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. Also 0.4 mL/L Multi-DM-32 additive is added to methyl ester of Jatropha to study the performance and exhaust emissions of diesel engine. Performance parameters like brake thermal efficiency, specific fuel consumption, brake power were determined. Exhaust emissions like CO_2, CO, NOx and smoke have been evaluated. For comparison purposes experiments were also carried out on 100% esterified Jatropha and diesel fuel.

Fig. 2: Seeds of Jatropha

Fig. 3: Jatropha oil

E. Materials and Method

A lot of research work has been carried out to use vegetable oil both in its neat form and modified form (Agarwal et al., 2008). Studies have shown that the usage of vegetable oils in neat form is possible but not preferable (Alton, 1998). The high viscosity of vegetable oils and the low volatility affect the atomization and spray pattern of fuel, leading to 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 (Pramanik, 2003). However, this adds extra cost of processing because of the transesterification reaction involving chemical and process heat inputs.

III. Evolution of Biodiesel as an Alternative fuel

Natural resources that our nation relies heavily upon such as oil, petroleum and natural gas are fossil fuels. This means that they will eventually cease to exist. This gives much economic and political power to the nations that have an abundance of these natural resources. The thought of this supply ending also causes a search for renewable resources that would never cease to exist. Petroleum or black gold provides the world with nearly half the energy used. 67% of the world's oil reserves are found in the Middle East. Saudi Arabia alone has one fourth of the world's oil. One tenth of the world's oil is found in Abu Dhabi, Iran, Iraq, and Kuwait. Compared with this extensive supply, the U.S. and Canada have only 3% of the world's reserves. Despite this, the U.S. and Canada consume more than four times the amount of petroleum than the Middle East.

It is often reported that Rudolph Diesel designed his engine to run on peanut oil, but this is not the case. Diesel stated in his published papers that Otto Company showed a small Diesel engine, which, at the request of the French government was run on arachide (earthnut or peanut) oil. It worked so smoothly that only a few people were aware of it. The engine was constructed for using mineral oil, and was then worked on vegetable oil without any alterations being made. The French Government at the time thought of testing the applicability to power the production of the Arachide, or earthnut, which grows in considerable quantities in their African colonies, and can easily be cultivated there. Diesel himself later conducted related tests and appeared supportive of the idea. During a speech delivered in 1912, Rudolph Diesel said, "the use of vegetable oils for engine fuels may seem insignificant today but such oils may become, in the course of time, as important as petroleum and the coal tar products of the present time" (Bijalwan et al [2]).

Biodiesel can be derived from vegetable oils and fats. India has about 100 MHectare degraded land, which can be utilized for producing raw material for biodiesel. Biodiesel has higher flash point temperature, higher cetane number, and lower sulphur content and lower aromatics than that of petroleum diesel fuel. It could also be expected to reduce exhaust emissions due to fuel containing oxygen. The main problems of current Indian diesel fuel are low flash point (35 ºC against world average of 52 ºC) and high sulphur content, which can be improved by blending it with biodiesel. In this regard, a typical data related to trends in improvements in cetane number, flash point and sulphur content by blending biodiesel are given in Table 2.1

Properties	Diesel	B20	B100
Cetane number	43.3	46	47.5
Flash Point (^{0}C)	62	90	146
Sulphur wt (%)	0.0476	0.037	0.00

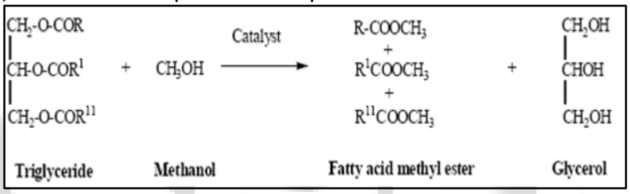
Table 2: Properties of Diesel, Biodiesel Blend (B20) and Biodiesel [6]

It is well established that significant reductions in emissions can be achieved by use of biodiesel (Graboski [7], Peterson [8]). 13–66% reduction in PM with 2–11% increase in NOx was reported by (Graboski [7]). CO_2 emission by use of biodiesel in diesel engines will be recycled by the crop plant resulting to no new addition into atmosphere (Peterson [8]). The non-regulated emissions like polycyclic aromatic hydrocarbon (PAH), nitrate polycyclic aromatic hydrocarbon (nPAH), sulphate emissions etc. are also significantly lower (National Biodiesel Board [9]).

A. *Materials and Transesterification Process*

The transesterification process can accomplish the conversion of Jatropha oil into its methyl ester. 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.

1) *Mechanism of Transesterification Reaction*



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 450mL methanol and 10gm 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 1000mL 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.

B. Work Done in India

In India, attempts are being made for using non-edible and under exploited oils for production of esters. The non-traditional seed oils available in the country, which can be exploited for this purpose, are Madhuca indica, Shorea robusta, Pongamia glabra, Mesua ferra (Linn), Mallotus Philippines, Garcinia indica, Jatropha curcas and Salvadora.

1) Details about large-scale jatropha plantations in India

- Reliance would take up jatropha plantation in an area of few thousand hectares in Andhra Pradesh/Rajasthan/ Maharashtra/Gujarat.
- The Government of Tamil Nadu along with the Tamil Nadu Agricultural University is to implement a developmental scheme on Jatropha curcas, and has a programme to cultivate in 40 000 hectares.
- The Indian Railway is to raise jatropha along the railway track, and plans to plant jatropha along 25,000-kilometer route on two sides of the track. They plan to replace 10% of their total petro diesel consumption by jatropha. The project has been started on a pilot scale.
- The Planning Board of Haryana government is planning to grow jatropha on 50,000 acres.
- Rajasthan would bring 2.2 lakh hectares under jatropha.
- The Ministry of Environment and Forests is working on 20,000 hectares of jatropha plantation as part of a CDM (clean development mechanism) project.
- Daimler Chrysler and Hohenheim University are conducting a research project in two different climatic zones of India. Each plantation will consist of 20 hectares of jatropha trees planted on wastelands.
- Indian Oil Corporation has planted one-lakh saplings on 70 hectares of railway land in Gujarat.
- The UBB (Uttaranchal Biofuels Board) has been constituted to bring two lakh hectares under jatropha plantation by 2012. Here, plantation in 29-gram panchayats covering an area of 350 hectares has been done.
- In Haryana, 19 districts have gone for jatropha plantation. In 12 districts, 820 acres of land has been brought under jatropha cultivation with the involvement of 146-gram panchayats.
- The Chhattisgarh government is planning to bring at least one million hectares of land under jatropha cultivation by 2014
- DBT (Department of Biotechnology) has planted five lakh plants, and has brought 200 hectares of area under plantation.
- SRIPHL (Society for Rural Initiatives for Promotion of Herbals) has put >33000 acres under jatropha cover with a target of 100000 hectares.
- Other organization engaged in the field is RCAC (Rural Community Assistance Corporation), women self-help groups, CDRC (Child Development and Rehabilitation Centre), CSMCRI (Central Salts and Marine Chemicals Research Institute), KAWAD (Karnataka Watershed Development Agency), SUTRA, and CRIDA (Central Research Institute for Dry land Agriculture).

IV. 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 r/min. 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 experimental set up is shown in Fig 4.

1) Engine
2) Hydraulic Dynamometer
3) Fuel Tank (Biodiesel)
4) Diesel Tank
5) Burettes
6) Air Box
7) Manometer
8) Exhaust

Manufacturer	Kirloskar engines Ltd
No of cylinders	One
No. of strokes	Four
Bore & Stroke	80 & 110 mm
Capacity	3.68 kW
BHP of engine	5
Speed	1500 r/min
Mode of injection	DI
Cooling system	Water

Table 3: Specifications of diesel engine are given below

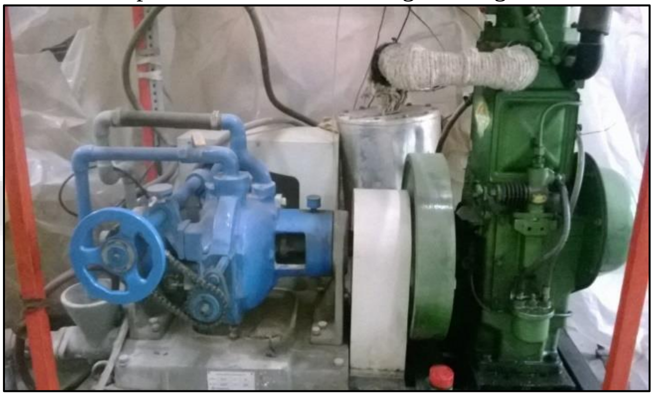


Fig. 4: Front view of the engine

T1	Engine cooling water inlet temperature
T2	Engine cooling water outlet temperature
T3	Calorimeter water inlet temperature
T4	Calorimeter water outlet temperature
T5	Exhaust gas calorimeter inlet temperature
T6	Exhaust gas calorimeter inlet temperature
T7	Room temperature

Table 4: Description of Temperature Measurement

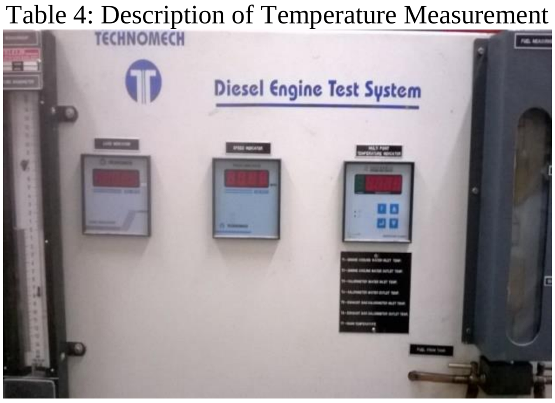


Fig. 5: Temperature, Load and Speed Indicator

Fig. 6: Rear View of the Engine

A. *Fuel Injection Pump*

Fig. 7: Fuel tank

The fuel injection pump manufactured by MICO BOSCH is used for injecting Diesel oil or biodiesel in to the engine. The camshaft operates the fuel injection pump and the fuel injection timing can be varied by adding/removing.

V. COMPARISON BETWEEN PROPERTIES OF DIESEL AND BIODIESEL (JATROPHA BIODIESEL)

Property	Mineral Diesel	Jatropha bio diesel	Jatropha oil
Density (kg/m^3)	840±1.732	879	917±1
Kinematic viscosity	2.44±0.27	4.84	35.98±1.3
Pour point (ºC)	6±1	3±1	4±1
Flash point (ºC)	71±3	191	229±4
Calorific Value (MJ/kg)	45.343	38.5	39.071
Cetane No.	48-56	51-52	23-41
Carbon (%, w/w)	86.83	77.1	76.11
Oxygen (%, w/w)	1.19	10.97	11.06
Hydrogen (%, w/w)	12.72	11.81	10.52
Ash Content (%, w/w)	0.01±0.0	0.013	0.03±0.0

Table 5: Fuel properties of mineral diesel, Jatropha biodiesel, Jatropha oil

Load (kgf)	Manometer Reading (cm)	Time taken for 25cc of F.C. (s)	Exhaust Gas temp (°C)
0	2.6	128	185
2	2.6	126	190
4	2.6	109	200
6	2.6	104	210
8	2.6	95	225

Table 6: Esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 25cc of F.C. (s)	Exhaust Gas temp (°C)
0	2.6	160	180
2	2.6	142	190
4	2.6	127	200
6	2.6	117	210
8	2.6	110	219

Table 7: 75% Diesel+25% esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 25cc of F.C. (s)	Exhaust Gas temp (°C)
0	2.6	153	175
2	2.6	134	190
4	2.6	122	200
6	2.6	114	205
8	2.6	106	220

Table 8: 50%Diesel+50% esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 25cc of F.C. (s)	Exhaust Gas temp (°C)
0	2.6	151	174
2	2.6	128	185
4	2.6	117	195
6	2.6	110	205
8	2.6	102	220

Table 9: 25%Diesel+75% esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C (s)	F.C (kg/h)	S.F.C. (kg/kWh)	B.P (kW)	Bth (%)	Exhaust Gas temp (°C)
0	2.6	135	0.416	-	0	0	190
2	2.6	98	0.573	1.154	0.496	7.45	260
4	2.6	85	0.661	0.670	0.992	12.83	270
6	2.6	75	0.750	0.503	1.488	17.1	290
8	2.6	68	0.826	0.416	1.984	20.65	320

Table 10: 100% Diesel Combustion Parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C (s)	F.C. (kg/h)	S.F.C. (kg/kWh)	B.P (kW)	Bth (%)	Exhaust Gas temp (°C)
0	2.6	128	0.523	-	0	0	185
2	2.6	126	0.531	1.071	0.496	8.0	190
4	2.6	109	0.614	0.619	0.992	13.84	200
6	2.6	104	0.644	0.432	0.488	19.84	210
8	2.6	95	0.705	0.355	0.984	24.84	225

Table 4.7: Esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C (s)	F.C. (kg/h)	S.F.C. (kg/kWh)	B.P (kW)	B^{th} (%)	Exhaust Gas temp (°C)
0	2.6	160	0.368	-	0	0	57
2	2.6	142	0.414	0.835	0.496	10.3	58
4	2.6	127	0.464	0.467	0.992	18.4	59
6	2.6	117	0.503	0.338	1.488	25.44	64
8	2.6	110	0.535	0.270	1.984	31.86	68

Table 4.8: 75%Diesel+25% esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C (s)	F.C. (kg/h)	S.F.C. (kg/kWh)	B.P (kW)	B^{th} (%)	Exhaust Gas temp (°C)
0	2.6	153	0.402	-	0	0	175
2	2.6	134	0.459	0.926	0.496	9.3	190
4	2.6	122	0.505	0.509	0.992	16.9	200
6	2.6	114	0.540	0.362	1.488	23.7	205
8	2.6	106	0.580	0.293	1.984	29.32	220

Table 4.9: 50%Diesel+50% esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C (s)	F.C. (kg/h)	S.F.C. (kg/kWh)	B.P (kW)	B^{th} (%)	Exhaust Gas temp (°C)
0	2.6	151	0.426	-	0	0	174
2	2.6	128	0.502	1.012	0.496	8.5	185
4	2.6	117	0.550	0.223	0.992	15.5	195
6	2.6	110	0.584	0.392	1.488	21.9	205
8	2.6	102	0.630	0.317	1.984	27.0	220

Table 4.10: 25%Diesel+75% esterified Jatropha oil combustion parameters

VI. GRAPH

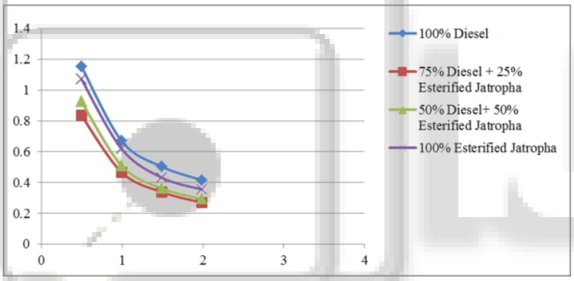


Fig. 8: Variation of brake power with specific fuel consumption (SFC Vs BP)

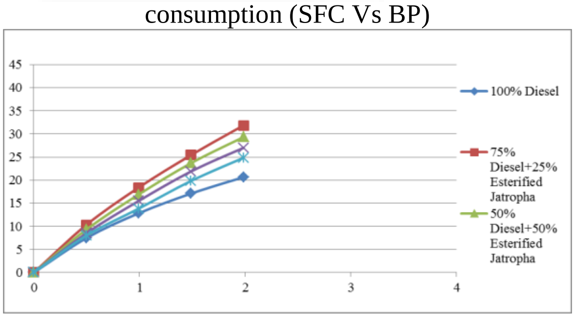


Fig. 9: Variation of brake power with brake thermal efficiency (η_{th} Vs BP)

In Figure 8 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. The percent increase in Specific Fuel Consumption was increased with decreased amount of diesel fuel in the blended fuels. This may be due to higher specific gravity and lower calorific value of the biodiesel fuel as compared with diesel fuel (Forson et al., 2004). The calorific value of the Jatropha biodiesel was about 7 % lower than that of diesel fuel.

Brake thermal efficiency is defined as actual brake work per cycle divided by the amount of fuel chemical energy as indicated by lower heating value of fuel (Senthil Kumar et al., 2003). In Graph 9 the brake thermal efficiency with biodiesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions. There was no difference between the biodiesel and its blended fuels on efficiencies. The brake thermal efficiencies of engine, operating with biodiesel mode were 22.2, 30.6 and 37.5 per cent at 2, 2.5 and 3.5 kW load conditions respectively.

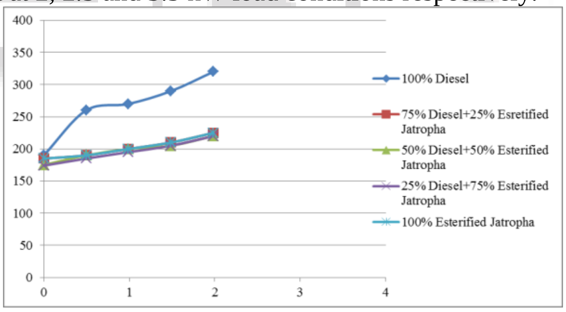


Fig. 10: Variation of brake power with exhaust gas temperature (T_{EX} VsBP)

The exhaust gas temperature gives an indication about the amount of waste heat going with exhaust gases. The exhaust gas temperature of the different biodiesel blends is shown in Figure 10. The exhaust gas temperature increased with increase in load and amount of blended biodiesel in the fuel. The exhaust gas temperature reflects on the status of combustion inside the combustion chamber (Takeda, 1982). The reason for raise in the exhaust gas temperature may be due to ignition delay and increased quantity of fuel injected. Adjusting the injection timing/injection pressure in to the diesel engine can reduce the exhaust gas temperature.

A. Emission Characteristics

The combustion product emissions from diesel engines are hydrocarbon emissions and form a significant part of the engine exhaust. Hydrocarbons in the exhaust may also condense to form white smoke during engine starting and warm up. Specific hydrocarbon compounds in exhaust gases are a source of diesel odor. Diesel engines are also a source of different particulate emissions. Between 0.2 to 0.5% of the fuel mass is emitted as small particles which consist primarily of soot with some additional hydrocarbon material. Diesel engines are not a very significant source of carbon monoxide emission comparatively. The other exhaust emissions include NO_X i.e. nitrogen oxides and aldehydes which are a significant source of air pollution. Half of NO_X, CO and HC pollutants in air are primarily because of IC engines. NO_X may react with solar radiation to form ozone. Hydrocarbons cause cellular mutations and are responsible for ground level ozone formation. SO_X formation is significant in diesel engines. However with the use of biofuels as fuels, the harmful constituents of HC, CO, SO_X can significantly be brought down. The emission constituents considered for evaluation are Carbon dioxide (CO_2), Carbon monoxide (CO), Oxides of Nitrogen (NO_X), Unburned Hydrocarbon (HC), Oxygen (O_2), and Oxides of Sulphur (SO_X). For each constituent, the variations for Diesel oil, Jatropha biodiesel and blends of Jatropha biodiesel with diesel as fuels are superposed and analyzed.

B. NO_X Emissions of Biodiesel

Many comparative tests have been studied to perform the effect of content of biodiesel on NO_X emissions, including blended fuel.

1) The vast majority of literatures reported that NO_X emissions will increase when using biodiesel. This increase is mainly due to higher oxygen content for biodiesel. Moreover, Cetane number and different injection characteristics also have an impact on NO_X emissions for biodiesel.
2) The content of unsaturated compounds in biodiesel could have a greater impact on NO_X emissions. The larger the content of unsaturated compounds is, the more NO_X emissions will reduce, which is a matter of concern.
3) The larger engine load is, the higher the level of NO_X emissions for biodiesel will be, which is in line with the mechanism of NO_X formation.
4) A further study is needed to perform the effect of injection timing and injection pressure on NO_X emissions of biodiesel.
5) The use of EGR will reduce NO_X emissions of biodiesel, but due to the change of combustion characteristics for biodiesel, EGR rates which are optimized to Mach the operating conditions of diesel may not fit well with the same conditions of biodiesel engines. This research area needs refinement.
6) Metallic additives, oxide additives, emulsifier, etc. seem to be useful to improve NOx emissions of biodiesel, but the comprehensive assessments on other emissions and engine performances (especially about power) are required in the future.

C. CO Emissions of Biodiesel

It is common trend that CO emissions reduce when diesel is replaced by pure biodiesel. It is found that there was deterioration in CO emissions for the pure biodiesel from Jatropha oil.

1) It is accepted commonly that CO emissions reduce when using biodiesel due to higher oxygen content and lower carbon to hydrogen ratio in biodiesel compared to diesel.
2) With content of pure biodiesel increasing in blends fuel, CO emissions of blends reduce.
3) CO emissions for biodiesel are affected by its feedstock and other properties of biodiesel such as cetane number and advance in combustion.
4) Engine load has been proven to have a significant impact on CO emissions. There is a largely unanimous conclusion about the effect of engine speed on CO emissions, that is, CO emissions for biodiesel decrease with an increase in engine speed. An oxidative catalytic converter, which is designed for diesel engine, plays an important role on CO emissions for biodiesel, but its conversion efficiency may become weak.
5) CO emissions of biodiesel reduce with metal-based additives, and methanol and ethanol also further improve CO emissions.

D. HC Emissions of Biodiesel

1) It is predominant viewpoint that HC emissions reduce when pure biodiesel is fueled instead of diesel.
2) Most of researches showed that HC emissions for biodiesel reduce with the increase of biodiesel content.
3) The feedstock of biodiesel and its properties has an effect on HC emissions, especially for the different chain length or saturation level of biodiesels. The advance in injection and combustion of biodiesel favors the lower HC emissions.
4) There are inconsistent conclusions about effect of engine load on HC emissions for biodiesel. Although an oxidative catalytic converter has a positive impact on HC emissions for biodiesel, its function seems be weakened.
5) Metal based additives have less efficiency to improve HC emissions for biodiesel than the others emissions. And a small proportion of ethanol and methanol added into biodiesel and its blends with diesel may be advantageous to HC emissions.

VII. CONCLUSIONS

A single cylinder compression ignition engine was operated successfully using methyl ester of Jatropha oil as the soul fuel with additives. 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 for methyl ester of Jatropha oil when compared with diesel.
- The vast majority of literatures agree that NO_X emissions will increase when using biodiesel. This increase is mainly due to higher oxygen content for biodiesel. Moreover, the cetane number and different injection characteristics also have an impact on NOx

emissions for biodiesel.
- It is predominant viewpoint that HC emissions reduce when biodiesel is fueled instead of diesel. This reduction is mainly contributed to the higher oxygen content of biodiesel.
- It can be concluded from the limited literatures that the use of biodiesel favors to reduce carbon deposit and wear of the key engine parts, compared with diesel. It is attributed to the lower soot formation, which is consistent to the reduced PM emissions of biodiesel, and the inherent lubricity of biodiesel.
- There is significant difference in smoke emissions when the methyl ester of Jatropha oil is used.
- Multi-MD-32, Bio-additive possesses many attributes as Multi-Functional fuel additive. Its ability to reduce the surface tension between two or more interacting immiscible liquids helped the fuel to flow better.
- Through injector and better atomization of fuel, which improved the combustion and performance of the engine at all variable loads.
- With proper adjustments at fuel injection pump settings bio additives will improve performance of IC engine.
- Use of bio additives for diesel will lead to better fuel economy and reduced emissions and should be used by Indian refineries.
- Automotive industry and oil industry must work closely to find solutions for lower emissions and conserving fuel.

Overall, biodiesel, especially for the blends with a small portion of biodiesel, is technically feasible as an alternative fuel in CI engines with no or minor modifications to engine. For environmental and economic reasons, their popularity may soon grow.

Abbreviations

- BTHE: Brake thermal effciency
- BSFC: Brake Specific Fuel Consumption
- BMEP: Brake Mean Effective Pressure
- EGT: Exhaust Gas Temperature
- BSU: Bosch Smoke Units
- MSP: Minimum Support Price
- MPP: Minimum Purchase Price
- CDM: Clean Development Mechanism
- IOC: Indian Oil Corporation
- UBB: Uttaranchal Biofuels Board
- FAME: Fatty Acid Methyl Esters
- ASTM: American Society for Testing and Materials

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References

[1] K.C. Pandey Investigations on the use of soyabean oil as a substitute fuel for diesel engines. unpublished PhD thesis, IIT Kharagpur; 2005.
[2] A Bijalwan, C.M. Sharma, V.K. Kediyal, Bio-diesel revolution, Science reporter; January 2006. pp. 14–17.
[3] I. De Carvalho Macedo, Greenhouse gas emissions and energy balances in bio-ethanol production and utilization in Brazil, Biomass and Bioenergy; Vol 14, No 1, pp. 77–81, 1998.
[4] M. Senthilkumar, A. Ramesh, B. Nagalingam, Complete vegetable oil fuelled dual fuel compression ignition engine, SAE, 2001-28-0067, 2001.
[5] W. Korbitz, Biodiesel production in Europe and North America, an encouraging prospect. Renewable Energy Vol. 16, pp. 1078–83, 1999
[6] C.A. Sharp, Exhaust emissions and performance of diesel engines with biodiesel fuels. Southwest Research Institute (SWRI) www.biodiesl.org/resources/reportsdatabase/reports/gen/19980701_gen-065.pdf, 1998.
[7] M.S. Graboski, R.L. Mccormick, Combustion of fat and vegetable oil derived fuels in diesel engines, Progress in Energy and Combustion Science, Vol 24, pp. 125–64, 1998.
[8] C.L. Peterson, T. Hustrulid, Carbon cycle for rapeseed oil biodiesel fuels. Biomass and Bioenergy, Vol 14, No 2, pp. 91–101, 1998.
[9] National Biodiesel Board, USA www.biodiesel.org/pdf_files/emissions.pdf.
[10] R. Vijayaraghavan, Ministry of Petroleum and Natural Gas Resolution, The Gazette of India. Part-II, Section-3. Minister of Petroleum & Natural Gas, Government of India September 4, 2002.
[11] M. Senthil Kumar, A. Ramesh, B. Nagalingam, An experimental comparison of methods to use methanol and Jatropha oil in a compression ignition engine, Biomass and Bioenergy, Vol 25, pp.309-318, 2003
[12] Agarwal D, Kumar L and Agarwal AK (2008) Performance Evaluation of a Vegetable oil fuelled CI Engine. Renewable Energy. 33, 1147-1156.
[13] Ali Y and Hanna M A (1994) Alternative Diesel Fuels from Vegetable Oils. Biores. Technol. 50, 153-163.
[14] Altõn R (1998) An experimental investigation on use of vegetable oils as diesel engine fuels. Ph.D Thesis, Gazi Univ. Institute of Sci. & Technol.
[15] Barnwal BK and Sharma MP (2005) Prospects of biodiesel production from vegetable oils in India. Renewable and Sustainable Energy Reviews. 9, 363–378.
[16] Canakci M and Van Gerpen J (2001) Biodiesel production from oils and fats with high free fatty acids. Transactions of ASAE. 44, 1429-1436.
[17] Forgiel R and Varde KS (1981) Experimental investigation of vegetable oil utilization in a direct injection diesel engine. SAE Alternate fuels for diesel engines, SP 500 fuels and lubricants meeting Tulsa, Ok.
[18] Forson FK, Oduro EK and Hammond-Donkoh E (2004) Performance of jatropha oil blends in a diesel engine. Renewable Energy. 29, 1135-1145.
[19] Harrington KJ (1986) Chemical and physical properties of vegetable oil esters and their effect on diesel fuel performance. Biomass. 9, 1–17.
[20] ISI (1980) Methods of test for internal combustion engines. IS: 10000 Part I-XII, Indian Standards Institute, New Delhi.

[21] Patil V and Singh K (1991) Oil gloom to oil boom, Jatropha curcas a promising agroforestry crop. Shree Offset Press, Nashik, India.
[22] Lapuerta M, Armas O, Rodríguez-Fernández J. Effect of biodiesel fuels on diesel engine emissions. Prog Energ Combust 2008
[23] Basha SA, Raja Gopal K, Jebaraj S. A review on biodiesel production, combustion, emissions and performance. Renew Sust Energ Rev 2009;13:1628–34.
[24] Aydin H, Bayindir H. Performance and emission analysis of cottonseed oil methyl ester in a diesel engine. Renew Energ 2010; 35:588–92.