Comparative study of Hemp and Jatropha oil blends used as an alternative fuel in diesel engine

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Abstract: The methyl esters of vegetable oils, known as biodiesel are becoming increasingly popular because of their low environmental impact and potential as a green alternate fuel for diesel engines. Use of vegetable oils in conventional not adapted 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 study, a comparison on the basis of the performance and emission characteristics of different blends of transesterified Hemp (B10 and B20)and Jatropha (B10 and B20) biodiesel was done on a 550 cm³ single cylinder four stroke water cooled diesel engine and the results were compared to that of diesel. Results indicated that in comparison to pure diesel and Jatropha, B20 blend of Hemp biodiesel provides better thermal efficiency, lower specific fuel consumption, reduced CO and CO_2 emissions but a considerable increase was found in NO_x emission and smoke density was decreased with increase in biodiesel concentration i.e. at 20%.

Keywords: bio-diesel, hemp oil, Jatropha oil, transesterification, engine performance, exhaust emissions, India

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1 Introduction

Energy demand is increasing due to ever increasing number of vehicles employing internal combustion engines. Also, world is presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. Fossil fuels are limited resources; hence, search for renewable fuels is becoming more and more prominent for ensuring energy security and environmental protection. The agriculture sector of India is completely dependent on diesel for its motive power and to some extent for stationary power application. Increased farm mechanization in agriculture further increases the requirement of this depleting fuel source.

According to International Energy Outlook 2007 published by the Energy Information Administration, the world consumption for petroleum and other liquid fuel will grow from 83 million barrels/day in 2004 to 97 million barrels/day in 2015 and just over 118 million barrels/day in 2025. Under these growth assumptions, approximately half of the world's total resources would be exhausted by 2025. Also, many studies estimating that the world oil production would peak sometime between 2007 and 2025. Therefore the future energy availability is a serious problem for us.

Fuels derived from renewable biological resources for use in diesel engines are known as biodiesel. Biodiesel is environmentally friendly liquid fuel similar to petrol-diesel in combustion properties. Biodiesel is an oxygenated fuel containing 10% to 15% oxygen by weight. Also it can be said that biodiesel is a sulfur-free fuel. These facts lead biodiesel to more complete combustion and less exhaust emissions of most emission components from diesel engine.

One of the better alternative fuels are bio-fuels derived from non-edible oils (Harrington, 1986; Srinivasa Rao and Gopalakrishnan, 1991). The use of any vegetable oils posses some problems when subjected to prolonged usage in Internal Combustion engines (Alton, 1998; Roger and Jaiduk, 1985). These problems are attributed to high viscosity, low volatility and polyunsaturated character of neat vegetable oils. High viscosity of vegetable oil causes some problems in atomization by injector systems and combustion in cylinders of diesel engines. Some of the common problems in the long run are coking and trumpet formation on the injectors, carbon deposits, oil ring sticking and gelling of lubricating oil as a result of contamination by the vegetable oils (Ryan, Dodge, and Challahan, 1984; Rewolinski and Shaffer, 1985). There are different methods for reducing viscosity of vegetable oils such as preheating, blending and transesterification.

The objective of the present research was to explore technical feasibility and comparison of performance and emission characteristics of Hemp oil and Jatropha oil methyl esters in direct injection compression ignition engine without any substantial hardware modifications. For comparison purposes, test runs were carried out for Jatropha, hemp and diesel fuel. Performance and emission parameters for the fuels and the blends were measured under a range of varying loads (torque) applied to the engine.

2 Materials and methods

Hemp oil- Non-refined hemp oil varies from off yellow to dark green in colour. Seed contains radium, thorium and rubidium and fatty oil like arachis oil. It is also having high essential fatty acids. The primary problem associated with the use of raw hemp oil as a fuel in compression ignition engines is due to its higher viscosity. Esterification of raw hemp oil with an alcohol provides a significant reduction in viscosity and thereby enhancing the physical properties of the fuel. The problem of high viscosity of vegetable oils can be removed by several ways such as preheating the oil blending or dilution with other fuels, transesterification and thermal cracking /pyrolysis. **Jatropha oil-** Jatropha curcas oil, a non-edible vegetable oil which has been considered as a potential alternative fuel for C.I. engines has been chosen to find out its suitability for use as fuel oil. Jatropha curcas 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, easy propagation and wide ranging usefulness have resulted in its spread far beyond its original distribution. Jatropha oil is slow-drying oil which is odourless and colorless when fresh but becomes yellow on standing. The oil content of jatropha seed ranges from 30% to 50% by weight and the kernel itself ranges from 45% to 60%.

2.1 Transesterification

The transesterification is a chemical reaction widely used in the production of biodiesel. It is a chemical process of reacting vegetable oils with alcohol in the presence of a catalyst. The monoesters produced by transesterification of vegetable oils or animal fats are known as biodiesel. Transesterification significantly reduces the viscosity of vegetable oils without affecting the heating value of the original fuel (Srivastava and Prasad, 2000; Demirbas, 2003). Therefore, fuel atomization, combustion, and emission characteristics will display better results than pure vegetable oils if the esters of vegetable oils are used in conventional diesel engines. The most common type of alcohol used in biodiesel production is methanol as it carries the high yield reaction quite easily and also the price of methanol is cheaper than for other alcohols.

Indeed, the transesterification can take place with or without presence of a catalyst. The chemical equation of transesterification reaction is shown in Figure 1.

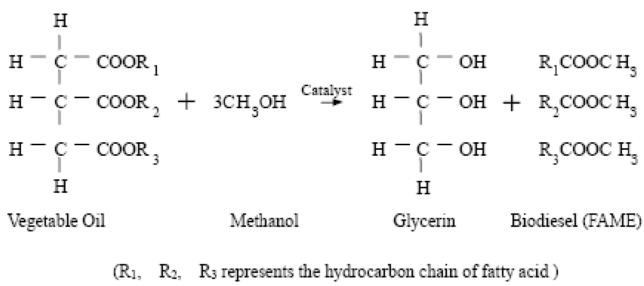


Figure1 Chemical equation of transesterification reaction

The catalysts used in transesterification are generally classified in two categories, acidic and alkaline. The mixture of alcohol and biodiesel was stirred continuously and then allowed to settle under gravity in a separating funnel. Two distinct layers form after gravity settling for 24 h. The upper layer was of ester and lower layer was of glycerol. The lower layer was separated out. The separated ester was mixed with some warm water (around 10 % volume of ester) to remove the catalyst present in ester and allowed to settle under gravity for another 24 h. The catalyst got dissolved in water, which was separated and the moisture was removed.

The methyl ester was then blended with mineral diesel in various concentrations for preparing biodiesel blends to be used in CI engine for conducting various engine tests.

2.2 Fuel Properties

A comparison of the fuel properties of pure diesel, brown Hemp oil and methyl ester of Hemp oil or transesterified Hemp oil is given in Table 1. A sharp decrease in the viscosity of methyl ester of Hemp oil (HOME) was observed in comparison to brown Hemp oil. The calorific value of the methyl ester of biofuel was found to be reduced by transesterification which may lead to little higher fuel consumption. Table 2 gives fuel properties of diesel oil, Jatropha oil and Jatropha oil methyl ester (JOME).

Table 1 Comparing fuel properties of Diesel oil, Brown Hemp oil and HOME

Fuel Properties	Diesel oil	Brown Hemp oil	Hemp oil methyl ester
Density (g/cm³)	0.830	0.888	0.858
Kinematic Viscosity (cSt)@40°C	3.55	42.72	5.13
Flash point (°C)	55	125	47
Fire Point (°C)	65	135	55
Cloud Point	-12	2	-4
Calorific Value(KJ/kg)	43000	43052	39081

Table 2 Comparing fuel properties of Diesel oil, Jatropha oil and JOME

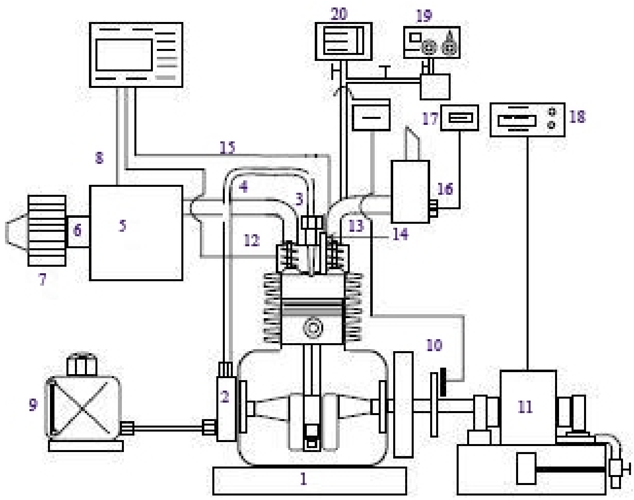
Property	Diesel	Jatropha oil	Jatropha oil methyl ester
Density(g/cm^3)	0.830	0.918	0.870
Kinematic Viscosity (cSt)	3.55	49.5	5.65
Flash point	56	240	170
Calorific value (KJ/kg)	43000	39774	38450

3 Experimental setup

The present study was carried out to investigate the performance and emission characteristics of Hemp and Jatropha methyl ester in a stationary single cylinder diesel engine and to compare it with diesel fuel. Technical specifications of the engine are given in Table 3.

Table 3 Engine specifications

Engine make	Legion Brothers
Compression Ratio	Variable 5:1 to 23:1
No. of cylinder	Single
Fuel	Diesel/Petrol
Speed	1500 rev/min
Horse Power	3 to 5 HP
Starting	Crank
Method of Cooling	Water
Dynamometer	Eddy current
Stroke Length	110 mm
Cylinder Bore	80 mm



1. Engine 2. Fuel injection pump 3.Fuel injection nozzle 4. Intake manifold 5.Intake air surge tank 6. Air flow meter 7. Air cleaner 8. Intake air temp sensor 9. Fuel tank 10. Crank angle detector 11. Electric dynamometer 12. Coolant temp sensor 13. Exhaust manifold 14.Compression pressure transducer 15. Exhaust gas temp sensor 16. Air-fuel ratio sensor 17. A/F meter 18. Dynamometer control panel 19. Gas analyzer 20. Smoke meter

Figure 2 Schematic diagram of experimental set-up

Before starting the engine experiments, the fuel tank, engine oil level, coolant and other proper conditions of the test engine were checked. And the test engine was started by lower engine speed until achieving the stable idling condition. Then the engine speed was increased gradually up to 1500 rpm. At the same time, the dynamometer, all analyzers and meters for measurements were switched on and the proper preparations and settings for measurements were carried out as the recommended methods by the makers' instruction manuals. When the test engine got stable condition and preparations and settings for the measurements were finished the experiments were started. The type of experiment is a steady state engine test. The applications of loads were five levels and they were 20%, 40%, 60%, 80% and 100% load respectively. The engine speeds at all load levels were adjusted for constant engine speed and fixed at 1500 rpm. The engine was operated on diesel first and then on methyl ester of Hemp and Jatropha blends. The exhaust gas was sent to the smoke meter and gas analyzer to measure smoke intensity, CO, CO_2, NO_x, smoke emission. In each load levels, the measurements of intake air, fuel consumption, intake air temperature, exhaust gas temperature, engine coolant temperature, air fuel ratio, fuel injection timing, combustion pressure, crank angle, hydrocarbon (HC) emission, carbon monoxide (CO) emission, nitrogen oxides (NO_x) emission and smoke emission were carried out and data were recorded. The same conditions, methods and procedures were used for both the experiments of biodiesel and diesel fuels. "Bxx" represents the percentage of ester (xx%) used in the mixture, i.e. 10% ester in the blend is represented by B10. The engine was operated for 10 days about 4 hrs per day. At each load, engine was operated for around 15 to 20 mins till the readings get stabilized. Exhaust analysis was done using 4 and 5 gas analyzer. Measurements were conducted at different loads like 2, 4, 6, 8, 10 kW.

4 Results and discussion

The experimental investigation was carried out for different blends of transesterified Hemp oil, Jatropha oil and pure diesel oil and the performance, combustion parameters and exhaust emissions of the engine with diesel and methyl ester of Hemp oil and Jatropha oil were presented and discussed below.

1) From the test results it was found that initially with increasing load, brake thermal efficiency (BTE) of the blends was increasing. The BTE with the blends of Hemp oil methyl ester was found to be slightly higher than that of diesel and Jatropha oil methyl ester at tested load conditions. Out of the two blends tested the performance of B20 Hemp oil methyl ester was better in terms of BTE as clearly indicated in Figure 3.

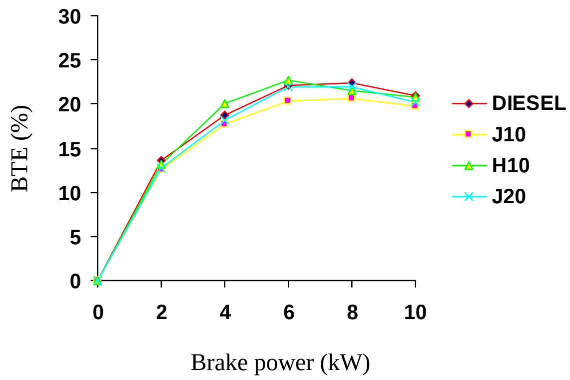


Figure 3 Variation of brake thermal efficiency with load

2) In Figure 4, it was observed that the specific fuel consumption (SFC) of the HOME and JOME as well as diesel blends decreased with increasing load. Though the blends of Jatropha curcas oil maintained a similar trend to that of diesel, the SFC in the case of the blends was higher than compared to diesel oil. This is mainly due to the combined effects of relative fuel density, viscosity and heating value of the different blends.

For both the blends of hemp oil at constant operated conditions specific fuel consumption (SFC) was nearly all time lower than for diesel and Jatropha blends. This is due to complete combustion, as additional oxygen is available from fuel itself. A lesser specific fuel consumption can be noted in case of B20 Hemp oil.

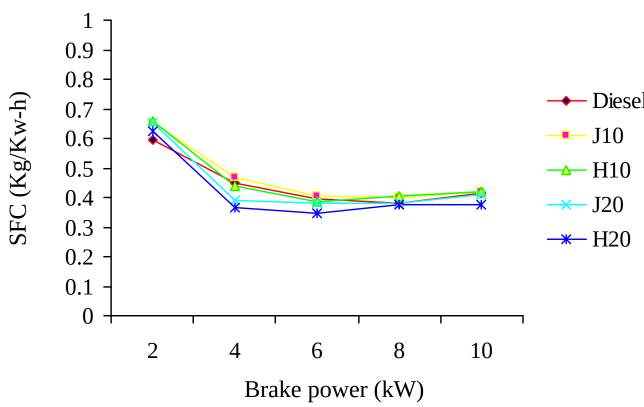


Figure 4 Variation of specific fuel consumption with load

3) The carbon dioxide emission from the diesel engine with different blends is shown in Figure 5. The

CO_2 increased with the increase of load conditions for diesel and for biodiesel blended fuels. The blends of Hemp oil followed the same trend of CO_2 emission as of diesel oil.

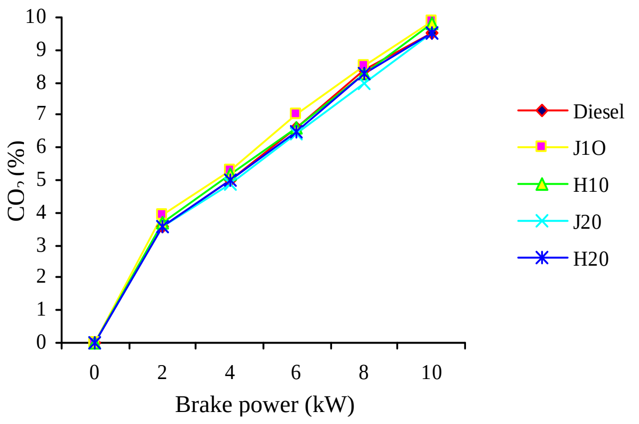


Figure 5 Variation of CO_2 emission with load

4) As the load increases, there was a gradual decrease in CO emission from the biofuel with respect to diesel. It can be estimated from Figure 6 that CO emission of B20 HOME is comparable to that of diesel over the given range of load while that of B10 HOME is little higher. CO emissions from Jatropha blends were between B10 HOME and B20 HOME blends. Biofuel being rich in oxygen gives lesser CO and CO_2 emissions. H10 represents the percentage of Hemp esters (10%) used in the mixture.

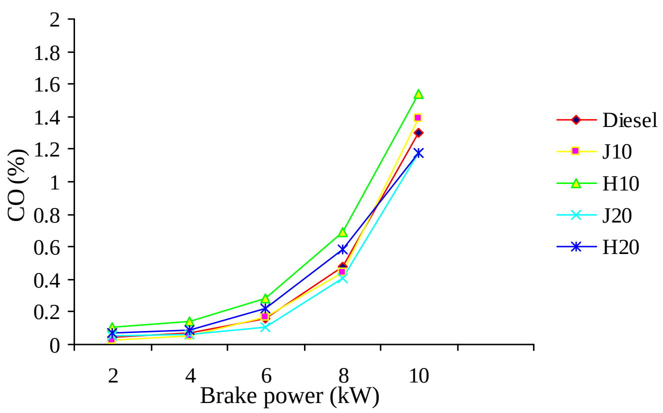


Figure 6 Variation of CO emission with load

5) Figure 7 shows the variation of NO_x emission with respect to load. At higher power output conditions, due to higher exhaust temperatures the NO_x values are relatively higher compared to low power output conditions.

An increase in NO_x was observed in blends of transesterified Hemp oil compared to diesel. This increase may be due to late burning of blends during expansion and may be due to sustained and prolonged duration of combustion associated with reduction in combustion temperature.

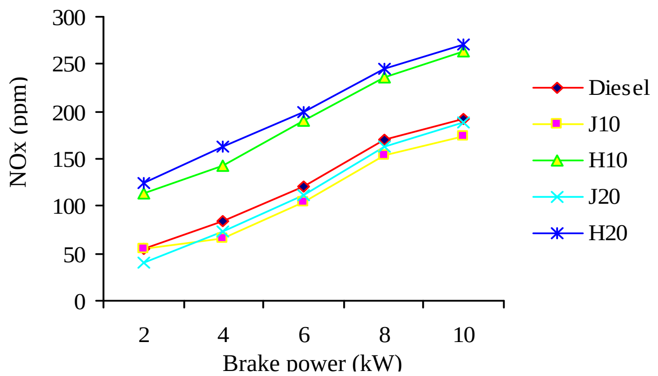


Figure 7 Variation of NO_x emission with load

6) Smoke increases with increase of load. Smoke emission was lesser for blends of transesterified Hemp oil compared to diesel with Jatropha oil methyl ester blends showing higher smoke emission. Figure 8 indicates that B20 Hemp oil emits least smoke among diesel and Jatropha blends. B10 Hemp oil follows nearly the same trend as of diesel.

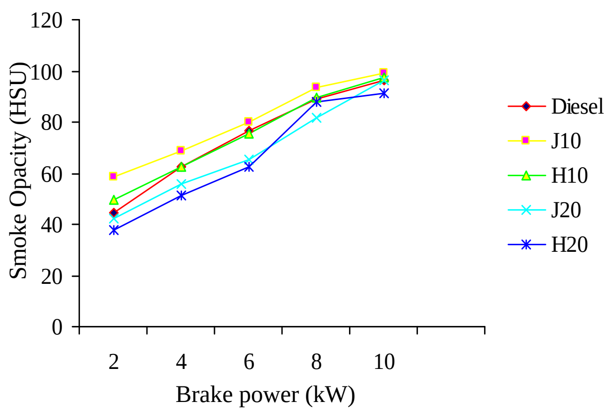


Figure 8 Variation of smoke emission with load

5 Conclusions

Engine works smoothly on the methyl ester of Hemp oil and Jatropha oil with performance comparable to diesel operation. Methyl ester of Hemp oil results in a slightly increased thermal efficiency as compared to that of diesel and Jatropha oil. CO_2 and CO emission was low at higher loads with methyl ester of Hemp oil as compared to methyl esters of Jatropha oil. NO_x emission was significantly increased with methyl ester of Hemp oil compared to diesel and Jatropha methyl ester. There was a considerable decrease in smoke emissions with the methyl ester of Hemp oil. 20% blend of Hemp oil methyl ester with diesel oil performed better than that of Jatropha methyl ester blends and pure diesel.

The methyl ester of Hemp and Jatropha oil along with diesel may reduce the environmental impacts of transportation, reduce the dependency on crude oil imports and offer business opportunities to agricultural enterprises for periods of excess agricultural production. On the whole it can be concluded that as compared to Jatropha, blends of Hemp oil methyl esters will be a better alternative fuel for diesel engines in near future.

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