PRODUCTION OF JATROPHA AND CASTOR BASED BIODIESEL AND PERFORMANCE AND EMISSION ANALYSIS OF DIESEL AND BIO-FUEL BLEND ON AN UNMODIFIED CI ENGINE

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Abstract

With abundance of forest and plant based non edible oils being available in our country such as jatropha, pongomia and castor oils, an attempt has been made to use these as substituent of diesel. But vegetable oils are not compatible with regular diesel (C.I.) engines, mainly due to the high viscosity of vegetable oils. Hence in our research we have tried to overcome this problem by reducing the viscosity and increasing the volatility. By careful review of literature and market survey we have come to the conclusion of selecting Jatropha Curcas and Castor oil blends. After successfully blending of biofuel after transesterification process we have tested its real application in a diesel engine. But before testing the Biodiesel in a C.I. engine we had make sure that the biodiesel derived from neutralized jatropha and cator oil is suited for use in diesel engines given that its kinematic viscosity, flash point, cloud point, and calorific value conform to the recommended international standards. So after this conformation we have carried out the performance analysis to get an idea about the practicality of the use of Jatropha and Castor oil as an alternative fuel.

Keywords: Biodiesel, Transesterification, Jatropha, Castor, Viscosity.

1. Introduction

Due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need for suitable alternative fuels for use in diesel engines. In view of this, vegetable oil is a promising alternative because it has several advantages—it is renewable, environ-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. Therefore, in recent years systematic efforts have been made by several research workers to use vegetable oils as fuel in engines. Obviously, the use of non-edible vegetable oils compared to edible oils is very significant because of the tremendous demand for edible oils as food and they are far too expensive to be used as fuel at present. [1]

India is not self-sufficient in edible oil production. Hence, some non-edible seeds available in the country is required to be tapped for biodiesel production. Biodiesel, which is made from renewable sources consists of simple alkyl esters of fatty acids.[2]With abundance of forest and plant based non edible oils being available in our country such as jatropha, pongomia and castor oils, an attempt has been made to use these as substituents of diesel.

From previous studies, it is evident that there are various problems associated with vegetable oils being used as fuel in compression ignition (C.I.) engines, mainly caused by their high viscosity. The high viscosity is due to the large molecular mass and chemical structure of vegetable oils which in turn leads to problems in pumping, combustion and atomization in the injector systems of a diesel engine.[3] Due to the high viscosity, in long term operation, vegetable oils normally introduce the development of gumming, the formation of injector deposits, ring sticking, as well as incompatibility with conventional lubricating oils.[4] Therefore, a reduction in viscosity is of prime importance to make vegetable oils a suitable alternative fuel for diesel engines. The problem of high viscosity of vegetable oils has been approached in several ways, such as preheating the oils, blending or dilution with other fuels, trans-esterification and thermal cracking/pyrolysis. This leads to improved atomization and lower combustion chamber temperatures.[5]

Therefore, the main objective of the study is to use jatropha and castor oil combined blends as fuel in a C.I engine and investigate its properties, performance and emission characteristics of the unmodified CI engine.

1.1 OBJECTIVES

- Selection of suitable biofuels and production of biodiesel through transesterification process.
- Testing of various fuel properties according to ASTM standards.
- To carry out blending and performance analysis of the tested fuels on unmodified C.I Engine.
- Validation of the results with literature survey.

2. MATERIALS & METHODS

2.1 Materials

Oils of Jatropha and Castor were obtained by mechanical pressing of seeds, which were collected from the plantation at Paritosh Harbals, Dehradun, Uttarakhand, India. All of the transesterification process was done in Laboratory of University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India.

2.2 Oil Extraction

Oil Extraction may be done:
Mechanically (by pressing the kernels)
Chemically; and
Enzymatically

2.3 Production Process:-

2.3.1 Transesterification

Is the process of chemically reacting a fat or oil with an alcohol in a presence of a catalyst.

Transesterification-ion reaction is carried out in a batch reactor.Alcohol used is usually methanol or ethanol Catalyst is usually sodium hydroxide or potassium hydroxide. The main product of transesterification is biodiesel and the co-product is glycerine. The best combination of the parameters was found as 6:1 molar ratio of Methanol to oil, 0.92% NaOH catalyst, 60 ^{0}C reaction temperature and 60 minutes of reaction time.

2.3.2 Separation

After transesterification, the biodiesel phase is separated from the glycerin phase; both undergo purification .The chemical properties of jatropha oil are given below.

Acid Value	38.2
Saponification value	195.0
Iodine Value	101.7
Viscosity (at 31 ^{0}C), Centistokes	40.4
Density (g/cm^3)	0.92

Table1: Chemical Properties of Jatropha oil

2.3.3 Neutralization

The vegetable oil contains about 14- 19.5 % free fatty acids in nature, it must be freed before taken into actual conversion process. The presence of about 14% of free fatty acid makes Jatropha oil inappropriate for industrial biodiesel production.

The dehydrated oil is agitated with 4 % HCl solution for 25 minutes and 0.82 gram of NaOH was added per 100 ml of oil to neutralize the free fatty acids and to coagulate by the following reaction .

$$RCOOH + NaOH \rightarrow \mathrm{RCOONa + H_2O}$$

The coagulated free fatty acid (soap) is removed by filtration. This process brings the free fatty acid content to below 2 % and is perfect source for biodiesel production.

2.4 Biodiesel production

In this study, the base catalyzed transesterification is selected as the process to make biodiesel from Jatropha oil. Transesterification-ion reaction is carried out in a batch reactor.[7]

For transesterification process 500 ml of Jatropha oil is heated up to 70 ^{0}C in a round bottom flask to drive off moisture and stirred vigorously. Methanol of 99.5 % purity having density0.791 g/cm^3 is used. 2.5 gram of catalyst NaOH is dissolved in Methanol in bi molar ratio, in a separate vessel and was poured into round bottom flask while stirring the mixture continuously. The mixture was maintained at atmospheric pressure and 60°C for 60 minutes.

After completion of transesterification process, the mixture is allowed to settle under gravity for 24 hours in a separating funnel. The products formed during transesterification were Jatropha oil methyl ester and Glycerin. The bottom layer consists of Glycerin, excess alcohol, catalyst, impurities and traces of unreacted oil. The upper layer consists of biodiesel, alcohol and some soap. The evaporation of water and alcohol gives 80-88 %pure glycerin, which can be sold as crude glycerin is distilled by simple distillation.

Jatropha methyl ester (biodiesel) is mixed, washed with hot distilled water to remove the unreacted alcohol; oil and catalyst and allowed to settle under gravity for 25 hours. The separated biodiesel is taken for characterization.

2.5 Biodiesel Characterization

The specific gravity reduces after transesterification, viscosity from 57 to 4.73 centistokes, which is acceptable as per ASTM norms for Biodiesel.

Flash point and fire point are important temperatures specified for safety during transport, storage and handling. The flash point and fire point of biodiesel

was found to be 128°C and 136°C respectively. Flash point of Jatropha oil decreases after transesterification, which shows that its volatile characteristics had improved and it is also safe to handle.

Higher density means more mass of fuel per unit volume for vegetable compared to diesel oil. The higher mass of fuel would give higher energy available for work output per unit volume.

Higher viscosity is a major problem in using vegetable oil as fuel for diesel engines. Cloud and pour point are criterion used for low temperature performance of fuel. The cloud point for Diesel is 4^0C which is very low and the fuel performs satisfactorily even in cold climatic conditions. The higher cloud point can affect the engine performance and emission adversely under cold climatic conditions. The pour point for Diesel is -4^0C. In general higher pour point often limits their use as fuels for Diesel engines in cold climatic conditions. When the ambient temperature is below the pour point of the oil, wax precipitates in the vegetable oils and they loose their flow characteristics, wax can block the filters and fuel supply line. Under these conditions fuel cannot be pumped through the injector. In India, ambient temperatures can go down to 0 ^{0}C in winters.

Fuels with flash point above 66 ^{0}C are considered as safe fuel.

3. Experiment/ tests conducted

Physical properties	Diesel	Jatropha oil	Biodiesel Jatropha	Biodiesel Castor
Flash point ^{0}C	65	214	130	147
Fire Point(celsius)	78	256	135	155
Pour Point(celsius)	-6	6	-2	-1
Viscosity (centistokes)	2.86	36.92	4	4.8
Calorific Value(Mj/kg)	44.34	39.76	42.80	39.80

Table 2: Comparison of physical properties of pure diesel & jatropha with biodiesel jatropha and castor

3.1 Test of fuels

The engine research laboratory of the Department of Mechanical Engineering, University of Petroleum & Energy Studies, Dehradun, India was used to carry out the transesterification process, blending and property analysis test of fuels. Six samples were considered for research.
These were
(a) 2.5% jatropha biodiesel with 97.5% diesel fuel (J2.5),
(b) 5% jatropha biodiesel with 95% diesel fuel (J5),
(c) 10% jatropha biodiesel with 90% diesel fuel (J10),
(d) 5 % castor biodiesel with 95 % diesel fuel (C5),
(e) 10 % castor biodiesel with 90 % diesel fuel (C10), and
(f) 20 % castor biodiesel with 80 % diesel fuel (C20).

These blended percentages are volume-based proportions.

4. RESULTS & DISCUSSION

It is clearly observed that the blend J (2.5) shows the best efficiency in comparison with J (5) and J (10)

4.1 Graphical Analysis

4.1.1 Brake Specific Fuel Consumption

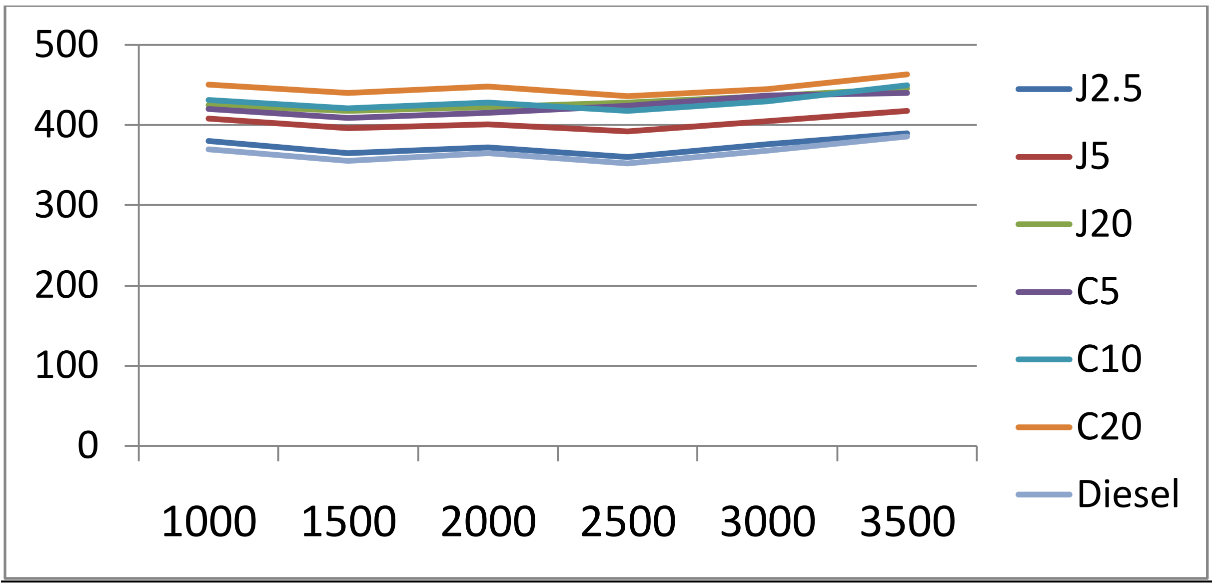

Figure 1: Load VS. Brake Specific Fuel Consumption

The Graph plotted between Load and Brake Specific Fuel Consumption efficiency clearly shows the variation of the tested fuels with engine load. It was found that the trend of variation of the J2.5 blend represent the lowest fuel consumption which is like the fuel consumption trend seen in D100.BSFC for J20 is higher when compared to J5.As compared to castor, jatropha blends have lesser fuel consumption due to better physical properties of jatopha oil methyl ester.

4.1.2 Brake Power

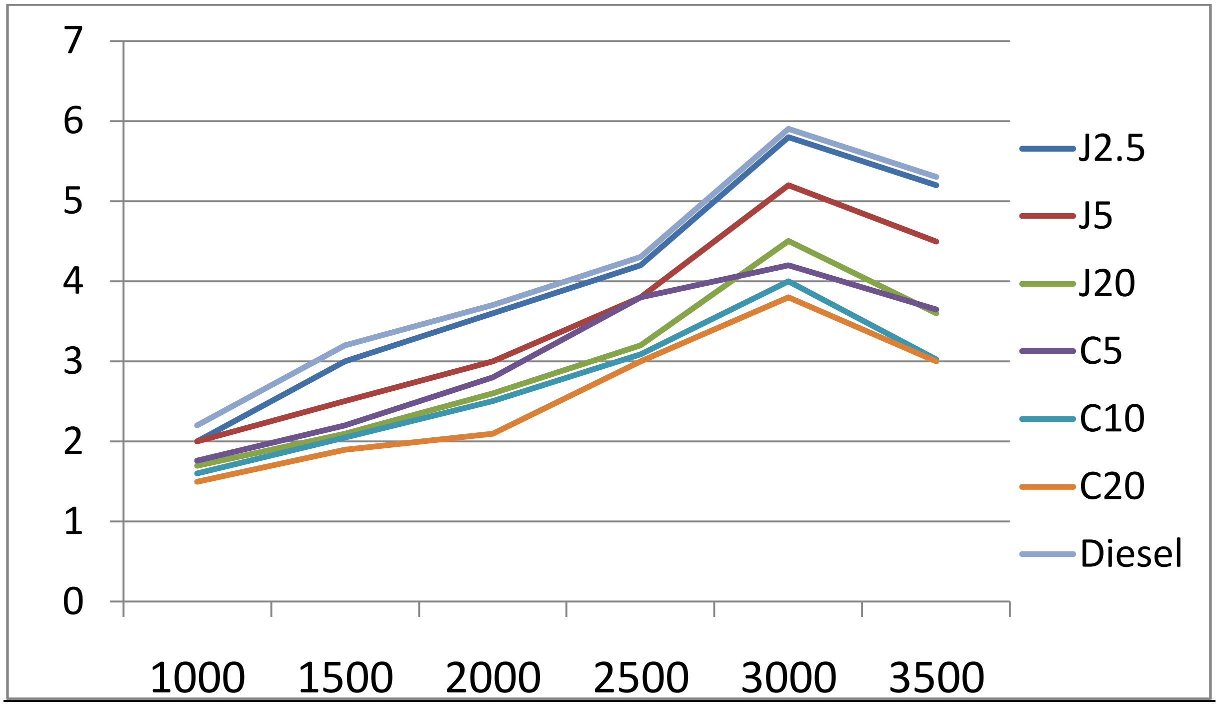

Figure 2: Load vs. Brake Power

The Graph plotted between Load and Brake Power clearly shows the variation of the tested fuels with engine load. It was found that the trend of variation of the J2.5 blend represent the highest efficiency. The BP was found to be lower for the tested blends of J5 and J20 compared to D100. BP for J20 is lower compared to J5. This reduction in Power is due to the poor atomization and combustion quality as a result of the low volatility, higher viscosity, and higher density of the jatropha-based biodiesel blend.The brake power for castor blends was found out to be much lower than jatropha blends due to more flash point of the castor blends hence less volatility.C20 has the best brake power out of the three.

4.2 EMISSIONS

4.2.1 NOX

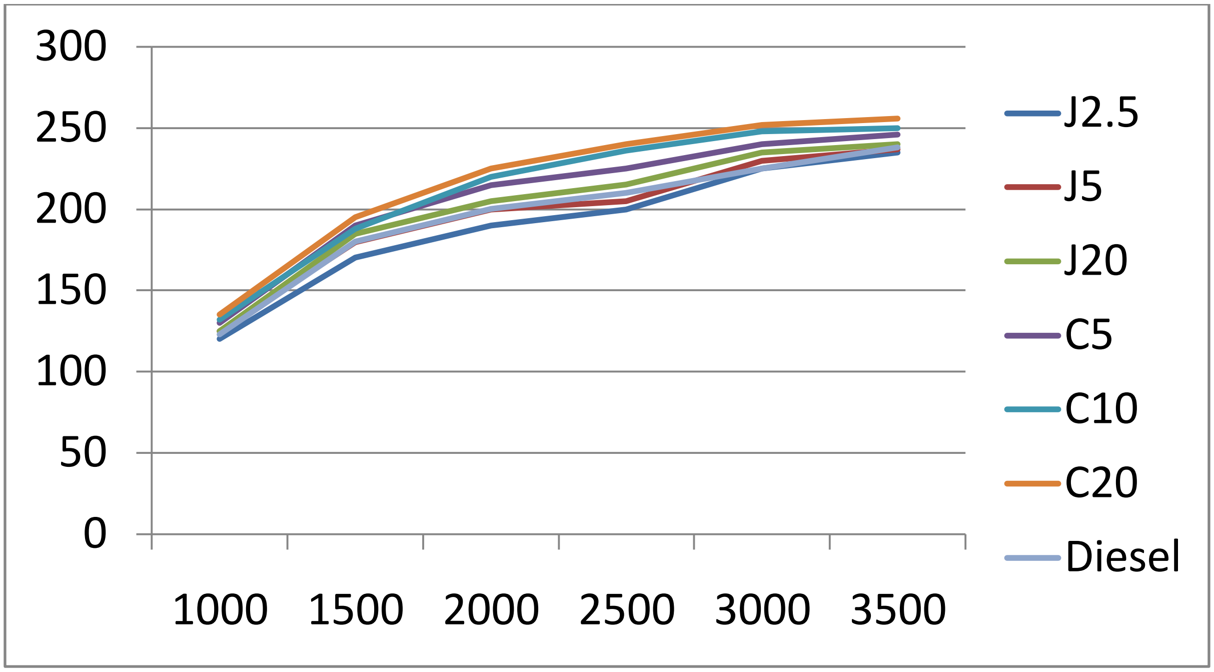

Figure 3: Load vs NOx emissions

It was observed that diesel had a pretty moderate value when it came to emission of nitrogen oxide compounds. However, the least NOx emissions were found in J2.5 blend and castor blends particularly C20 emitted the largest amount of nitrogen oxide compounds.

4.2.2 Hydrocarbons

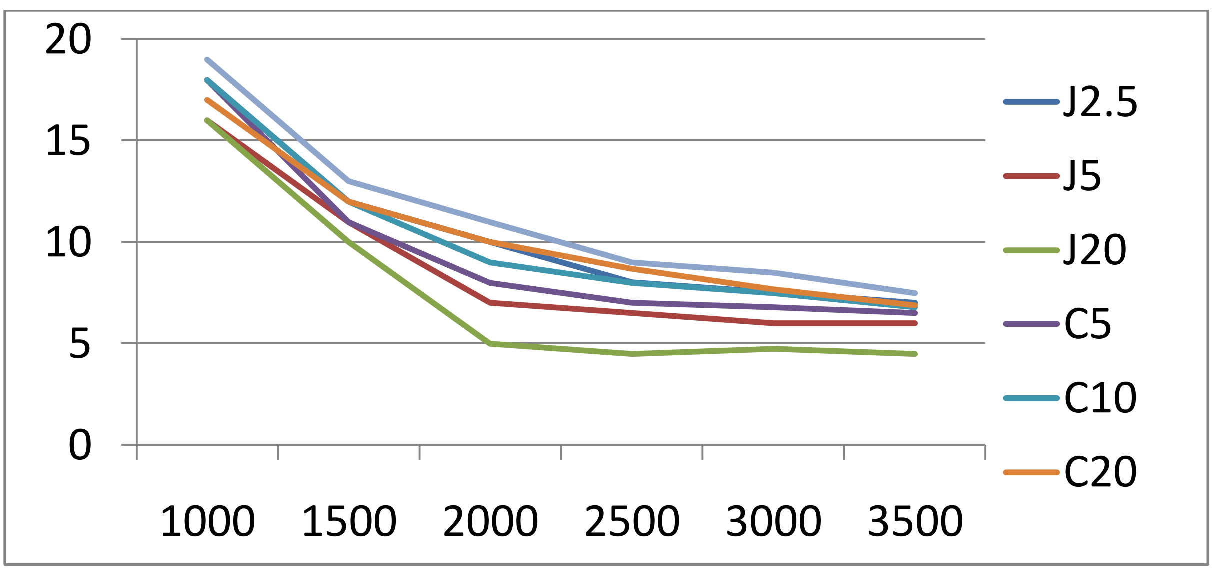

Figure 4: Load vs Hydrocarbon emissions

a. FURTHER ANALYSIS OF DATA TAKEN

The characteristic of the diesel engine is a known parameter. Various reading are taken for the calculation of BSFC, FC, BTE and BHP of the engine and are plotted for better understanding. The graph of the BTE should be increasing and then decreasing after the maximum economy point. Where as we get only the increasing portion of the graph.
The graph of the BSFC should be on the other side first decreasing and then increasing after the maximum economy.
We have used two different blends in the test. One with 2.5% jatropha and other with 5% jatropha blended with diesel.
5% jatropha:
For this fuel sample the BTE is little bit lesser than of diesel. As the amount of jatropha increase the reduction in the BTE. The can be explained with the help of the following. As the jatropha increases it makes the fuel more dense which makes them suffer worse atomization and vaporization followed by inadequate mixing with air. But if we can decrease the amount of jatropha the resulting fuel can act as energy booster.
2.5% jatropha:
This fuel sample has 2.5% jatropha and 97.5% diesel. For the maximum test load of 800W it has been observed that this increases the BTE compared to diesel. From the environmental point of view also it is favourable, by minimizing the carbon foot print. This special blend of fuel also has highest Cetain number and better engine performance than the diesel fuel suggesting that jatropha oil can be used as ignition accelerator additive for diesel fuel.
The results for the variation in the brake specific fuel consumption (BSFC) with increasing load in the engine for the various fuels are presented in Graph 14. For all fuels, the BSFC falls with increasing load. However values for the 97.5% diesel and 2.5% jatropha fuel blends are generally low compared to the other fuels at all loads.
It can be seen from Graph15, that the 97.5% diesel to 2.5% jatropha fuel blend indecently gives higher efficiencies at all load. The diesel fuel produces the lowest thermal efficiency at all loads. The higher thermal efficiency of the vegetable oil fuels may be due to their low heat input requirement for higher power output at a given engine load.It can be postulated from the above observation that 2.5% by volume of jatropha introduced into the diesel fuel enhances the performance of the engine and therefore the jatropha oil can be used as a fuel enhancement additive for the diesel oil.
Out of the castor blends it was observed that C20 gave the highest brake power with less emissions and brake specific fuel consumption as compared to C10 and C5.However, as compared to jatropha, castor blends gave much inferior values as due to better biodiesel properties of jatropha oil.
Therefore, jatropha oil is preferred as compared to castor oil as alternative fuel.

5. CONCLUSION

In our investigation, it had been confirmed that Jatropha oil may be used as resource to obtain biodiesel. The experimental result shows that transesterification is a promising technique for the production of biodiesel in large scale.
The analysis of different parameters like temperature,time and catalyst concentration was done to calculate their effect on biodiesel yield obtained. After transesterification, the viscosity of vegetable oils reduce greatly. Biodiesel characteristics like density, flash point, cloud point and pour point are also comparable to diesel.
After analysing the effect of the biodiesel obtained from non edible vegetable oils on an unmodified CI engine; we have come to the conclusion that jatropha oil is a better alternative fuel for diesel as compared to the castor oil. The result obtained is mainly due to better physical properties of the

jatropha oil biodiesel produced by transesterification process. Particularly J2.5 that is 2.5 % jatropha by volume shows performance characteristics closest to diesel and even better too.

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Acknowledgements:

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