# Process optimization for biodiesel production from Jatropha oil and its performance evaluation in a CI engine

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**Abstract - Biodiesel production through transesterification process of Jatropha oil were studied. This paper investigates the influence of KOH (catalyst) amount; molar ratio of methanol to oil; reaction time and reaction temperature on Jatropha biodiesel yield were studied. The optimal combination of process parameters for maximum yield was found out by using Taguchi's Techniques. A four stroke, single cylinder diesel engine was used to carry out performance and emission tests. Different blends of Jatropha biodiesel with neat diesel were tested. The result concluded that Jatropha oil can be used as an alternative fuel in existing diesel engines without any engine modifications.**

## I.INTRODUCTION

Biodiesel is one of the sources for replacement of fossil fuel, thereby reducing country's dependence on importing crude petroleum from overseas country. Petroleum resources are finite and therefore, it is required to search for alternative fuel in all over the world. Depletion of oil reserves, rising prices of petroleum fuels and stiff regulations on exhaust emissions have necessitated the substitution of fossil fuels with less polluting and easily available renewable fuels for use in IC engines. Development of biodiesel as an alternative and renewable source of energy for the agricultural and transportation sector has become critical in the national effort towards maximum self-reliance for the corner stone of our energy management strategy [4].

The idea of using vegetable oil as an engine fuel was originated from the demonstration of first diesel engine by the inventor of diesel engine ''Rudolf Diesel" at the World Exhibition at Paris in 1900 by using peanut oil as fuel. However, due to abundant supply of petro-diesel, R&D activities on vegetable oil were not seriously pursued. It received attention recently when it was realized that petroleum fuels are depleting fast and environment-friendly renewable substitutes must be identified [1]. Direct use of non-edible oil as fuel for diesel engine can cause particle agglomeration, injector fouling due to its low volatility and high viscosity, which is about 10 to 20 times greater than diesel. Increased carbon chain length and reduced number of double bonds were associated with increased oil viscosity, cetane rating and reduced gross heat content. It was found that except for castor oil, there was little difference between gross heat content of any of the vegetable oils. Heat contents were approximately 88% of that of diesel. There are four techniques applied to reduce the high viscosity of vegetable oils: dilution, micro-emulsification, pyrolysis and transesterification. Among these methods, the transesterification seems to be the best option since this process can significantly reduce the high viscosity of vegetable oils. The main reason to adopt this process is the simplicity and the generation of the by-product, glycerol which has got numerous applications in industries. Triglycerides, which are basically esters of glycerol, react with alcohol in presence of a catalyst through transesterification reaction to form three fatty acid alkyl ester and glycerol. Methanol is the commonly adopted alcohol owing to its low cost [6].

A catalyst is usually used to improve the transesterification reaction rate and biodiesel yield. Acid and alkalis can catalyze the reaction. For transesterification, alkali catalyst is preferred due to their faster esterification reaction and less corrosive nature. Alkali catalyst is used in the concentration range of 0.4-1.0% by weight for 92-96% conversion of vegetable oil into esters. A molar ratio of 6:1 is normally used to obtain methyl ester yield.

Temperature plays an important role to obtain maximum yield of methyl ester. In industrial processes maximum yield of esters occurs at temperatures range from 60□ to 80□C. The conversion rate has been found to increase with reaction time. The reaction time range from 45 to 75 minute for 92-95% conversion..

## II. Experimental setup

Biodiesel from Jatropha was produced in a laboratory scale set up which consists of heating mantle, reaction flask and mechanical stirrer. The working capacity of reaction flask is 1L. It consists of three necks for stirrer, condenser and inlet of reactant as well as for placing the thermocouple to observe the reaction temperature. The flask has a stopcock at the bottom for collection of the final product.

Table-1

| Property | Diesel | 20% Biodiesel blend | 40% Biodiesel blend | 60% Biodiesel blend | 80% Biodiesel blend | 100%Jatropha Biodiesel |
|---|---|---|---|---|---|---|
| Flash point (°C) | 75 | 86 | 98 | 115 | 133 | 155 |
| Cloud point (°C) | 6.4 | 7.1 | 7.7 | 8.9 | 10.1 | 11.2 |
| Pour point (°C) | 3.0 | 3.4 | 3.7 | 4.0 | 4.4 | 4.7 |
| Density at 15 °C | 853 | 858 | 863 | 869 | 875 | 880 |
| Viscosity at 40 °C | 285 | 300 | 327 | 356 | 390 | 423 |
| Calorific value | 44050 | 43730 | 43335 | 42939 | 42646 | 42374 |

## III Experimental Procedure

Taguchi's design of experiment were carried out according to L9 orthogonal array(Table-1), in order to determine the operating conditions that maximize the biodiesel yield.

For this experimental study, the following independent variables were identified, and the number of levels was set in

| Trial No | Column Factors | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 | 2 |
| 3 | 1 | 3 | 3 | 3 |
| 4 | 2 | 1 | 2 | 3 |
| 5 | 2 | 2 | 3 | 1 |
| 6 | 2 | 3 | 1 | 2 |
| 7 | 3 | 1 | 3 | 2 |
| 8 | 3 | 2 | 1 | 3 |
| 9 | 3 | 3 | 2 | 1 |

Table 2 The basic Taguchi L9 Orthogonal array**

table3.

Table-3: Process variables and their levels

| S.No. | Process Parameter Design | Process Parameter | Levels | | |
|---|---|---|---|---|---|
| | | | Low | Medium | High |
| 1. | A | Temperature (ºC) | 65 | 70 | 75 |
| 2. | B | Time (Hr.) | 1 | 1.5 | 2 |
| 3. | C | Molar Ratio of Methanol to oil (ml) | 65 | 80 | 95 |
| 4. | D | KOH Amount (gm) | 6 | 8 | 10 |

Potassium hydroxide (KOH) was dissolved in methanol and then added to the oil. The reactants were heated and stirred simultaneously in the reactor. The final product was then kept in a separating funnel. Washing the esters with distilled water thrice, made the traces of soap and glycerin to get removed. Washing was done by adding approximately 15% by volume of distilled water to the methyl ester and shaking the contents slightly in the first two and vigorously in the third washing. After each washing, the contents were allowed to settle at least for 12 hr and then separated. The clear esters were than collected in bottle for further analysis.

**Engine Specification**

| | |
|---|---|
| Make | Kirloskar Oil Engines Ltd. India |
| Cylinder | Single, vertical and water cooled |
| Stroke | 110 mm |
| Bore | 95 mm |
| Power | 6 kw |
| Speed | 1500 rpm |

A single phase 50 Hz alternator is connected with the engine.

## IV Results and Discussion

The experiments are conducted to study the effect of process parameters over the output response characteristics and the experimental results for biodiesel yield given in Table 3. For analyzing the results first calculate S/N ratio for yield with higher the better criterion and analysis of S/N ratio are done with the help of Taguchi design of experiment using Minitab-16 software. The mean response refers to the average value of the performance characteristic for each parameter at different levels. The average values of yield for each parameter at levels 1, 2 and 3 are calculated, plotted and tabulated in Fig. 6 and Table 6. The average values of S/N ratios of various parameters at different levels are also plotted and tabulated in Fig. 6 and Table 5. It is clear from mean response and S/N ratio analysis in Fig. 6 that biodiesel yield is maximum at the 3rd level of each parameter.

Table-4: Experimental Data Related, S/N and yield values

| Trial No | Column Factors | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | Yield | S/N ratio |
| 1 | 65 | 1 | 65 | 6 | 89.80 | 39.0655 |
| 2 | 65 | 1.5 | 80 | 8 | 93.12 | 39.3809 |
| 3 | 65 | 2 | 95 | 10 | 95.05 | 39.5590 |
| 4 | 70 | 1 | 80 | 10 | 94.01 | 39.4635 |
| 5 | 70 | 1.5 | 95 | 6 | 92.68 | 39.3397 |
| 6 | 70 | 2 | 65 | 8 | 93.84 | 39.4478 |
| 7 | 75 | 1 | 95 | 8 | 94.53 | 39.5114 |
| 8 | 75 | 1.5 | 65 | 10 | 94.95 | 39.5499 |
| 9 | 75 | 2 | 80 | 6 | 92.80 | 39.3510 |

Table-5 Response Table for Signal to Noise Ratios of yield

| **Level** | **C1** | **C2** | **C3** | **C4** |
|---|---|---|---|---|
| **1** | **39.34** | **39.35** | **39.35** | **39.25** |
| **2** | **39.42** | **39.42** | **39.40** | **39.45** |
| **3** | **39.47** | **39.45** | **39.47** | **39.52** |
| **Delta** | **0.14** | **0.11** | **0.12** | **0.27** |
| **Rank** | **2** | **4** | **3** | **1** |

Table-6: Response Table for Means of yield

| **Level** | **C1** | **C2** | **C3** | **C4** |
|---|---|---|---|---|
| **1** | **92.66** | **92.78** | **92.86** | **91.76** |
| **2** | **93.51** | **93.58** | **93.31** | **93.83** |
| **3** | **94.09** | **93.90** | **94.09** | **94.67** |
| **Delta** | **1.44** | **1.12** | **1.22** | **2.91** |
| **Rank** | **2** | **4** | **3** | **1** |

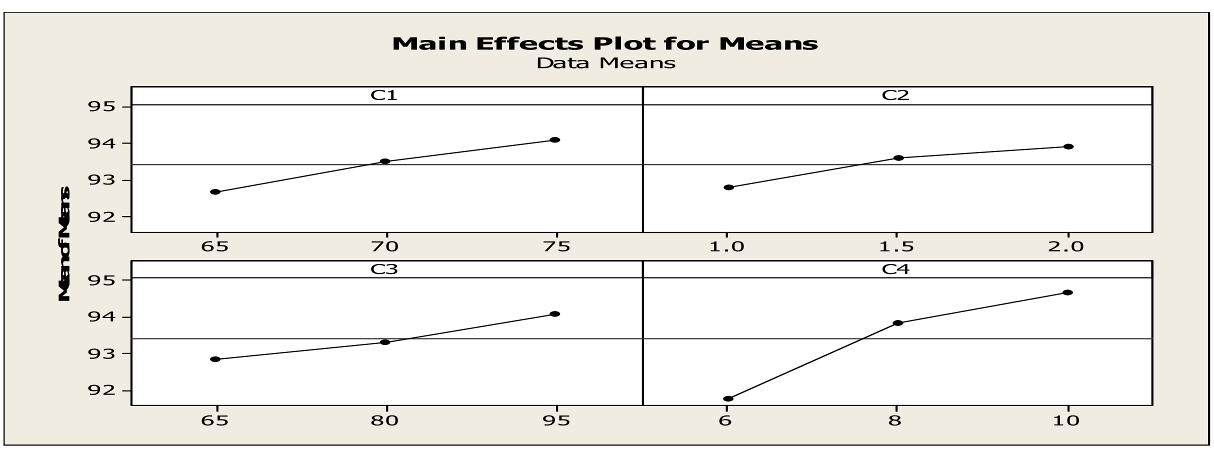


Fig. 1 Main Effects Plot for Means

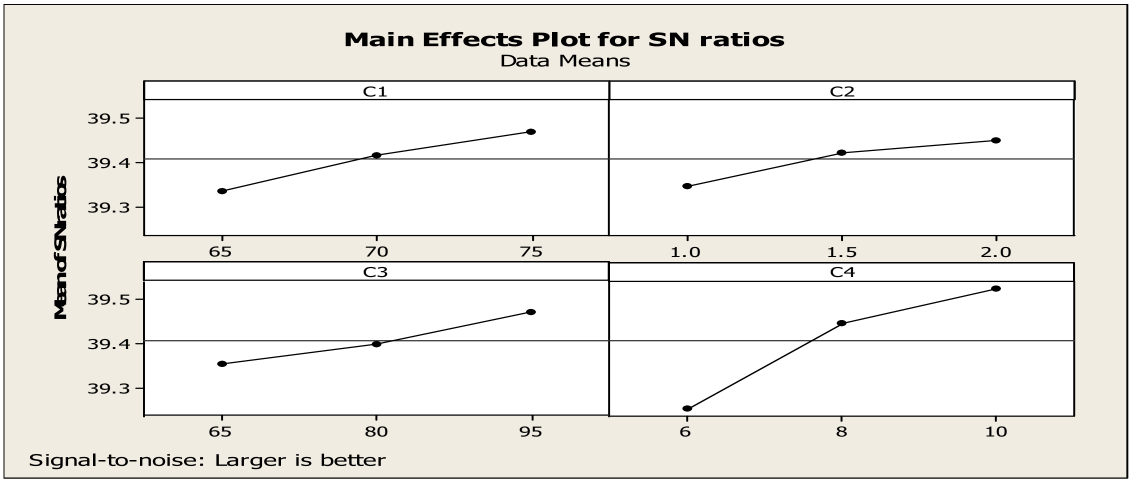


Fig.2 Main Effects Plot for SN ratios

## V. Performance and Emission Characteristics

Jatropha biodiesel were used separately as the fuel for compression ignition engine without any engine modifications. The performance evaluation and emissions of the engine with diesel, blends of biodiesel and diesel, and neat biodiesel are presented below.

From Fig. 3 shows the variation of brake specific energy consumption (BSEC) with brake mean effective pressure. As the brake mean effective pressure increases, brake specific energy consumption decreases for all fuel blends. At highest pressure JB80 shows the lowest BSEC.

From fig. 4, it can be seen that brake thermal efficiency is higher for JB100 for all brake mean effective pressures.

Fig. 5 illustrates the carbon monoxide emission vs load. At full load, JB 100 shows the highest CO emissions. Figure 6 and fig. 7 indicates the HC and NOx emissions in unblanded and blanded diesels. Figures show that HC emission is higher in unblended diesel and NOx is higher in pure jatropha biodiesel.

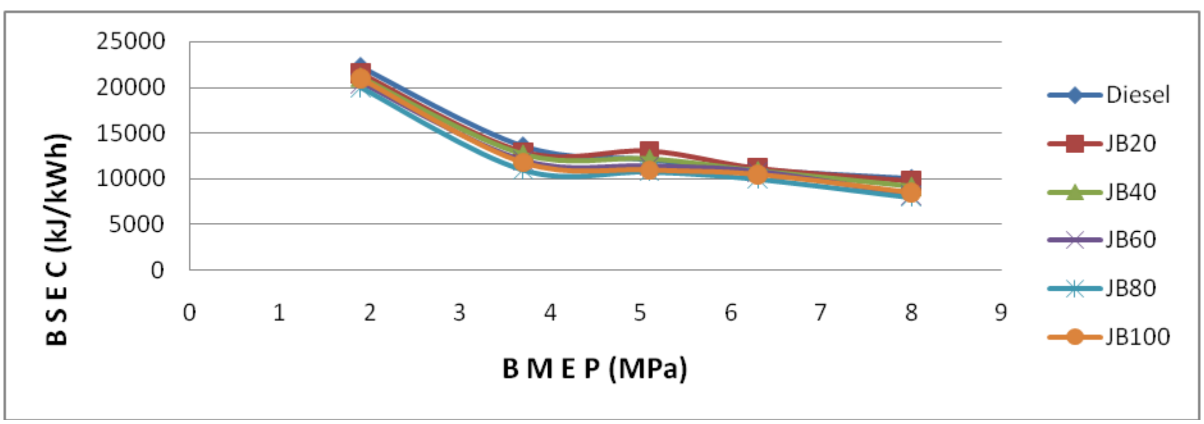


Fig. 3 Effect of BMEP on BSEC for Diesel and Jatropha Biodiesel and their blends

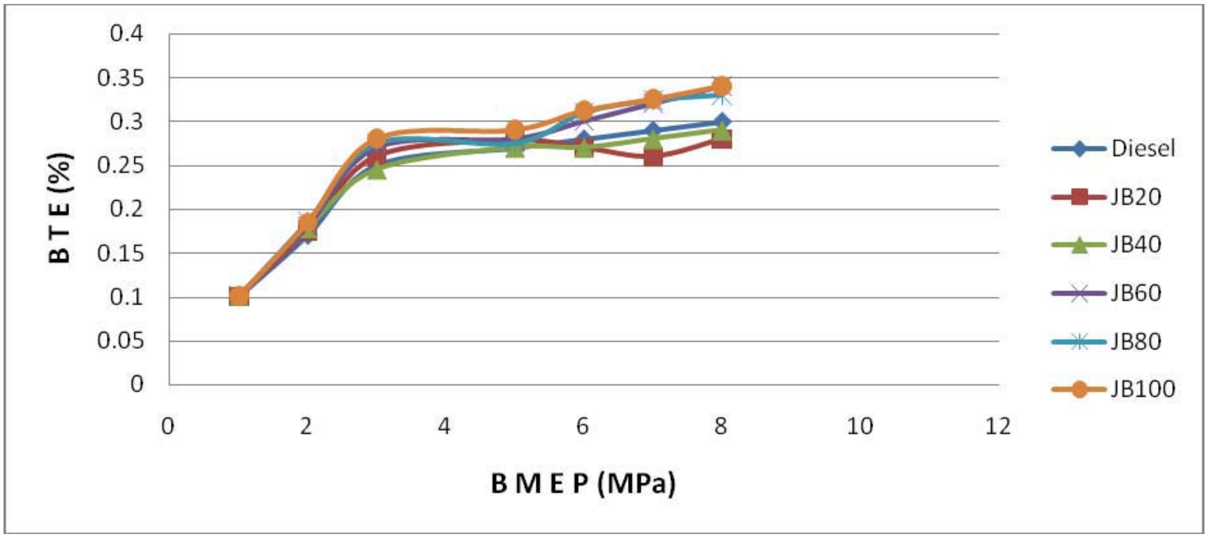


Fig.4 Effect of BMEP on BTE for Diesel and Jatropha Biodiesel and their blends.

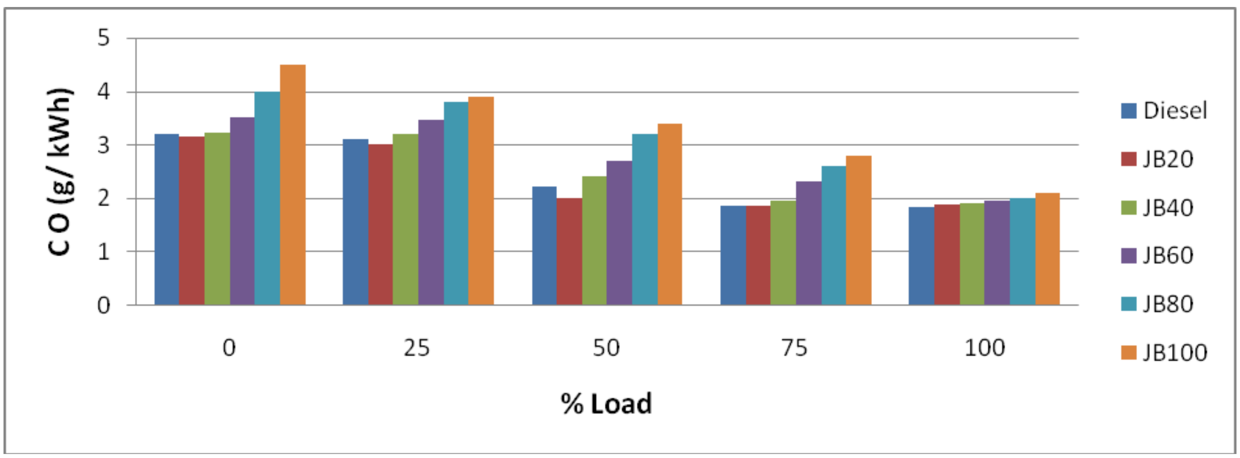


Fig.5 Variation of CO with Load

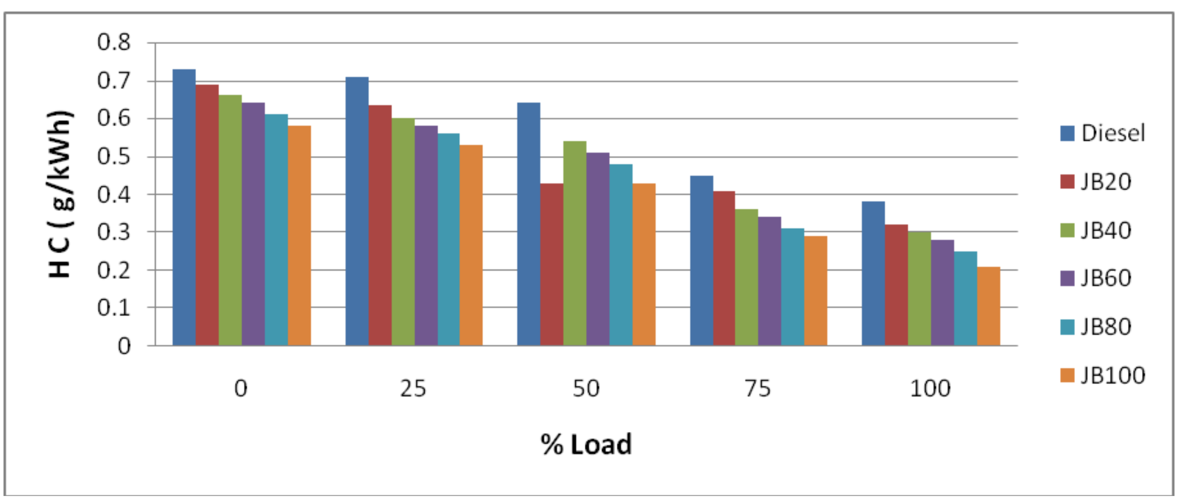


Fig.6 Variation of HC with Load

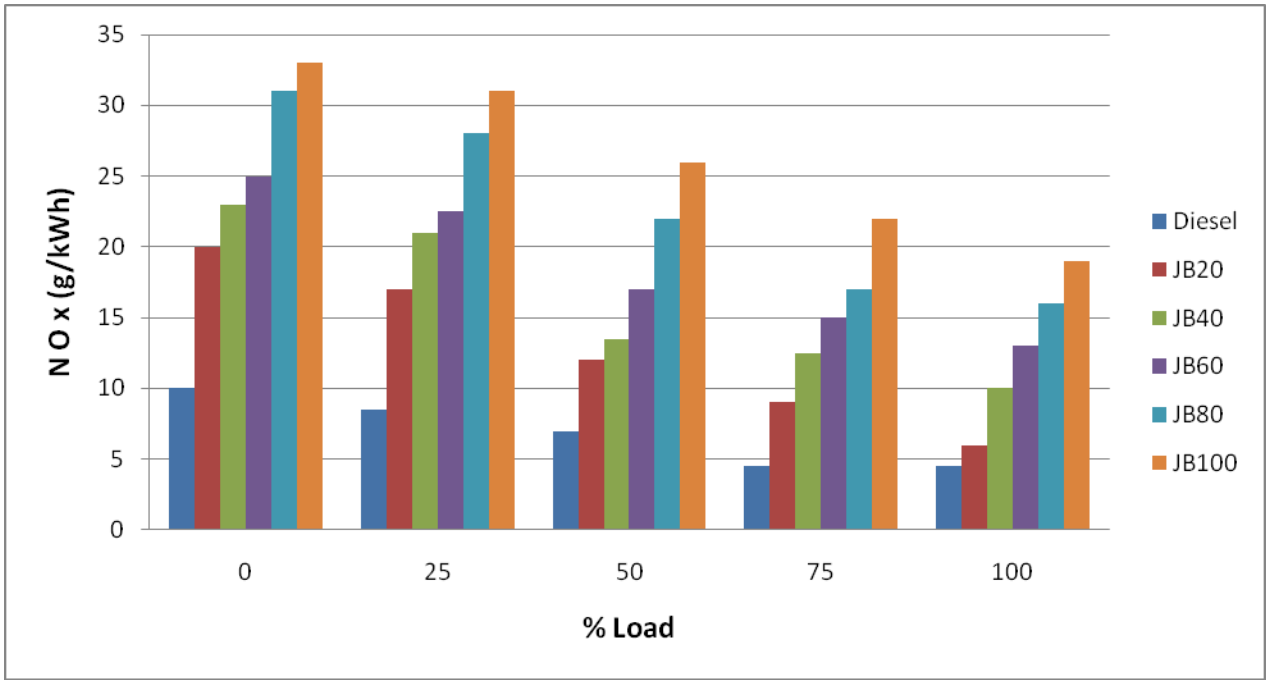


Fig.7 Variation of NOx with Load

## V. Conclusion

The process variables have been optimized by Taguchi's Technique. The optimum process parameters for using KOH as catalyst were: KOH Amount 10 gm, Molar Ratio of Methanol to oil 95 ml , reaction time 2 hr. and Temperature 75□C.

Transesterification of jatropha oil has been carried out by using KOH as catalyst. Jatropha biodiesel and its blends have been analyzed for their physical properties. Among them 20% jatropha biodiesel has been found highly comparable with unblended petroleum diesel.

The experimental investigations revealed that :

1. Compression ignition engines can perform well on jatropha biodiesel without any modifications in engine.
2. Among the blends 20% Jatropha biodiesel shown better engine performance and emission characteristics.
3. Jatropha biodiesel can be considered as an effective fuel source for the future.

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