Performance characteristics of non-edible Jatropha oil with adjustable compression ratios

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Abstract. Non-edible biodiesel extracted from jatropha oil is broadly studied to solve the twin problem of reduction of fossil fuels and environmental degradation. The present study is conducted on unmodified variable compression ratio (VCR) diesel engine for exploring the effect of biodiesel blends. The performance characteristics of Jatropha oil are compared with diesel fuel at two compression ratios 17 and 18. The viscosity and density are 23% and 3.9% higher with respect to diesel for pure jatropha methyl ester and calorific value is lower for J100, 6.8% with respect to diesel. Performance and emission have been observed better when compression ratio increases from 17 to 18 and also notice that the hydrocarbon (HC) and carbon monoxide (CO) emission reduced but corban dioxide CO₂ and NOx emission increases.

1. Introduction

In today’s energy scenario, different elective energizes for diesel motors have been investigated by numerous analysts in the course of recent decades. Among the different conceivable outcomes, biodiesel is the theme of intrigue today, since it is inexhaustible, oxygenated biodegradable, non-poisonous, and condition neighbourly. Also, in numerous nations, agrarian land is plentifully accessible where biodiesel can be delivered with ease. Biodiesel is a fuel made out of mono-basic esters of long chain unsaturated fats that are acquired from triglycerides, for example, vegetable oil, creature fat [1]. Many researchers suggested use of biodiesel in compression ignition (CI) engine directly. Biodiesel offers closely equal fuel effectiveness and lower gas emission in compression to standard diesel. Due to higher density it has poor cold flow properties and higher consistence and better emission of chemical element oxides compared to a diesel fuelled engine [2]. Jatropha oil trans-esterification reduced kinematic viscosity and specific gravity. The Jatropha oil has high density and low calorific value than diesel [3]. Density increases and calorific value reduces as Jatropha oil increases in the blends. It's seen that the viscosities of blend 10 and blend 20 (3.7135 mm²/s and 3.7878 mm²/s) are practically nearer to the diesel fuel, so it can be used directly in diesel engine without significant alteration [4]. Jatropha oil is produced additional NOX than diesel. The rise in NOX emission is qualified to the presence of mono-unsaturated (40.8%) and unsaturated (32.1%) fatty acids gift. CO emission in jatropha oil and its blends is a smaller amount than that of diesel oil. The decrease in CO emission for JBD is qualified to the high cetane value and also the presence of element within the molecular structure of the jatropha oil. Greenhouse gas emission of biodiesel is a smaller amount than that of diesel oil. [5-7] When increase in compression ratio from 14 to 18 results increase in break thermal efficiency. [8-9] For compression ratio 14, 16 and 18 two biodiesels (jatropha and Karanja oil) were tested in a single cylinder VCR DI diesel engine [10]. Peak pressure of blend 50 is higher at low and high engine speed, whereas that of Blend 10 and Blend 20 are a unit optimum at economic medium speed [11-13]. Preheating (90 to 100°C) the jatropha oil reduces the viscousness [14]. The employment of jatropha biodiesel in a very standard diesel motor decreases its torsion and BTE, the decrease being additional with increase within the biodiesel share within the blends [15].

The research work, a study on jatropha biodiesel blends to measure performance and emission characteristics of a DI engine fueled with jatropha biodiesel blends. Attempt has been made to compare
the fuel properties of selected blends and study the effect of blends on performance. Compare the performance of (10%, 15%, 20%, 25%, 30%) blends and emission properties with diesel at two compression ratio 17 and 18. Evaluate the optimum blending percentage and compression ratio for desired performance and emission properties.

2. Experimental setup details
A single cylinder four stroke, water cooled, direct injection (DI) and variable compression ratio (VCR) engine have used for experimentation. The pictorial view and specification of engine are shown in Figures 1 and table 1, respectively.

![Figure 1. Four stroke variable compression ratio engine setup](image)

Table 1 Kirloskar Engine Specifications

| Sr.No. | Parameters                      | Specification                        |
|--------|---------------------------------|--------------------------------------|
| 1      | Manufacturer                    | Kirloskar TV1                        |
| 2      | Engine type                     | Single cylinder, four stroke, VCR engine |
| 3      | Evaluated power                 | 5.20 KW                              |
| 4      | Bore/stroke                      | 87.50(mm)/ 110.00(mm)                |
| 5      | Swept volume / clearance volume | 661.45 (cc) / 38.9 (cc) at CR 18     |
| 6      | Compression ratio               | 12 to 18                             |
| 7      | Rated speed                     | 1500 rpm                             |

3. Blends preparation and properties
The jatropha methyl ester was taken from SVM Agro Processor, Nagpur. The main properties of biodiesel are given in the table 2. Diesel was procured from local market. The test has been conducted with diesel and biodiesel (1 Litre sample) at various blending ratio. Pure diesel -1000 ml, J10 (jatropha methyl ester 10% and diesel 90%), J15 (jatropha methyl ester 15% and diesel 85%), J 20 (jatropha methyl ester 20% and diesel 80%), J 25 (jatropha methyl ester 25% and diesel 75%), J 30 (jatropha methyl ester 30% and diesel 70%). The blends are prepared by volume basis i.e. J10, J15, J20, J25, J30 to investigate the following characteristics of JME (jatropha methyl ester) and its blends.
Table 2 Pure diesel physico-chemical properties with jatropha methyl ester (JME) blends

| S.N | Blends    | Density (g/ml) | Viscosity(cst) | Calorific value(cal/gm) |
|-----|-----------|----------------|---------------|-------------------------|
| 1   | Pure diesel | 0.838          | 3.35          | 10476                   |
| 2   | J10       | 0.841          | 3.43          | 10413                   |
| 3   | J15       | 0.843          | 3.47          | 10370                   |
| 4   | J20       | 0.846          | 3.51          | 10338                   |
| 5   | J25       | 0.849          | 3.56          | 10304                   |
| 6   | J30       | 0.851          | 3.62          | 10269                   |
| 7   | J100      | 0.870          | 4.12          | 9814                    |

4. Experimental procedure
To attend a rated speed engine has started at no load, after 30 minutes it comes on steady state. After achieving steady state fuel Consumption, revolution per minutes, exhaust gas temperature, CO, NOx, HC and power output were conjointly measured. The engine was loaded bit by bit keeping the speed with within the permissible vary and therefore the observations of various parameters were evaluated. Short term performance tests were done out on the engine with diesel to come up with the bottom line information and afterwards genus Jatropha biodiesel blends have accustomed assess its suitableness as a fuel. The performance and emission characteristics of blends are evaluated and compared with diesel oil. The engine has continually started with diesel as a fuel and once it runs for 20-25 minutes, it switches over to genus Jatropha oil.

5. Result and Discussion

5.1. Performance characteristics
In this paper, engine concert has evaluated in terms of brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC). The performance of the test engine on diesel and jatropha bio-diesel blends at two compression ratios 17 and 18 for different load are summarized below.

5.1.1. Brake specific fuel consumption (BSFC)
BSFC is that the magnitude relation between mass flow rate of the biodiesel to effective engine power. It depends on fuel injection systems, fuel density, viscousness and heating rate. At compression ratio 17 and 18, variation of BSFC for jatropha blends with respect to the engine load are shown in figure 2 and figure 3. Maximum BSFC (Figure 2 and Figure 3) for CR17 and CR18 are 20.27 % and 16.67% higher with respect to diesel at load 2 kg and minimum BSFC at 6 kg load for both compression ratios are 31.04% and 28.5% for blends J 30 and J 0.
At compression ratio 18, increase in BSFC for blends J10, J15, J20, J25, J30 are 6.66%, 10%, 16.67%, 23.33% and 26.67% with respect to diesel at full load.

**Figure 2.** Variation of BSFC (Jatropha oil) with load at compression ratio 17

**Figure 3.** Variation of BSFC (Jatropha oil) with load at compression ratio 18.

### 5.1.2 Brake thermal efficiency (BTE)

The variation of brake thermal efficiency (BTE) of the engine with jatropha biodiesel blends at different load is shown in figure 4-5 and compared with base line data of diesel. In the figure 4 and figure 5 shows
that maximum BTE achieve at load 6 kg for both compression ratio. The maximum BTE for diesel (J0) and blends (J30) at compression ratio 17 and 18 are (27.12% and 23.504%) and (27.82% and 24.03%). At compression ratio 18, reduction in BTE for blends J10, J15, J20, J25, J30 are 3.14%, 5.84%, 8.61%, 11.13% and 13.20% with respect to diesel.

Figure 4. Variation of BTE (Jatropha oil) with load at compression ratio 17.

Figure 5. Variation of BTE (Jatropha oil) with load at compression ratio 18.

5.2. Emission characteristics
The emissions analysis has been conducted at 0, 2, 4, 6 and 8 kg engine load. The variation of NOX, HC, CO and CO2 emissions for J0, J10, J15, J20, J25 and J30 are shown in following figures 6-13. At full load and compression ratio 17 and 18, maximum reduction in CO emission are 37.5% and 50%.
respectively. At compression ratio 18 reductions in CO emission are 14.28%, 28.5%, 35.71%, 42.86% and 50% for J10, J15, J20, J25 and J30 with respect to diesel.

![CO vs LOAD CR 17](image1.png)

**Figure 6.** Variation of carbon monoxide with load at compression ratio 17.

![CO vs LOAD CR 18](image2.png)

**Figure 7.** Variation of carbon monoxide with load at compression ratio 18.

Maximum CO$_2$ emission observed at full load due to lower air/fuel ratio inside the combustion chamber. At compression ratio 17 and 18, maximum reduction in CO$_2$ emission is 16.63% and 10.78% respectively. At compression ratio 18 reduction in CO$_2$ emission 2.98%, 5.05%, 7.58%, 10.1% and 10.77% for J10, J15, J20, J25 and J30 with respect to diesel.
The values of un-burnt gas emission from the DI engine in case of jatropha methyl ester and its blends are lower than neat diesel because in the jatropha biodiesel 10-12% more oxygen. Maximum HC emission observed at full load due to deficiency of oxygen inside the combustion chamber. At
compression ratio 17 and 18 HC emission for diesel and J30 are (28 and 23 PPM) and (27 and 22 PPM) and reduction in HC are 17.85% and 18.52% respectively. At compression ratio 18 decrease in HC emission 1.85%, 5.55%, 9.26%, 14.8% and 18.5% for J10, J15, J20, J25 and J30 with respect to diesel.

The variations of NO\textsubscript{X} emissions for all the test fuels are shown in Figure 12-13. Maximum NO\textsubscript{X} emission observed at full load due to higher temperature inside the combustion chamber. At compression ratio 17 and 18 NO\textsubscript{X} emission for diesel and J30 are (963 and 1143 PPM) and (987 and 1258) and increases in NOX emission are 18.69% and 25.66% respectively. At compression ratio 18 increase in NOX emission 1.97%, 8.95%, 14.36%, 17.7% and 25.66% for J10, J15, J20, J25 and J30 with respect to diesel.
Conclusion
The impact of biodiesel mixes on execution and outflow qualities at two pressure proportions 17 and 18. The BTE of Jatropha methyl ester and its mixes are lower and BSFC has been observed to be higher than diesel. Emissions like HC, CO and CO₂ are found to be lower with blends and NOₓ emissions are higher than Diesel. When compression ratio increases from 17 to 18 then it is observed that BTE has been improved up to 3.91% and BSFC lowers up to 8.33%. It is also observed that HC and CO reduce up to 5.76% and 22.22% respectively. Similarly, CO₂ and NOₓ increase up to 12.43% and 11.81% respectively. For blends J20, J25 and J30, BTE is lower by 8.61%, 11.13% and 13.20% respectively while BSFC is higher by 16.67%, 23.33% and 26.67% respectively. NOₓ emission is higher for J20, J25
and J30 by 14.36%, 17.69% and 25.67% respectively. HC and CO emission are reduced 9.26%, 14.8%, 18.5% and 35.71%, 42.86%, 50% respectively for blends J20, J25 and J30.

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