JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# Experimental Analysis on Combustion Characteristics of soyabean Biodiesel in Single Cylinder Compression Ignition Engine

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**Abstract**

Energy is the basic input for the socio-economic development of a country. As the demand of energy is increasing day by day. It is essential for every country to opt for other sources of energy which are non-depleting and biodegradable. Among all the existing sources of energy, bio fuels seem to be one of the most important energy sources. As diesel engine dominates Indian agricultural Sector, Industry, Transportation Sector etc. it is necessary to identify economical renewable energy sources which can substitute petroleum diesel and hence biodiesel is found to be one of the promising fuels for diesel engine. Biodiesel defined as the mono alkyl esters of long chain fatty acids derived from liquid feedstock such as vegetable oils or animal fats can be used as a substitute or an additive to diesel fuel. Compared to fossil-based diesel fuel, biodiesel possesses many advantages such as cleaner engine emissions, biodegradable, renewable and superior lubricating property. In spite of the many advantages of biodiesel, it is not yet commercialized all over the world because of the low availability of the good quality oil and their high prices. A diesel engine test rig was use for experimental work in the present dissertation work. Combustion test were also carried out when fuelled with petroleum diesel and diesel-biodiesel blends. The engine experimental result shows that the performance of the engine is 16.93% higher in terms of brake thermal efficiency. HRR and cylinder temperature is higher 1.25% and 1.15% of B100 compared to D100 at full load.

**Keywords:** Soya bean Biodiesel, Biodiesel blend, Conventional diesel, Diesel engine, fuel properties, engine combustion characteristics.

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## 1.Introduction:

Soyabean is a cool season legume which can be grown from south to north throughout much of the eastern half of the U.S. Soyabeans and other legumes have a unique relationship with a bacteria brady rhizobium species, will colonize on soyabean roots forming a nodule. The two species form a symbiotic relationship where the soyabean plant provides nutrition and the bacteria fixes nitrogen from the air. This relationship reduces the need for supplemental nitrogen fertilizer in soyabean production. Soyabeans flower in response to day length and temperature. Varieties grown in the United States are divided into 13 maturity groups from maturity group 000 being the earliest and adapted to northern regions of Minnesota and southern Canada, to maturity group X adapted to southern regions such as south Texas. The earlier varieties bloom when days are long and nights are short, while the later-maturing varieties bloom under relatively shorter days and longer nights. Summer days are longer at northern latitudes, where early maturing varieties will initiate flowering when days are longer. Maturity groups develop differently and knowing the growth habit of different maturity groups can help with the crop management.

### 1.2 Production Challenges

Soyabean production generally known as a compliments corn production in the upper Midwest. Both corn and soyabeans enjoy a long history of production on millions of acres in the upper Midwest. This history has led to a large infrastructure of equipment, storage, rail, barge and truck transportation. Soyabeans like many crops face insect and disease pests along with weather related challenges. An emerging disease has gained much attention in recent years. Soyabean rust, a fungal disease native to Asia has spread to the soyabean fields of South America and finally to U.S. soyabeans. Rust control is expensive requiring fungicide applications and yield damage can be extreme.

### 1.3 Estimated Production Cost

Production costs will vary depending on location, cropping systems, and fluctuation in price of energy. Major expenditures in soyabean production include; Planting, harvesting, seed and pesticides. An example of a Nebraska rainfed budget for no-till soyabeans for 2010 lists $115 per acre for field operations, materials and services. When including overhead costs for land, insurance, etc. the total is approximately $200 per acre. Total costs for irrigated soyabeans are around $400 per acre. Biodiesel profitability is extremely variable and based on the continuously changing prices biodiesel, soyabean oil, co-product glycerine, methanol and natural gas. Price of soyabean oil feedstock is one of the driving factors in profitability, compared to petroleum diesel which has a fossil energy ration of 0.84.

## 2. Literature Review:

Previous studies on the use of biodiesel in internal combustion engines have revealed a range of effects on engine output and combustion characteristics. Numerous research haves looked into the thermal efficiency, emission profiles, and combustion characteristics of biodiesel and its blends in diesel engines. However, there isn't much information available about using Soybean biodiesel in single-cylinder compression ignition engines.

**Shailendra Sinha et al., (2007)** the experiment is carried out the transesterification process for production of rice bran oil methyl ester has been investigated. The various process variables like temperature, catalyst concentration, amount of methanol and reaction time were optimized with the objective of producing high quality rice bran oil biodiesel with maximum yield. The optimum conditions for transesterification of rice bran oil with methanol and NaOH as catalyst were found to be 55-degree centigrade reaction temperature, 1 h reaction time, 9:1 molar ratio of rice bran oil to methanol and 0.75% catalyst (w/w). Rice bran oil methyl ester thus produced was characterized to find its suitability to be used as a fuel in engines. Results showed that biodiesel obtained under the optimum conditions has comparable properties to substitute mineral Diesel, hence, rice bran oil methyl ester biodiesel could be recommended as a mineral Diesel fuel substitute for compression ignition (CI) engines in transportation as well as in the agriculture sector.

**Yinnam Yuan et al., (2008)** carried out the experiment on combustion analysis and emission by using soyabean biodiesel. The combustion and heat release of engines using diesel fuel and bio-diesel fuel have been investigated. The results shows that the combustion happens in advance and the ignition delay period is shortened. The initial heat release peak declines a little, the corresponding crankshaft angle changes in advance, and the combustion duration is prolonged. The economic performance and emission features of diesel engines using diesel fuel and bio-diesel fuel are compared. The results also show that the specific fuel consumption of bio-diesel increases by about 12%. The emissions, such as CO, HC, and particulate matter.

**Emil Akbar et al., (2009)** the experiment is carried out by using Jatropha Curcas oil and check the characteristic and composition of that. The lipid fraction of Jatropha oil seed was extracted and analysed for their chemical and physical properties such as acid value, percentage free fatty acids (% FFA), iodine value, peroxide value and saponification value as well as viscosity, and density. The fatty acid and triacylglycerol (TAGs) composition of the extracted lipid was revealed using the gas chromatography (GC) and high-pressure liquid chromatography (HPLC) method. Both oleic acid (44.7%) and linoleic acid (32.8%) were detected as the dominant fatty acids while palmitic acid and stearic acid were the saturated fatty acids found in the Jatropha oil.

**Junxing Hou et al., (2022)** The experiment carried out an experimental analysis of combustion behaviours and emission characteristics of pure biodiesel and biodiesel−dimethyl ether (DME) blends and determined the impacts of the biodiesel ratio and the nozzle parameter on the combustion pressure characteristics in the time domain/frequency domain and emission characteristics. The findings show in this studies that with a decrease in the biodiesel proportion in biodiesel−DME blends, the maximum combustion pressure and fuels in the premixed combustion stage decrease with a retarded maximum value phase, but the maximum heat release in diffusive combustion increases and the maximum amplitude of pressure rise acceleration decreases. All of the pressure level curves of BD100, BD80, and BD50 contain a rapid decrease stage 1, a slow decrease stage 2, and a fluctuating stage 3. With a decrease in the biodiesel proportion, the exhaust gas temperature, $NO_x$ emissions, and smoke emissions of BD100, BD80, and BD50 decrease gradually. Compared with a 5 × 0.43 mm nozzle, the maximum combustion pressure and maximum heat release rate of BD50 for a 4 × 0.35 mm nozzle were higher and the phase of the maximum value was advanced. Soot emissions for the 4 × 0.35 mm nozzle were lower, which is especially obvious under a high brake mean effective pressure (BMEP).

**3. Objective of the present study**

The present work compares the combustion analysis of soyabean biodiesel with mineral diesel and soyabean biodiesel-diesel blends in different proportion such as D100, B100, B50, B20 in single cylinder compression ignition engine. The goal of this work is to determine the usefulness of various proportion of soyabean biodiesel in a different load condition as alternative fuel of internal combustion engine.

**4. Experimental Setup**

A Kirloskar made, single cylinder, water cooled, direct injection AV1 model diesel engine is selected for the present research work and shown in Figure 1. For conducting the desired set of experiments and measuring required data from the engine, it is essential to get the various instruments mounted at the appropriate location on the experimental setup.

**Figure 1** Shows the schematic diagram of engine set up. The setup enables study of combustion characteristics of engine and performance characteristics of engine, for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, air fuel ratio, and heat release rate. Lab-view based engine performance analysis software package “Engine soft” is provided for on line performance evaluation.

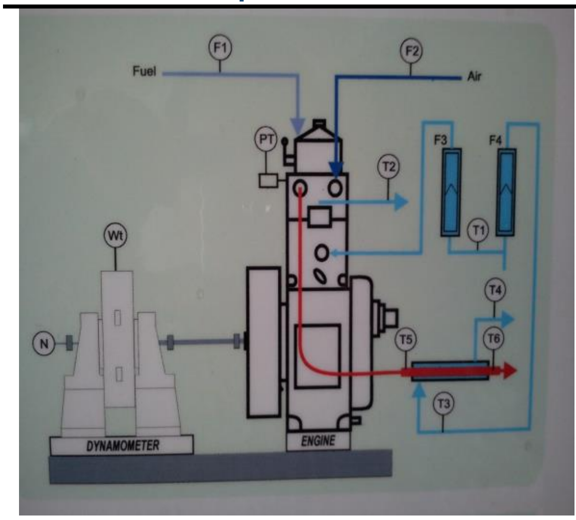


Figure 1: Schematic Diagram of Engine Test Rig.
T1, T3: Inlet Water Temperature
T2: Outlet Engine Jacket Water Temperature
T4: Outlet Calorimeter Water Temperature
T5: Exhaust Gas Temperature before Calorimeter
T : Exhaust Gas Temperature after Calorimeter
F1: Fuel Flow DP (Differential Pressure) unit
F2: Air Intake DP unit
F3: Engine water jacket water flow
F4: Calorimeter water flow
PT: Pressure Transducer
Wt: Load in Kg
N : RPM Decoder

## 5. Physical and Chemical Properties of soyabean biodiesel fuel

| **Fuel properties** | **Diesel** | **Refined Soybean Oil** | **Soybean Methyl Ester** |
|---|---|---|---|
| Kinematic Viscosity at 38°C, cs | 2.935 | 35.38 | 5.02 |
| Relative Density at 15°C | 0.816 | 0.926 | 0.839 |
| Heat of Combustion, MJ/kg | 45.72 | 37.21 | 40.03 |
| Cloud Point, °C | 7.1 | -9.1 | 15.2 |
| Pour Point, °C | -8.1 | -12.1 | 5.2 |
| Flash Point, °C | 54 | 283 | 54 |
| Fire Point, °C | 58 | 291 | 61 |
| Acid Value, mg of KOH/g | 0.23 | 0.54 | 0.28 |
| Ash Content, % | 0.0004 | 0.16 | 0.0047 |
| Carbon Residue, % | 0.18 | 7.21 | 0.46 |
| Free glycerine | - | - | 0.014 |
| Total glycerine | - | - | 0.212 |

Table 5.1: Physical and Chemical Properties of soyabean biodiesel fuel

## 6. Results and discussions for Combustion Characteristics

### 6.1 Cylinder Pressure Vs Crank Angle

**Figure 2** shows the variation of cylinder pressure with crank angle at different load throughout the compression and expansion strokes for the different diesel biodiesel blends. At low load (0%) the cylinder pressure of the B100 is 50.22 bar which is maximum and full load (100%) the inside cylinder pressure is 74.85 bar at 372 crank angles. The reason for increasing the inside cylinder pressure is complete combustion of the soyabean biodiesel. When load is increasing then inside cylinder Pressure is also increasing. It is clear that peak pressure increases while increasing the load. All diesel biodiesel blends B100, B50 and B20 combustion starts earlier in comparison to diesel. It is also observed that peak pressure shifts towards TDC with increasing load for biodiesel and diesel-biodiesel blends. Much of variation in combustion process is not observed among B50 and B20.The maximum deviation of peak pressure for B100 than pure diesel.

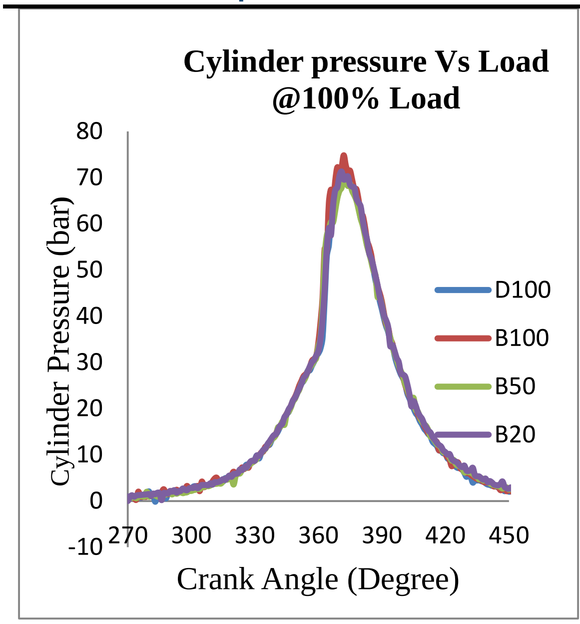


Figure 2: Cylinder Pressure Vs Crank Angle at 100% Load

### 6.2 Cylinder Pressure Vs Volume diagram

In order to analyse the P-v diagrams for D100, B100, B50 and B20, the engine was run at wide open throttle, with various load settings. The P-v diagrams shown below indicate the areas enclosed and the load setting for each one of the diesel and biodiesel blends. The maximum pressure varies for each of the fuels D100 is 49.95 bar, B100 is 50.22 bar, B50 is 48.69 bar and B20 is 48.45 bar at 0 % load while the maximum pressure varies for D100 is 70.59 bar, B100 is 74.85 bar, B50 is 69.98 bar and B20 is 71.29 bar at 100 % load.

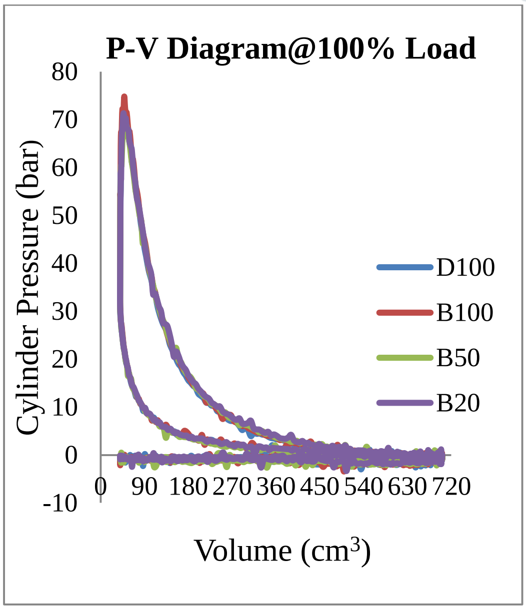


Figure 3: Cylinder Pressure Vs Volume at 100% Load

### 6.3 Heat Release Rate

It is observed that when engine is fuelled with soyabean biodiesel, the combustion starts earlier under all operating conditions and also soyabean biodiesel have shown shorter ignition delay compare to diesel. Because of the vaporization of the fuel accumulated during ignition delay, at the beginning a negative heat release is observed and, after combustion is initiated, this becomes positive. Biodiesel experiences identical combustion stages with diesel. After the ignition delay, premixed fuel–air mixture burns rapidly, followed by diffusion combustion, where the burn rate is controlled by fuel–air mixing. At lower engine loads, the heat release rate for diesel is slightly lower than that for biodiesel, but at higher engine loads, the heat release rate for biodiesel (B100) is higher. The crank angle at which the maximum heat release rate occurs is in advance for biodiesel. This is due to the start of combustion after TDC for biodiesel fuels at lower engine loads and the combustion starts later for diesel than for biodiesel. As the engine load is increased, the heat release rate for diesel and diesel biodiesel blends is higher because of the longer ignition delay, during which more fuel is accumulated in the combustion chamber to release higher heat during the premixed combustion phase. Biodiesel diesel blends in the blend increases, the maximum heat release rate decreases.

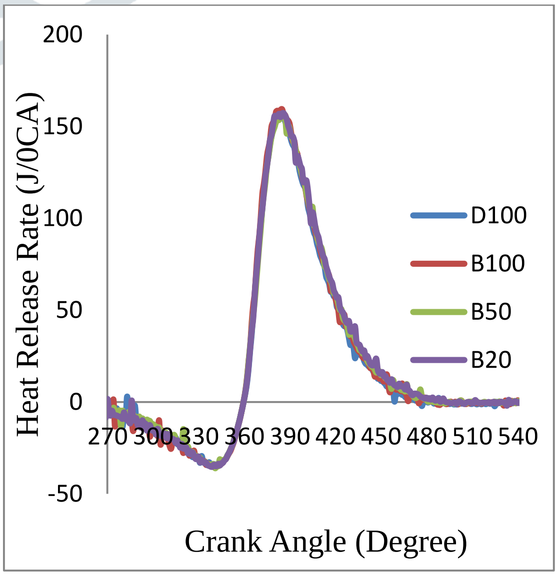


Figure 4: Heat Release Rate Vs Crank Angle at 100% Load

### 6.4 Cumulative Heat Release Rate

Cumulative heat release rate is indicative of the energy spent for a given output. It is again reconfirming the heat release for soyabean biodiesel blends. Cumulative heat release is higher for B100 than B50 and B20 compared to mineral diesel possibly because of lower calorific value of biodiesel and diesel biodiesel blends and higher density. D100 has lower cumulative heat release rate than biodiesel in most of the load.

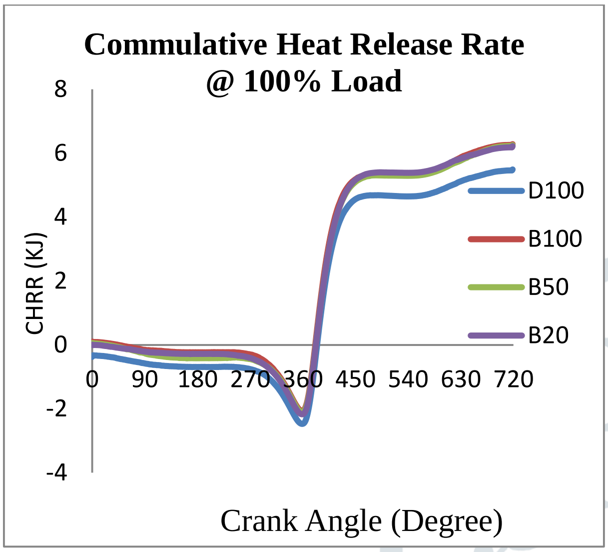


Figure 5: CHRR Vs Crank Angle at 100% Load

## 7. Conclusion

1. The peak cylinder pressure of soyabean biodiesel and its blends found to be higher than pure diesel for all loads. Pure soyabean biodiesel have 0.057% higher peak cylinder pressure compared to pure diesel at full load. The Cylinder pressure of pure diesel, pure soyabean biodiesel, B50 and B20 was found to be 70.58, 74.85, 69.98 and 71.29 bar respectively at full load.
2. Maximum heat release rate of soyabean biodiesel and its blends was found higher as compared to pure diesel. Pure soyabean biodiesel have 14.79% higher heat release rate as compared to pure diesel at full load condition. The maximum heat release to be found for pure diesel, B100, B50 and B20 were 265.24, 310.93, 308.03 and 252.11J/Deg.CA at full load.
3. Cumulative heat release rate of soyabean biodiesel and its blends were found to be higher than pure diesel for all loads. CHRR increased as load increases. The maximum value of CHRR for pure soyabean biodiesel, B50, B20 and pure diesel were 2.89, 2.86, 2.86 and 2.84 kJ respectively at full load.

## 8. Scope for Future Work

Following are the major areas in which work can be extended related to this problem.

1. Exhaust Gas Recirculation system could be used to reduce the emission.
2. Variation of fuel injection timing as well as injection pressure to check the performance and combustion analysis as well as emission.
3. Preheating of the fuel could be attempted.

## 9. Acknowledgement

The authors would like to acknowledge Department of Mechanical Engineering, School of Engineering, Eklavya University Damoh, Madhya Pradesh.

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