Engine Performance Characteristics of 4-Stroke Compression Ignition Engine Fuelled With Blends of Biodiesel Extracted From Waste Cooking Oil

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***Abstract* - There is an increasing interest in India to search for suitable alternative fuels that are environmental friendly. Environmental concerns and limited amount of petroleum resources have caused interests in the development of alternative fuels for internal combustion (IC) Engines. As an alternative, biodegradable, renewable and sulphur free biodiesel is receiving increasing attention. The use of biodiesel is rapidly expanding around the world, making it imperative to fully understand the impacts of biodiesel on the diesel engine combustion process and pollutant formation. Biodiesel is known as the mono-alkyl-esters of long chain fatty acids derived from renewable feedstock, such as, vegetable oils or animal's fats, for use in compression ignition engines. Therefore, in this study, different parameters for the optimization of biodiesel production were investigated in the first phase, while in the next phase of the study performance test of a diesel engine with neat diesel fuel and biodiesel mixtures was carried out. Biodiesel was made by the well known transesterification process. Soyabean oil was selected for biodiesel production. The transesterification results showed that with the variation of catalyst, methanol, variation of biodiesel production was realized. A maximum of 92% biodiesel was produced with 20% methanol in presence of 1.8% KOH. The engine experimental results showed that among three different blends of biodiesel (B10, B15 and B20), B10 blend of biodiesel has the highest performance characteristic value of brake power, brake thermal efficiency lowest value of brake specific fuel consumption.**

Nomenclature:
BP- Brake power
BSFC- Brake specific fuel consumption
EGT- Exhaust gas temperature
BMEP- Brake mean effective pressure
B10- 10% of biodiesel & 90% of diesel
B15- 15% of biodiesel & 85% of diesel
B20- 20% of biodiesel & 80% of diesel
B100- 100% of biodiesel & 0% of diesel
LPH- Litre per hour
KOH- Potassium Hydroxide

Units Used:
^oC- Degree Celsius
KW- Kilowatt
KJ/KG- Kilo joule per kilogram
mm^2/sec- Millimeter square per second
RPM- Revolution per minute
Cc- Cubic centimeter
Mm-Millimeter
Kg-Kilogram

***Keywords* - Biodiesel, transesterification, Engine performance characteristics**

I. Introduction

In the most general sense, biodiesel refers to any diesel fuel substitute derived from renewable biomass. More specifically, biodiesel is defined as an oxygenated, sulphur-free, biodegradable, non-toxic, and eco-friendly alternative diesel oil. Chemically, it can be defined as a fuel composed of mono-alkyl esters of long chain fatty acids derived from renewable sources, such as vegetable oil, animal fat, and used cooking oil designated as B100, and also it must meet the special requirements such as the ASTM and the European standards. Biodiesel is made from a variety of natural oils such as soybeans, rapeseeds, coconuts, and even recycled cooking oil. Rapeseed oil dominates the growing biodiesel industry in Europe. The injection and atomization characteristics of the vegetable oils are significantly different than those of petroleum derived diesel fuels, mainly as the result of their high viscosities. Modern diesel engines have fuel-injection system that is sensitive to viscosity change. One way to avoid these problems is to reduce fuel viscosity of vegetable oil in order to improve its performance. The conversion of vegetable oils into biodiesel is an effective way to overcome all the problems associated with the vegetable oils. Dilution, micro emulsification, pyrolysis, and transesterification are the four techniques applied to solve the problems encountered with the high fuel viscosity. Transesterification is the most common method and leads to mono alkyl esters of vegetable oils and fats, now called biodiesel when used for fuel purposes. The methyl ester produced by transesterification of vegetable oil has a high cetane number, low viscosity and improved heating value compared to those of pure vegetable oil which results in shorter ignition delay and longer combustion duration and hence low particulate emissions.

Mushtaq Ahmadet al [1]. To achieve optimum yield of biodiesel from non edible oil seeds, alkali based transesterification was carried out. Alkali-catalyzed transeterification is much faster than acid-catalyzed and is used in commercial production of biodiesel. Even at ambient temperature, the alkali-catalyzed reaction proceeds rapidly usually reaching 95% conversion in 1-2 h. G.Nithya and Litty Koria [2] .The aim of this study was to evaluate rice bran oil as a potential raw material for biodiesel production. The biodiesel sample prepared in the present study showed better results and not deviating from ASTM standard except the free and total glycerol content which can be rectified by further suitable methods. Use of the biodiesel as a partial diesel substitute can boost the farm economy, reduce uncertainty of fuel availability and make farmers of fuel availability and make farmers more self-reliant. Also, this help in controlling air pollution to a great extent. P.K gupta et al [3] showed that percent conversion as well as yield was good at molar ratio of 6:1, reaction time of 4 hour and oil temperature of 60oC. Yield showed an increasing trend with increase in oil temperature or reaction temperature. However, oil temperature and reaction temperature did not affect the percent conversion much. Increase in FFA content resulted in decreased yield but conversion remained unaffected. Washing of bio-diesel with warm water prepared from oil of high FFA facilitates better yield. Heating of oil to 10 (to remove traces of moisture) helps in better conversion and yield of bio-diesel. Bio-diesel prepared under low ambient temperature should be given washing with warm water in order to obtain good yield. N.R. Banapurmath et.al [4] Experiments have been conducted on a single cylinder, four-stroke, direct injection, water-cooled CI engine operated in single fuel mode using Honge, Neem and Rice Bran oils. In dual fuel mode combinations of Producer gas and three oils were used at different injection timings and injection pressures. Dual fuel mode of operation resulted in poor performance at all the loads when compared with single fuel mode at all injection timings tested. However, the brake thermal efficiency is improved marginally when the injection timing was advanced. Decreased smoke, NOx emissions and increased CO emissions were observed for dual fuel mode for all the fuel combinations compared to single fuel operation. C.D. Rakopoulos et.al [5] An experimental investigation is conducted to evaluate the use of sunflower and cottonseed oil methyl esters (bio-diesels) of Greek origin as supplements in the diesel fuel at blend ratios of 10/90 and 20/80, in a fully instrumented, six-cylinder, turbocharged and after-cooled, direct injection (DI), Mercedes-Benz, mini-bus diesel engine installed at the authors' laboratory. When working with neat diesel fuel and the two bio-diesels are determined and compared. Theoretical aspects of diesel engine combustion with the differing physical and chemical properties of these blends, aid the correct interpretation of the observed engine behavior.

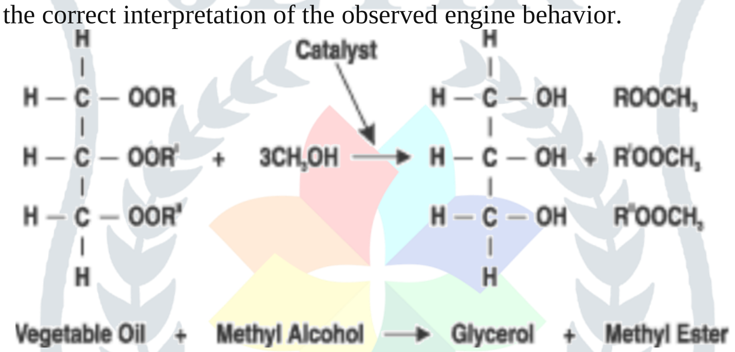

Figure 1. Transesterification process of converting vegetable oils to biodiesel

II. PROBLEM FORMULATION

Objective:

- Biodiesel preparation from waste cooking oil (soybean oil).
- To study engine performance characteristics of 4-stroke compression ignition engine fuelled with blends (B10, B15, B20) of the extracted biodiesel.

Biodiesel preparation methodology:

- Starting from the raw material used for biodiesel production along with its method for biodiesel production is explained. Biodiesel prepared with different percentage of KOH (1%, 1.3%.1.5% &1.8%) but for the same composition of methanol.
  Following raw materials were used: Waste cooking soyabean oil, Methanol (Methyl alcohol), Potassium hydroxide (KOH) as base catalyst

Biodiesel preparation:

Procedures involved

1. Some known quantity of waste cooking soyabean oil was taken in a conical flask.
2. The oil in the flask was then heated on a heating plate up to a temperature of 60°C.
3. A mixture of known quantity of Potassium hydroxide (KOH) as base catalyst and methanol was then mixed with the oil.
4. The preheated oil mixture was then subjected to 1 hour constant stirring at a constant temperature of 60°C inside a water bath shaker.
5. After 1 hour of constant stirring the mixture was poured into a separating funnel for glycerol to settle down.
6. After 1-2 hours settled down glycerol is separated and removed.
7. Remaining is methyl ester (biodiesel) of waste cooking soyabean oil (Yield 90%) which is further purified by washing and drying for removal of excess KOH, methanol and water.

Table 1.Properties of soyabean methyl ester

Property parameters	Test method	Soyabean methyl ester
Relative Density	Hydrometer	0.92
Viscosity at 40 ºC, mm²/sec	Redwood Viscometer	5.23
Flash point, ºC	Closed cup flash and fire point apparatus	100
Fire point, ºC	Closed cup flash and fire point apparatus,	110
Calorific value, (KJ/KG)	Bomb Calorimeter	40000

Experimental methodology

Here a brief description of the apparatus and its method of operation are given. Along with it different performance parameters are also discussed.

Engine Performance Evaluation

Evaluation of the engine performance is described in sequence of steps below:

1. Engine description
2. Operation
3. Parameters evaluated

1. Engine description:

The performance characteristics were carried out on variable compression diesel engine. The specifications of the engine are as stated as below.

Figure 2. 2 cylinders, 4 stroke diesel engine test setup

Table 2.Specifications of the engine

Engine test setup	2 cylinder, 4 stroke, diesel
Capacity	1322 cc, make kirloskar, model TV2
Cooling media	Water cooled
Rated capacity	10.3 kW @ 1500 RPM
Cylinder diameter	87.5 mm
Stroke length	110 mm
Connecting rod length	234 mm
Compression ratio	17.5:1
Orifice diameter	20 mm
Dynamometer	type hydraulic

The set up has stand-alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement.

2. Operation:

Experimental procedure

For getting the base line data of the engine first the experimentation is performed with diesel and then with blends of waste soyabean methyl ester (10%, 15% and 20%).

1. Fill the diesel in fuel tank in required quantity.
2. Start the water supply. Set cooling water flow for engine at 400 LPH and calorimeter flow at 100 LPH.
3. Also ensure adequate water flow rate for dynamometer cooling.
4. Check for all electrical connections.
5. Supply the diesel to the engine by opening the valve provided at the burette.
6. Start the engine and let it run for few minutes under no load condition.
7. Turn on the fuel supply knob. The first reading for the engine gets noted for the no load condition. Turn the fuel knob back to regular position.

8. Repeat the experiment for different loads like 10,15,20,25.
9. All the readings will be displayed on the control panel. Note down readings.
10. Similarly change the fuel in the fuel tank.
11. Repeat the experiment for particular blends of fuel like B10, B15, and B20.
12. At the end of the experiment bring the engine to no load condition and turn off the engine.
13. After few minutes also turn off the water supply.

3. Parameters evaluated:

1. Brake power (BP)
2. Brake thermal efficiency (BTE)
3. Brake specific fuel consumption (BSFC)
4. Brake mean effective pressure (BMEP)

III. RESULTS AND DISCUSSION

Performance Parameters

Results obtained from the experimental evaluation are discussed in this chapter.

1. Brake Power (BP)

Variation of the brake power (BP) as a function of load with different blends of biodiesel i.e. B10, B15, B20 and diesel are shown in Figure A.

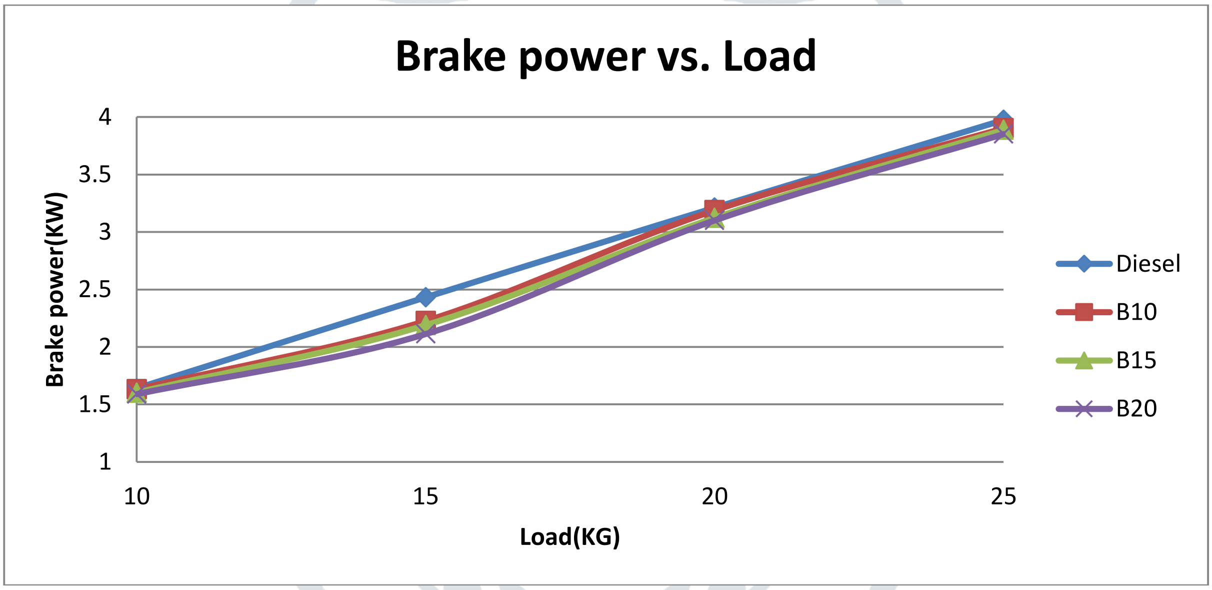

Figure A. Variation in brake power with change in load

Brake power of the engine increases with increase in the load on the engine. Brake power is the function of calorific value and the torque applied. Diesel has more calorific value than the biodiesel, so diesel has the highest brake power among the different blends of biodiesel. Due to the more calorific value of B10 blend of biodiesel than B15 and B20, it has the more brake power as shown in figure A. It can also be seen that as we increases the load, torque increases and thus there is an increase in brake power with the load.

2. Brake specific fuel consumption (BSFC)

Variation of the Brake specific fuel consumption (BSFC) as a function of load with different blends of biodiesel i.e. B10, B15, B20 and diesel are shown in Figure B. BSFC decreased with increase in load. One possible explanation for this reduction is the higher percentage of increase in brake power with load as compared to fuel consumption. It can be seen from the figure B that in case of biodiesel mixtures, the BSFC values were determined to be higher than those of neat diesel fuel.

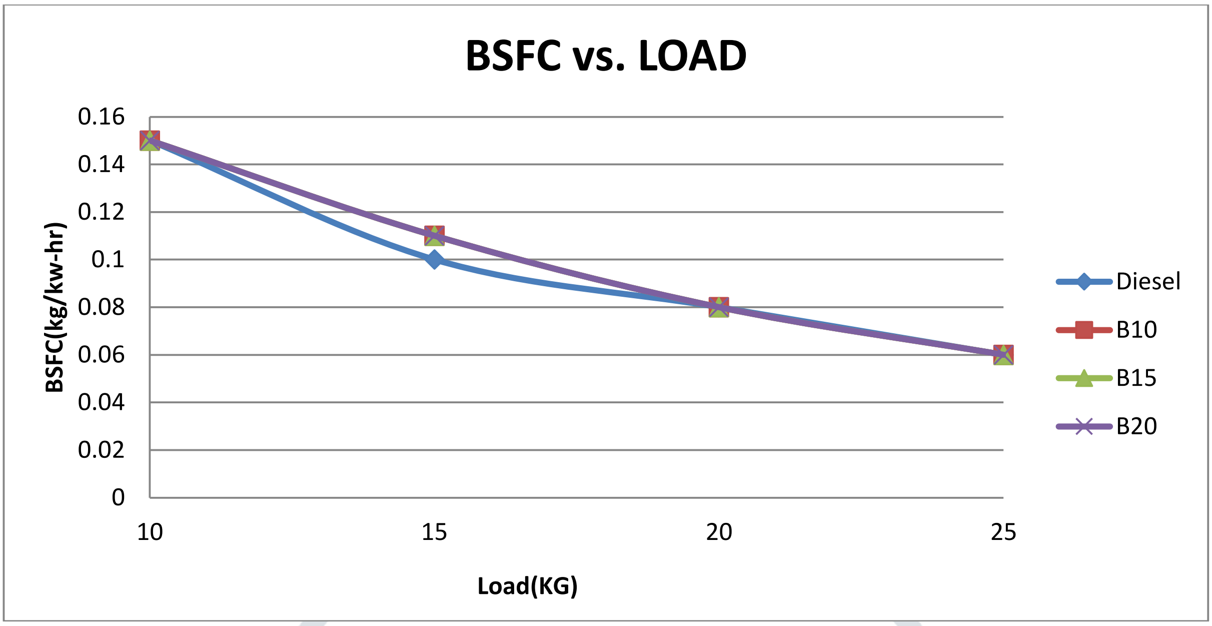

Figure B.Variation in brake specific fuel consumption with change in load

This trend was observed owing to the fact that biodiesel mixtures have a lower heating value than does neat diesel fuel, and thus more biodiesel mixtures was required for the maintenance of a constant power output. It is well known that brake specific fuel consumption is inversely proportional to the brake thermal efficiency. So diesel has the lowest brake specific fuel consumption. Among the three different blends of biodiesel B10 has the lowest value of brake specific fuel consumption.

3. Brake thermal efficiency (BTE)

Variation of the Brake thermal efficiency (BTE) as a function of load with different blends of biodiesel i.e.B10, B15, B20 and diesel are shown in figure C.

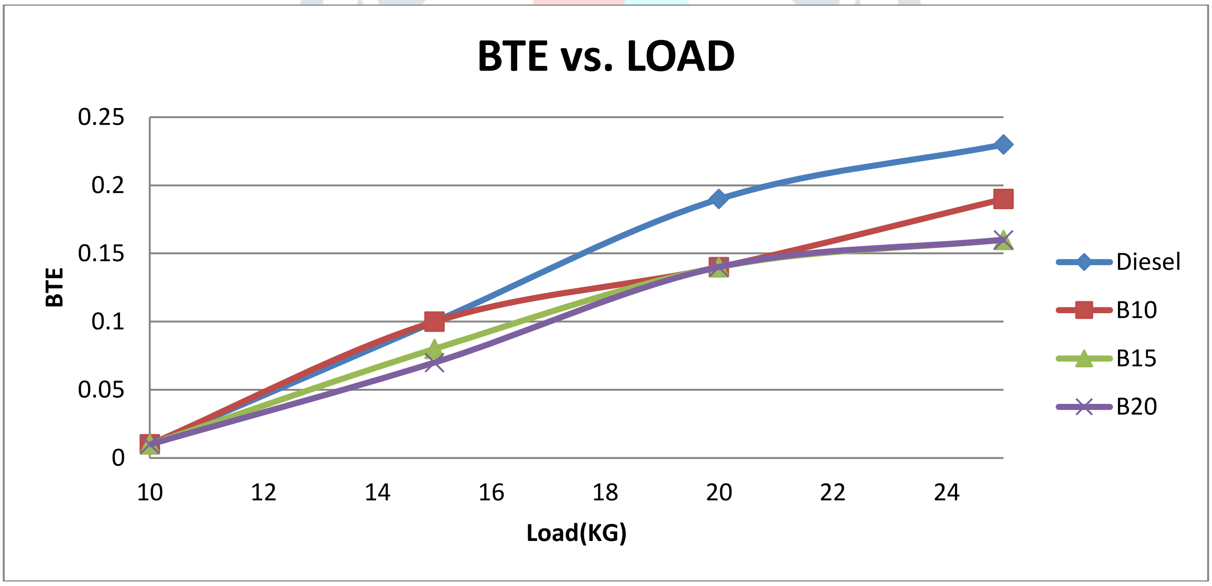

Figure C.Variation in brake thermal efficiency with load

The factors like lower heating values and higher viscosity of the esters may affect the mixture formation process and hence result in slow combustion hence reducing the brake thermal efficiency. The molecules of bio-diesel (i.e. methyl ester of the oil) contain some amount of oxygen, which takes part in the combustion process. Test results indicate that when the mass percent of fuel oxygen exceeds beyond some limit, the oxygen loses its positive influence on the fuel energy conversion efficiency in this particular engine. So the brake thermal efficiency of diesel is more than that of biodiesel blends. Among the three different blends of biodiesel, B10 has higher brake thermal efficiency than B15 and B20.

4. Exhaust gas temperature (EGT)

Variation of the Exhaust gas temperature (EGT) as a function of load with different blends of biodiesel i.e. B10, B15, B20 and diesel are shown in Figure D.

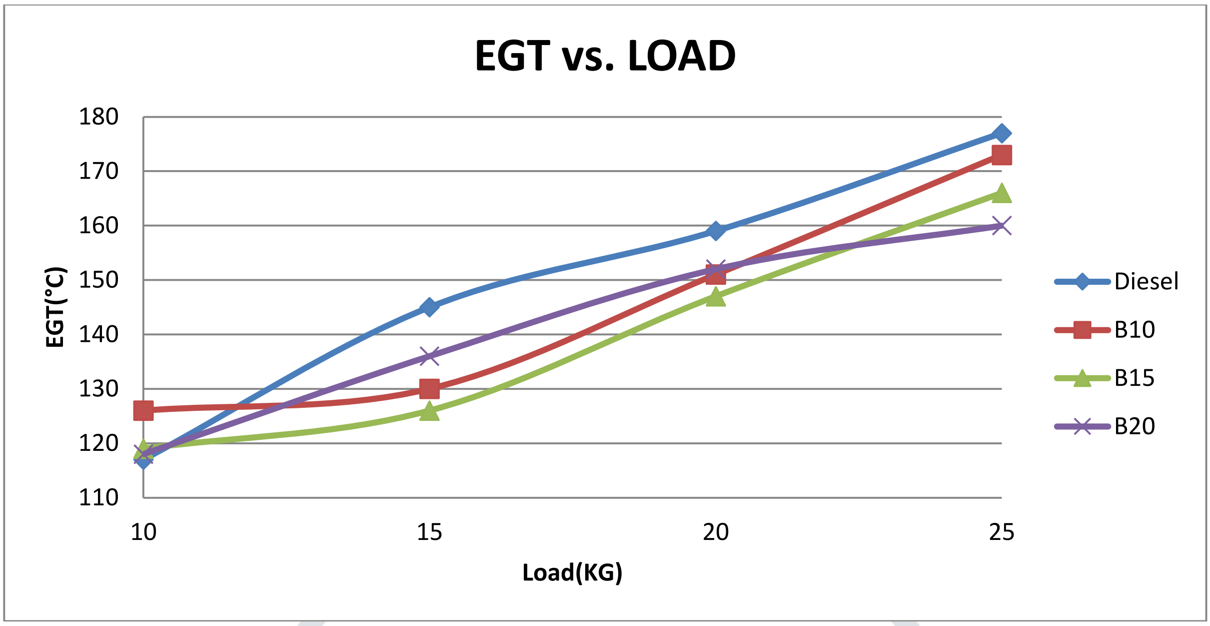

Figure D.Variation in exhaust gas temperature with change in load

The biodiesel contains some amount of oxygen molecules in the ester form. It is also taking part in combustion. When biodiesel concentration is increased, the exhaust gas temperature increases by small value. Using different blends of biodiesel of soya bean methyl ester, higher exhaust gas temperature is attained at full load, which is indicating more energy loss in this case. The exhaust gas temperature increases with increase in load. Diesel has the least exhaust gas temperature among the B10, B15, B20 and Diesel. The reason of EGT being more in the case of biodiesel blends is the presence of more oxygen atoms in the biodiesel. So, the exhaust gas temperature increases and it increases with increase in load. As the load on the engine increases, more fuel is burnt. So exhaust gas temperature increases continuously with rise in load.

IV. CONCLUSION

Based on the results obtained from experimental evaluation and biodiesel prepared following conclusions are drawn:

1. The recovery of ester by transesterification of waste soybean cooking oil with methanol is affected by process parameters such as catalyst concentration and reaction temperature.
2. Biodiesel produced using 1.8 % of KOH is more efficient than other composition and its viscosity value lies between desired range.
3. The graphical results show that diesel has better performance characteristics than biodiesel and biodiesel blends. Among the three different blends of biodiesel, B10 has the better performance characteristics than B15 and B20 blend of biodiesel when fuelled in an internal combustion engine.

V. Scope of Future Work

Biodiesel has distinct advantage as an automotive fuel. Initial cost may be higher but feedstock diversity and multi-feedstock production technologies will play a critical role in reductions in production cost and making the fuel economically viable.

The following points may be considered before introducing the fuel in India:

1. Biodiesel may be introduced as a diesel fuel extender or blends (B10, B15, and B20) and not as a sole diesel engine fuel (B100).
2. Proper planning, streamlining, quality control logistics and institutional arrangements need to be worked out before introduction of the fuel.
3. Government may consider providing support to the activities related to collection of seeds, production of oil from non-edible sources, production of bio-fuels and its utilization for cleaner environment.
4. Legal framework should be there to enforce regulations on bio-fuels.
5. The blends prepared for this project work were utilized within short time span. Thus, long term stability of blends was not studied. So there is scope for study of long term stability of blends.
6. Long-term performance and endurance test evaluate the durability of the engine with prolonged operation on these blends.
7. Energy education on biodiesel program and storing information and database for wider information dissemination among the public at large should be taken up at a larger scale.

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