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# Assessment of Diesel Engine performance using Cotton Seed Biodiesel

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## ABSTRACT

Environmental concerns and energy crisis of the world has led to the search of viable alternatives to conventional sources of fuel. FAME (Fatty Acid Methyl Ester) is environment friendly, alternative, and nontoxic, safe, biodegradable has a high flash point and is also termed as Bio-Diesel. It is commonly produced by the process transesterification. For its production, establishment of suitable process, selection of proper feedstock and reaction parameters is of utmost importance in present scenario. This paper is an attempt to investigate diesel engine performance with cotton seed biodiesel. A higher BTE was found with the preheated with B20, B40 and B60 that 3.74%, 10.46%, 3.27% at full load more than that for diesel. Smoke was reduced with considerable factor when quantity of biodiesel is increased in pure diesel.

*Keywords: Biodiesel, Cotton Seed, BTE, BSFC, Engine Performance*

## INTRODUCTION

Energy comes in a variety of renewable forms; wood, biomass, wind, sunlight. It also comes in the non - renewable form of fossil fuels- oil and coal and their use is a major source of pollution of land, sea and above all the air we breathe. Two centuries of unprecedented industrialization, driven mainly by fossil fuels, have changed the face of this planet. The present civilization can't survive without motor cars and electricity. The increasing rate at which the changes in human lives are occurring has important consequences for the environment and carrying capacity of earth. Pollution and accelerating energy consumption has already affected equilibrium of earths land masses, oceans and atmosphere. Recent survey on the world energy consumption highlights that a major portion of the total energy consumed is derived from the combustion of fossil fuels. Among the fossil fuels, liquid petroleum based fuels contributes a maximum of portion. Unfortunately, the reserves of fossil fuels, specially the liquid fuels are not unlimited and may exhaust, if not utilized economically. About 71 barrels are burnt everyday throughout the world. And this consumption rate goes on increasing by 2% every year. The 2% doubles the quantity every 34 years. At the current rate of consumption 1600 billion barrels would be depleted in 60 years. It's high time to think about the alternative fuels. An alternative fuel to petro-diesel must be technically feasible, economically competitive, environmentally acceptable, and easily available. The current alternative diesel fuel can be termed biodiesel. Biodiesel can offer other benefits, including reduction of greenhouse gas emissions, regional development and social structure, especially to developing countries[1]. Biodiesel methyl esters improve the lubrication properties of the diesel fuel blend. Biodiesel reduced long term engine wear in diesel engines. Biodiesel is a good lubricant (about 66% better than petro-diesel)[2]. Biodiesel is pure, or 100%, biodiesel fuel. It is referred to as B100 or ''neat" fuel. A biodiesel blend is pure biodiesel blended with petro-diesel. Biodiesel blends are referred to as $B_{XX}$. The XX indicates the amount of biodiesel in the blend (i.e., a $B_{80}$ blend is 80% biodiesel and 20% petro-diesel). Monyem and Gerpen[3] evaluate the impact of oxidized biodiesel on engine performance and emissions. The engine performance of the neat biodiesels and their blends was similar to that of other engine having diesel fuel with the same thermal efficiency, but higher fuel consumption. Compared with unoxidized biodiesel, oxidized neat biodiesel produced 15 and 16% lower exhaust carbon monoxide and hydrocarbons, respectively. Roskilly et.al[4] performed the experiment of testing of two small marine craft diesel engines fuelled with biodiesel. The test results show that the power output for both trial engines operating with biodiesel were comparable to that fuelled with fossil diesel, but with an increase in fuel consumptions. Zheng[5] checks the biodiesel engine performance and emissions in low temperature combustion.

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## Biodiesel

Biodiesel is an alternative fuel for diesel engines produced by chemically reacting a vegetable oil or animal fat with an alcohol. Alcohols are the most frequently used acyl acceptors, particularly methanol and, to a lesser extent, ethanol. Other alcohols can also be used, e.g., propanol, butanol, isopropanol, tert-butanol, branched alcohols and octanol but the cost is much higher. Regarding the choice between methanol and ethanol, the former is cheaper, more reactive and the fatty-acid methyl esters (FAME) produced are more volatile than fatty-acid ethyl esters (FAEE). However, ethanol is less toxic and is considered more renewable because it can be easily produced from renewable sources by fermentation. In contrast, methanol is currently mainly produced from non-renewable fossil sources, such as natural gas. Regarding their characteristics as fuels, FAME and FAEE show slight differences; for example, FAEE have slightly higher viscosities and slightly lower cloud and pour points than the corresponding FAME.[6] The reaction requires a catalyst, usually a strong base, such as sodium or potassium hydroxide, and produces new chemical compounds called methyl esters. It is these esters that have come to be known as biodiesel.[7,8]

## Use of Vegetable Oils

The interest in the use of renewable fuel started with the direct use of vegetable oils as a substitute for diesel. Vegetable oils have become more attractive recently because of their environmental benefits and the fact that they are made from renewable resources. More than 100 years ago, Rudolph Diesel tested vegetable oil as the fuel for his engine.[9] Vegetable oils have the potential to replace a fraction of the petroleum distillates and petroleum-based petrochemicals in the near future. However, their direct use in compression engines was restricted due to high viscosity which resulted in poor fuel atomization, incomplete combustion and carbon deposition on the injector and the valve seats causing serious engine fouling.[10,11] Chemically speaking, vegetable oils and animal fats are triglyceride molecules in which three fatty acid groups are esters attached to one glycerol molecule.[12] Fats and oils are primarily water-insoluble, hydrophobic substances in the plant and animal kingdoms that are made up of 1 mol of glycerol and three moles of fatty acids and are commonly referred to as triglycerides.[13] Triglyceride vegetable oils and fats include not only edible but also inedible vegetable oils and fats such as linseed oil, castor oil, and tung oil. More than 350 oil-bearing crops have been identified, of which only soybean, palm, sunflower, safflower, cottonseed, rapeseed, and peanut oils are considered potential alternative fuels for diesel engines.[14,15] Dwivediet.al.[12] reviewed Impact analysis of biodiesel on engine performance and concluded Bio-diesel scores very well as an alternate fuel of choice as it helps in decreasing dependence on fossil – fuels and also as it has almost no sulphur. Higher cetane of biodiesel as compared to petro diesel implies its much improved combustion profile in an internal combustion engine.[21]

## Production Of Biodiesel

Considerable efforts have been made to develop vegetable-oil derivatives that approximate the properties and performance of hydrocarbon-based diesel fuels. The problems with substituting triglycerides for diesel fuels are mostly associated with their (i) high viscosity; (ii) low stability against oxidation (and the subsequent polymerization reactions); and (iii) low volatility, which influences the formation of a relatively high amount of ash due to incomplete combustion.[16] These can be changed in at least four ways, as follows.

## Direct Use and Blending

Vegetable oil can be mixed with diesel fuel and used directly for running an engine. The successful experimental blending of vegetable oil with diesel fuel has been done by various researchers. A diesel fleet was powered with a blend of 95% filtered used cooking oil and 5% diesel in 1982. In 1980, Caterpillar Brazil Company used pre-combustion chamber engines with a mixture of 10% vegetable oil to maintain total power without any modification to the engine. A blend of 20% oil and 80% diesel was found to be successful[17]. Pramanik[18] found that a 50% blend of Jatropha oil can be used in diesel engines without any major operational difficulties but further study is required to determine the long-term durability of the engine. The direct use of vegetable oils and/or the use of oil blends have generally been considered to be unsatisfactory and impractical for both direct and indirect diesel engines. The high viscosity, acid composition, free fatty-acid content, gum formation due to oxidation, polymerization during storage and combustion, carbon deposits and lubricating-oil thickening are the obvious problems.

## Micro-emulsion

Micro-emulsions are isotropic, clear or translucent, thermodynamically stable dispersions of oil, water, surfactant. The droplet diameters in micro-emulsions range from 100 to 1000 A. A micro-emulsion can be made of vegetable oils with an ester and dispersant (co-solvent), or of vegetable oils, an alcohol and a surfactant, with or without diesel fuels. Because of their alcohol contents, micro-emulsions have lower volumetric heating values than diesel fuels, but these alcohols have high latent heats of vaporization and tend to cool the combustion chamber, which reduces nozzle coking. A micro-emulsion of methanol with vegetable oils can perform nearly as well as diesel fuels. The use of 2-octanol as an effective amphiphile in the micellarsolubilization of methanol in triolein and soybean oil has been demonstrated; the viscosity was reduced to 11.2 cStat 25°C. The reported engine tests on a micro-emulsion consisting of soybean oil:methanol:2-octanol: cetane improver (52.7:13.3:33.3:1) indicated the accumulation of carbon around the orifices of the injector nozzles and heavy deposits on exhaust valves.[19]

## Pyrolysis

Pyrolysis is the conversion of one organic substance into another by means of heat or by heat in the presence of a catalyst. The pyrolysed material can be vegetable oil, animal fat, natural fatty acids or methyl esters of fatty acids. The pyrolysis of fats has been investigated for more than 100 years, especially in those areas of the world that lack deposits of petroleum. Many investigators have studied the pyrolysis of triglycerides to obtain products suitable for diesel engines. Thermal decomposition of triglycerides produces alkanes, alkenes, alkadienes, aromatics and carboxylic acids.[18,20]

## Transesterification

Transesterification is a process of reacting a triglyceride such as vegetable oil with an alcohol in the presence of an alkaline catalyst to produce fatty-acid esters and glycerol. Among the alcohols, methanol and ethanol are used commercially because of their low cost and their physical and chemical advantages. They are easily dissolved in and react quickly with tri-glycerides and NaOH. A catalyst is used to improve the reaction rate and yield. An alkaline- catalyzed transesterification process is normally adopted for biodiesel production because alkaline metal alkoxides and hydroxides are more effective than acid catalysts. Sodium and potassium methoxide are much more effective catalysts for the base-catalyzed transesterification of triglycerides.

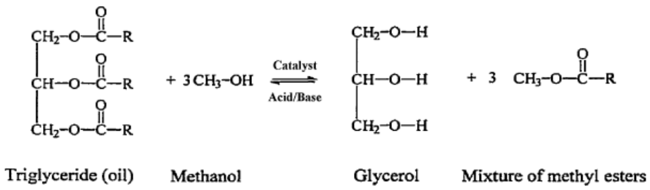


**Figure 1.** Chemical reaction for Tranesterification Process.

A transesterification reaction is represented in Fig. 4. A catalyst is usually used to speed up the reaction that may be basic, acid or enzymatic in nature. Transesterification is a method of transforming of an ester into another when a vegetable oil is reacted with methanol in the preserve of catalyst to give methyl ester also biodiesel and amount of glycerin.

In recent studies Performance Evaluation of Diesel Engine Using Biodiesel from Pongamia Oil was done and results showed that The fuel properties like density, flash point, viscosity and calorific value of B10, B20 are very similar to diesel and therefore diesel may be well replaced by biodiesel in near future. The performance evaluation of engine has found that BSFC for B100 in case of Pongamia biodiesel was 30.4 % higher than diesel at full load, thereby indicating that more amount of B100 produce power similar to diesel.[21,22]

## Biodiesel preparation

KOH is selected as base for transesterification and methanol is selected as alcohol for both the reactions. After completion of the reaction, the reaction mixture was transferred to separating funnel and both the phases were separated. Upper phase was biodiesel and lower phase contained glycerin. Alcohol from both the phases was distilled off under vacuum. The glycerin phase was neutralized with acid and stored as crude glycerin. Upper phase i.e. methyl ester (biodiesel) was washed with the water five times to remove the traces of glycerin, unreacted catalyst and soap formed during the transesterification.

## Performance Evaluation Of IC Engine

In order to study the performance of IC engine using biodiesel and its blends with diesel, an experimental study has been carried out. The efficiency and brake specific fuel consumption (BSFC) of the engine was measured under variable load conditions for different blends. The engine was directly coupled with alternator and loaded by electrical resistance. The separate fuel measurement unit was connected with engine. A resistive load panel was attached with the output of the generator. First engine was run on diesel and reading were taken for zero load and then similarly for 20%, 40%, 60%, 80% and full load. Similar procedure was executed for Cotton seed biodiesel having blends B10, B20, B30, B40, B50 and B100. The fuel consumption was measured by using stopwatch. At the same time the reading of voltmeter, current meter and energy meter were also noted down.

## Results and Discussion

### A. BSFC of Biodiesel from Cotton Seed Oil

Figure 2 shows Brake Specific Fuel Consumption (BSFC) decreases as the load on the engine increased. At Full Load, Brake Specific Fuel Consumption for Pure Diesel, B0 is found to be 0.2762 kg/kwh. Similarly for Biodiesel blends like for B20 0.2728kg/kwh, B40 0.2559 kg/kwh, B60 0.2786 kg/kwh and for B100 it is 0.3484kg/kwh. As it is seen for lower percentage of biodiesel in blend, BSFC is similar or less and as the percentage is increased, BSFC also tend to increase. With full replacement, BSFC was found to be considerably higher than pure diesel. This indicates that biodiesel–diesel blends have higher fuel conversion efficiency than that of diesel fuel.

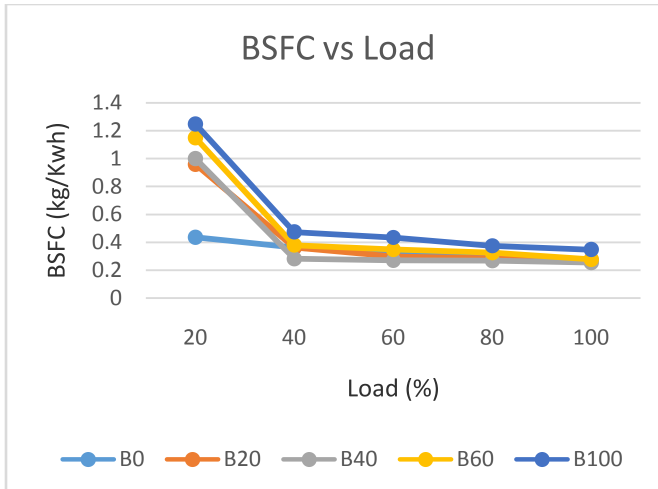


**Figure 2.** BSFC Variation with Load for Biodiesel from Cotton Seed Oil

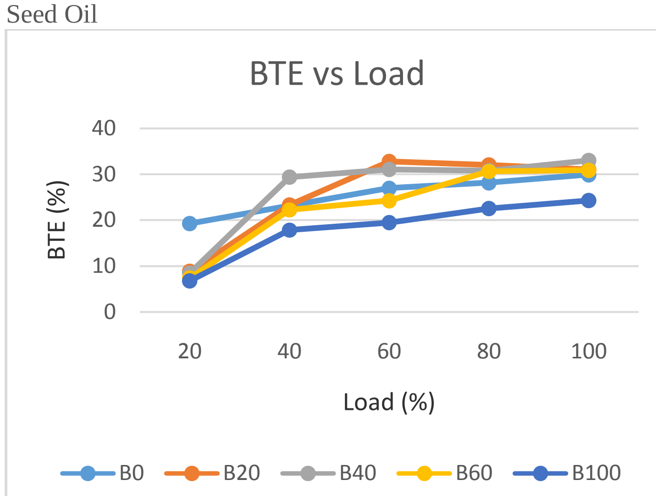


Figure 3. BTE Variation with Load for Biodiesel from Cotton Seed Oil

### B. BTE of Biodiesel from Cotton Seed Oil

Figure 3 shows variation of Brake Thermal Efficiency with Load. BTE at full load was found to be 29.92% for B0, 31.04

for B20, 33.05% for B40, 30.9% for B60 and 24.30% for B100. Above data shows that B60 blend is most suitable for replacement of diesel with cotton seed biodiesel, as it comprises to be of higher brake thermal efficiency. The reason for higher efficiency up to B60 may be because of better combustion due to inherent oxygen and higher Cetane number. Beyond B60, the lower calorific value and higher viscosity might be dominating factor responsible for poor atomization of fuel in the engine cylinder.

### C. Variation of Smoke Intensity

Figure 4 Shows Variation of Smoke Intensity in terms of Hartridge Smoke Units with Load percentage. As it is clear from figure that blends cotton seed biodiesel has more clean smoke at every load percentage in comparison to pure diesel. Lesser the HSU value more the smoke is cleaner or less opacity.At full load HSU for Petro-Diesel was found to be 45.4 whereas for blends of cotton seed biodiesel with pure diesel it was found to be 30.6 for B20, 28.5 for B40, 26.5 for B60 and 22.5 for B100.

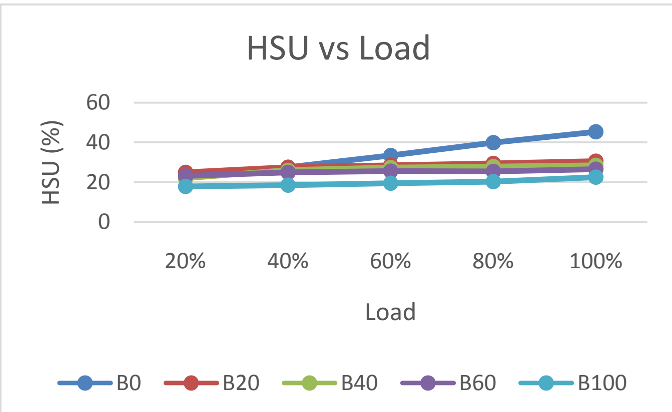


**Figure 4.** Variation of Smoke Intensity

## Conclusion

Based on the experimental investigations conducted on a single cylinder DI diesel engine using Cotton Seed oil mixed diesel fuel the following major conclusions were arrived.

1. A higher BTE was found with the preheated with B20, B40 and B60 that 3.74%, 10.46%, 3.27% at full load more than that for diesel. So based on BTE Comparison B40 blend was found to be more suitable.
2. At full replacement of diesel with cotton seed biodiesel, smoke opacity was found to be 50.44% less than pure diesel at full load.

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