# Performance and emission study of a CI engine fuelled with biodiesel blended with kerosene

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**Abstract**— Due to the concern on the availability of recoverable fossil fuel reserves and the environmental problems caused by the use those fossil fuels, considerable attention has been given to biodiesel production as an alternative to petrodiesel. Biodiesel is an eco friendly, alternative diesel fuel prepared from domestic renewable resources i.e. produced from vegetable oils and animal fats. It is a renewable source of energy seems to be an ideal solution for global energy demands including India as well. The general way to produce biodiesel fuel is by transesterification of vegetable oil with methanol in the presence of either alkaline or strong acid catalysts. Transesterification reaction is quite sensitive to various parameters. An ideal transesterification reaction differs on the basis of variables such as fatty acid composition and the free fatty acid content of the oil. Other variables include reaction temperature, ratio of alcohol to vegetable oil, catalyst, mixing intensity, purity of reactants. This review paper describes the chemical composition of vegetable oils, fuel properties vegetable oils and biodiesel, transesterification process, the most important variables that influence the transesterification reaction, environmental consideration and economic feasibility of biodiesel.

## 1 Introduction

The energy crisis is the concern that the world's demands on the limited natural resources that are used to power industrial society are diminishing as the demand rises. These natural resources are in limited supply. While they do occur naturally, it can take hundreds of thousands of years to replenish the stores. Governments and concerned individuals are working to make the use of renewable resources a priority, and to lessen the irresponsible use of natural supplies through increased conservation.

The energy crisis is a broad and complex topic. Most people don't feel connected to its reality unless the price of gas at the pump goes up or there are lines at the gas station. The energy crisis is something that is ongoing and getting worse, despite many efforts. The reason for this is that there is not a broad understanding of the complex causes and solutions for the energy crisis that will allow for an effort to happen that will resolve it.

India is one of the largest consumers of energy in the world uses a large chunk of liquid fuels which is met by imports. About 30% of is only produced within the country. The ever growing demand for this liquid fuel is growing at a speed of 4.8% and expected to rise at a much higher rate. Liquid fuel meets most of the energy requirement of the transport sector with a continuous rise in the demand over the past decades across the country. The growth of the demand for the liquid fuel is increasing almost 30% over every 4-5 years. The crude oil supply from the domestic sources, hardly reach 30% of the demand, while the rest met out of the imports. This has lead to the corporate race of finding more resources. This involves digging deeper and deeper into the ground. This further causes the scraping off ever more layers of precious top soil. Alternative fuels on the other hand are safer. They do not cause pollution in the atmosphere. Nor do they involve harassment of any natural resources. Also unlike the fossil fuels, the resources for the alternative fuels are entirely renewable. This makes it a smart decision to option for the alternative fuels. There are many alternative fuels like Biodiesel, Ethanol, Methanol and more to help us. We should make it a point to adapt these fuels and save our environment at the earliest. Various biofuels energy resources explored includes biomass, biogas, primary alcohols, vegetable oils, animal fats, biodiesel, etc. These alternative energy resources are largely environment-friendly but they need to be evaluated on case-to-case basis for their advantages, disadvantages and specific applications. Some of these fuels can be used directly while others need to be formulated to bring the relevant properties closer to sectors, this study concentrates on assessing the viability 9.5

## 2 Overview

A **biofuel** is a fuel that is produced through contemporary processes from biomass, rather than a fuel produced by the very slow geological processes involved in the formation of fossil fuel, such as oil. Since biomass technically can be used as a fuel directly (e.g. wood logs), some people use the terms biomass and biofuel interchangeably. More often than not however, the word biomass simply denotes the biological raw material the fuel is made of, or some form of thermally/chemically altered solid end product, like torrefied pellets or briquettes. The word biofuel is usually reserved for liquid or gaseous fuels, used for transportation.

## 3 Biodiesel

Biodiesel is the most common biofuel in Europe. It is produced from oils or fats using transesterification and is a liquid similar in composition to fossil/mineral diesel. Chemically, it consists mostly of fatty acid methyl (or ethyl) esters (FAMEs). Feedstocks for biodiesel include animal fats, vegetable oils, soy, rapeseed, jatropha, mahua, mustard, flax, sunflower, palm oil, hemp, field pennycress, Pongamia pinnata and algae. Pure biodiesel (B100, also known as "neat" biodiesel) currently reduces emissions with up to 60% compared to diesel Second generation B100.

Biodiesel can be used in any diesel engine when mixed with mineral diesel. It can also be used in its pure form (B100) in diesel engines, but some maintenance and performance problems may then occur during wintertime utilization, since the fuel becomes somewhat more viscous at lower temperatures, depending on the feedstock used.

## 4 NEED FOR BIODIESEL

The scarcity of known petroleum reserves will make renewable energy resources more attractive. The most feasible way to meet this growing demand is by utilizing alternative fuels. Biodiesel is defined as the monoalkyl esters of vegetable oils or animal fats. Biodiesel is the best candidate for diesel fuels in diesel engines. The biggest advantage that biodiesel has over gasoline and petroleum diesel is its environmental friendliness. Biodiesel burns similar to petroleum diesel as it concerns regulated pollutants. On the other hand, biodiesel probably has better efficiency than gasoline. One such fuel for compression-ignition engines that exhibit great potential is biodiesel. Diesel fuel can also be replaced by biodiesel made from vegetable oils. Biodiesel is now mainly being produced from soybean, rapeseed and palm oils. Biodiesel has over double the price of petrodiesel. The major economic factor to consider for input costs of biodiesel production is the feedstock, which is about 80% of the total operating cost. The high price of biodiesel is in large part due to the high price of the feedstock. Economic benefits of a biodiesel industry would include value added to the feedstock, an increased number of rural manufacturing jobs, an increased income taxes and investments in plant and equipment. The production and utilization of biodiesel is facilitated firstly through the agricultural policy of subsidizing the cultivation of non-food crops. Secondly, biodiesel is exempt from the oil tax. The European Union accounted for nearly 89% of all biodiesel production worldwide in 2005. By 2010, the United States is expected to become the world's largest single biodiesel market, accounting for roughly 18% of world biodiesel consumption, followed by Germany.

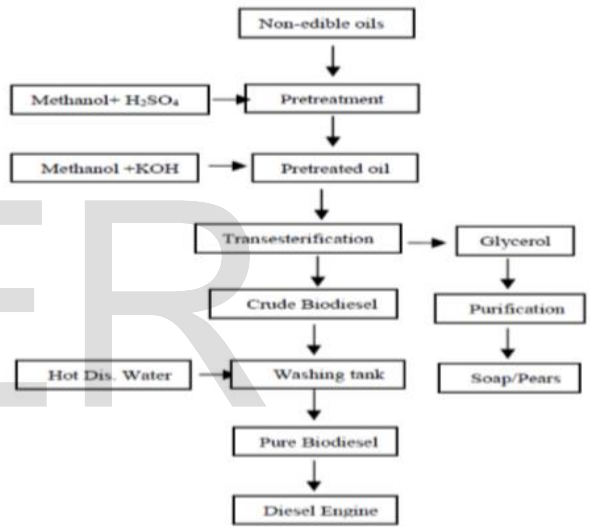
## 5 PRODUCTION OF BIODIESEL

As mentioned above biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils. There are three basic routes to biodiesel production from oils and fats:

- Base catalyzed transesterification of the oil.
- Direct acid catalyzed transesterification of the oil.
- Conversion of the oil to its fatty acids and then to biodiesel.

Almost all biodiesel is produced using base catalyzed transesterification as it is the most economical process requiring only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report.

The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerine. The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters, ethanol produces ethyl esters) and is base catalysed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, either base can be used for the methyl ester. A common product of the transesterification process is Rape Methyl Ester (RME) produced from raw rapeseed oil reacted with methanol.




## 6 STEPS INVOLVED IN PRODUCTION

### Finding out the FFA of the vegetable oil

Free fatty acids are presented in crude oils but they are removed during refining process. Free fatty acids are more susceptible to autoxidation than esterified fatty acids. Thus, free fatty acids act as pro-oxidants in edible oil. These compounds have a hydrophilic and a hydrophobic group in their structure. The carbonyl group is the hydrophilic group and the hydrocarbon chain is the hydrophobic group. The carbonyl group of these compounds are preferably concentrated on the surface of edible oil, decreasing the surface tension and increasing the diffusion rate of oxygen from the headspace into the oil, so accelerating oil oxidation.

<u>Measurement of FFAs</u>

The measurement of FFAs is also known as the measurement of oil acidity. The most common method for the determination of the FFA level uses acid/base titrations with phenolphathlein as an indicator. The oil is dissolved in an organic solvent and titrated with an alkaline solution such as sodium hydroxide. The results are given as % FFA as oleic acid, as by IOC regulation. Briefly, 1 g of oil is weighed in an Erlenmeyer flask and 10 ml of 95% ethanol and 0.5 ml of phenolphthalein are added; titration is then carried out drop by drop with 0.5% NaOH solution until the color changes. Acidity is calculated as a percentage by mass as follows

$$FFA\,\% = \frac{(V-B)\times N\times 28.2}{w}$$

Where,
( V- B) = difference between initial reading and final reading of titrant solution
N = the normality, usually 0.25
w = weight of the oil used ( 1 g )

**Transesterification**

Straight vegetable oils used in engine lead to various problems like fuel filter clogging, poor atomization and incomplete combustion because of high viscosity, high density and poor non-volatility. Transformation of vegetable oils into biodiesel can be realized using four technologies: (i) Heating/pyrolysis, (ii) dilution/blending, (iii) micro-emulsion, and (iv) transesterification. Among all these techniques, the transesterification is an extensive, convenient and the most promising method for the reduction of viscosity, density and other properties of the straight vegetable oils. However, this adds extra cost of processing because of the transesterification reaction involving chemical and process heat inputs (Barnwal and Sharma 2005; Bari et al. 2002)

There are so many investigations on biodiesel production of nonconventional feedstock of oils and have reached a faster pace in the last few years. An adaptation of the vegetable oil as a CI engine fuel can be done by four methods (1) Pyrolysis; (2) micro-emulsification; (3) dilution; and (4) transesterification. Transesterification is the method of biodiesel production from oils and fats and can be carried out by two ways.

(a) Catalytic Transesterification.
(b) Supercritical Methanol Transesterification.

**Catalytic Transesterification**

The “Catalytic Transesterification” process is the reaction of a triglyceride (fat/oil) with an alcohol in the presence of some catalyst to form esters and glycerol which is shown in Fig.1.1. A triglyceride has a glycerin molecule as its base with three long chain fatty acids attached. The characteristics of the oil/fat are determined by the nature of the fatty acids attached to the glycerin. The nature of the fatty acids can in turn affect the characteristics of the biodiesel.

**Super Critical Transesterification**

The simple transesterification processes discussed above are confronted with two problems, i.e. the processes are relatively time consuming and needs separations of the catalyst and saponified impurities from the biodiesel. The first problem is due to the phase separations of the vegetable oil/ alcohol mixture, which may be dealt with by vigorous stirring. These problems are not faced in the supercritical method of transesterification. This is perhaps due to the fact that the tendency of two phase formation of vegetable oil/alcohol mixture is not encountered and a single phase is found due to decrease in the dielectric constant of alcohol in the supercritical state (at 340°C and 43 MPa). As a result, the reaction was found to be complete in a very short time within 2-4 mins. Further, since no catalyst is used, the purification of biodiesel is much easier, trouble free and environment friendly (Demirbas, 2005).

**Biodiesel Preparatiosns By Catalytic Transesterification Method**

Refined pongamia seed oils were esterified by the transesterification method. Transesterification is otherwise known as alcoholysis. It is the reaction of fat or oil with alcohol to yield esters and glycerin. Transesterification of selected oils was carried out by heating the oil. In this process, alcohol combines with triglyceride molecule from acid to form glycerol and ester. The glycerol is then removed by density separations. Simple alcohols are used for transesterification and his process is usually carried out with a basic catalyst (NaOH, KOH) in the complete absence of water. Transesterification decreases the viscosity of oil, making it similar to diesel fuel in characteristics. A catalyst is used to improve the reaction rate and yield. Transesterification of triglycerides using alcohol is shown in Figure 4.3.

## 7 RESULTS AND DISCUSSION

### 7.1 Engine Performance

**Brake Thermal Efficiency (BTE)**

Figure (2) shows the brake thermal efficiency of the engine for different blends. It can be seen that Biodiesel-kerosene blends show higher BTE than diesel fuel due to the oxygen content (about 10%) in biodiesel fuel, which enhances the combustion. The BTE of kerosene was higher which means that kerosene is suitable for use in diesel engines, due to the higher heating value, and the low viscosity of kerosene enhances the atomization of fuel. The BTE is increased with the increase of kerosene percentage in the blends. On average, the BTE of Bk15 increased about 2% compared to BK45.

**Brake-Specific fuel Consumption (BSEC)**

Figure (3) shows the BSFC of different blends at three different speeds and constant load (80%). BSFC is defined as the fuel consumption rate to produce unit brake power. BSFC is directly proportional to the fuel mass flow rate. BSFC decreases with the addition of kerosene due to the high heating value of kerosene and its better thermal efficiency as compared to D100 and B100. The decrease in BSFC is in the range of 2.5-3.5% for BK15 compared to D100 at different speeds and constant load. It is also clear that BSFC follows the same trend for all fuels; it decreases with engine speed increase until 2000rpm and then increases with engine speed increase.

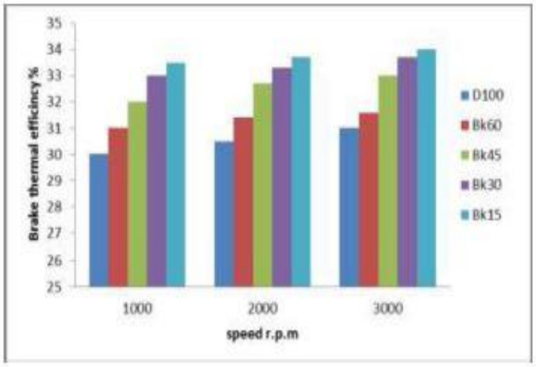



**Fig. 1 : Brake thermal Efficiency vs speed**

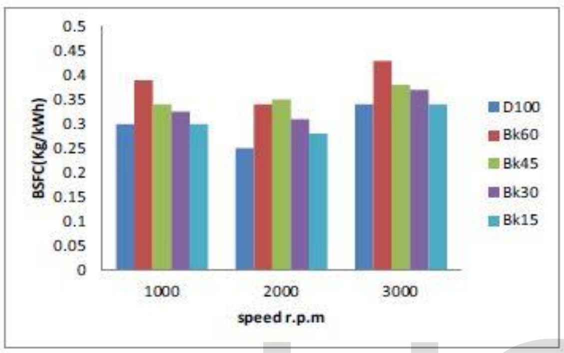



**Fig. 2: Brake specific fuel consumption vs speed**

### 7.2 Emissions

**CO Emissions**

Figure (4) shows CO emission of the blends, at constant engine load and various speeds. CO and HC are products of incomplete combustion. Biodiesel has more oxygen content (about 10%) than petroleum diesel (D100); hence, more complete combustion takes place and therefore less CO and unburnt hydrocarbon (HC) are expected. Kerosene has a slightly lower CO than D100, and with the addition of kerosene in biodiesel; a noticeable increase in CO is observed. The extra oxygen content in fuel blends ensures the oxidation of CO, even on locally fuel-rich zones which helps to reduce CO emission [17,18]. Therefore the CO emissions for kerosene-biodiesel blends are about40%lower than that of diesel.

**HC Emissions**

Figure (5) illustrates HC emissions at constant load and different engine speeds. It is clear that HC emissions decrease with the increase in engine speed. This decrease in HC emission is attributed to the increase in combustion temperature and complete fuel combustion. HC trend is quite similar to that of CO, there is about 45-55% of HC reduction for biodiesel-kerosene blends than that of D100. Adding kerosene in blends significantly increases HC emissions. It can also be observed that oxygenated compounds available in the biodiesel made the HC emissions lower in the case of biodiesel-kerosene blends. However, BK60 always produces lower HC than other blends and D100.

**NOx Emissions**

Figure (6) shows a comparison of NOx emissions of the diesel and the blends of biodieselkerosene at different engine speeds and constant load. The reasons behind the high NOx emission are high combustion temperature and oxygen content in fuels. Due to 10% oxygen content in biodiesel, Biodieselkerosene blends produced about 10-28% more NOx thanD100 at different engine operation conditions. Kerosene NOx emissions are similar to that of diesel. Adding kerosene in biodiesel helps in reducing NOx emissions.

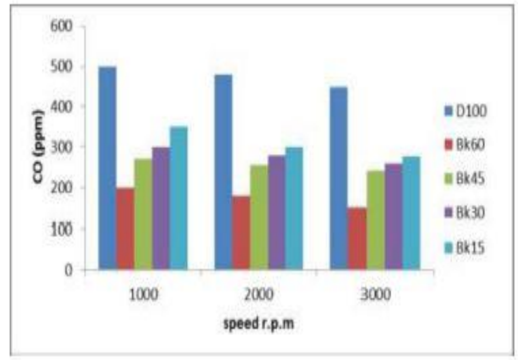



**Fig. 4.9: CO emission vs Brake power**

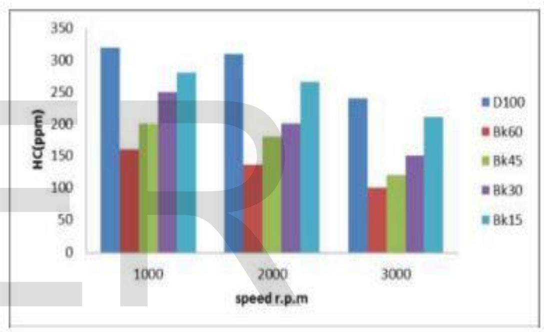



**Fig. 5: HC emission vs speed**

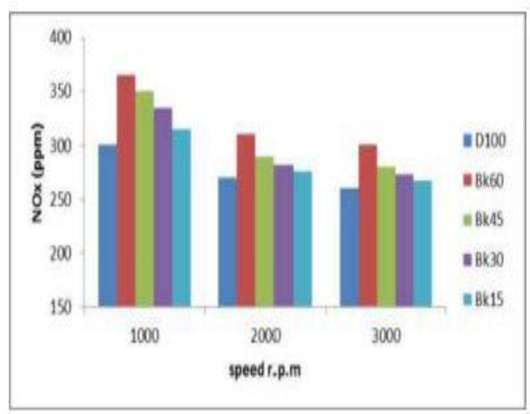



**Fig. 5.1: NOx emission vs speed**

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