CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The present work summarizes detailed review of the research in the field of biodiesel from vegetable oils. Journals related to different biodiesel tests performed were reviewed. Review was done in the following fields:

i) Vegetable oils and their methyl esters as fuels for diesel engines.

ii) Properties of blends of unesterified Jatropha curcas oil and diesel fuel in compression ignition engine.

iii) Performance analysis of Linseed oil blend in Diesel Engine

iv) Estimation of yield of Biodiesel by NMR Spectra

v) Transesterification of Sal Oil into Biodiesel-An Experimental Study.

2.2 VEGETABLE OILS AND THEIR METHYL ESTERS

Srinivasa Rao (1991) has done his work on Vegetable oils and their methyl esters as fuels for diesel engines. The tests reported in this paper were conducted with the main objective of evaluating the performance of some vegetable oils and methyl esters of some vegetable oils. He tested the vegetable oils *Pongamia glabra*, Rice bran oil and palm oil during the first
phase on a single cylinder diesel engine. In the second phase, the tests were conducted with methyl esters of Rapeseed oil and Neem oil. The results of the tests were discussed with reference to the thermal efficiency and combustion parameters like delay period. The performance of the diesel engine has also been included for comparison. His results indicated that the vegetable oils and their methyl esters performed with acceptable thermal efficiencies as fuels for diesel engines. Methyl esters of vegetable oils had shorter ignition delays and longer combustion duration than diesel oil. The other problems associated with the vegetable oils were bad smell and high viscosity.

2.3 PROPERTIES OF BLENDS OF UNESTERIFIED JATROPHA CURCAS OIL AND DIESEL FUEL IN COMPRESSION IGNITION ENGINE.

Pramanik (2003) analyzed the properties and use of *Jatropha curcas* oil without transesterification and diesel fuel blends in compression ignition engine. From this journal, it is known that the blends of varying proportions of *Jatropha curcas* oil and diesel were prepared, analyzed and compared with diesel fuel. The effect of temperature on the viscosity of Biodiesel and Jatropha oil was also studied. The performance of the engine using blends and Jatropha oil was evaluated in single cylinder C.I. engine and compared with the performance obtained with diesel. Significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to the blend of vegetable oil. Acceptable thermal efficiencies of the engine were obtained with blends containing up to 50% volume of Jatropha oil. From the properties and engine test results it has been established that 40 to 50% of Jatropha oil can be substituted for diesel without any engine modification and pre heating of the blends. The result showed that *Jatropha curcas* oil without transesterification could be used along with diesel
in blends unto 30% to have appreciable results (Pramanik 2003). Since the viscosity of unesterified jatropha oil is high, it can not be used for continuous running of the engine, because it will block the smooth running of the engine.

2.4 PERFORMANCE ANALYSIS OF LINSEED OIL BLEND IN DIESEL ENGINE

P.T. Nitnaware and Prof. J.V. Bhandari (Wealth of India 2008) carried out their work on linseed oil biodiesel blend with diesel. They found that 20% biodiesel blend was found to be the optimum that improved the thermal efficiency of the engine by 2.5 % reduced the exhaust emissions and the specific energy consumption was higher and there was the reduction in exhaust smoke levels. Exhaust temperatures was increased due to higher percentage of Linseed Oil Methyl Ester (LOME) which led to 5 % increase in NOx. It was conclusively proved that self lubricity of LOME in biodiesel played a key role in engine performance. BioDiesel is proved to be a potential candidate for partial substitute of mineral diesel oil. It was noticed that after a certain limit of biodiesel concentration, the thermal efficiency trend reversed and it started decreasing. The B20 was also reported to provide additional lubricity compared to conventional fuels and demonstrate similar fuel consumption horsepower and torque as petroleum fuels. The present study also demonstrated that the results were in full agreement with the findings of the earlier researchers.

2.5 BIODIESEL PRODUCTION PROCESS: AN OVERVIEW

About 0.6 gms of catalyst are dissolved in 20ml methanol to prepare alkoxide, which is required to activate the alcohol. Then stirring is done vigorously in a covered container until the alkali is dissolved completely for 20 min. The mixture is protected from atmospheric carbon dioxide and moisture as both destroy the catalyst. The alcohol-catalyst (KOH) mixture is
then transferred to the reactor containing 80 ml moisture free vegetable oil. Stirring of the mixture is continued for 5 hours at a temperature between 60° and 65°C. Provision is made to condense the evaporating methyl alcohol by fixing the condenser on the top of the reactor. Then remove the condenser and stirring is done for one hour to remove the excess methyl alcohol. The mixture is turned into turbid orange brown color within the first few minutes, then it changes to a clear transparent brown color and finally as the reaction is completed, the mixture again becomes somewhat turbid and orange brown due to the emulsified free glycerol formed during the reaction.

After a lapse of one hour, the mixture is taken out and poured in to the separating funnel, soon the glycerol component of the mixture starts settling at the bottom. The mixture is allowed to settle by gravity in a separating funnel overnight. It is observed that there are two distinct layers formed, one is pale yellow at the top & the other being dark brown at the bottom. Without disturbing the funnel the bottom layer is separated out, which is glycerol, which can be sold as a resource material for soap or paint industry. The layer, which is retained in the funnel, is Methyl ester of the vegetable oil. Water washing is done to remove any moisture. To do this, distilled water about 30% by volume of the ester is added, shaken properly and the mixture is once again transferred to the separating funnel wherein again the water with any emulsion formed settles at the bottom. The upper layer is pure methyl ester that is Biodiesel, ready for the use in diesel engine. Biodiesel is also prepared by the above procedure using ethanol and iso-amyl alcohol substituting for methanol.
2.6 VEGETABLE OIL MODIFICATION

Petroleum diesel fuel is a complex mixture of saturated, unsaturated, branched, non-branched, straight chain and aromatic molecules with carbon atoms ranging from 12 to 18. In contrast, vegetable oils are a mixture of organic compounds ranging from simple straight chain compounds to complex proteins, fat-soluble vitamins and fatty acids. Fatty acids vary in carbon chain length and in the number of unsaturated bonds (double-bonds). Vegetable oils are usually triglyceride with a number of branched chains of different length. The high viscosity of vegetable oils (25-200 cSt) as compared to diesel oil (4 cSt) at 40°C leads to unfavorable pumping & spray characteristics (atomization and jet penetration etc.).

The inefficient mixing of fuel with air contributes to incomplete combustion. The high flash point due to lower volatility characteristics result in increased carbon deposit formation, injector choking, piston ring sticking, lubrication oil dilution and degradation. The combination of high viscosity and low volatility of vegetable oils cause poor cold starting, misfire and longer ignition delay. The polyunsaturated nature of the vegetable oils causes long-term problems due to slow polymer gum formation causing ring sticking etc. Because of these problems, vegetable oils need to be converted to more compatible fuels for existing engines. Thus, neat vegetable oils need to be modified to bring their combustion related properties closer to those of mineral diesel oil. This fuel modification is mainly aimed at reducing the viscosity and increasing the volatility. Low Cetane number of the oil causes poor cold weather starting, improper combustion etc. The polyunsaturated nature of the vegetable oils causes long-term problems due to slow polymer gum formation causing ring sticking, excessive engine wear due to dilution of lubricating oil.
Considerable efforts have been made to develop vegetable oil derivatives that approximate the properties and performance of the hydrocarbon based fuels. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. These can be changed in at least four ways: Pyrolysis, Micro emulsification, Dilution and Transesterification.

2.7 EVALUATION OF NON EDIBLE OILS IN DIRECT INJECTION DIESEL ENGINE

There are two types of vegetable oils derived, namely edible oil and no-edible oils. The major problem associated with direct use of vegetable oils is their high viscosity and low volatility. One possible method to reduce viscosity is transesterification, which produces esters (Biodiesel) of respective oils. Biodiesel is a fatty acid alkyl ester, which can be derived from any vegetable oil by transesterification. In this study, Honge and Rice Bran Oils (RBO) were transesterified with methanol using sodium hydroxide as catalyst to obtain their respective biodiesels namely Honge Methyl Ester (HOME) and Esterified Rice Bran Oil (ERBO). These biodiesels were tested in a computerized single cylinder, four stroke, direct injection, constant speed, and compression ignition diesel engine to evaluate the performance and emission characteristics. All the tests were conducted at different loads and for three injection timings of 19°, 23° and 27° before TDC and injection pressure of 200 bar.

In view of this Honge and Rice Bran oils being non-edible oils could be regarded as alternative fuels for CI engine application. The Honge oil is popularly known as Pongamia Pinnata or Karanja oil. The Honge oil is extracted from the seeds of Honge tree also called Karanja tree. Rice Bran oil is a high viscosity, low volatility and polyunsaturated character of non-edible oil. Neat use of vegetable oils poses some problems when subjected to
prolonged usage in CI engines. These problems are attributed to high viscosity, low volatility and polyunsaturated character of neat vegetable oils (Adams et al 1983). The properties of diesel, Honge and Rice bran oil and their biodiesels are summarized in Table 2.2.

The objective of the study includes determination of optimization parameters for the production of Honge and Rice bran biodiesels and to investigate their suitability as diesel engine fuels. This paper presents the results of investigations carried out on a single cylinder direct injection engine operating on diesel fuel, Honge and Rice Bran oils. Engine tests have been carried out with the aim of obtaining comparative measures of brake thermal efficiency, brake specific fuel consumption, brake power, exhaust gas temperature and smoke.

2.7.1 Engine Test

The performance of biodiesel using HOME and ERBO were studied in comparison with diesel fuel. Table 2.1 shows the specifications of the test engine used. It is Kirloskar make 1500 rpm four stroke diesel engine. An eddy current dynamometer is used for loading the engine. The fuel flow rate is measured on the volumetric basis using a burette and stopwatch. The engine and dynamometer were interfaced to a control panel, which is connected to a digital computer. The computer software was used for recording the test parameters such as fuel flow rate, temperatures, airflow rate, load etc. The calorific value and density of the fuel used were fed to the computer for calculating various performance parameters. The smoke characteristic is measured by using Hartridge smoke meter.
Table 2.1 Specification of diesel engine used (Prasad et al 2007)

<table>
<thead>
<tr>
<th>Make</th>
<th>Kirloskar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>AVI, Single cylinder, Diesel Engine</td>
</tr>
<tr>
<td>General details</td>
<td>Four stroke</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>One</td>
</tr>
<tr>
<td>Bore</td>
<td>87.5 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>110 mm</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>16.5:1</td>
</tr>
<tr>
<td>Rated output</td>
<td>5.2 kW at 1500 rpm</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Injection pressure</td>
<td>200 bar</td>
</tr>
<tr>
<td>Fuel injection timing</td>
<td>$23^0$ BTDC</td>
</tr>
</tbody>
</table>

The engine was started on neat diesel fuel and the readings were recorded at steady state conditions. Similar procedures were repeated for the HOME and ERBO fuels. Each test was done for 3 hours.

2.7.2 Effect of Temperature on Viscosity of Honge and Rice Bran Oils

Figure 2.1 shows the effect of temperature on kinematic viscosity of diesel, honge, HOME, RBO and ERBO. The viscosity of all oils decreases with increase in temperature. The kinematic viscosity of Honge oil was found to be 17.94 times more than that of diesel determined at 40 °C. After esterification, the kinematic viscosity reduced to 2.336 times than that of pure Honge oil. The kinematic viscosity of RBO was found to be 18.72 times more than that of diesel determined at 40 °C. After esterification, the kinematic viscosity reduced to 2.58 times than that of pure ERBO. Transesterification brings the viscosity of honge oil and rice bran oil nearer to that of diesel.
2.7.3 Engine Performance

The engine tests were conducted with raw Honge oil, HOME, RBO and ERBO for no load to full load condition at 200 bar for two injection timings of 190, 230 before TDC.

2.7.3.1 Effect of injection pressure on brake thermal efficiency

Figure 2.2 Effect of injection pressure on Brake Thermal efficiency indicates the effect of injection pressure on brake thermal efficiency for neat diesel, neat raw honge and honge methyl ester oils at two injection timings for full load. It follows that at an injection pressure of 200 bar brake thermal efficiency is maximum for both diesel and Honge oil. This is because better atomization of fuel, fuel penetration and mixture formation occurs resulting in better combustion. At an injection timing of 23\(^0\) before TDC and injection pressure of 200 bar, the brake thermal efficiency of diesel and Honge oil is found to be maximum and the values are 29.728% and 26.859% respectively.
However at an injection timing of 19° before TDC and same injection pressure, the brake thermal efficiency of diesel and Honge oil is found to be 29.55% and 27.117% respectively. Similar trend has been observed for rice bran oil also.

![Effect Of Injection Pressure on BTE](image)

**Figure 2.2** Effect of injection pressure on brake thermal efficiency

### 2.7.3.2 Effect of injection timing on brake thermal efficiency

Figure 2.3 indicates effect of injection timing on brake thermal efficiency for neat diesel, raw Honge, HOME, RBO and ERBO at an injection pressure of 200 bar and injection timing of 19°bTDC. For all the fuels brake thermal efficiency increases with an increase in load. This is due to reduction in heat loss and increase in power with increase in load. The brake thermal efficiency for Honge and Rice Bran oil is lower as compared to diesel at all loads. Brake thermal efficiency of an engine depends on heating value and specific gravity. The combination of heating value and mass flow rate indicate energy input to the engine. This energy input or consumption to the engine in case of HOME and ERBO is more compared to diesel. The maximum
efficiency at an injection timing of $19^0$ before TDC obtained is 29.55% and 27.11% and 26.27% for diesel, raw Honge oil and HOME respectively at 80% load.

![Figure 2.3 Brake thermal efficiency vs. load](image)

For CRBO and ERBO, brake thermal efficiency is 23.21% and 25.52%. It is observed that brake thermal efficiency of diesel is higher at 29.728 % for an injection timing of $23^0$ before TDC as compared to other injection timings. However, performance with Rice Bran oil operation was not smooth at $23^0$ before TDC. Whereas performance of Honge and Rice Bran oils are better for retarded injection timing of $19^0$ before TDC. This is due to higher Cetane number of vegetable oils and their oxygen content. As the timing is retarded, a decreasingly smaller amount of combustion may take place during pre-mixed combustion and a corresponding increase in diffusion phase occurs. The decrease in amount of pre-mixed combustion may correspond with a shortening of the ignition delay as timing is retarded.
2.7.3.3 Brake specific fuel consumption

Figure 2.4 Brake specific fuel consumption vs. Load shows the variation of BSFC with load for diesel, raw Honge, HOME, RBO and ERBO respectively at an injection timing of 19° before TDC and an injection pressure of 200 bar. From the figure it follows that BSFC of Honge and Rice Bran oil is considerably higher than diesel for all the loads. This is mainly due to lower calorific value of vegetable oils, poor atomization due to higher viscosity that leads to improper mixture formation. At 80% load, BSFC of diesel, raw Honge, HOME, RBO and ERBO respectively is 0.287, 0.34, 0.35, 0.355 and 0.349 kg/kWh respectively.

![Variation of SFC with Load](image)

**Figure 2.4  Brake specific fuel consumption vs. load**

2.7.3.4 Exhaust gas temperature

The variation of exhaust gas temperature with load for different non-edible oils is shown in Figure 2.5 Exhaust gas temperature vs. load. It follows from graph that exhaust gas temperature increases with increase in
load. EGT for diesel is lower than the non-edible oils. The EGT for Honge, rice bran oils and their esters is higher than diesel oil. The higher viscosity, changes in the spray pattern, larger droplets resulting in longer combustion duration may be responsible for this.

![Exhaust gas temperature vs. load](image)

**Figure 2.5 Exhaust gas temperature vs. load**

Table 2.2 shows the properties of diesel, Honge, rice bran oil and their biodiesel. Hundred percent conversion has taken place using methanol due to prolonged heating of 5 hours during transesterification process.

Ethanol/Rectified spirit generally contains 4.5% water; this water has decreased the percentage conversion to 21%. The presence of water has hindered transesterification process. Ethanol containing 4.5% water should be converted into absolute alcohol and transesterification process can be tried.
Table 2.2 Properties of the diesel, Honge and Rice bran oil and their biodiesel

<table>
<thead>
<tr>
<th>Property</th>
<th>Diesel</th>
<th>Honge Raw oil</th>
<th>Home</th>
<th>CRBO</th>
<th>ERBO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density kg/m$^3$</td>
<td>830</td>
<td>915</td>
<td>870</td>
<td>915</td>
<td>927</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.830</td>
<td>0.915</td>
<td>0.870</td>
<td>0.915</td>
<td>0.927</td>
</tr>
<tr>
<td>Kinematic Viscosity (cSt) @ 30$^\circ$ C</td>
<td>2.5</td>
<td>44.850</td>
<td>5.84</td>
<td>46.815</td>
<td>6.56</td>
</tr>
<tr>
<td>Flash point $^\circ$C</td>
<td>56</td>
<td>230</td>
<td>170</td>
<td>285</td>
<td>153</td>
</tr>
<tr>
<td>Calorific value kJ/kg</td>
<td>43000</td>
<td>35800</td>
<td>38874</td>
<td>43135</td>
<td>44859</td>
</tr>
</tbody>
</table>