The earth’s limited reserves of fossil fuel have been a matter of global concern as these are under threat of depletion due to exploitation. Because of the increase in petroleum prices especially after the petrol crisis in 1973 and the gulf war in 1991, geographically reduced availability of petroleum and more stringent regulations on exhaust emissions, more research have been turned on to alternative fuels. Biofuels are generally considered as offering many priorities including renewability, sustainability, reduction of greenhouse gas emissions, regional development, rural manufacturing jobs and biodegradability.

Biodiesel was first produced by Duffy and Patrick in 1853 – forty years before the invention of the diesel engine. In 1893, Rudolf Diesel operated the first diesel engine using peanut oil as the fuel. Recent interest in biodiesel started in 1991 with the operation of the first industrial-scale biodiesel plant in Austria. Since then several plants were opened in many European countries, and by 1998, 21 countries were commercially producing biodiesel.

2.1 Sources of biofuel

A large variety of vegetable oils have been used as biofuel. Most of the biodiesel currently being produced is mainly dependent on edible oil sources. The major feedstocks for the production of biodiesel include edible oils such as rapeseed (*Brassica napus*), sunflower (*Helianthus annuus*), palm oil (*Elaeis guineensis*), soybean (*Glycine max*), canola, sunflower, coconut, olive, peanut, castor, tung and corn oil. Soybean oil is one of the important vegetable oil sources for biodiesel production due to its high oil content (around 20%).

Biodiesel is, therefore competing limited land availability with the food industry for the same oil crop. Thus, instead of arable land being utilized to grow food, it is now being used to grow fuel. This will raise the price of edible oil making the biodiesel produced economically feasible as compared to petroleum derived. Besides, the
availability of oil crop is limited. In order to overcome this issue, other sources were researched in order to find alternative raw material for the process which does not drain on the edible vegetable oil supply.

Biofuel research is therefore focused on waste cooking oil, animal fats and oils from non-edible oil-producing plants. In recent years systematic effort have been made by several researchers to use non-edible oils like *Nicotiana tabacum* (tobacco), *Cerbera odollam* (sea mango), *Ceiba pentandra* (silk cotton tree), *Simmondsia chinensis* (jojoba), *Euphorbia tirucalli* and babassu tree as alternate fuel for diesel which are easily available in many parts of the world including India and are very economical compared to edible oils. The cultivation of these plants is easier and has high oil content. Rice bran was also found to be suitable material for biodiesel production. The most commonly considered animal fats include those derived from poultry, beef, and pork. The potential availability of tree-borne oilseeds in India is presented in table 2.

**Table 2. Tree-borne oilseeds in India (Kumar, 2003)**

<table>
<thead>
<tr>
<th>Tree-Borne Oilseeds (Botanical name)</th>
<th>Seed Yield (Million Tonnes)</th>
<th>Oil Content (%)</th>
<th>Oil Yield (Million Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sal (<em>Shorea robusta</em>)</td>
<td>6.2</td>
<td>12</td>
<td>0.74</td>
</tr>
<tr>
<td>Mahua (<em>Madhuca indica</em>)</td>
<td>0.52</td>
<td>35</td>
<td>0.18</td>
</tr>
<tr>
<td>Neem (<em>Azadirachta indica</em>)</td>
<td>0.50</td>
<td>20</td>
<td>0.10</td>
</tr>
<tr>
<td>Ratanjyote (<em>Jatropha curcus</em>)</td>
<td>0.38</td>
<td>50</td>
<td>0.12</td>
</tr>
<tr>
<td>Rubber (<em>Hevea brasiliensis</em>)</td>
<td>0.08</td>
<td>45</td>
<td>0.04</td>
</tr>
<tr>
<td>Karanja (<em>Pongamia pinnata</em>)</td>
<td>0.11</td>
<td>27</td>
<td>0.03</td>
</tr>
<tr>
<td>Kusum (<em>Schleicheria oleosa</em>)</td>
<td>0.05</td>
<td>33</td>
<td>0.02</td>
</tr>
<tr>
<td>Khakan (<em>Salvadora oleoides</em>)</td>
<td>0.04</td>
<td>33</td>
<td>0.01</td>
</tr>
<tr>
<td>Undi (<em>Calophyllam inophyllum</em>)</td>
<td>0.01</td>
<td>60</td>
<td>0.007</td>
</tr>
<tr>
<td>Dhupa (<em>Vateria indica</em>)</td>
<td>0.01</td>
<td>19</td>
<td>0.002</td>
</tr>
</tbody>
</table>

These oils, whether edible or non-edible are limited and not sufficient to sustain the constant supply for production of biodiesel in coming years. This has given the way for search of new raw materials such as algae. Algae can produce oil when they are starved of nitrogen and are hence a potential alternative to
vegetable oils for large scale production of biodiesel in near future. Many species of algae can be successfully grown in wastewater ponds and saline water ponds utilizing CO\textsubscript{2} from power plants as their food. Utilizing CO\textsubscript{2} from power plants to grow algae helps to sequester CO\textsubscript{2} for productive use and at the same time reduces the build-up of CO\textsubscript{2} in the atmosphere. Research on the feasibility of this raw material is in progress in United States and in other countries as well.

Several studies on the feasibility of these neat vegetable oils for the use in combustion engines have been carried out at different environments.

2.2 Production and characterization of biodiesel

As evident from the literature, the high viscosity of vegetable oils is responsible for a lot many problems in CI engines. Therefore reduction in viscosity of vegetable oils is of prime importance to make them suitable for diesel engines. Vegetable oils and animal fats, the important feed stocks of biodiesel mainly consist of triglyceride molecules. Glycerides make the oil thick and sticky with higher viscosity. In order to reduce the viscosity and to make the fuel usable in a diesel engine, pure oil is converted from natural oil triglyceride into three mono-alkyl esters by transesterification. It is, in principle, the action of one alcohol displacing another from an ester, referred to as alcoholysis. Glycerol is removed as by-product and esters are known as biodiesel (Haseeb et al., 2011).

![Transesterification reaction](image)

**Figure 1. Transesterification reaction**

Transesterification consists of a sequence of three consecutive reversible reactions. The first step is the conversion of triglycerides to
diglycerides, followed by the conversion of diglycerides to monoglycerides, and finally monoglycerides into glycerol, yielding one ester molecule from each glyceride at each step. The reactions are reversible, although the equilibrium lies towards the production of fatty acid esters and glycerol (Ma and Hanna, 1999).

\[
\text{Triglyceride + ROH} \rightarrow \text{Diglyceride + R'COOR (1)} \\
\text{Diglyceride + ROH} \rightarrow \text{Monoglyceride + R'COOR (2)} \\
\text{Monoglyceride + ROH} \rightarrow \text{Glycerol + R'COOR (3)}
\]

Biodiesel thus obtained has been accepted as clean fuel by most of the developed and developing countries. The necessity of organized quality protection has emerged through the increased number of biodiesel producers and trading enterprises. Standards and quality control of manufacturing and distribution of biodiesel are being developed to assure that reliable and consistent fuels are supplied to users. As an alternative fuel, biodiesel has physical and chemical properties qualifying to the operation of diesel engines. These properties play a vital role in quality control in the petroleum-based diesel fuel industry. The main criterion for these parameters always is the fuel quality that is received by consumers. The most common standard referenced for pure biodiesel in the United States is standard ASTM D6751, in Europe EN14214, in Germany DIN V 51606 and in India ISO 15607.

The R & D work related to the production of biodiesel by various methods and its characterization has been reviewed and is presented.

2.3 *Jatropha curcus* – a promising biofuel feed stock
The biodiesel industry is still young and relatively small, so as it grows to a larger scale and when an infrastructure is developed, the costs of producing and marketing biodiesel may decline. However, in the longer term, the biggest challenge may be the ability of the feedstock supply to keep up with growing demand. The supply of soybeans, rapeseeds and other feedstocks available for biodiesel production will be limited by competition from other uses and land constraints.

As such the key to the future of biodiesel is finding inexpensive feed stocks that can be grown by farmers on marginal agricultural land, and jatropha is one of many plants that hold a great deal of promise. Jatropha proves to be a promising biofuel plantation and could emerge as a major alternative to diesel thus reducing the dependence on oil imports and saving the precious foreign exchange besides providing the much needed energy security.

The name *Jatropha curcus* (Figure 2) is derived from a Greek word ‘Jatros’ meaning ‘Doctor’ and ‘trophe’ meaning ‘nutrition’ because of the potential of this plant for medicinal purposes (Patil and Singh, 1991). It is found in almost all the tropics and subtropics in Africa/Asia. In India, *Jatropha curcus* known as *ratanjyote* or *kattamanakkku* is found almost in all the states and is generally grown as a live fence for protection of agricultural fields from damage by livestock as it is not eaten by cattle. Jatropha oil cannot be used for nutritional purposes without detoxification; hence its use as energy or fuel source is attractive.
- Jatropha curcus is a drought-resistant perennial, growing well in marginal/poor soil.

- It is easy to establish, grows relatively quickly and lives, producing seeds for 50 years.

- Its seed yield ranges from 7.5 to 12 tons per hectare per year, after five years of growth.

- The wonder plant hardy to dry weather conditions, produces seeds with an oil content of 37%.

- It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine.

- Medically it is used for diseases like cancer, piles, snakebite, paralysis, dropsy etc.

- The plant serves as oil crop, for enrichment of soil, for ornamental purpose, prevent soil erosion, raw material for industrial use, potential feed stock (to feed tusser silk worm), as insecticide/pesticide etc.

- Being rich in nitrogen, the seed cake is an excellent source of plant nutrients.

These characteristics along with its versatility make this plant vital in developing countries as an alternate fuel.

2.4 Biofuel: Corrosion issues

Biofuels are generally heterogeneous in nature, and their composition varies considerably depending on the feedstock growth area, seasonal variations, and fertilization. Even biodiesel from feedstocks grown in the same area may vary in composition and properties, likely based on cultivation practices. It has been found that the ash content and other minerals (C, N, Al, Ca, Cl, Fe, K, Mg, Na, P, S, and Si) found in stems, leaves, and other parts of
biofuel crops may have effects on the properties of biodiesel. The biofuel produced from a plant with the highest ash and mineral content also had the highest tendency to slag, foul, and corrode. It has been found that leaves produce greater deterioration in the biofuel quality than stems and flower heads. Studies have also found that biofuels from straw and cereals containing heavy metals, K, Na, Cl, and S – have higher corrosion and fouling tendencies in the furnace than those from wood and wood ashes. By delaying the harvest of crops, the content of alkalis and chlorine which cause fouling and corrosion during combustion has been reduced by a factor of 2 to 6.

The use of fatty acid methyl esters and their mixtures as alternative energy sources will require their stability during storage periods when the biofuels are not being used. While these fats are being stored, they must be relatively stable so that the fuel properties will not deteriorate before the biofuel is used. Previous works has examined the stability of biodiesel and found that this form of fuel is quite stable during long term storage.

Corrosion studies on biodiesel and biodiesel-fossil diesel blends have been conducted under storage, transportation, combustion, and automobile operational conditions. Biodiesel-induced corrosion in storage (both in tanks and in automobiles) and transportation occurs by electrochemical mechanism (wet corrosion) mostly due to the presence of entrained water. Though as-received fuels are virtually water-free, during storage or use, due to its hygroscopic nature it can absorb moisture from atmosphere. However, the water content of biodiesel exposed with different metals is almost similar. This indicates that increasing water content is not depended on the types of metal exposed in biodiesel. Upon exposure of metals into biodiesel, water may condense on metal surface and thereby enhance the corrosion process. In the combustion and automobile operational conditions, the corrosion caused by biodiesel occurs at elevated temperatures mostly under dry conditions (dry corrosion).
Over the decades, a substantial amount of research has been carried out to find a new renewable and sustainable energy source to substitute the fossil fuels. Various methods employed to produce biofuel, their characterization and the stability of these renewable fuels has been dealt by researchers. Clearly, at present, there is a serious lack of scientific data based on which confident decisions about the durability of metals during storage and transport conditions could be made. More data are necessary to comment on the safe use of biofuels without corrosion problems.

Hence the present work is designed to have a clear idea on the interaction of jatropha biofuel with a few metals like aluminium, copper, brass and two types of carbon steel that come in contact during storage and transport.