Chapter 2: Literature Review

2.1 Introduction of Literature review: This research shows the resources for future regarding mustard oil based biodiesel used as a renewable and alternative fuel in place of fossil diesel. The efficiently use of straight vegetable oil (SVO) in a diesel engine, may require there is complicated and necessary modification in the fuel injection system and engine specification, which is much costly. But with the help of Preheating, Blending and transesterification process the problem of engine specification and modification can be easily solved out in the uses of vegetable oil. Preheating and blending of mustard oil decrease the viscosity. Mixing of mustard oils with fossil diesel can cause to decrease the viscosity drastically and the fuel injecting system of engine can inject the mustard oil based biodiesel blends easily. On the basis of experimental results, it is found that with the help of transesterification process the mustard oil can be convert into simple esters effectively, to solve the problems related to mustard oil direct use in a diesel engine.

With the use straight vegetable oil (SVO) directly in diesel engine, various problems faced during the working can be classified in two groups (A) operational (short-term), (B) durability (long-term) problems. At 40°C, the viscosity of mustard oil is 35-60 cSt and diesel oil that have 4 cSt, this very high viscosity of mustard oil create problem in spray and pumping properties like atomization & penetration. Also there is lower volatility property due to its higher flash point attributes. This results in lubricating oil dilution, oil degradation, piston-ring sticking, and carbon deposition and injector stoppage. Mustard oils have higher viscosity and low volatility which may cause ignition delay, and poor cold starting problems. The mustard oils consist polyunsaturated chain of ester which may cause’s durability (long-term) problems such as grease formation, ring sticking etc. To avoid these problems there is a great requirement to change the chemical structure of mustard oils that will be more suitable and ideal fuel for test rig kirloskar diesel engines. So there is some problems are short-term and some problems are long-term with utilization of mustard oils in engine are shown in Table 5. This table also shows reasons and particular solutions for these problems.
## Table 5: Vegetable oils use’s Problems and their solutions in an engine

<table>
<thead>
<tr>
<th>Problems</th>
<th>Problem’s cause</th>
<th>Problem’s solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Winter starting</td>
<td>Low firing point, low cetane no., and High viscosity</td>
<td>Pre heat fuel before entering into engine.</td>
</tr>
<tr>
<td>2. Stoppage of filters, injectors and pipes</td>
<td>Gums formation.</td>
<td>Filter the oil with the help of 4 microns filter, to remove gums.</td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Carbon deposits on piston and head of engine and choking.</td>
<td>Incomplete combustion and High viscosity of vegetable oil,</td>
<td>Pre heat fuel before entering into engine and Adjust injection timing.</td>
</tr>
</tbody>
</table>

### 2.2 Preparation of Bio-Diesel from Mustard Oil via Transesterification

For preparation of bio diesel from mustard oil we prefer the transestrification reaction as

**Transesterification**:- Transesterification is the process of obtaining ester or monoglyceride as biodiesel from triglyceride in the presence of alcohol and catalyst. Transesterification reaction has been used to reduce the viscosity of the vegetable oil. The reaction rate is strongly affected by the temperature at which reaction is take place i.e. (50±2) ° C approximate. Then with the help of washing remove the catalyst, soap and excess methanol from bio diesel.
In our work we have been use the Dr. Peepers style, for the transesterification of mustard oil. According to Dr. Peepers style, first of all, take a 250 ml methanol CH$_3$OH (90% pure) in the glass container then mixed 150 ml NaOH of 1 Normality and swirl the container until methanol is completely dissolved in NaOH. When NaOH reacts with methanol CH$_3$OH an exothermic reaction is take place due to which the glass container gets warm so it is very carefully done to swirl the mixture, safety precautions.

After that start to heat up the one liter pure mustard oil up to 60º C and then added this hot one liter mustard oil to the glass container and start to swirl the glass container up to 10 minutes so that the mustard oil is completely dissolve in the mixture. After the reaction, the product is kept for a certain time for pure biodiesel separation (approx. 24 hours or more) of bio-diesel and glycerol separation. The more time of separation gives the better result, that means gives more pure bio diesel.

After 24 hours there are two distinctive layers are appears in the glass container. The upper layer is more transparent as compare to lower layer. The upper layer consist the mixture of methyl esters, residual methanol and catalyst, and impurities, whereas the lower layer having a mixture impurities like soap, glycerol etc. The upper layer gives the 100% pure bio diesel and lower layer gives the concentrated glycerol. Then the pure mustard bio diesel is separated from the glass container if this bio diesel contains impurities like, methanol CH$_3$OH, moisture and soap. The methanol and moisture can easily remove from the bio diesel by heating the bio diesel up to 100º C under reduced pressure by rotary evaporator.
2.3 Parameters that effect the Transesterification Reaction

2.3.1. Molar ratio effects

The molar ratio (alcohol: oil) directly affect the transesterification reaction during acid esterification 6:1 molar ratio and during alkaline esterification gives the optimum amount for biodiesel production rubber and polanga seed respectively. Similarly for Karanja seed the optimum yield of biodiesel production is obtained during acid esterification by taking 8:1 molar ratio and for alkaline esterification the molar ratio should be 9:1.

It is essential for the transesterification reaction for convert the triglyceride into monoglycerid (ester) in the presence of methanol in suitable amount. But large amount of methanol may create some problem and not sure for optimize biodiesel production. It is not necessary that the biodiesel production is increase or optimum, with the increase of the 6:1 molar ratio of methanol/oil.

2.3.2. Moisture and water presence effect

The presence of water and moisture in the feedstock must have a negative effect on biodiesel production. Some observation gives important information that a small amount of water may be 0.1% would decrease the ester conversion in the transesterification reaction. This reduces the biodiesel production yield due to moisture presence in feed stock which may cause soapification and the catalyst action less effective. The water and moisture contents may be removing by heating the feedstock for one hour at 100 ºc.

2.3.3 Presence of fatty acids effect

The presence of fatty acids may reduce the biodiesel yield upto 2% in the transestrification reaction. These fatty acids may convert the feedstock into soap instead of biodiesel.

2.3.4. Temperature effect

The temperature has an accountable effect on biodiesel production. According to an observation the various stage of transesterification reaction have different range between 318 K and 338 K. Temperature higher than boiling point of alcohol may cause burn or damage the alcohol and biodiesel production in lesser yield. A temperature higher than 323 K for neat oil had a negative effect on the yield of biodiesel production, but for waste oil had a positive effect with higher viscosities at 323 K.
2.3.5. Stirring process effect

Stirring is an enthusiastic process of mixing or rotating of biodiesel upto a speed 600 RPM. Since the transestrification reaction is incomplete, when speed is below than 1800 RPM. A speed of 360 or more can give the optimum yield of biodiesel production. The yield can vary upto a value 85% to 90% with 180 RPM to 360 RPM respectively.

2.3.6. Specific gravity factor

The specific gravity is very helpful in separation of biodiesel, soap and glycerine or other byproducts. The specific gravity can be influence by temperature of reaction and quantity of catalyst used. The specific gravity of the biodiesel decreased sharply, when we use reaction time 2 hour and 30:1 molar ratio as compare to when we use reaction time of 4 hour and molar ratio 30:1.

2.4 Various Vegetable Oils used as biofuel

Vegetable oils are the best replacement of fossil fuel for diesel engine because vegetable oil consist some favorable properties for diesel engine use. Vegetable oil also renewable in nature, so it can be consider as a best future fuel for source of energy. But due to the uncertainty in availability of fossil diesel with the price of fossil diesel increase then biodiesel make acceptable. Since vegetable oil consist some drawback as compare to fossil diesel like lower volatility, higher viscosity. These drawbacks may cause large carbon deposition, injector coking, oil ring sticking and gum formation.
The various vegetable oils that can be used as fuel in various engines shown in the table 6;

**Table 6: The Oil species used in biodiesel production**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Species</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Major oil</td>
<td>Palm, Coconut, canola, olive, Mustard, sunflower, and soybean.</td>
</tr>
<tr>
<td>2</td>
<td>Nut oils</td>
<td>Groundnut, Almond, cashew, hazelnut, macadamia, pecan, pistachio and walnut</td>
</tr>
<tr>
<td>3</td>
<td>Other edible oils</td>
<td>Algaroba, amaranth, apricot, artichoke, avocado, babassu, bay laurel, beechnut, ben, Borneo tallow nut, cohune, coriander seed, false flax, grape seed, hemp, kapok seed, lallemantia, lemon seed, acauba fruit meadow foam seed, mustard, okra seed (hibiscus seed), perilla seed, pequi, (Caryocarbrasiliensisseed), pine nut, poppy seed, prune kernel, quinoa, ramtil (Guizotiaabyssinicaseed or Niger pea), rice bran, tallow, tea (camellia), thistle (Silybummariannumseed), and wheat germ</td>
</tr>
<tr>
<td>4</td>
<td>Inedible oils</td>
<td>Algae, babassu tree, copaiba, honge, jatropha or ratanjyote, jojoba, karanja or honge, mahua, milk bush, nagchampa, neem, petroleum nut, rubber seed tree, silk cotton tree, and tall</td>
</tr>
<tr>
<td>5</td>
<td>Other oils</td>
<td>Castor, radish, and tung</td>
</tr>
</tbody>
</table>
2.5 Vegetable Oil Resources

The various vegetable oil resources can be dividing into two categories; Edible oil resources and non edible resources

2.5.1 Edible Oil Resources
The edible oil are such oil that can be edible in nature like Mustard, poppy seed, Borneo tallow nut, algaroba, grape seed, amaranth, beech nut, apricot, artichoke, tea oil, avocado, babassu, thistle seed, bay laurel, prune kernel, ben, rice bran, lemon seed, quinoa, acauba fruit meadow foam seed, wheat germ, perilla seed, pequi seed, ramtil seed, tallow, and okra seed (hibiscus seed).

2.5.2 Inedible Oil Resources
The non-edible oils such oil which cannot be used for edible purpose like as neem, mahua, jatropha or ratanjyote, karanja, silk cotton tree, mahua, microalgae, karanja, and rubber seed. The inedible are very cheap as compare to edible oil and easily available anywhere. The oils from neem and rubber are very highly viscous and contain high free fatty acid (FFA). These high amounts of FFAs easily react with NaOH that lead to formation of soap and make the biodiesel and glycerol separation process very complicated. The chemical structure of vegetable oils is very different than fossil fuel. Vegetable oils containing triglyceride and when these triglycerides react with methanol in an optimum molar ratio then triglyceride breaks into monoglyceride or ester (biodiesel) with some by products like glycerol, soap etc. so, the vegetable oils have the great tendency to replace the fossil diesel in the near future.

The main advantage of biodiesel is its renewability, higher cetane number, portability, easy availability, higher biodegradability, and lower dangerous gases emission. The main advantage of biodiesel is its domestic production, which would reduce dependency on petroleum.
The disadvantages of use of pure biodiesel are its injector stopping, higher pour point, higher cloud point, higher viscosity, higher nitrogen oxide (NOx) emission rates, lower engine speed and power, and higher engine wear.

2.6 Vegetable Oil Processing

The vegetable oil production including various processes like cleaning, crushing, husking and extraction process (pressing of seed and boiling of fruits) of raw material that is used for oil production. The various vegetable oil can be extracted from various seed, nuts and fruits. Crude vegetable oil can be obtained by pressing the seed at higher pressure and separate oil from seed. Vegetable oil processing involves the extraction and processing of oils from vegetable. The oils are extracted by pressing process are triglyceride and can available for converting into monoglyceride (biodiesel) production. Volatile components are eliminating by using steam injection at higher temperature. The pure oil then filter and store for uses.

2.6.1 Vegetable Oils from Plants

Vegetable oils can be extracted from various plants like coffee, tobacco, oil from oilseeds, and extraction of oils for perfumes by different extraction techniques like chemical extraction, physical extraction, and Supercritical fluid extraction (SFE). In the process of oil extraction from various plants may be including extraction of nicotine from tobacco, decaffeination of coffee etc. The example of chemical extraction process may be removal of solvents from petroleum using supercritical carbon dioxide while in the physical extraction oil seed may be goes through some physical treatment like pressing, crushing etc. Supercritical fluid extraction (SFE) process involves the mechanically stirring at some critical pressure and temperature. SFE the technique is very attractive than other classical extraction techniques because it can reduce sample preparation time.

2.6.2 Refining of Vegetable Oil

Naturally crude vegetable oils contain many undesirable particles like phosphatides, free fatty acids and unsaturated fats. So there is an essential requirement of physical refining for extracting these particles for optimum yield of biodiesel and better quality purposes. The refining process consist physical refining, bleaching, chemical refining, degumming, and deodorization. In the oil refining process deodorization is an important step. During this step, steam of high temperature
at 500 K to 550 K and pressure about 1 mm Hg to 7 mm Hg is added into the oil to remove unsaturated hydrocarbons, fatty acids, and other undesirable particles, which may cause undesirable smell and taste in the oil.

2.7 Vegetable Oils use as Diesel Fuel
The use of vegetable oils in diesel engines is start at the time of discovery of diesel engine. But the use of vegetable oil as an alternate of fossil fuel is considered in 1980. Dr. Rudolph Diesel also use the peanut oil as fuel in his engine but due to the high temperature creation the different vegetable oil can be used for designed original diesel engine.

2.7.1 Physical and Chemical Properties of Vegetable Oils
Biodiesel produce from vegetable oils can also be replaced the diesel fuel. The vegetable oils that extracted from various plant and seed contain 22% to 58% oil in the form of triglycerides. This triglycerides can be convert into monoglycerides by reacting triglycerides with methanol in the presence of sodium hydroxide and this monoglycerides is the pure biodiesel in the form of ester. USA shows the primary interest in soybean oil, while many European countries show interest in rapeseed oil like palm oil or coconut oil. In Asians and Europeans many seed oil is used for different purposes like in lamps, as a food material etc. The various chemical and physical properties of vegetable oils can be evaluated by using standard test methods. Some method are used for examine physical property like kinematic viscosity (KV), cetane number (CN), and carbon residue (CR), while the standard test methods are used for examine chemical property like fire point, sulfur content, iodine value, and saponification value. Gas chromatographic (GC) is used to examine fatty acid quantity compositions in oil samples. The chemical and physical property of different oil sample are given in table 7 as:
Table 7: Lists the physical and chemical properties of the various oil samples.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Vegetable oil</th>
<th>KV</th>
<th>CR</th>
<th>CN</th>
<th>HHV</th>
<th>AC</th>
<th>SC</th>
<th>IV</th>
<th>SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saybean</td>
<td>32.91</td>
<td>0.25</td>
<td>37.97</td>
<td>39.5</td>
<td>0.006</td>
<td>0.01</td>
<td>69.91</td>
<td>220.85</td>
</tr>
<tr>
<td>2</td>
<td>Sunflowerseed</td>
<td>34.4</td>
<td>0.28</td>
<td>36.7</td>
<td>39.6</td>
<td>0.01</td>
<td>0.01</td>
<td>132.32</td>
<td>192.1</td>
</tr>
<tr>
<td>3</td>
<td>Sesame seed</td>
<td>36.0</td>
<td>0.25</td>
<td>40.4</td>
<td>39.5</td>
<td>0.002</td>
<td>0.01</td>
<td>91.81</td>
<td>211.04</td>
</tr>
<tr>
<td>4</td>
<td>Rapeseed</td>
<td>37.3</td>
<td>0.31</td>
<td>37.5</td>
<td>39.8</td>
<td>0.006</td>
<td>0.01</td>
<td>108.04</td>
<td>197.07</td>
</tr>
<tr>
<td>5</td>
<td>Safflowerseed</td>
<td>31.6</td>
<td>0.26</td>
<td>42.0</td>
<td>39.5</td>
<td>0.007</td>
<td>0.01</td>
<td>140.04</td>
<td>190.25</td>
</tr>
<tr>
<td>6</td>
<td>Castor</td>
<td>29.8</td>
<td>0.22</td>
<td>42.3</td>
<td>37.5</td>
<td>0.01</td>
<td>0.01</td>
<td>88.72</td>
<td>202.71</td>
</tr>
<tr>
<td>7</td>
<td>Bay laurel leaf</td>
<td>23.2</td>
<td>0.2</td>
<td>33.6</td>
<td>39.3</td>
<td>0.006</td>
<td>0.01</td>
<td>69.91</td>
<td>220.83</td>
</tr>
<tr>
<td>8</td>
<td>Linseed</td>
<td>28.1</td>
<td>0.25</td>
<td>27.7</td>
<td>39.4</td>
<td>0.01</td>
<td>0.01</td>
<td>157.13</td>
<td>189.13</td>
</tr>
<tr>
<td>9</td>
<td>Peanut kernel</td>
<td>40.0</td>
<td>0.22</td>
<td>53.01</td>
<td>40.04</td>
<td>0.01</td>
<td>0.02</td>
<td>98.62</td>
<td>197.67</td>
</tr>
<tr>
<td>10</td>
<td>Corn Marrow</td>
<td>34.8</td>
<td>0.22</td>
<td>37.5</td>
<td>39.6</td>
<td>0.01</td>
<td>0.01</td>
<td>119.41</td>
<td>194.14</td>
</tr>
<tr>
<td>11</td>
<td>Almond kernel</td>
<td>34.2</td>
<td>0.22</td>
<td>34.5</td>
<td>40.01</td>
<td>0.01</td>
<td>0.01</td>
<td>102.35</td>
<td>197.6</td>
</tr>
<tr>
<td>12</td>
<td>Cotton seed</td>
<td>33.8</td>
<td>0.26</td>
<td>33.8</td>
<td>39.4</td>
<td>0.02</td>
<td>0.01</td>
<td>113.2</td>
<td>207.73</td>
</tr>
<tr>
<td>13</td>
<td>Olive kernel</td>
<td>29.4</td>
<td>0.23</td>
<td>49.4</td>
<td>39.7</td>
<td>0.007</td>
<td>0.02</td>
<td>100.16</td>
<td>196.83</td>
</tr>
<tr>
<td>14</td>
<td>Walnut kernel</td>
<td>36.8</td>
<td>0.24</td>
<td>33.6</td>
<td>39.6</td>
<td>0.02</td>
<td>0.02</td>
<td>135.28</td>
<td>190.85</td>
</tr>
<tr>
<td>15</td>
<td>Poppysseed</td>
<td>42.4</td>
<td>0.25</td>
<td>36.7</td>
<td>39.6</td>
<td>0.02</td>
<td>0.01</td>
<td>117.01</td>
<td>197.21</td>
</tr>
<tr>
<td>16</td>
<td>Wheat grain</td>
<td>31.9</td>
<td>0.23</td>
<td>35.2</td>
<td>39.3</td>
<td>0.02</td>
<td>0.02</td>
<td>120.96</td>
<td>206.17</td>
</tr>
</tbody>
</table>

Where,
- KV is Kinematic viscosity in mm²/s at 311 K,
- CN is Cetane Number,
- IV is Iodine value in centigram I/g Oil,
- SC is Sulfur content in wt%,
- SV is Saponification value in mg KOH/g oil,
- HHV is Higher heating value in MJ/kg,
- CR is Carbon residue in wt%,
- AC is Ash content in wt%.
2.7.2 Advantages and Disadvantages of vegetable Oils Used in Diesel Engines

The different types of vegetable oils are used as an alternative renewable fuel in different engines due to the following advantages:

1. Easy Portability,
2. Due to their easy availability,
3. Due to the renewal nature,
4. At burning result higher amount of heat release,
5. At burning leave less amount of sulfur particle,
6. Vegetable oil contain lesser amount of aromatic particle,
7. Best and optimize biodegradable property.

Complete combustion of a fuel in cylinder is take place only when stoichiometric ratio of air fuel ratio is present. But it is not completion when stoichiometric amount of air fuel ratio not present because of oxygenated property of fuel. Mainly the oxygen particle is responsible for the combustion efficiency of fuel and since vegetable oil consist high amount of oxygen particle they shows the higher combustion efficiency and also shows the higher cetane number than fossil diesel. Due to this reason the combustion efficiency of alcohols are higher than fossil petroleum.

The disadvantages of vegetable oils based fuel are:

- Due to triglyceride present in vegetable oil shows higher viscosity,
- Non mixing with and other fluid shows lower volatility,
- Due to presence of long unsaturated hydrocarbon chain in vegetable oil shows different reactivity.

The different vegetable oil can be used for operating various engines. But various problems are like carbon deposition, gum formation, fuel injector choking, oil ring sticking and not proper atomization of fuel in engine. Some problems are short time and some problems are long time. These problems are due to triglyceride present in vegetable oil and non-mixing nature of vegetable oil with other fluid, these problems can be remove by preheating, mixing with fossil fuel and by transestrification reaction.
2.8 Preparation of Biodiesel

As the crude fuel resource is non-renewable and limited, so the fuel price at faster pace is continuously increases for regularly fulfillment of demand and diminishing supply. By continuously consumption of fossil fuel or crude oil results, there is speedy declining in reserve of fossil fuels. The most important point is that the fuel prices have strongly goes on increasing that will create the interest in the use of bio-oils. In our modernization life there is regularly and very faster consumption of crude oil but the resource of crude oil are limited so that there is a necessity to invent an option for future to find an alternate of diesel/petrol which is most optimal, renewable and easily accessible in nature. So there is great interest has been arising in production of bio fuel from vegetable oils as alternative fuels for diesel engine.

The various process uses for bio fuel production are;

1. Pyrolysis of Vegetable Oils,
2. Cracking of Vegetable Oils.

2.8.1 Pyrolysis of Vegetable Oils

Pyrolysis involve the various steps initiate with preheating of vegetable oil is heated to get thermal degradation of triglyceride form into monoglyceride. This step not requires any catalysts and oxygen also. The final result of this process is production of aromatic compound, alkenes, alkadienes, and alkanes. According to pyrolysis process’s operating condition these processes can be following types as:

1. Classical and ordinary process,
2. Speedy process,
3. Fire process.

2.8.2 Cracking of triglyceride oil

Cracking is then process in which heavy molecular weight particle (like large alkane molecules) can be transform into lighter weight particle (like small alkane molecules) with the help of temperature. In the hydrocracking process larger hydrocarbons can be convert into smaller hydrocarbons, with the help of hydrogen and catalyst, at 273 °C temp. to 385 °C tempareturer, at high pressure. The presence of catalyst in cracking process not only increases the yield of petroleum but also improves the quality of the petroleum by breaking large hydrocarbons into smaller hydrocarbons.
2.9 Triglyceride Analyses

2.9.1 Viscosity

Viscosity may be defined as a fluid property which create or measure the internal oppose/ friction in any dynamic change of flowing fluid. Or Viscosity of the fuel may be defined as if we divide the fuel in different layer then the resistance force exerted to oppose the flow of fuel. High viscosity must causes low atomization and high penetration of the nozzle jet. On the other hand, very low viscosity of fuel would cause the leakage problems of piston and piston wall. Vegetable oils are more viscous than fossil diesel. The viscosity of pure vegetable oil based biodiesel can be reduced with the help of blending process or by mixing the pure biodiesel with alcohol.

2.9.2 Density

Density is defined as ratio of mass contain by object to the volume occupy by that object. Density is an important property of fuel at a given temperature. While the specific gravity may be define as ratio of density of an object to the density of water. So, during diesel engine performance density is importance parameter that measures the fuel injection volume.

2.9.3 Cetane Number

The cetane number (CN) is a number that estimate the quantity of ignition and finally measure the ignition delay and CN measure the how much time require igniting the liquid fuel when injected into the engine cylinder head in the compression process of an engine. CN is depend on two particle like,

1. Hexa-decane, having CN 100,
2. Hepta-methylnonane, having CN 15.

Saturated hydrocarbons that have straight chain of hydrocarbon have higher CN than the hydrocarbons that contain same amount of carbon atom and equal molecular weight but branched chain or aromatic compounds have lower CN.

2.9.4 Cloud Point and Pour Point

These two points are used to indicate the temperature application during winter (for low-temperature applications) usability of a fuel. Cloud point (CP) is the point of temperature under cooled condition, the first crystal of cloud is obtained. While the pour point (PP) is the point of
under cooled condition a sufficient amount of wax is obtained from the gelly solution fuel; thus pour point is the minimum temperature at which fuel can start to flow.

2.9.5 Distillation Range
It is the property of liquid fuel which explains the boiling temperature limit range by different methods. The distillation range is the important parameters that must be require maintaining the safety and performance of that fuel. This property can measure the engine warm up and start position parameters. When distillation of vegetable oils are observed then there are two-phase of distillations. Primary stage evaluation examine the C-H bonding present in that fuel, because the different vegetable oil having different C-H bonding strength. Secondary stage examines the soap formation property of different vegetable oil.

2.9.6 Calorific Value
This property of a fuel gives the amount of heat energy release when burning process of a fuel take place. Calorific value of a fuel also refers as the heating value of a fuel during combustion. Calorific value may be define during the burning process of a fuel if unit quantity of mass is burn and then how much amount of energy is released. It is generally determined by the use of bomb calorimeter.

2.9.7 Water Content
This property of a fuel gives the quantity of water or moisture present in that particular fuel and how much amount of water quantity is present. So by calculate the quantity of water present in a fuel it is very easy to find out the how much quantity of pure fuel is present. To determine the water content present in fuel, different methods like distillation and evaporation can be used in evaporation method the mass of evaporated water vapors is calculated with the help of evaporation method. While in distillation method the amount of distilled water is calculated with the help of distillation process. Table 8 shows the different vegetable oil with their different properties.
Table 8; different 20 vegetable oil having different property like density, viscosity, flash point and distillation range.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Vegetable oil</th>
<th>Viscosity mm2/s</th>
<th>Density in gm/liter</th>
<th>Flash point in ºC</th>
<th>Distillation limit range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anthus</td>
<td>29.9</td>
<td>919</td>
<td>267</td>
<td>423–623</td>
</tr>
<tr>
<td>2</td>
<td>Bay</td>
<td>22.9</td>
<td>922</td>
<td>259</td>
<td>418–618</td>
</tr>
<tr>
<td>3</td>
<td>Beech</td>
<td>34.7</td>
<td>916</td>
<td>268</td>
<td>428–633</td>
</tr>
<tr>
<td>4</td>
<td>Beech nut</td>
<td>37.9</td>
<td>913</td>
<td>278</td>
<td>428–636</td>
</tr>
<tr>
<td>5</td>
<td>Corn</td>
<td>35.2</td>
<td>909</td>
<td>283</td>
<td>428–638</td>
</tr>
<tr>
<td>6</td>
<td>Cotton</td>
<td>34.1</td>
<td>916</td>
<td>273</td>
<td>443–638</td>
</tr>
<tr>
<td>7</td>
<td>Cramb</td>
<td>53.0</td>
<td>905</td>
<td>291</td>
<td>–</td>
</tr>
<tr>
<td>8</td>
<td>Hazel nut</td>
<td>24.0</td>
<td>922</td>
<td>261</td>
<td>433–623</td>
</tr>
<tr>
<td>9</td>
<td>Linseed kernel</td>
<td>27.2</td>
<td>923</td>
<td>271</td>
<td>438–638</td>
</tr>
<tr>
<td>10</td>
<td>Mustard oil</td>
<td>34.1</td>
<td>919</td>
<td>270</td>
<td>440–640</td>
</tr>
<tr>
<td>11</td>
<td>Peanut</td>
<td>39.6</td>
<td>904</td>
<td>284</td>
<td>440–644</td>
</tr>
<tr>
<td>12</td>
<td>Poppy</td>
<td>42.4</td>
<td>908</td>
<td>281</td>
<td>443–643</td>
</tr>
<tr>
<td>13</td>
<td>Rapeseed</td>
<td>37.3</td>
<td>913</td>
<td>277</td>
<td>--</td>
</tr>
<tr>
<td>14</td>
<td>Safflower</td>
<td>31.3</td>
<td>915</td>
<td>277</td>
<td>438–641</td>
</tr>
<tr>
<td>15</td>
<td>H.O.</td>
<td>41.2</td>
<td>903</td>
<td>286</td>
<td>–</td>
</tr>
<tr>
<td>16</td>
<td>Sesame</td>
<td>35.5</td>
<td>913</td>
<td>278</td>
<td>–</td>
</tr>
<tr>
<td>17</td>
<td>Soybean</td>
<td>32.6</td>
<td>915</td>
<td>275</td>
<td>–</td>
</tr>
<tr>
<td>18</td>
<td>Spruce</td>
<td>35.6</td>
<td>915</td>
<td>267</td>
<td>423–623</td>
</tr>
<tr>
<td>19</td>
<td>Sunflower</td>
<td>33.9</td>
<td>917</td>
<td>280</td>
<td>428–634</td>
</tr>
<tr>
<td>20</td>
<td>Walnut kernel</td>
<td>36.8</td>
<td>913</td>
<td>274</td>
<td>433–628</td>
</tr>
</tbody>
</table>

2.10 Biodiesel

2.10.1 Introduction to Biodiesel

Biodiesel is the pure ester (monoglyceride) recovered by triglyceride of vegetable oil. Biodiesel is renewable in nature, emitted fewer amounts of environmental pollution gases and have better fuel
efficiency than petrodiesel. Biodiesel input as fuel for engine have a great potential regarding output. Biodiesel combustion in engine as like fossil diesel but biodiesel also control the pollution gases, with giving the better efficiency than fossil diesel. Due to the above reason biodiesel made from vegetable can be consider as a strong replacement fuel of fossil diesel for engine.

Now a day biodiesel is producing from various seed oil and vegetable oil like mustard oil, soybean, palm, Corn, jatropha, and some other rapeseed oil. The biodiesel release high heating value as compare to other some fossil diesel. Fossil diesel gives 43 MJ/kg; petroleum gives 42 MJ/kg, while biodiesel give 39 MJ/kg to 41 MJ/kg higher than coal heating value 32 MJ/kg.

The general representation of pure biodiesel by a symbol B100 and the general representation of biodiesel blending by a symbol Bxx, where xx gives about how much amount of biodiesel is mix with pure fossil diesel. eg. B60 blend means 60% biodiesel and 40% fossil diesel.

The conventional source of energy fulfill the mostly requirement of energy of the whole world. But these conventional energy sources are present in limited amount of reservoirs in certain fixed region of the universe. Due to this limited region of presence of conventional sources of energy becomes the biodiesel more attractive source of energy.

In many developed countries the various new technologies are developed for producing biodiesel which becomes biodiesel more competitive with fossil diesel regarding each factor like feasibility, price and enviormental concerns etc.

2.10.2 History of Biodiesel:

Biodiesel production from vegetable oil and seed are not new process. The process of biodiesel production is use basically since from 1800s to today. The conversion of triglycerides of vegetable oil into monoglyceride pure ester is known as transesterification reaction, and the transesterification reaction is used for biodiesel production.

Firstly, transesterification reaction is used by Duffy and Patrick in 1853.

The discovery of engine is start by German scientist Dr. Rudolph Diesel in 1893.

Dr. Diesel designed and introduced for work first Sadi Carnot engine run by vegetable oil in 1878. Because of the efficiency of Carnot theory based engine is higher than other engines. Compression ratio is the main parameter that must be directly responsible for the efficiency of Carnot engine. In 1876 Nicklaus Otto discover an engine in which fuel is burn in the cylinder
head with the help of spark plug. Spark plug ignites the air fuel mixture at fix time during the expansion stroke. Because due to compression the air becomes hotter and if there is high air fuel ratio is present then the higher temperature of compression will ignite the fuel before time of combustion. To avoid this premature burning of fuel compression ratio must be limited and this may result poor output.

2.10.3 Definitions of Biodiesel

Biodiesel made by two words, first is bio which mean life sources and other word is diesel that is comes from German scientist Rudolf Diesel. So biodiesel is refer to diesel equivalent fuel that is produced from biological sources. So biodiesel can be produced from various renewable biological sources like organic oil and fat, which is renewable in nature. Biodiesel is a variety of pure ester based monoglyceride that is produced from triglyceride of vegetable oil. Biodiesel is the pure ester (monoglyceride) recovers by triglyceride of vegetable oil. Biodiesel is renewable in nature, emitted fewer amounts of enviormental pollution gases and have better fuel efficiency than petrodiesel. Biodiesel input as fuel for engine have a great potential regarding output. Biodiesel combustion in engine as like fossil diesel but biodiesel also control the pollution gases, with giving the better efficiency than fossil diesel. Due to the above reason biodiesel made from vegetable can be consider as a strong replacement fuel of fossil diesel for engine. Now a day biodiesel is producing from various seed oil and vegetable oil like mustard oil, soybean, palm, Corn, jatropha, and some other rapeseed oil. Table 9 shows the technical properties of biodiesel as;

**Table 9: Technical properties of biodiesel**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Common chemical name</th>
<th>Fatty acid methyl ester</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Common name</td>
<td>Biodiesel</td>
</tr>
<tr>
<td>2</td>
<td>Carbon atom range present</td>
<td>C14–C24</td>
</tr>
<tr>
<td>3</td>
<td>Viscosity range at 313 K</td>
<td>20-44</td>
</tr>
<tr>
<td>4</td>
<td>Density range (kg/m3, at 288 K)</td>
<td>860–894</td>
</tr>
<tr>
<td>5</td>
<td>Boiling point range (K)</td>
<td>273-475</td>
</tr>
<tr>
<td>6</td>
<td>Flash point range (K)</td>
<td>430–455</td>
</tr>
<tr>
<td>7</td>
<td>Distillation range (K)</td>
<td>470–600</td>
</tr>
</tbody>
</table>
35

<table>
<thead>
<tr>
<th>9</th>
<th>Vapor pressure (mm of Hg, at 295 K)</th>
<th>Greater than 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Solubility in water</td>
<td>Insoluble in water</td>
</tr>
<tr>
<td>11</td>
<td>Physical appearance</td>
<td>Light to dark yellow</td>
</tr>
<tr>
<td>12</td>
<td>Odor</td>
<td>Light musty odor</td>
</tr>
<tr>
<td>13</td>
<td>Biodegradability</td>
<td>More biodegradable than fossil diesel</td>
</tr>
<tr>
<td>14</td>
<td>Reactivity</td>
<td>Less reactive</td>
</tr>
</tbody>
</table>

2.10.4 Biodiesel: Alternative Fuel

Biodiesel consist methyl esters as a major component. In our modernization life there is regularly and very faster consumption of crude oil but the resource of crude oil are limited so that there is a necessity to invent an option for future to find an alternate of diesel/petrol which is most optimal, renewable and easily accessible in nature. As the crude fuel resource is non-renewable and limited, so the fuel price at faster pace is continuously increases for regularly fulfillment of demand and diminishing supply. By continuously consumption of fossil fuel or crude oil results, there is speedy declining in reserve of fossil fuels. The most important point is that the fuel prices have strongly goes on increasing. Biodiesel can be made by vegetable oil with the help of a chemical reaction which is known as transesterification. Due to the renewable nature of vegetable oil the research has been more concentrate on biodiesel and considered as a best additive of fossil diesel. Biodiesel fuel also an eco-friendly and emitted lesser amount of pollution gases.

The biodiesel consist following advantages as:

(A) Renewability in nature and made easily anywhere,
(B) They are very environmentally friendly,
(C) Due to fossil fuel prices increase continuously biodiesel provide better economic potential,
(D) Biodiesel reduces a country’s dependency on imported petroleum.

So, biodiesel must be a better alternative fuel than fossil diesel.

2.10.5 Sources of Biodiesel

The vegetable oils are renewable in nature and can be used for biodiesel production. The important sources that used for biodiesel production are: Ailanthus, Bay laurel, Coconut, fish oil, Mahua, Beechnut, karanja, sesame, Sunflower, Jatropha, Soybean, Mustard oil, Peanut,
Rapeseed, Poppy seed, Sesame, groundnut, Rubber, Walnut kernel, Safflower, Corn, Beech, Crambe, almond, andirobabassu, Barley, camelina.

2.11 Biodiesel Production

For preparation of bio diesel from vegetable oil we prefer the transestrification reaction as

**Transesterification:**- Transesterification is the process in which the triglyceride of vegetable oil can be converted into glycerol or monoglycerol or ester when react with alcohol in the presence of strong acid or strong base. Transesterification reaction is also helpful to reduce the viscosity of biodiesel. Experimental study shows that the major variables affecting the transesterification reaction are: the molar ratio of alcohol and oil, temperature, reaction time, and mixing speed. The reaction temperature and reaction rate are two important factors that affect the yield of biodiesel production. Then with the help of washing remove the catalyst, soap and excess methanol from bio diesel.

Figure 9 is the reaction in which triglyceride of vegetable oil convert into monoglyceride or ester. A catalyst can improve the rate of reaction and also improve the biodiesel yield, because of its low cost of catalyst and increase rate of reaction. The transesterification reaction must need a strong acid or strong base as catalyst that breaks the oil triglyceride molecules into monoglyceride molecule that is pure form of ester and also give some by products like glycerin, soap etc. The main byproduct is glycerin.

\[
\begin{align*}
\text{CH}_2\text{OOC}\text{-}R_1 & \quad \text{R}_1\text{COO}\text{-}R & \quad \text{CH}_2\text{OH} \\
\text{CH}\text{OOC}\text{-}R_2 & + \quad 3\text{ROH} & \quad \text{Catalyst} & \quad \text{R}_2\text{COO}\text{-}R & + \quad \text{CH}\text{OH} \\
\text{CH}_2\text{OOC}\text{-}R_3 & \quad \text{R}_3\text{COO}\text{-}R & \quad \text{CH}_2\text{OH}
\end{align*}
\]

**Figure 9: Transesterification of triglycerides with alcohol**

Different types of transestrification reactions used for biodiesel production are;

1. Catalytic Transesterification,

2. Supercritical Alcohol Transesterification,

2.11.1 Catalytic Transesterification
This is the reaction of triglyceride of oil in which the pre heated oil can be react with large amount of alcohol or acid in the presence of catalyst. Catalytic transesterification can be use different alcohols like ethanol, methanol as well as different type of catalyst like NaOH, KOH, and H2SO4 etc.

2.11.2 Supercritical Alcohol Transesterification
Generally, methanol and ethanol are used in supercritical alcohol transesterification. But due to some drawbacks like soap formation, reduction of effectiveness of catalyst by consuming catalyst etc. shown by these alcohols will result higher biodiesel production cost and large consumption of energy. For remove these problems, biodiesel may be produced with supercritical methanol (SCM) is a transestrefication reaction in the absence of catalyst. Supercritical methanol reaction required very short time for reaction and requires pressures of 35 MPa to 60 MPa and temperatures of 525 K to 675 K.

2.11.3 Biocatalytic Transesterification Methods
Biocatalytic transesterification method is another process for producing biodiesel from triglyceride form of vegetable oil. In this method a Methyl acetate has been developed for biodiesel production.

2.12 By Products Recovery
After the biodiesel production process by transesterification pure biodiesel is separated and byproducts are collect separately. The important factors that must be satisfied for transesterification optimum yield:
(a) Time of reaction,
(b) Catalyst removal,
(c) Alcohol removal,
(d) Glycerol removal,
In the transesterification of mustard oil, first of all, take a 250 ml methanol CH3OH (90% pure)
in the glass container then mixed 150 ml NaOH of 1 Normality and swirl the container until methanol is completely dissolved in NaOH. When NaOH reacts with methanol CH3OH an exothermic reaction is take place due to which the glass container gets warm so it is very carefully done to swirl the mixture, safety precautions.

After that start to heat up the one liter pure mustard oil up to 60º C and then added this hot one liter mustard oil to the glass container and start to swirl the glass container up to 10 minutes so that the mustard oil is completely dissolve in the mixture. For separation of biodiesel from biodiesel to other byproduct the solution container is kept without undisturbed for 24 hours. The more time of separation gives the better result, that means gives more pure bio diesel.

After 24 hours there are two distinctive layers are appears in the glass container. The upper layer is more transparent as compare to lower layer. The upper layer consist the mixture of methyl esters, residual methanol and catalyst, and impurities, whereas the lower layer having a mixture of glycerol, excess of methanol, catalyst and impurities. The upper layer gives the 100% pure bio diesel and lower layer gives the concentrated glycerol. Then the pure mustard bio diesel is separated from the glass container if this bio diesel contains impurities like, methanol CH3OH, moisture and soap. The methanol and moisture can easily remove from the bio diesel by heating the bio diesel up to 100º C under reduced pressure by rotary evaporator.

2.13 Transesterification Reaction Mechanisms
Transesterification is the process of conversion of triglyceride to glycerol and ester. Another name of transesterification is alcoholysis, in the alcoholysis reaction one alcohol is replaced by other alcohol in place of ester just similar to hydrolysis process. In hydrolysis process water is used in place of alcohol. The trasesterification reaction reduces the viscosity of vegetable oil. Experimental study shows that the major variables affecting the transesterification reaction are: the molar ratio, temperature of reaction, time of reaction and water contents presence in feedstock oil. Then with the help of washing remove the catalyst, soap and excess methanol from bio diesel. Biodiesel yield can be increase by using an excess amount of the alcohol and to allow the various steps for biodiesel separation from the glycerol.
2.14 Properties of Biodiesels

The different property of biodiesel may be density, viscosity, cloud point and pour point, cetane number, distillation range, and fire point. The major variables factors that affecting the transesterification reaction are: the molar ratio, temperature of reaction, time of reaction and water contents presences in feedstock oil. With the help of transesterification reaction the viscosity of biodiesel must be reduce. The different properties of biodiesel are:

2.14.1 Viscosity

Viscosity may be defined as a fluid property which create or measure the internal oppose/ friction in any dynamic change of flowing fluid. Or Viscosity of the fuel may be defined as if we divide the fuel in different layer then the resistance force exerted to oppose the flow of fuel. High viscosity must causes low atomization and high penetration of the nozzle jet. On the other hand, very low viscosity of fuel would cause the leakage problems of piston and piston wall. Vegetable oils are more viscous than fossil diesel. The viscosity of pure vegetable oil based biodiesel can be reduced with the help of blending process or by mixing the pure biodiesel with alcohol.

2.14.2 Density

Density is defined as ratio of mass contain by object to the volume occupy by that object. Density is an important property of fuel at a given temperature. While the specific gravity may be define as ratio of density of an object to the density of water. So, during diesel engine performance density is importance parameter that measures the fuel injection volume.

2.14.3 Cetane Number

The cetane number (CN) is a number that estimate the quantity of ignition and finally measure the ignition delay and CN measure the how much time require igniting the liquid fuel when injected into the engine cylinder head in the compression process of an engine. CN is depend on two particle like,

1. Hexa-decane, having CN 100,
2. Hepta-methylnonane, having CN 15.
Saturated hydrocarbons that have straight chain of hydrocarbon have higher CN than the hydrocarbons that contain same amount of carbon atom and equal molecular weight but branched chain or aromatic compounds have lower CN.

2.14.4 Cloud Point and Pour Point
These two points are used to indicate the temperature application during winter (for low-temperature applications) usability of a fuel. Cloud point (CP) is the point of temperature under cooled condition, the first crystal of cloud is obtained. While the pour point (PP) is the point of under cooled condition a sufficient amount of wax is obtained from the gelly solution fuel; thus pour point is the minimum temperature at which fuel can start to flow.

2.14.5 Distillation Range
It is the property of liquid fuel which explains the boiling temperature limit range by different methods. The distillation range is the important parameters that must be require maintaining the safety and performance of that fuel. This property can measure the engine warm up and start position parameters. When distillation of vegetable oils are observed then there are two-phase of distillations. Primary stage evaluation examine the C-H bonding present in that fuel, because the different vegetable oil having different C-H bonding strength. Secondary stage examines the soap formation property of different vegetable oil.

2.14.6 Calorific Value
This property of a fuel gives the amount of heat energy release when burning process of a fuel take place. Calorific value of a fuel also refers as the heating value of a fuel during combustion. Calorific value may be define during the burning process of a fuel if unit quantity of mass is burn and then how much amount of energy is released. It is generally determined by the use of bomb calorimeter.

2.14.7 Water Content
This property of a fuel gives the quantity of water or moisture present in that particular fuel and how much amount of water quantity is present. So by calculate the quantity of water present in a fuel it is very easy to find out the how much quantity of pure fuel is present. To determine the water content present in fuel, different methods like distillation and evaporation can be use. In
evaporation method the mass of evaporated water vapors is calculated with the help of evaporation method. While in distillation method the amount of distilled water is calculated with the help of distillation process. The properties of biodiesel are similar to the properties of fossil diesel fuels.

Table 10 shows the basic standard require properties for biodiesel,

### Table 10: Basic Standard properties of biodiesel

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Property</th>
<th>Units</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Viscosity</td>
<td>mm²/s</td>
<td>23-55</td>
</tr>
<tr>
<td>2</td>
<td>Density</td>
<td>Kg/m³</td>
<td>850-910</td>
</tr>
<tr>
<td>3</td>
<td>Fire point</td>
<td>ºC</td>
<td>100-600</td>
</tr>
<tr>
<td>4</td>
<td>Cetane no.</td>
<td>No unit</td>
<td>50-110</td>
</tr>
<tr>
<td>5</td>
<td>Moisture presence</td>
<td>Mg/kg</td>
<td>0—500</td>
</tr>
<tr>
<td>6</td>
<td>Pure ester</td>
<td>%(m/m)</td>
<td>95—no limit</td>
</tr>
<tr>
<td>7</td>
<td>Sulphur</td>
<td>Mg/kg</td>
<td>0—10</td>
</tr>
<tr>
<td>8</td>
<td>Strong acid presence</td>
<td>mg</td>
<td>0—0.5</td>
</tr>
<tr>
<td>9</td>
<td>Iodine value</td>
<td>No unit</td>
<td>0—125</td>
</tr>
<tr>
<td>10</td>
<td>Stability time</td>
<td>hours</td>
<td>6—no limit</td>
</tr>
<tr>
<td>11</td>
<td>Glycerine</td>
<td>%(m/m)</td>
<td>0—0.02</td>
</tr>
</tbody>
</table>
Table 11 show the difference between fossil diesel and biodiesel are,

**Table 11: Difference between Fossil diesel and Biodiesel**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Property name</th>
<th>Fossil diesel value range</th>
<th>Biodiesel value range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flash point</td>
<td>Mini. 325 K</td>
<td>Mini. 403 K</td>
</tr>
<tr>
<td>2</td>
<td>Density</td>
<td>250–300 Kg/m³</td>
<td>850–910 Kg/m³</td>
</tr>
<tr>
<td>3</td>
<td>Viscosity</td>
<td>Mini. 15 mm²/s</td>
<td>Mini. 22 mm²/s</td>
</tr>
<tr>
<td>4</td>
<td>Cetane number</td>
<td>47–55</td>
<td>46–70</td>
</tr>
<tr>
<td>5</td>
<td>Fire point</td>
<td>60–70 °C</td>
<td>100–600 °C</td>
</tr>
<tr>
<td>6</td>
<td>Cloud point</td>
<td>256–265 K</td>
<td>262–289 K</td>
</tr>
<tr>
<td>7</td>
<td>Pour point</td>
<td>237–243 K</td>
<td>258–286 K</td>
</tr>
<tr>
<td>8</td>
<td>Specific gravity</td>
<td>840–860 kg/m³</td>
<td>860–895 kg/m³</td>
</tr>
<tr>
<td>9</td>
<td>Sulfur</td>
<td>0.04–0.01 wt.%</td>
<td>0.0000–0.0024 wt.%</td>
</tr>
<tr>
<td>10</td>
<td>Ash</td>
<td>0.06–0.01 wt.%</td>
<td>0.002–0.01 wt.%</td>
</tr>
<tr>
<td>11</td>
<td>Iodine number</td>
<td>–</td>
<td>60–135</td>
</tr>
<tr>
<td>12</td>
<td>Kinematic viscosity</td>
<td>1.9–3.8 at 313 K</td>
<td>3.6–5.0 at 313 K</td>
</tr>
<tr>
<td>13</td>
<td>Heating value</td>
<td>45.3–46.7 MJ/kg</td>
<td>39.3–39.8 MJ/kg</td>
</tr>
<tr>
<td>14</td>
<td>Pure ester</td>
<td>0% (m/m)</td>
<td>95%—no limit %m/m</td>
</tr>
<tr>
<td>15</td>
<td>Sulphur</td>
<td>5–15 Mg/kg</td>
<td>0–10 Mg/kg</td>
</tr>
<tr>
<td>16</td>
<td>Strong acid presence</td>
<td>2–4 mg</td>
<td>0–0.5 mg</td>
</tr>
<tr>
<td></td>
<td>Iodine value</td>
<td>Stability time</td>
<td>Glycerine</td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>----------------</td>
<td>-----------</td>
</tr>
<tr>
<td>17</td>
<td>0—125</td>
<td>1—300 hours</td>
<td>0% (m/m)</td>
</tr>
</tbody>
</table>

### 2.15 The main advantages and disadvantages of vegetable oil based biodiesel

The triglyceride of vegetable oil can be use as an alternative renewable fuel in different engine due to the following advantages;

1. Easy Portability,
2. Easy presence of vegetable oil everywhere,
3. Vegetable oil based biodiesel can be renewable in nature,
4. Due to presence of pure ester biodiesel show high heat efficiency,
5. Vegetable oil based biodiesel can be emitted lesser amount of sulphur content,
6. In vegetable oil based biodiesel lesser amount of aromatic content is presence,
7. Vegetable oil based biodiesel are more biodegradable.

Complete combustion of a fuel in cylinder is take place only when stoichiometric ratio of air fuel ratio is present. But it is not sufficient condition for burning that not only stoichiometric ratio is required but also there must be oxygenate property of fuel must be present. Because oxygen particle have better burning efficiency for burning process of the fuel.

Vegetable oil based biodiesel have following disadvantages;

1. Vegetable oil based biodiesel have higher viscosity. So there is big problem in atomization of fuel, when used in engine
2. Biodiesel are less volatile in nature,
3. Biodiesel are lesser reactive due to presence of unsaturated hydrocarbon chain,
4. Higher nitrogen oxide (NOx) emissions,
5. Biodiesel have high pour point and high cloud point,
6. Injector coking,
7. Lower energy content,
8. Due to lower energy produce by biodiesel engine speed and torque is lower,
9. Biodiesel is responsible for high engine wear,
10. High price,

When an engine is operate with vegetable oil based biodiesel then various problems are like carbon deposition, gum formation, fuel injector choking, oil ring sticking and not proper atomization of fuel in engine. Some problems are short time and some problems are long time. These problems can be remove by preheating, mixing with fossil fuel and by transestrification reaction.

2.16 Exhaust Gas Analysis with Biodiesel use
Fossil diesel release 20 to 50 times more sulfur content as compare to biodiesels. Biodiesel combustion also reduces the N2O emission make biodiesel more attractive than fossil fuel use. The amount of N2O reduction is strongly dependent upon concentration present initially in a particular fuel. The amount of N2O reduction also increases with increase in temperature. The amount of N2O and SO2 are depend on the initial amount of N2O and SO2 present in biodiesel and this initial amount depend on the species use for biodiesel production. The amount of CO2 emission can be reduce from a value 104 g/MJ to 77 g/MJ, when we use biodiesel in place of fossil fuel.