Biodiesel: Source, Production, Composition, Properties and Its Benefits

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Abstract: Biodiesel is an eco-friendly, alternative diesel fuel prepared from domestic renewable resources i.e. vegetable oils (edible or non-edible oil) and animal fats, that runs in diesel engines-cars, buses, trucks, construction equipment, boats, generators, and oil home heating units. Biodiesel has been gaining worldwide popularity as an alternative energy source because it is non toxic, biodegradable & non flammable. Various edible and non edible oils, like rice bran oil, coconut oil, Jatropha curcas, castor oil, cottonseed oil, mahua, karanja which are either surplus and are nonedible type can be used for preparation of biodiesel. Biodiesel can be used either in the pure form or as blends on conventional petrodiesel in automobiles without any major modifications. Its biodegradability makes it eco-friendly. It may lead to a revolutionary transformation of the current economic & energy scenario with an era of economic bloom & prosperity for our society. This review paper describes the production, its properties, composition and future potential of biodiesel.

Key words: degradation, employment generation, transesterification, biodiesel, biocatalyst

1 Introduction

Recent petroleum crisis (1), increasing cost and unavailability of petroleum diesel gave impetus to the scientists to work on alternative fuel, biodiesel. Biodiesel has been gaining worldwide popularity as an alternative energy source because it is non toxic, biodegradable & non flammable and has significantly fewer emissions than petroleum-based diesel (petrodiesel) when burned. Biodiesel is an eco-friendly, alternative diesel fuel prepared from domestic renewable resources i.e. vegetable oils (edible or non-edible) and animal fats, that runs in diesel engines-cars, buses, trucks, construction equipment, boats, generators, and oil home heating units. Various edible and non edible vegetable oils, like rice bran oil, coconut oil, Jatropha curcas, castor oil, cottonseed oil, mahua, karanja which are either surplus and are nonedible type, can be used for the preparation of biodiesel. (2). It is an alternative fuel derived from the conversion of agricultural lipids and a simple alcohol into fatty acid alkyl ester and glycerol and is defined as “mono alkyl esters of fatty acids derived from vegetable oil or animal fats”. These natural oils and fats are made up mainly of triglycerides. These triglycerides have striking similarity to petroleum derived diesel so that it is known as “biodiesel”.

Biodiesel functions in current diesel engines, and is a possible candidate to replace fossil fuels as the world’s primary transport energy source.
2 History

Transesterification of a vegetable oil was conducted as early as 1853, by scientists E. Duffy and J. Patrick, many years before the first diesel engine became functional. Rudolf Diesel’s prime model, a single 10 ft (3 m) iron cylinder with a flywheel at its base, ran on its own power for the first time in Augsburg, Germany on August 10, 1893. In remembrance of this event, August 10 has been declared International Biodiesel Day. Diesel later demonstrated his engine and received the “Grand Prix” (highest prize) at the World Fair in Paris, France in 1900. This engine stood as an example of Diesel’s vision because it was powered by peanut oil—a biofuel, though not strictly biodiesel, since it was not transesterified. He believed that the utilization of a biomass fuel was the real future of his engine. In a 1912 speech, Rudolf Diesel said, “the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time.” During the 1920s, diesel engine manufacturers altered their engines to utilize the lower viscosity of the fossil fuel (petrodiesel) rather than vegetable oil, a biomass fuel. The petroleum industries were able to make inroads in fuel markets because their fuel was much cheaper to produce than the biomass alternatives. The result was, for many years, a near elimination of the biomass fuel production infrastructure. Only recently have environmental impact concerns and a decreasing cost differential made biomass fuels such as biodiesel a growing alternative. In the 1990s, France launched the local production of biodiesel fuel (known locally as diester) obtained by the transesterification of rapeseed oil. It is mixed to the proportion of 5% into regular diesel fuel, and to the proportion of 30% into the diesel fuel used by some captive fleets (public transportation). Renault, Peugeot, and other manufacturers have certified truck engines for use with up to this partial biodiesel. Experiments with 50% biodiesel are underway. From 1978 to 1996, the U.S. National Renewable Energy Laboratory experimented with using algae as a biodiesel source in the “Aquatic Species Program”. A recent paper from Michael Briggs at the UNH Biodiesel Group, offers estimates for the realistic replacement of all vehicular fuel with biodiesel by utilizing algae that has a greater than 50% natural oil content.

3 Source of Biodiesel

Biodiesel can be produced by animal fats, cooking waste and vegetable oils. Biodiesel production from various vegetable oils in different countries is given in Table 1(3).

4 Production of Biodiesel

Sylwatk et al. (4) gave the method for biotechnical preparation of fatty acid methyl esters (biodiesel) based on whey. Biodiesel is produced in a combined microbial/chemical process in which Cryptococcus curvatus in a sterile whey fraction preferably deproteinized 20% whey concentration without further additives produces an intracellular fatty acid-rich triglyceride, “single cell oil”. After disruption of the cells, the oil is removed from the culture and cell fragments and is directly reacted to known chemicals to produce the fatty acid methyl esters.

Lee et al. (5) gave a one step process for manufacture of biodiesel and synthetic lubricating base oils from animal wastes and agricultural wastes. Animal derived feeds, as safe nutritional ingredients as well as fatty acid esters as biodiesel and synthetic lubricating base oils, were prepared from animal and plant derived agricultural wastes without prior fat or oil extension pro-

Table 1 Production of Biodiesel in Different Countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Source of biodiesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Soyabean (mustard is under study)</td>
</tr>
<tr>
<td>Brazil</td>
<td>Soyabean</td>
</tr>
<tr>
<td>Europe</td>
<td>Rapeseed oil (&gt;80%) and sunflower oil</td>
</tr>
<tr>
<td>Spain</td>
<td>Linseed and olive oil</td>
</tr>
<tr>
<td>France</td>
<td>Sunflower oil</td>
</tr>
<tr>
<td>Italy</td>
<td>Sunflower oil</td>
</tr>
<tr>
<td>Ireland</td>
<td>Animals fat, beef tallow</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Palm oil</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Palm oil</td>
</tr>
<tr>
<td>Australia</td>
<td>Animals fat, beef tallow and rapeseed oil</td>
</tr>
<tr>
<td>China</td>
<td>Guang pi</td>
</tr>
<tr>
<td>Germany</td>
<td>Rapeseed oil</td>
</tr>
<tr>
<td>Canada</td>
<td>Vegetable oil/animals fat</td>
</tr>
</tbody>
</table>
cesses that involved deactivation, fat hydrolysis and esterification, transesterification and separation processes.

Vicenta et al. (6) discussed the properties, combustion characteristics, advantages and production technologies involved in the use of methyl esters of sunflower oil fatty acids as an alternative to diesel fuel. The oil is extracted from the seeds, refined and subjected to transesterification. The combustion properties of the biodiesel are compared to those of diesel fuels, exhaust emissions show reduced level of CO, SO₂, particulates, aromatic hydrocarbons and increased levels of aldehydes.

Encinar et al. (7) described the preparation and properties of biodiesel obtained from Cyanara cardunculus oil. In this method of transesterification of Cyanara cardunculus oil by means of methanol, using sodium hydroxide, potassium hydroxide and sodium methoxide as catalysts. The objective of work was to characterize the methyl esters for use as biodiesels in internal combustion motors. The operation variables used were methanol concentration (5-21 wt%), catalyst concentration (0.1-1 wt%) and temperature (25-60 °C). The evolution of the process was followed by gas chromatography, for determining the concentration of the methyl esters at different reaction times. The biodiesel was characterized by determining its density, high heating value, cetane number, cloud and pour points, rams bottom carbon residue, flash and combustion points according to ISO norms. The biodiesel with the best properties was obtained using 15% methanol, sodium methoxide as catalyst (1%) and 60 °C temperature. This biodiesel has very similar properties to those of petroleum diesel.

Shah et al. (8) gave a method of production of biodiesel by lipase catalyzed transesterification of Jatropha oil. In the process of enzymatic transesterification of Jatropha oil, three different lipases (Chromobacterium viscosum, Candida rugosa and Porcina pancreas) were screened and only lipase from Chromobacterium viscosum was found to give appreciable yield. It was seen that immobilization of lipases and optimization of transesterification conditions resulted in adequate yield of biodiesel in the case of enzyme based process.

Du et al. (9) studied the effects of temperature, oil/alcohol molar ratio and byproduct glycerol during lipoenzyme TLIM-catalyzed continuous batch operation when short chain alcohols were used as the acyl acceptors. In noncontinuous batch operation, the optimal oil/alcohol ratio and temperature were 1:4 and 40-50 °C; however, during continuous batch operation, the optimal oil/alcohol ratio and temperature were 1:1 and 30 °C. 95% of enzymatic activity remained after 10 batches when iso-propanol was adopted to remove byproduct glycerol during repeated use of lipase.

Komers et al. (10) studied the biodiesel fuel obtained from rapeseed oil, methanol and KOH and presented a review paper on analytical methods in research and production of biodiesel. In this review the enumeration of the analytical methods used in the production of biodiesel were published till 1997. Some of the original methods for individual or simultaneous determination of the main components in the reaction mixture were described. All these methods can be also used to analyze the non equilibrium complex and heterogenous mixtures.

Hillon et al. (11) gave a method of producing biodiesel by a continuous process using a heterogenous catalyst. This catalyst consists of a mixed oxide of zinc and aluminium which promotes the transesterification reaction without catalyst loss. In this heterogenous process the catalyst was stable with no metal leaching, no formation of either glycerate salts or metal soaps.

5 General Method of Production of Biodiesel

5.1 Basic Technology

5.1.1 Chemical reaction

The feed stock is degummed, clarified and dried. The two step process involves the esterification of fatty acids with an acid catalyst followed by transesterification of triglycerides by an alkaline catalyst (12). Transesterification (13-15) is also called alcoholysis. It is displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis except that an alcohol is used instead of water. The reaction can be represented as shown below:

Equation 1 Chemical Reaction of Synthesis of Biodiesel.

\[
\begin{align*}
\text{CH}_2\text{COO-}R_1 + R''\text{COO-}R' & \rightarrow \text{CH}_3\text{OH} \\
\text{CH-COO-}R_2 + 3\text{R'OH} & \rightarrow \text{R''COO-}R' + \text{CHOH} \\
\text{CH}_2\text{COO-}R_3 + \text{R''COO-}R' & \rightarrow \text{CH}_3\text{OH}
\end{align*}
\]

Agro fat Alcohol Fatty acid esters Glycerol
This reaction is associated with several other side reactions, which if uncontrolled can severely hamper the product yield & quality. Some of the factors that affect the reaction kinetics are:

- Concentration of the catalyst.
- Presence of water and the subsequent soap formation.
- Presence of free fatty acids.
- Separation of glycerol phase.

Therefore, the key to a successful process technology is to have the above factors under control to get maximum yield & product purity.

5.1.2 Thermodynamics (16)

In the esterification reaction same type of bonds are broken and remade on either sides, so heat effects are bound to be low. Since both reactants and products are liquids, entropy change would be near zero. Hence, equilibrium constant (of order exp (-dG/RT)) is low. However equilibrium can be shifted, say by glycerol removal.

5.1.3 Reaction kinetics (16)

In chemical reaction, the effect of intermediate products such as mono & di-glycerides has to be considered. In the initial stages of reaction, production of methyl ester is rapid then diminishes & finally reaches equilibrium. The decrease in reaction rates is believed to be due to formation of glycerol as a second phase, which leads to a loss of methanol and catalyst. It is difficult to make general predictions, but the best kinetic model appears to be a pseudo-second order for the initial stages of reaction.

Komers et al. (17) studied the kinetics and mechanism of KOH catalyzed methanalysis of rapeseed oil for biodiesel production. The reaction of rapeseed oil with MeOH, catalyzed by KOH, consists of two sequences. The first sequence expressed the methanalysis of rapeseed oil to methyl esters (biodiesel) whereas the second sequence described the always present side reaction separation of glycerides and methyl esters by KOH. The proposed chemical model was described by a system of differential kinetic equations, which were solved numerically by two independent computing methods. Kinetic and equilibrium results were compared numerically and/or graphically with the experimental parameters.

5.1.4 Reactor types

5.1.4.1 Batch reactor

Batch routes are traditionally selected for slow reactions, but plants tend to be bulky & labor intensive.

5.1.4.2 CSTR

Since reactions are slow, CSTR is likely to low conversion for a given reactor volume.

5.1.4.3 Continuous reactor without recycle

Presents flow regime problems owing to low flows (however, literature reports that some success has been achieved with reaction columns oscillators).

5.1.5 Key unit operations

5.1.5.1 Liquid liquid operations

It can be handled by combination of gravity setters, coalescers or centrifuges depending on capacity and constraints.

5.1.5.2 Solvent recovery by distillation

Conventional, however, if ethanol is used then an azeotrophic separation is required for obtaining rectified spirit.

5.1.5.3 Oil degumming

Combination of hot water and acid degumming may be required depending on type of feed stock & route selected.

5.1.6 General method of manufacturing

Triglycerides are readily transesterified batch wise in the presence of alkaline catalyst at atmospheric pressure and at 60-70°C with an excess of methanol. The mixture at the end of reaction is allowed to settle. The lower glycerin layer is drawn off, while the upper methyl ester is washed to remove entrained glycerin and then processed further. The excess methanol is recovered in the condenser, sent to the rectifying column for purification and recycled.

5.1.7 Effect of different parameters on the production of biodiesel

5.1.7.1 Impurities

Impurities present in oils also effect conversion level. For alkali catalyzed transesterification, the glycerides and alcohol must be substantially anhydrous as water causes a partial saponification which produces soap(18), that consumes the catalyst, reduces the catalytic efficiency, as well as causing an increase in viscosity, the formation of gels, and difficulty in achieving separation of glycerol.

5.1.7.2 Alcohol type

Methanol and ethanol are most commonly used for transesterification of vegetable oils and fats but other alcohols can also be used. It is reported that yield of alcohol esters was the highest with methanol, as methanol is the shortest chain alcohol and is more reac-
tive to oil with the added advantage of alkali catalysts being easily soluble in methanol.

5.1.7.3 Reactants ratio

The stoichiometry of the transesterification reaction requires 3 mol of alcohol per mol of triglyceride to yield 3 mol of fatty esters and 1 mol of glycerol. The reaction is reversible so it is necessary to use either large excess of alcohol or to remove one of the products from the reaction mixture to favorably shift reaction to the product side.

5.1.7.4 Catalysts used in transesterification

Three type of catalysts are used in the production of biodiesel. These are:

5.1.7.4.1 Basic catalyst

Alkali catalyzed transesterification is much faster than other type of the catalysts. Alkalis included sodium hydroxide, sodium methoxide, sodium hydride, potassium hydroxide, potassium hydride etc.

5.1.7.4.2 Acid catalyst

However, if glyceride has a higher level of FFA and more water then acid catalyzed transesterification suitable, that can be sulphuric, phosphoric, hydrochloric or organic sulfonic acid. Acid catalyzed methylation is energy sensitive because it is usually conducted at high temperature. Palm oil with 3% \( H_2SO_4 \) gives highest yield of 78% of methyl esters (19) at 23:1 ratio.

5.1.7.4.3 Biocatalyst

Recovery of acid and alkali catalysts in the production of biodiesel is very difficult. it can effect the process economically as well as ecologically. Several reports describe enzymatic alcoholysis of vegetable oils. When \( \text{EtOH, iso-propanol, butanol and long chain alcohols were used as substrates, the oil were efficiently converted to their fatty acid esters. The efficiency of} \) conversion was low with methanol (21). Lipase catalyzed alcoholysis in the absence of solvent is important in industrial application. In an earlier study, the crude lipase from the yeast, \( \text{Cryptococcus spp.} \) was shown to possess considerable stability in solvents and it could be used for the hydrolysis of vegetable oils (20).

5.1.7.5 Reaction time

The conversion rate increases with time. On transesterification of beef tallow, the reaction time was determined. The reaction was very slow during the first minute due to the mixing and dispersion of methanol into beef tallow; from one to five minute reaction proceeded very fast. An approximate yield of 80 percent was observed after 1 min for soybean and sunflower oils at methanol to oil ratio of 6:1, 5percent of sodium methoxide catalyst at 60°C. After 1 hr, the conversions were almost the same (93-98 percent). The effect of reaction time for palm oil at 40:1 methanol: oil (mol/mol) with 5 percent \( H_2SO_4 (v/w) \) at 95°C for 9 hr., gave a maximum esters yield (20) of 97 percent.

5.1.7.6 Reaction temperature

The rate of reaction is strongly influenced by reaction temperature. However, given enough time, the reaction will proceed to near completion even at room temperature. Generally the reaction is conducted close to boiling point of methanol, 60-70°C, at atmospheric pressure. These mild reaction conditions, however, require the removal of free fatty acids from the oil. The pretreatment is not required if the reaction is carried out under high pressure (9000 kPa) and temperature (240°C). Under these conditions, simultaneous esterification and transesterification take place. The maximum yield of esters occurs at 60-80°C, with molar ratio of alcohol to oil of 6:1. Further increase in temperature has negative effect on the conversion.

5.1.7.7 Stirring effect

In the transesterification reaction, the reactants initially form a two phase liquid system. The reaction is diffusion controlled and poor diffusion between the phases results in a slow rate. As methyl esters formed, they act as a mutual solvent for the reactants and a single phase system is formed. The mixing effect is most significant during the slow rate region of reaction, as the single phase is established, mixing becomes insignificant. Conversion of soybean oil as a function of time and stirring (21) after optimization of the reaction conditions-methanol: oil ratio of 7.5:1 at 60°C with 1% sodium methoxide at 600 rpm-90% conversion was noted after 30 minutes.

6 Fatty Acid Composition of Biodiesel

Many Scientists have studied the Fatty acid composition of biodiesel obtained from different sources, some of those are given in Table 2.

7 Properties of Biodiesel

Biodiesel is an alternative source of energy that is replacing the use of gasoline & diesel. The emergence of biodiesel fuel substitutes has led to several studies on
their properties. Which are:

7.1 Surface Tension, Viscosity and Cloud Point

The ASTMD-445 specification for viscosity at 40 °C of 4 centistokes is generally met by biodiesel and biodiesel blends. However, the viscosity of biodiesel and its blends is higher than diesel. Soy methyl ester is reported to have a viscosity ranging from 3.8 to 4.1 centistokes at 40 °C. Glycerine contamination will cause biodiesel viscosity to increase, among other problems. Estimates of the surface tension of biodiesel suggest that it may be two to three times as great as that for diesel. Higher viscosity and cloud point is a major problem of using biodiesel in diesel engines. High viscosity of vegetables oils and animal fats tends to cause problems when directly used in diesel engines (24-27). These properties affect the fuel droplet size during injection. Biodiesel has both larger viscosity and surface tension, resulting in larger droplets, one of a number of contributing factors that have been identified as possible causes for higher NOx emissions. If the oils and fats are transesterified using short chain alcohols, the resulting monoesters have viscosities that are closer to petroleum based diesel fuel (28-30).

Noureddini et al. (31) investigated a system and process for producing biodiesel fuel with reduced viscosity and cloud point. In this process triglycerides were reacted in a liquid phase reaction with a homogenous basic catalyst and alcohols such as ethanol and methanol. The reaction yields a separated two phase result with an upper located non polar phase consisting principally of transesterified triglycerides and/or glycerol phase. Each separation was passed through strong cationic ions exchanger to remove anions, resulting in neutral product(s). The crude glycerol was then flashed to remove alcohols and was reacted with an etherifying agent such as isobutylene and iso-amylene, in the presence of a strong acid catalyst to produce glycerol ethers. The glycerol ethers were then added back to the transesterified triglycerides to provide and improved biodiesel with lower viscosity and cloud point.

7.2 Storage Stability/Oxidative Stability

Oxidative stability is a major industry issue for diesel and biodiesel fuels. Oxidative stability is measured by

<table>
<thead>
<tr>
<th>Oil or Fat</th>
<th>Fatty acid composition (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12:0</td>
</tr>
<tr>
<td>Babassu</td>
<td>44-45</td>
</tr>
<tr>
<td>Canola</td>
<td>4-5</td>
</tr>
<tr>
<td>Coconut</td>
<td>44-51</td>
</tr>
<tr>
<td>Corn</td>
<td>7-13</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>0.8-1.5</td>
</tr>
<tr>
<td>Linseed</td>
<td>6</td>
</tr>
<tr>
<td>Olive</td>
<td>1.3</td>
</tr>
<tr>
<td>Palm</td>
<td>0.6-2.4</td>
</tr>
<tr>
<td>Peanut</td>
<td>0.5</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>1.5</td>
</tr>
<tr>
<td>Safflower</td>
<td>6.4-7.0</td>
</tr>
<tr>
<td>Safflower (high oleic)</td>
<td>4-8</td>
</tr>
<tr>
<td>Sesame</td>
<td>7.2-9.2</td>
</tr>
<tr>
<td>Soybean</td>
<td>2.3-11</td>
</tr>
<tr>
<td>Sunflower</td>
<td>3.5-6.5</td>
</tr>
<tr>
<td>Tallow (beef)</td>
<td>3-6</td>
</tr>
</tbody>
</table>
ASTM D2274. It is reported that when compared to diesel, biodiesel fuels were far more prone to oxidation. The degree of saturation of the fatty acid chains tends to be correlated with its stability. Stability of fatty compounds is influenced by factors such as presence of air, heat, traces of metal, peroxides, light, or structural features of the compounds themselves, mainly the presence of double bonds. The more conjugated or methylene-interrupted double bonds in a fatty molecule, the more susceptible the material is to oxidation and degradation.

Early storage tests gave the following decreasing order of stability for different refinement grades of various vegetable oils (32) soybean oil > degummed soybean oil > refined soybean oil = crude sunflower oil > degummed sunflower oil = crude sunflower oil. The stability of the crude and degummed oils was significantly improved by the addition of diesel fuel (in 1:1 mixtures) but this did not improve the stability of refined oils. The storage stability of 1:1 mixtures were in the decreasing order of crude soybean oil = crude sunflower oil > degummed soybean oil > degummed sunflower oil > refined soybean oil > refined sunflower oil. A degummed oil/diesel blend with better stability characteristics than that of a refined oil/diesel blend could be prepared. Additionally, the purity of the degummed oils was sufficiently improved by the addition of diesel fuel to meet the required fuel specification.

A study on the stability of the methyl and ethyl esters of sunflower oil reports that ester fuels (biodiesel) should be stored in airtight containers, the storage temperature should be < 30°C, that mild steel (rust-free) containers could be used, and that tert.-butylhydroquinone (TBHQ), an oxidation inhibitor, has a beneficial effect on oxidation stability (33). Methyl esters were slightly more stable than ethyl esters. Light caused only a small increase in the oxidation parameters of esters stored at the high temperature level. The changes in the samples were reflected by increasing acid and peroxide values in storage at 50°C and increases in ultraviolet (UV) absorption.

Two parameters, namely temperature and the nature of the storage container, were claimed to have the greatest influence on the storage stability (34). Samples stored in the presence of iron behaved differently than those stored in glass. Higher temperature favored degradation of the hydroperoxide at a faster rate than when it was stored at room temperature. Secondary oxidation products were formed in greater amounts in the presence of iron (from the primary peroxides) while in glass the concentration of primary oxidation products is higher. Acidity values were also monitored in this work. Even for samples stored at 40°C, the increase in free acids was within the limits of technical specifications. The free acids need to be controlled because they are mainly responsible for corrosion.

7·3 Crystallization Temperature

Biodiesel has low crystallization temperature as compared to petrodiesel. To reduce the tendency of biodiesel to crystallize at low temperatures, branched chain alcohols were used to esterify various fats and oils.

Dittmar et al. (35) investigated the production of biodiesel and studied the cold flow stability of fatty acids alkyl esters. According to this article, the cold resistance of biodiesel at low temperature arises many problems due to insufficient fuel supply. This phenomenon was investigated with regard to the fatty acid profile and structure of the alkyl groups of the fatty acid alkyl esters. In order to improve the cold resistance of biodiesel branched chain fatty acid alkyl esters were synthesized using different feedstock. The CFPP values were measured for the individual esters. The derived math-statistical dependence between the CFPP value and composition of biodiesel (determined by GC) were discussed.

Lee et al. (36) reduced the crystallization temperature of biodiesel by winterizing methyl soyate. The use of biodiesel fuels based on blends of methyl soyate and diesel fuel (soy diesel), is limited in spite of their environmental benefits (37-41). Problems with soy diesel often developed from plugged fuel lines and filters caused by crystallization of high melting saturated methyl esters at cold operating temperatures. The crystallization properties of biodiesel fuel traditionally methyl or ethyl esters of vegetable oils or animal fats can be improved by replacing the straight chain methyl or ethyl moieties with branched chain alcohol moieties, such as isopropyl or 2-butyl (42). Another alternative is to remove saturated methyl esters by inducing crystallization with cooling, and separating the high melting components by filtration, a process known as winterization. Winterization is commonly used in producing refrigerator-stable salad oils by removing components.
that are responsible for turbidity in certain vegetable oils (43-45). In this study, winterization was assessed as a process for reducing the crystallization temperature of biodiesel fuels, based on the methyl esters of typical and low palmitate soybean oil.

7.4 Cetane Number

Cetane number is widely used diesel fuel quality parameter related to the ignition delay time and combustion quality. The higher cetane no of biodiesel compared to petro-diesel indicates potential for higher engine tests have shown that bio diesel has similar or better fuel consumption, horse power and torque and haulage rates as conventional diesel.

The cetane number of the fuel, specified by ASTMD-613, is a measure of its ignition quality. The cetane number of biodiesel exceeds that of conventional diesel, which implies that biodiesel may provide cetane enhancement when used neat or in blends, and may provide emission benefits that have been correlated to cetane number. Higher cetane numbers (as high as 55 to 60) generally improve diesel emissions, but above that level little improvement is demonstrated. The cetane index is a calculated property that correlates well with cetane number for natural petroleum stocks, and is defined by ASTM-976. Cetane index is also a measure of fuel aromaticicity. It is not relevant to biodiesel. The cetane number of biodiesel depends on the oil or fat feedstock. Fatty acids consist of long chains of carbon atoms attached to carbonyl groups. Fats and oils contain a distribution of carbon chains of varying lengths, typically ranging from 10 to 18 carbons (referred to as C10 to C18 chains). Some carbon chains contain 0, 1, 2, or more double bonds between the carbons, and have carbonyl groups in different locations. Cetane number increases with chain length, decreases with number and location of double bonds, and changes with various locations of the carbonyl group. As bonds or carbonyl move toward the center of the chain, the cetane number decreases. Cetane numbers increases from 47.9 to 75.6 when the number of carbons in the fatty acids in biodiesel increases. When the number of carbons in the fatty acid chains exceeds C12, the cetane number exceeds 60. For soy methyl ester, reported cetane numbers range from 45.8 to 56.9. The variation is due to the distribution of carbon chain lengths in each fuel tested. The average of the available data is 51.3. Generally, the cetane number for a blend of biodiesel and conventional 2 diesel fuel is a nearly linear function equal to the average of the cetane numbers for the fuels. This implies that the neat cetane numbers for diesel and biodiesel can be used to estimate the cetane number over the entire range of mixtures of biodiesel with diesel fuel.

Knothe et al. (46) studied the cetane number of branched and straight fatty esters determined in an ignition quality tester. In this work, the cetane numbers of 29 samples of straight chain and branched chain C1-C4 esters as well 2-ethyl-hexyl-ester of various common fatty acids were determined. The cetane numbers of these esters are not significantly affected branching in the alcoholic moiety. Therefore, branched esters, which improved the cold flow properties of biodiesel, can be employed without greatly influencing ignition properties compared to the more common methyl esters. Unsaturation in the fatty acid chain was again the most significant factor causing lower cetane numbers.

Wong et al. (47) gave a green approach for the production of bio-cetane enhancer for diesel fuels. Catalytic hydro-treatment of vegetable oils and fats had been tested on a pilot scale to convert many types of biomass oil into a 60-90 cetane number middle distillate. This bio-cetane product can be used as a neat diesel fuel or as a blending agent for ordinary diesel fuel.

7.5 Flash Point

Flash point, as defined by ASTMD-93, is a measure of the temperature to which a fuel must be heated such that a mixture of the vapor and air above the fuel can be ignited. All conventional diesel fuels have high flash points (54°C, minimum; 71°C, typical). The flash point of neat biodiesel is typically greater than 93°C. The U.S. Department of Transportation considers a material with a flash point of 93°C or higher to be non hazardous. From the perspective of storage and fire hazard, biodiesel is much safer than diesel. In blends, the diesel flash point will prevail. The Engine Manufacturers’ Association expressed concern that the oxidative instability of some types of biodiesel may result in fuels that have unacceptably low flash points after storage. Some biodiesels have excellent storage histories; others have tended to oxidize rapidly. An ASTM test method on oxidative stability of biodiesel is under development to help researchers test biodiesel and determine its storage characteristics. The number and location of the double bonds have been identified as possibly contributing to
the instability of biodiesel fuels. Fatty acid chains can be saturated (adding hydrogen or alcohol) to reduce the number of double bonds, and it may be possible to remove the fatty acids with excessive double bonds if indeed, these characteristics are confirmed as sources of the problem. In addition, soy oil contains natural antioxidants, which can be added back to the fuel if removed during processing. The current minimum cetane number of 40 is intended to regulate the aromatic content in diesel fuel antioxidants have been identified that significantly reduce the amount of oxidation that occurs during storage. Research is continuing in this area.

7.6 Distillation

Biodiesel fuels have a narrow range of boiling points from 327°C to 346°C. Some B20 blends have met the ASTM-90 distillation specification, using ASTMD-86. However, others have reported that intake valve deposit formation is a problem with soy methyl esters at light load, which may be related to the large percentage of olefinic content in the B20 mixtures. Excess glycerine and glycerides in the fuel have also been associated with deposits. Quality control on biodiesel fuel standards was not evident before 1997 and remains an industry problem today; off spec fuel may also contribute to some of the fuel problems identified in past studies.

7.7 Specific Gravity

Specific gravity is determined by ASTM-287. Diesel exhibits a specific gravity of 0.85. Biodiesel specific gravity is reported to vary between 0.86 and 0.90 depending on the feedstock used. The average gravity reported for soy methyl esters is 0.885. The specific gravities of biodiesel and diesel are very similar.

7.8 Energy Content

Generally, fuel consumption is proportional to the volumetric energy density of the fuel based on the lower or net heating value. Petroleum diesel contains about 131,295 Btu/gal while biodiesel contains approximately 117,093 Btu/gal. If biodiesel has no impact on engine efficiency, volumetric fuel economy would be approximately 10% lower for biodiesel compared to petroleum diesel. However, fuel efficiency and fuel economy of biodiesel tend to be only 2%-3% less than that of diesel. The reasons behind this unexpected difference have not been established.

7.9 Flow Properties (cold temperature sensitivity)

The key flow properties for winter fuel specification are cloud and pour point. These are static tests that indicate first wax and non-flow temperatures for the fuel. Cloud point, as defined by ASTM-2500, is a measure of the temperature at which the first wax crystals form, and is related to the warmest temperature at which these will form in the fuel. Wax crystals cause fuel filter plugging. Pour point is a measure of the fuel gelling temperature, at which point the fuel can no longer be pumped. The pour point, as defined by ASTM-97, is always lower than the cloud point. Additives called flow improvers do not generally affect the cloud point of conventional diesel fuel; however, they do reduce the size of the wax crystallites that form when the fuel cools. Additives tend to allow the fuel filters to operate at lower temperatures. Diesel and kerosene are common pour point additives that reduce the fuel gelling temperature significantly when mixed with diesel. Refiners and marketers vary fuel cloud and pour points to meet local climatic conditions, and ASTM provides recommended fuel characteristics by season and be degree of latitude. The cloud point of soy methyl ester, used in this study, can be 30°C higher than that for diesel. The difference in pour points may be 10°C higher for soy methyl ester. The relevant structural properties of biodiesel that affect freezing point are degree of unsaturation, chain length, and degree of branching. Fully saturated fatty acid chains tend to become solids at relatively high temperatures (tallow, hydrogenated soy oil, palm oil). Rape and canola methyl esters have lower cloud and pour points than soy methyl ester. Tallow methyl ester has a cloud point of 16°C and a pour point of 10°C. Producing biodiesel with ethanol instead of methanol tends to reduce the cloud and pour points by a few degrees. Rape ethyl esters have cloud points of 10°C and a pour point of 15°C. Isopropyl alcohol has been used to make a biodiesel with a pour point 90°C lower than methanol-based biodiesel; pour point temperature was reduced by 30°C. Other solutions, such as customizing the fatty acid profiles of the fuel, remain possible but unexplored. Traditionally, cloud and pour points of biodiesel blends have been modified by changing the amount of biodiesel in the blends. Blends of more than 35% biodiesel demonstrate significant winter problems in the Midwest. In Europe, cold weather additives have been identified for use with rape
methyl esters, but they are not effective with soy methyl esters. Several studies have shown that a number of diesel flow improvers do not work for biodiesel blends. The biodiesel industry continues to fund research in this critical area. Currently, solutions are limited to recommending lower blends of biodiesel in the winter compared to summer, blending with diesel or kerosene, and using heated storage tanks and in-line fuel heating systems in vehicles.

There were two field demonstrations in the winter (1997-1998) using biodiesel blends of 20% to 35% in heavy-duty, on-road vehicles but the precautions discussed earlier have been taken. An approach being considered by the industry is marketing specific types of biodiesel to meet cold temperature by altering the types of alcohol and oil feed stocks used. By customizing seasonal fuel compositions, similar to diesel producers, more acceptances in cold weather could be established. Additives may still be necessary. A lot of research remains to be done in this area.

7.10 Sulfur, Aromatic, Ash, Sediments, Water, Methanol, Glycerine, and Glyceride Content

These contaminates, if they exist at all, are limited less than 2% in the biodiesel, in total. The ester content of a fuel-grade biodiesel generally exceeds 98%. Biodiesel is non aromatic and does not contain sulfur. Sodium and potassium containing ash may be present because of contamination from catalysts used in transesterification. Phosphorous may be present from inferior oil refining (poor gum removal). Water and sediments may be by-products of long-term storage. Glycerine and methanol in the biodiesel may scavenge water. Glycerine, glycerides, and excess alcohol are major fuel contamination problems, and newly developed industry standards have taken aim at controlling these contaminants. Sediment may result from oxidation of esters and reactive glycerides in the fuel. Algae growth may also produce sediment.

8 Benefits of Biodiesel

8.1 Similar to Diesel Fuel

Biodiesel is similar to petroleum diesel fuel in many chemical and physical properties. Engine performance & the fuel consumption were favorable that make it better substitute to diesel fuel. The comparison of properties of vegetable oil biodiesels and standard specifications of diesel oil are given in Table 4 (49-54).

Development in many developing countries increases the energy demand. The demand for liquid fuels will increase by transportation, industry & generation of electricity. In addition, urgent protection of the remaining areas requires the substitution of firewood by liquid gas, which leads to increase imports. Most of the developing countries including India are large petroleum importers & there dependence on external energy sources from highly unstable regions would increase to uncomfortable levels. India is sale of economic development is the need to import about 70 percent of its petroleum demand. The petroleum import bill is currently about 13 billion dollar (about 30 percent of the total import bill) compared to the current trade deficit of about USD 11 billion. The current yearly consumption of diesel fuel in India is approximately 40 percent of the total petroleum product consumption. The ongoing economic expansion would increase the demand for transportation fuel at high rates. India produces only 22% of its diesel requirement and 78% is imported at a huge cost in foreign currency and our expenditure and outlay for the import of Petroleum fuel is second to our Defence budget. Using biodiesel keeps our fuel buying dollars at home instead of sending it to foreign countries. This reduces our trade deficit and creates jobs so with the introduction of compulsory use of 10-20% biodiesel in UK, USA, France, Germany, Japan and other countries who specify a 40-50% mix by 2010. In India the import of liquid fuels creates approximately 850 jobs in saffination storage, distribution and administration. Because of tight economic situation the one and the only way to replace imported petroleum from the market is the production of alternative. According to an economic survey conducted by Government of India, the cultivable land area about 175 mha has been classified as waste or degraded land which is suitable for cultivation of some of the plant like Jatropha curcas. It is significant to point out that the non edible vegetable oil of Jatropha curcas has the requisite potential of providing a promising and commercially viable alternative to diesel as it has the desirable physicochemical and performance characteristics comparable to diesel to facilitate necessitating much change in design. Indian Railways have already completed a trial run on Amritsar-shatabdi express. The Chief Minister of Chattisgarh runs his official vehicle on biodiesel, Haryana state
### Table 3  Biodiesel Standard DIN V51606 (Germany) (48).

<table>
<thead>
<tr>
<th>Property</th>
<th>Min.</th>
<th>Limits</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 15°C, g/mL</td>
<td>0.875</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Kinetic viscosity at 40°C, mm²/s</td>
<td>3.500</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>Flash point (Pensky-Martens), °C</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Cold filter plugging point, °C 15 Apr-30 Sep 1 Oct-15</td>
<td>0.00</td>
<td>-10.00 -20.00</td>
<td>-10.00</td>
</tr>
<tr>
<td>Nov 16 Nov-28 Feb 1 Mar-14 April</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur, percent (w/w)</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon residue, percent (w/w), 10 percent distillation</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cetane number</td>
<td>49.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash, percent (w/w)</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water, mg/kg</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total dirt, mg/kg</td>
<td>20.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper corrosion for 3 h. at 50°C</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutralization no. mg KOH/g</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol, percent (w/w)</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monoglycerides, percent (w/w)</td>
<td>0.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diglycerides, percent (w/w)</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triglycerides, percent (w/w)</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free glycerol, percent (w/w)</td>
<td>0.02</td>
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<td></td>
</tr>
<tr>
<td>Iodine no. g Iodine/100 g</td>
<td>115.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus, mg/kg</td>
<td>10</td>
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</tr>
</tbody>
</table>

### Table 4  Properties of Vegetable Oil Biodiesel and Diesel Fuel 8.2 Economic Studies.

<table>
<thead>
<tr>
<th>vegetable oil</th>
<th>kinematic viscosity at 38°C (mm²/s)</th>
<th>cetane number (°C)</th>
<th>flash point (°C)</th>
<th>lower heating value (MJ/kg)</th>
<th>cloud point (°C)</th>
<th>density (kg/l)</th>
<th>pour point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>peanut</td>
<td>4.9</td>
<td>564</td>
<td>176</td>
<td>33.6</td>
<td>5</td>
<td>0.883</td>
<td>–</td>
</tr>
<tr>
<td>soyabean</td>
<td>4.5</td>
<td>45</td>
<td>178</td>
<td>33.5</td>
<td>1</td>
<td>0.885</td>
<td>–7</td>
</tr>
<tr>
<td>sunflower</td>
<td>3.6</td>
<td>63</td>
<td>127</td>
<td>31.8</td>
<td>4</td>
<td>0.875</td>
<td>–</td>
</tr>
<tr>
<td>palm</td>
<td>5.7</td>
<td>62</td>
<td>164</td>
<td>33.5</td>
<td>13</td>
<td>0.880</td>
<td>–</td>
</tr>
<tr>
<td>babassu</td>
<td>4.6</td>
<td>49</td>
<td>183</td>
<td>33.5</td>
<td>1</td>
<td>0.860</td>
<td>–</td>
</tr>
<tr>
<td>tallow</td>
<td>–</td>
<td>–</td>
<td>96</td>
<td>–</td>
<td>12</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>diesel</td>
<td>3.06</td>
<td>50</td>
<td>76</td>
<td>43.8</td>
<td>–</td>
<td>0.855</td>
<td>–16</td>
</tr>
<tr>
<td>20% biodiesel blend</td>
<td>3.2</td>
<td>51</td>
<td>128</td>
<td>43.2</td>
<td>–</td>
<td>0.859</td>
<td>–16</td>
</tr>
</tbody>
</table>

transport buses have been run from Kharagpur and all lands by the side of Railway tracks in India will be planted with *Jatropha* and Indian oil and other agencies in possession of a Biodiesel Processing units will eventually process the Jatropha oil into Biodiesel for Indian Railways and for the national needs.

In earlier studies of biodiesel production, the main economic criteria were capital cost, manufacturing cost and biodiesel break even price. Results of three recent studies are given in Table 5 (55) evaluated from economic feasibility of a plant producing approximately 10,000 tonne/year of biodiesel.

### 8.3 Sustainability & Non-Toxicity

Biodiesel is 100% renewable. Being plant based it does not emit sulphur/CO on burning and is non polluting, biodegradable and environmentally safe. Bunger *et al.* (56) studied the cytotoxic and mutagenic effects of diesel engine emissions using biodiesel and petroleum diesel as fuel. In this study the particulates associated emissions from the DEP of biodiesel and common petroleum diesel fuel and their vitro cytogenic and mutagenic effects were compared and the results showed the lower mutagenic potency of biodiesel as compared to diesel fuel.

### 8.4 Environmental and Health Effects of Biodiesel

In view of environmental considerations (57), biodiesel is considered ‘carbon neutral’ because all the carbon dioxide released during consumption had been sequestered from the atmosphere for the growth of vegetable oil crops. Studies have shown that the combustion of 1 l of diesel fuel leads to the emission of about 2.6 kg of CO₂ against 1 kg of CO₂/kg of biodiesel (58), so the use of biodiesel may directly displace this amount of CO₂ when used in engines. The combustion of biodiesel has been reported to emit lesser pollutants compared to diesel. The emission of SO₂, soot, CO, hydrocarbons (HC, polyaromatic hydrocarbons (PAH), and aromatics is given in Fig. 1 (59), which indicates that the engine exhaust contains no SO₂, and shows decreasing emissions of PAH, soot, CO, HC and aromatics. The NOx emissions are reported to be in the range between G 10% as compared to diesel depending on engine’s combustion characteristics.

Environmental problem that might crop up from increased fuel consumption also need taken into account. India has a huge requirement by 2010 to meet the world norms and emission standards and a national policy has already been given a green signal by the GOI in the year 2003. A Harvard University study has come out with the dramatic figure of death per hour in Delhi(INDIA) caused by air pollution. Increased green house gases and resultant climatic change has dramatically increased the number of natural disasters .Increased consumption of energy results in the increase release of green house gases into the atmosphere, mainly transport related pollutant emission causes air pollution. Biodiesel is nearly carbon-neutral, meaning it contributes almost zero emissions to global warming. Biodiesel also dramatically reduces other emissions fairly dramatically. For example the characteristics of Jatropha oil biodiesel are comparable to European specifications. The analysis of exhaust gases suggests that Jatropha oil biodiesel will be environmentally safer fuel. Tests conducted the USEPA have shown that the use of biodiesel almost completely eliminates life cycle of CO₂ emissions.

Makareviciene *et al.* (60) studied the environmental

<table>
<thead>
<tr>
<th>Table 5 Recent Studies on Capital Cost, Manufacturing and Break Even Price of Biodiesel (55).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nelson <em>et al.</em></strong></td>
</tr>
<tr>
<td><strong>Plant capacity</strong></td>
</tr>
<tr>
<td><strong>Process type</strong></td>
</tr>
<tr>
<td><strong>Raw material</strong></td>
</tr>
<tr>
<td><strong>Total capital cost</strong></td>
</tr>
<tr>
<td><strong>Total manufacturing cost</strong></td>
</tr>
<tr>
<td><strong>Biodiesel break-even price</strong></td>
</tr>
<tr>
<td><strong>Glycerine credit</strong></td>
</tr>
</tbody>
</table>
effect of the rapeseed oil ethyl esters. Exhaust emissions tests were conducted on rapeseed methyl esters, rapeseed oil ethyl esters and fossil fuels as well as on their mixtures. Results showed that when considering emissions of nitrogen oxides (NOx), carbon-monoxide and smoke, rapeseed ethyl esters had less negative effect on the environment in comparison with that of rapeseed oil methyl esters.

Zhang et al. (61) studied the biodegradability of biodiesel in the aquatic environment. The biodegradability of various biodiesel fuels were examined by the CO2 evolution method (EPA 560/682003), BOD (EPA 405.1), COD (EPA 410) and gas chromatography (GC) analysis in aquatic system. The fuel examined included the methyl and ethyl esters of rapeseed oil and soyabean oil, neat rapeseed oil, neat soyabean oil and phillips 2-D low sulphur, refined petroleum diesel. Blends of biodiesel/petroleum diesel at different volumetric ratios, including 80/20, 50/50, 20/80 were also examined. The results demonstrated that all the biodiesel fuels are readily biodegradable. In the presence of rapeseed ethyl ester, the degradation rate of petroleum diesel increased to twice that of petroleum diesel fuel alone. The pattern of biodegradation in the blends and reason why biodiesel is more readily degradable than petroleum were discussed. The biodegradation monitoring results from both, the CO2 evolution and GC methods were compared.

8·5 Good Lubricity and Long Engine Life
The super or lubricating properties of biodiesel increases functional engine efficiency. The biodiesel molecules are simple hydrocarbon chains having no sulphur or aromatic substances. They use higher amount of O2 (up to 10 percent) that ensures more complete combustion.

Ball et al. (62) studied the fuel lubricity from blends of di-ethanol-amine derivatives and biodiesel. The investigation relates to the use of blends of di-ethanol-amine derivatives and biodiesel as an additive for improving lubricity in low-S fuels (e.g. diesel fuel, jet fuel, kerosene, gasoline, gasoline alcohols blends) and to fuels and additives concentrations comprising the lubricity additives. Typically the additive can eliminate failure of a fuel injection pump caused by inadequate fuel lubricity.

Karonis et al. (63) studied the effect of the addition of biodiesels on the lubricity of Greek road diesel. In this study, a series of representative fuels of the Greek fuel market were tested. In some of them, the lubricity was measured three times, during a period of three months from the day of each sample was produced. In all cases a decrease of the wear scar diameter (WSD) was measured; this behaviour can be attributed to the oxidation reactions that take place during the storage period. In order to monitor the effect of the addition of biodiesel on the lubricity of road diesel, biodiesel produced from sunflower oil and olive oil were used. The use of rapeseed oil biodiesel as a diesel fuel substitute was a common event in central Europe; in the United States the soybean oil biodiesel has been examined in detail. However, biodiesels prepared from other starting materials, such as sunflower oil and olive oil had not been examined extensively, although the above types of vegetable oil comprise interesting candidates for biodiesel production in Southern Europe. The methyl esters of sunflower oil and olive oil were added in the diesel fuels in concentrations varying from 0.25 to 10 volume. In all cases noticeable decrease in WSD was observed, which eventually approached asymptotically a constant value.

8·6 Drivability
We have yet to meet anyone who doesn’t notice an immediate smoothing of the engine with biodiesel. It just runs quieter, and produces less smoke. Biodiesel can be used 10%, 20% or in any proportion doping the petro-diesel and it can be very safely used as 100% replacement of petro-diesel in all kinds of diesel engines without any modification of the currently available diesel engines.

Serdari et al. (64) studied the impact of using biodiesel of different origin and additives on the perform-
ance of a stationary diesel engine. With the exception of rapeseed oil which is the principal raw material for biodiesel production, sunflower oil, corn oil and olive oil, which are the abundant in the southern Europe, along with the some wastes such as used frying oils, appear to be attractive candidates for biodiesel production. In this study, the fuel consumption and exhaust emissions measurement from a single cylinder, stationary diesel engine were described. The engine was fueled with fuel blends containing four different types of biodiesel at proportions up to 100%; the further impact of the usage of two specific additives was also investigated. The four types of biodiesel were appeared to have equal performance, their addition to the traditional diesel.

9 Conclusion

Biodiesel is a better fuel than petrodiesel and meets most of the chemical/physical standards of Petrodiesel. Biodiesel can be considered as the best option and has the largest potential, which meets the requirements and could ensure fuel supply in the future. Plant oils, biodiesel, biogas and ethanol have been successfully introduced and are already in use. Fuels derive from biomass are not only potentially renewable but also sufficiently similar in origin to the fossil fuels to derived direct substitute. They can be converted into a wide variety of energy carriers (biogas, biodiesel, ethanol, methanol, DME, diesel, gasoline, hydrogen) as of recent fossil fuel through conversion technologies & thus have the potential to be significant new sources of energy into the 21st century. In future, alternative fuels should offer the possibilities to be used as the current fuels within existing infrastructure, to contribute in reduction of green house gases, to promote the development of new technologies of the recent combustion systems and energy generetics (i.e. fuel cells), to be affordable, sustainable and should be renewable.

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