A Review of Algae Biodiesel as an Alternative Fuel for Compression Ignition Engine

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Abstract

In the last few years, many researchers had carried out experiments on compression ignition engine for finding the alternative to Diesel fuel. The same was also published as a literature. The paucity of available petroleum product as well as its increasing cost plays a vital role in search of various biodiesel feedstocks. This paper is a review of various biodiesel feedstock potential as an alternative to fossil based petroleum diesel focusing on Algae Biodiesel and also describes the method for biodiesel production. The comparison of properties of various biodiesel is also given in tabular for better understanding. The comprehensive review revels that, the biodiesel obtained from algae have large potential and could be used as alternative fuel.

KEYWORDS: Review, Biodiesel, Feedstock, Algae, Thermo-Physical Properties.

1. INTRODUCTION:

Petroleum is the complex mixtures of chemical compound which are derived from crude oil and processed in oil refineries. This petroleum is transformed to various petroleum products, which are used as fuel for several applications.

Depending on crude oil composition and market oil refineries generate petroleum products. The largest one is fuel oil and gasoline. Jet fuel, diesel, heating oil are various grades and comparatively less volatile are converted in to asphalt, tar, paraffin wax, lubricating and other oils.

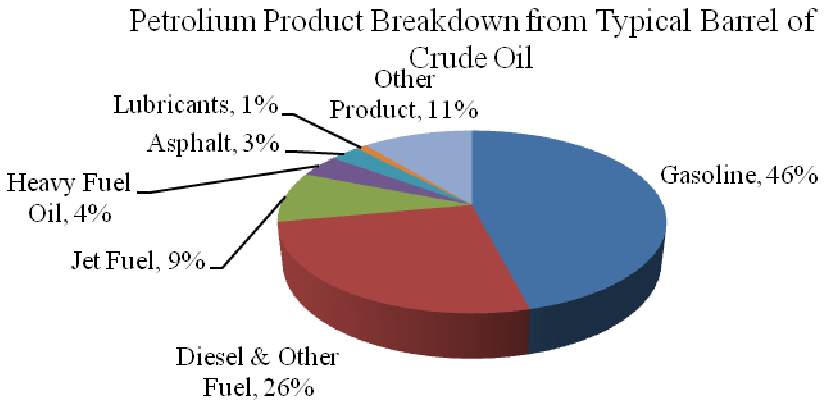

Figure 01: Petroleum Product Breakdown from Typical Barrel of Crude Oil

Biodiesel is a clean burning, Eco-Friendly natural fuel obtained from tree-born oils by a Chemical conversion process called as transesterification. Transesterification is an old chemical process and is a better method of Transforming Vegetable oils or fats into Biodiesel (Alkyl Esters of Fatty acids) and Glycerin plus some soaps etc.

Biodiesel refers to a non-petroleum-based diesel fuel consisting of short chain alkyl (methyl or ethyl) esters, prepared by Transesterification of vegetable oil or animal fat, which can be used purely, or blended form in unmodified diesel-engine vehicles.

Dr. Rudolf Diesel introduces the concept of bio fuel (Biodiesel) in 1985 by building the first diesel engine with the intention of running it on vegetative oils. In 1912 he observed that the use of vegetable oils for engine fuels may seem insignificant that day, but such oils play a vital role in future and become as key product as petroleum and the coal tar products.

A simple chemical process which could reduce the viscosity of vegetable oils considerably so that they perform as diesel fuel in modern engine was discovered by scientist in 1970. From that there is a great technical development which established the vegetable oil as bio fuel, equivalent to diesel now a day.

India is one of the largest petroleum consuming and importing country. The existing yearly consumption of diesel oil in India is approximately 40 million tones constituting about 40% of the total petro-product consumption. To fulfill this demand India imports about 70 % of petroleum. This demand can be satisfied in some proportion if biodiesel can be used as an alternative fuel for compression ignition engines. [2]

2. BIODIESEL FEEDSTOCKS

The interest in biodiesel is fueled by necessity to come across the sustainable alternative fuel to diesel. Because of environmental concern, dependency of conventional fuel this interest was increased more. There are several feedstocks' which will give the biodiesel. The quality of biodiesel depends on quality of feedstock, processing technology, catalyst used and off course the source. The various biodiesel feedstocks are discussed here.

A feedstock is defined as any renewable, biological material that can be used directly as a fuel, converted to another form of fuel or energy product or blended with petroleum. Biomass feedstocks are the plant and algal materials which are used to derive fuels like ethanol, butanol, biodiesel, and other hydrocarbon fuels.

a. Maize

At this time, maize in the USA provides more than half of all fuel ethanol produced in the world [IEA 2013]. There is larger increase in yield per hectare of maize than any other major crop in USA in last few decades. Currently maize production is more in comparison with any other grain or seed.

b. Sugarcane

Sugarcane is a chief crop grown in the tropical and subtropical regions of the world, producing 550Mt dry biomass in 2012. Sugarcane has a well-established agricultural production system and processing infrastructure to make it among the most advanced feedstocks for bio-energy. More notably, it has a positive net energy balance across a range of production systems and environments. It releases considerably less carbon oxides than petroleum when used to produce transportation fuel.

c. Oil Crops

The main feedstock for the production of biodiesel fuels are oil crops. The conversion of oil crops to biodiesel is more efficient than the conversion of starch or lignocelluloses crops to bioethanol in terms of cost and energy efficiency. Pure vegetable oils (100%) as well as its blends with diesel can be used in some engines but this can reduce engine lifetime. Almost all commercially available biodiesel is produced by transesterifying them to their methyl or ethyl ester derivatives, termed as fatty acid methyl esters (FAME). Different crop oils have different physiothermal properties which allow them to be blended with diesel to produce various types of biodiesel fuel. For example, for winter conditions, higher melting point blends are more suitable while more unsaturated lower melting point blends perform better under warmer/summer conditions. Catalytically hydrogenated oils are also used produce high performance blends which meet the required specifications for aviation and advanced diesel engines fuels.

The various vegetable oil feedstocks are discussed below.

a. Corn

Due to relatively high cost and high value as edible oil corn oil has not considered viable biodiesel feedstock in past. Corn oil feedstocks could help to meet market demand. But recently it attracts the researcher's interest.

b. Soybean

For the country like India soybean oil is important oil from economic point of view for the biodiesel since this oil is mainly used as edible oil. It is the less expensive and is the second most widely used vegetable oil after palm oil. Togetherlly (Palm and soybean oils) constitute approximately 68% of global eatable oil. Soya bean oil share is around 22.85%. Recently, Soybean oil trade has developed at the rate of 4.05% which indicates around 25% of the global aggregate oils and fats production. Brazil, China, Argentina, and India alongside USA are the significant contributors of soybean oil for the development. [3- 4]

c. Camelina

Camelina is said to be adapted to grow at any region where wheat can be grown for biodiesel production. Camelina production is pretty good; yield up to 2,200 pounds per acre. As per the research Camelina is an annual crop and can be planted on marginally productive cropland. More than 100 million gallons of oil could be added to the market depending on the production (Extraction) process..

d. Canola

In the 1970s, Canola was first developed. It is a type of rapeseed. This Canadian plant breeder developed for its nutritional advantages compared to industrial rapeseed. Because of its variety of uses and the nutritional value compared to contending crops, canola is most popular. In some countries where similar crops are unable to grow because of short growing seasons canola can be cultivated.

e. Brassica Juncea

The common name for multiple species in the *Brassica* genus is Mustard. Yellow mustard is the species of which people are aware. It also referred as white mustard in Europe. It is grown primarily for condiment mustard seed. It does not have high oil content as the other commonly known Indian mustard.

f. Jatropha

Jatropha is a small but versatile bush/tree. The tree flowers produces clusters of about 10-15 fruits with a seed containing high concentrations of oil. *Jatropha Curcas* is most popular potential feedstock for biodiesel production because of its high oil content and ability to grow in less than ideal conditions. However, large scale

production of jatropha is restricted because of harvesting and logistical challenges and abundance of low labor cost.

Previously, Jatropha has been grown in tropical areas including Africa and Asia, especially India. More recently, it has been grown almost in all around the world.

g. Peanuts

Among twenty four peanut varieties, Georganic or similar varieties may be considered as the future of peanut biodiesel. It can be planted and grown with just one herbicide application for weed control, compared to the others. Additionally, these are grown without fungicides, which are the greatest cost saving in traditional peanut production.

h. Chinese Tallow Tree

The Chinese tallow tree is a native plant of central China. The tree is favorably grown in warm climates with well-drained soils. The fruit is being harvested in early winter (spring). According to studies one seed of Chinese tallow tree contains about 20% oil, 24% tallow, 8% fibrous coat and 37% shell. The oil probably does not need refining.

i. Algae

Lipid production from algae holds much promising alternative for biodiesel industry. Microalgae are microscopic aquatic plants that carry out the mechanism of photosynthesis converting sunlight, water and carbon dioxide into biomass, lipids and oxygen. Algae production does not require fresh water or land used for cultivation of food crops. Biodiesel from algal lipids is very little up to date. Most of the algae production companies have pointed out that the biodiesel produced from algae will meet the ASTM D6751 specification. The oils production from algae species has a wide range & differs according to algal species.

There are again some more biodiesel feedstocks which are on research stage and got wide popularity as commercial biodiesel feed stock which include cottonseed, karanja, neem, kusum, kokum, jojoba, and Sal seed. The said feedstocks come under the non edible oil category in our country and hence can be used as biodiesel.

3. BIODIESEL CHEMISTRY

There are basically three methods for production of biodiesel from oils and fats

1) Transesterification base catalyst
2) Transesterification using Direct acid catalyst
3) Firstly Conversion of base oil to its fatty acid and then to biodiesel

Majority of biodiesels are produced by Transesterification base catalyst. It is economical and requires less temperatures and pressures and gives 98 percent yield conversion. Looking towards use, only transesterification is discussed in this paper.

a. Transesterification:

It is the chemical reaction of fat/oil (triglyceride) with an alcohol to form esters (methyl/ethyl) and glycerol. During transesterification, the oil is reacted with alcohol in the presence of strong alkaline catalyst such as sodium hydroxide. The alcohol is reacted with the fatty acid to form mono-alkyl ester, or biodiesel and crude glycerol.

Mostly methanol or ethanol is used with potassium or sodium hydroxide as catalyst. Methanol gives methyl esters whereas ethanol gives ethyl esters. Potassium hydroxide is more suitable for production of ethyl esters. The process is said to be successful when esters and glycerol layers are separated completely after reaction time. As glycerol is heavier, it settles down and can be sold as it is or after purification to pharmaceutical and cosmetic industries. [1-2]

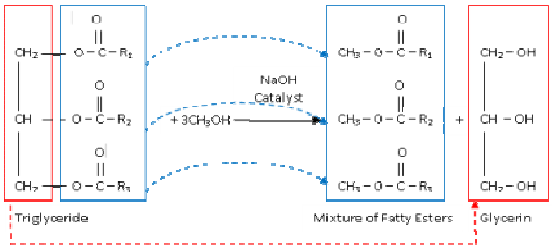

Figure 2: Biodiesel Production Chemistry

4. THERMO-PHYSICAL PROPERTIES

Table 1.Physical and thermal properties of vegetable oils [1, 2, 4]

Fuel Property/Fuel	Diesel	Corn	Cotton Seed	Peanut	Safflower	Soyabeen	Sunflower	Palm
Kinematic viscosity at 40^{O}C	2.5	34.9	33.5	39.5	31.3	32.6	33.9	39.6
Cetane No.	51	37.7	41.8	41.8	41.3	37.9	37.1	42
Cloud Point(^{0}C)	-	-1.1	1.7	12.8	18.3	-3.9	7.2	31
Pour Point (^{0}C)	15	-40	-15	-6.7	-6.7	-12.2	-15	
Flash Point (^{0}C)	66	277	234	271	260	254	274	267
Density (Kg/I)	0.830	0.909	0.914	0.902	0.914	0.913	0.916	0.918
Carbon Dregs (wt%)	-	0.24	0.24	0.24	0.25	0.27	0.23	
Sulphar (wt%)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	

5. ALGAE BIODISEL POTENTIAL

Algae Biodiesel

Various algae contain different levels of oil which make it best suitable for biodiesel. Algae consume carbon dioxide during biodiesel production process. That is, by means of photosynthesis, algae consume carbon dioxide from the atmosphere and replace it with oxygen. That's why algae biodiesel plants are close to energy manufacturing plants that produce lots of carbon dioxide. Recycling carbon dioxide reduces pollution. Algae also create a few more useful byproducts such as fertilizer and feedstock without depleting other food sources.

Algae biodiesel production (per acre per year depends) on:

- The type of algae being used
- The way the algae is grow
- The method of oil extraction

Potential of Microalgal Biodiesel

For the developing country like India, microalgae biodiesel will appears to be feasible solution to overcome petro-diesel demand. The estimated annual consumption of petroleum product in India is nearly about 120 million tones per year,

and no other feedstock except microalgae has the capacity to replace this large volume of oil.

for a crop like soybean or palm to acquiesce enough oil capable for replacement of petro-diesel completely, a huge percentage of land need to be utilized only for biodiesel crop production from available land, which is reasonably infeasible. For small countries, it is also impossible to dedicate available land only for biodiesel crop cultivation and production. Nevertheless, if the feedstock is to be algae, owing to its high oil yield per acre of cultivation, it has been calculated approximately that less than 2 to 3 % of total Indian cropping land is sufficient to produce enough biodiesel from algae to replace all petro-diesel demand in country. Obviously microalgae are superior alternative feedstock for large scale biodiesel production

6. CONCLUSION

Because of its environmental benefits and the fact that it is produce from renewable resources, biodiesel has become more attractive recently. Most biodiesel are chemically derived by esterification process, which brings a change in the molecular structure of the vegetable oil molecules, thus decreasing the levels of viscosity considerably. The calorific value of biodiesel was found to be a little bit lower in comparison with petro- diesel. The critical review revels that almost all the thermo-physical properties of biodiesel are in very close to the petro- diesel which makes it a potential candidate for the application in CI engines.

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