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BIODIESEL: A Review

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Abstract—Self-reliance in energy is vital for overall economic development of our country. The need to search for alternative sources of energy which are renewable, safe and non- polluting assumes top priority in view of the uncertain supplies and frequent price hikes of fossil fuels in the international market. Biodiesel has become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. The used cooking oils are used as raw material, adaption of continuous transesterification process and recovery of high quality glycerol from biodiesel by-product (glycerol) are primary options to be considered to lower the cost of biodiesel. There are four primary ways to make biodiesel, direct use and blending, micro emulsions, thermal cracking (pyrolysis) and transesterification. Biodiesel fuel typically comprises lower alkyl fatty acid (chain length C14–C22), esters of short-chain alcohols, primarily, methanol or ethanol. Methanol is the commonly used alcohol in this process, due in part to its low cost. Biodiesel seems to be a realistic fuel for future; it has become more attractive recently because of its environmental benefits. Biodiesel is an environmentally friendly fuel that can be used in any diesel engine without modification. This also includes production of biodiesel by transesterification of Jatropha Curcas oil.

Keywords— biodiesel, transesterification, Methanol, Jatropha Curcas, fossil fuel

I. INTRODUCTION

The scarcity of conventional fossil fuels, growing emissions of combustion-generated pollutants, and their increasing costs will make biomass sources more attractive [1]. Petroleum-based fuels are limited reserves concentrated in certain regions of the world. These sources are on the verge of reaching their peak production.

The fossil fuel resources are shortening day by day. The scarcity of known petroleum reserves will make renewable energy sources more attractive [2]. Biodiesel (Greek, bio, life + diesel from Rudolf Diesel) refers to a diesel-equivalent, processed fuel derived from biological sources. Biodiesel fuels are attracting increasing attention worldwide as a blending component or a direct replacement for diesel fuel in vehicle engines. Biodiesel, as an alternative fuel for internal combustion engines, is defined as a mixture of mono-alkyl esters of long chain fatty acids (FAME) derived from a renewable lipid feedstock, such as vegetable oil or animal fat. Rudolf Diesel tested vegetable oil as fuel for his engine [3]. With the advent of cheap petroleum, appropriate crude oil fractions were refined to serve as fuel and diesel fuels and diesel engines evolved together. In the 1930s and 1940s Vegetable oils were used as diesel fuels from time to time, but usually only in emergency situations. Recently, because of increases in crude oil prices, limited resources of fossil oil and environmental concerns there has been a renewed focus on vegetable oils and animal fats to make biodiesel fuels. Continued and increasing use of petroleum will intensify local air pollution and magnify the global warming problems caused by CO2 [3].

1.1 Advantages of biodiesel:

Biodiesel is the only alternative fuel that runs in any conventional, unmodified diesel engine. It is biodegradable, nontoxic and free of aromatics. It is a renewable fuel, based on oil crops or trees. 100% domestic fuel. Based on Ames Mutagenicity tests, Biodiesel provides a 90% reduction in cancer risks. Cetane number is significantly higher than that of conventional diesel fuel. Lubricity is improved over conventional diesel fuel. Has high flash point (more than 1200C) compared to that of conventional diesel, which has a flash point of 65-700C.Less consumption of environmental resources compared to fossil diesel and therefore, lowers environmental protection costs. Reduction in mineral oil imports and or petroleum diesel fuel imports [4].

1.2 Disadvantages of biodiesel:

The major disadvantages of biodiesel are its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide (NOx) emissions, lower engine speed and power, injector coking, engine compatibility, and high price [5]. The biodiesels on the average decrease power by 5% compared to that of diesel at rated load [6]. The maximum torque values are about 21.0 Nm at 1500 rpm for the diesel fuel, 19.7 Nm at 1500 rpm for the biodiesel. The torque values of commercial diesel fuel are greater than those of biodiesel. Peak torque applies less to biodiesel fuels than it does to No. 2 diesel fuel but occurs at lower engine speed and generally its torque curves are flatter [7]. The specific fuel consumption values of biodiesel are greater than those of commercial diesel fuel. The effective efficiency and effective pressure values of commercial diesel fuel are greater than those of biodiesel [8]. Important operating disadvantages of biodiesel in comparison with petrodiesel are cold start problems, the lower energy content, higher copper strip corrosion and fuel pumping difficulty from higher viscosity [9]. Fuel consumption at full load condition and low speeds generally is high. Fuel consumption
first decreases and then increases with increasing speed.

II. BIODIESEL STANDARDS

Fuel Property	Diesel	Biodiesel	Units
Fuel Standard	ASTM D975	ASTM D6751	
Lower Heating Value	~ l29,050	~ l 18,170	Btu/gal
Kinematic Viscosity @ 40^0 C	1.3 - 4.1	1.9 - 6.0	mm^2/s
Specific Gravity @ 60° C	0.85	0.88	kg/l
Density	7.079	7.328	lb/gal
Water and Sediment	0.05 max	0.05 max	% volume
Carbon	87	77	wt.%
Hydrogen	13	12	wt.%
Oxygen	0	11	
Sulphur	0.0015	0.0 to 0.0024	wt.%
Boiling Point	180 to 340	315 to 350	°C
Flash Point	60 to 80	130 to 170	° C

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Cloud Point	-15 to 5	-3 to 12	°C
Pour Point	-35 to -15	-15 to 10	°C
Cetane Number	40 to 55	47 to 65	
Lubricity SLBOCLE	2,000 to 5,000	>7,000	grams
Lubricity HFRR	300 to 600	<300	microns

Table 1: Selected Properties of Typical No. 2 Diesel and Biodiesel
Source: U.S. Department of Energy, Biodiesel Handling and Use Guidelines (2nd Edition, March 2006)

III. BIODIESEL PROCESS

3.1 Sources of biodiesel:

Typical raw materials of biodiesel are rapeseed oil, canola oil, soybean oil, sunflower oil and palm oil. Beef and sheep tallow and poultry oil from animal sources and cooking oil are also sources of raw materials. There are various other biodiesel sources: almond, andiroba (Carapa guianensis), babassu (Orbignia sp.), barley, camelina (Camelina sativa), coconut, copra, cumaru (Dipteryx odorata), Cynara cardunculus, fish oil, groundnut, Jatropha curcas, karanja (Pongamia glabra), laurel, Lesquerella fendleri, Madhuca indica, microalgae (Chlorella vulgaris), oat, piqui (Caryocar sp.), poppy seed, rice, rubber seed, sesame, sorghum, tobacco seed, and wheat [10]. Vegetable oils are renewable fuels. They have become more attractive recently because of their environmental benefits and the fact that they are made from renewable resources. Vegetable oils are a renewable and potentially inexhaustible source of energy, with energy content close to that of diesel fuel. Global vegetable oil production increased from 56 million tons in 1990 to 88 million tons in 2000, following a below-normal increase. The source of this gain was distributed among the various oils. Global consumption rose 56–86 million tons, leaving world stocks comparatively tight [10].Commonly accepted biodiesel raw materials include the oils from soy, canola, corn, rapeseed, and palm. New plant oils that are under consideration include mustard seed, peanut, sunflower, and cotton seed. The most commonly considered animal fats include those derived from poultry, beef, and pork [11]. Rapeseed has been grown in Canada since 1936. Hundreds of years ago, Asians and Europeans used rapeseed oil in lamps. Cottonseed oil is used almost entirely as a food material. Sesame, olive, and peanut oils can be used to add flavor to a dish. Walnut oil is high-quality edible oil refined by purely physical means from quality walnuts. Algae can grow practically anywhere where there is enough sunshine. Some algae can grow in saline water. All algae contain proteins, carbohydrates, lipids and nucleic acids in varying proportions. While the percentages vary with the type of algae, there are algae types that are comprised up to 40% of their overall mass by fatty acids [12]. The most significant distinguishing characteristic of algal oil is its yield and hence its biodiesel yield. According to some estimates, the yield (per acre) of oil from algae is over 200 times the yield from the best-performing plant/vegetable oils [13]. Microalgae are the fastest-growing photosynthesizing organisms. They can complete an entire growing cycle every few days. Approximately 46 tons of oil/hectare/year can be produced from diatom algae. Different algae species produce different amounts. Crude Jatropha oil, a non-edible vegetable oil shows a greater potential for replacing conventional diesel fuel quite effectively as its properties are compatible to that of diesel fuel. It is however found from researches that the neat Jatropha oil can be used to run the engines in mini-vans for rural transportation haulage trucks, farm tractors and other agricultural machinery, with or without modification in engine [4].

3.2 Feedstock preparation:

The healthy seeds are selected and are cleaned, dried at 100-105OC. For 30 minutes. The dried seeds were taken for oil extraction through ordinary mechanical oil extractor [4].

3.3 Pre-treatment:

In this method, the Jatropha oil is first filtered to remove solid material then it is preheated at 110o C for 30 min to remove moisture (presence of moisture responsible for saponification in the reaction)12 After demoisturisation of oil we removed available wax, carbon residue, unsaponificable matter and fiber that are present in a very small quantity [4].

3.4 Esterification:

Jatropha oil contains 6%- 20% (wt) free fatty acids. The methyl ester is produced by chemically reacting Jatropha oil with an alcohol (methyl), in the presence of catalyst. A two stage process is used for the transesterification of Jatropha oil. The first stage (acid catalysed) of the process is to reduce the free fatty acids (FFA) content in Jatropha oil by esterification with methanol (99% pure) and acid catalyst sulfuric acid (98% pure) in one hour time at 57^{o}C in a closed reactor vessel. The Jatropha crude oil is first heated to 50^{o}C and 0.5% (by wt) sulfuric acid is to be added to oil then methyl alcohol about 13% (by wt) added. Methyl alcohol is added in excess amount to speed up the reaction. This reaction was proceed with stirring at 650 rpm and temperature was controlled at 55-57^{o} C for 90 min with regular analysis of FFA every after 25-30 min. When the FFA is reduced upto 1 % , the reaction is stopped. The major obstacle to acid catalyzed esterification for FFA is the water formation. Water can prevent the conversion reaction of FFA to esters from going to completion19. After dewatering the esterified oil was fed to the transesterification process [14].

3.5 Transesterification Reaction:

Transesterification or alcoholysis is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except an alcohol is used instead of water.
This process has been widely used to reduce the high viscosity of triglycerides. Transesterification is a chemical reaction between triglyceride and alcohol in the presence of catalyst. It consists of a sequence of three consecutive reversible reactions where triglycerides are converted to diglycerides and then diglycerides are converted to mono-glycerides followed by the conversion of monoglycerides to glycerol. In each step an ester is produced and thus three ester molecules are produced from one molecule of triglycerides [15]. The transesterification reaction requires a catalyst such as sodium hydroxide to split the oil molecules and an alcohol (methanol or ethanol) to combine with the separated esters. Out of these three methods transesterification is the most viable process adopted known so far for the lowering of viscosity. It also gives glycerol
as a byproduct which has a commercial value. Among all these alternatives, transesterification seems to be the best choice as the physical characteristics of fatty acid methyl esters (biodiesel) are very close to those of diesel fuel and the process is relatively simple. In the esterification of an acid, an alcohol acts as a nucleophilic reagent; in the hydrolysis of an ester, an alcohol is displaced by a nucleophilic reagent. This alcoholysis (cleavage by an alcohol) of an ester is called transesterification [16].

IV. BIODIESEL ECONOMICS

India imports more than 40% of its edible oil requirement and hence non-edible oils are used for the development of biodiesel. India is a agrarian nation and has rich plant biodiversity which can support the development of biodiesel. India also has a vast geographical area with agricultural lands as well as wastelands on which oil bearing plants can be planted. Common non-edible oil bearing plants and trees include neem, karanja, mahua, jatropha, etc. The oil yields from these species at present are insufficient to meet the demand for raw material on large scale production of biodiesel. Hence, there has been government initiatives and interest from few private firms to enhance the production and distribution facilities of biodiesel throughout the country. The Petroleum Ministry has set a target for biodiesel to meet 20% of India's diesel demand. Government's initiative has resulted in large scale plantation of J. curcas in the state Andhra Pradesh. Oil and Natural Gas Corporation (ONGC) has planned to build an export oriented refinery at kakinada in Andhra Pradesh which will have a annual production capacity of 5.5–7.5 million tonnes [17]. Various factors contributing to the cost of biodiesel include raw material, other reactants, nature of purification, its storage, etc. However, the major factor which contributes the cost of biodiesel production is the feedstock, which is about 80% of the total operating cost [18]. The profits from glycerol and capital cost for operation was not included [19]. In a study of review on biodiesel production cost found the feedstock to contribute a substantial portion in production cost [20]. A process model was prepared by the author to estimate biodiesel production costs. Taking all the factors into account viz. raw material (vegetable oil, methanol, catalysts), utilities (electricity, etc.), labour, supplies, general works and depreciation, the cost of biodiesel was estimated to be US $0.561. The cost of biodiesel after blending with petrodiesel will reduce as the cost of biodiesel becomes less significant in blended form. At present, biodiesel can be blended with 80% petrodiesel (B20) without any engine modification.

V. CONCLUSION

This review suggests that the Jatropha oils can be used as a source of triglycerides in the manufacture of biodiesel by transesterification reaction. The biodiesel from refined vegetable oils meets the Indian requirements of high speed diesel oil. But the production of biodiesel from edible oil is currently much more expensive than diesel fuels due to relatively high cost of edible oil. There is a need to explore nonedible oils as alternative feed stock for the production of biodiesel non-edible oil like Jatropha. It is easily available in many parts of the world including India and it is cheaper compared to edible oils. Edible oils are in use in developed nations such as USA and European nations but developing nations are not self sufficient in the production of edible oils and hence have emphasized in the application of a number of non-edible oils. In a country like India, which is rich in plant biodiversity, there are many plant species whose seeds remain unutilized and underutilized have been tried for biodiesel production. These species have shown promises and fulfils various biodiesel standards. However, there still is paucity in terms of all the standards which should be fulfilled for the large commercial application and its acceptance from public and governing bodies. Blends of up to 20% biodiesel mixed with petroleum diesel fuels can be used in nearly all diesel equipment and are compatible with most storage and distribution equipment. Biodiesel can be used directly or as blends with diesel fuel in a diesel engine. Biodiesel is a biodegradable and renewable fuel. It contributes no net carbon dioxide or sulfur to the atmosphere and emits less gaseous pollutants than normal diesel. Carbon monoxide, aromatics, polycyclic aromatic hydrocarbons (PAHs) and partially burned or unburned hydrocarbon emissions are all reduced in vehicles operating on biodiesel.

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