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BIODIESEL: AN ALTERNATIVE TO CONVENTIONAL FUELS

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ABSTRACT

As we move towards future, we are becoming more and more aware of the depletion of fossil fuel reserves and its ill environmental effects. The world's energy demand is increasing year after year due to rapid urbanization, better standard of living and increasing population. This rapid increase in demand for energy has stimulated the researchers to find out new sources of fuel, which is renewable and environmentally benign. Thus Biodiesel has become an attractive alternative in the recent years and will make substantial contribution to meet the growing energy demands of the emerging economies. This paper reviews the history and recent development in the field of Biodiesel, including different types of biodiesel, performance and emission of biodiesel from different feedstock's, characteristics, processing and economics of biodiesel industry, its application in automobile and challenges of the biodiesel industry development are discussed as well.

Keywords: Biodiesel, Feedstock, Emission, Properties, Effect, Future.

I. INTRODUCTION

With the socio-economic growth of the society, the energy demand has increased manifold globally. Energy is one of the most important resource for mankind and its development. Fuels are utmost important for this development as they can be burned to produce significant amounts of energy. The various sectors that require energy are transport, agriculture etc. Various energy sources such as wood, coal, petroleum, nuclear, solar, wind etc. are available. But majority of the world's surface transport depends primarily on petroleum fuels [2]. Many aspects of day to day life rely on fuels, in particular transport of goods and people. Many industries use diesel powered machine for their production processes and in the transport sector, the private vehicles, buses, trucks and ships consume significant proportion of diesel and gasoline. Thus we can see that we are very much dependent on fossil fuel reserves which are non-Renewable. It requires millions of years for formation of fossil fuels [1]. Also the emission of greenhouse gases produced by combustion of fossil fuels is major contributor to pollution and global warming. This critical situation has stimulated scientist to search for cleaner and greener alternatives fuels for diesel engines.

II. ABOUT BIODIESEL

Biodiesel is one promising alternative to fossil fuel for diesel engines and has become increasingly important due to environmental consequence of the fossil fuels. It is renewable, Biodegradable, environmentally friendly and ecofriendly fuel [1]. In principle, any vegetable or seed oil which essentially comprises Triglycerides of long chain saturated and unsaturated fatty acids can be used in diesel engines. But the initial research of using vegetable oil as fuel in diesel engine led to problems like gumming, injector fouling, piston ring sticking etc. in the long run use [2]. This is due to high viscosity, density and poor non-volatility. Using unmodified vegetable oil in diesel engine can cause excessive carbon buildup in combustion chamber and reluctance to start [1]. Thus it was required to reduce viscosity for better combustion of vegetable oil by using certain methods which will be discussed later.

Different potential feedstocks for biodiesel production have been put forward. Biodiesel made from first generation feedstocks (edible vegetable oil) has been a cause of concern recently as they raise many challenges such as Food V/s Fuel debate that might cause starvation. It also raised other ecological problems caused by usage of much of available arable land and cutting down forests for plantation purposes in the developing countries, thus damaging wildlife. Therefore, Non edible vegetable oils or second generation feedstocks have been more attractive for biodiesel production. These do not compete with existing agricultural resources and

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are more efficient and environment friendly than first generation feedstocks. Other advantages include renewability, higher heat content, low sulfur content, low aromatic content and biodegradability [3].

Edible Vegetable oil: Sunflower, Soybean, Coconut, Palm, Sesame seed, Peanut etc.

Non-Edible Vegetable oil: Jatropha, Karanjaor, Neem, Jojoba, Linseed, Cottonseed, Algae etc. Animal Fats: Tallow, Yellow Grease, Chicken fat and by-products from Fish oil etc.

The production and utilization of biodiesel as diesel fuel has been well tested and evaluated in several countries. As its properties is similar to those of diesel, it can be used as a viable substitute without any significant modification in existing diesel engines, as well as fuel storage and distribution infrastructure.[2]

III. TECHNOLOGIES OF BIODIESEL PRODUCTION FROM NON-EDIBLE OILS

As discussed previously that viscosity is the main hurdle which prevents the direct use of oils in conventional diesel engines, a few techniques, methods and processes have been put forward recently to produce biodiesel from various non-edible feedstocks. These are listed below:

1. Pyrolysis (Thermal Cracking)

It is the thermal conversion of organic matters present in oil in presence of a catalyst and in absence of O2. Thermal cracking of triglycerides produces carboxylic acids, aromatics, alkanes, alkenes, and alkadines. It was observed that the liquid fraction produced after thermal decomposition is likely to approach diesel fuels. The pyrolyzate had lower viscosity, flash point and pour point than diesel fuels and similar calorific values, but cetane number was less as compared to diesel fuels. Though it contained acceptable amount of sulphur, water content; it also had unacceptable ash and carbon residue [3].

2. Micro emulsification

It is transparent, thermodynamically stable colloidal dispersion of microstructure with diameter ranging from 100 to 1000 A° and is being considered as a possible approach to solve the problem of high viscosity. It is made from vegetable oils with an ester and dispersant (Co- solvent) or with an alcohol such as ethanol, butanol, hexanol and surfactant along with cetane improver [3].

3. Dilution

This method does not require any chemical process; Non-edible oil is diluted with diesel to reduce the viscosity and improve the performance of engine. Blending of 20-25% vegetable oil to diesel has been considered to give good results for diesel engines. The use of blends of conventional diesel fuel with variety of non-edible oils such as rubber seed, turpentine, cotton seed etc. has been described in various literature [3].

4. Trans-Esterification.

This method is used to convert vegetable oil to a form that can be used in diesel engines and is called Biodiesel. . It can be prepared by combining any natural oil or fat with an alcohol such as Methanol/Ethanol (majorly used due to their low cost and availability). It is basically conversion of triglycerides to ester

R'OH	+	R"OOR	------->	R"OH	+	R'OOR
1st Alcohol		Vegetable Oil		2^{nd} Alcohol		Biodiesel Ester

Trans esterification can be carried out in two ways a) catalytic b) non-catalytic

Catalytic Trans-esterification has 2 problems; it is time-consuming and needs separation of vegetable oil/alcohol/catalyst mixture from biodiesel and waste water generated thereby is not environment friendly. Thus supercritical alcohol trans-esterification is one option to solve the problem. It employs two phase methanol/oil mixture by forming a single phase as a result of lower value of dielectric constant of methanol in supercritical stage. The advantages of this option is shorter processing time, easier purification of biodiesel as no catalyst is required during supercritical process thus preventing saponification to occur. But the drawbacks of this process are due to high temperature and pressure that result in high cost of apparatus [3].

IV. ADVANTAGES OF EMISSION PRODUCED BY BIODIESEL AND DYNAMIC PROPERTY OF DIESEL ENGINES

The Carbon cycle of Biodiesel is dynamic as shown in figure 1. Plants absorb CO2 which is more than those discharged by the biodiesel combustion process. Thus using biodiesel can more effectively reduce the emission of

CO_2, protect the natural environment and maintain the ecological balance compared to use of Fossil Fuels. The emission of SO_2 is also much lower than normal diesel oil which will effectively reduce acid rain. Furthermore, CO, HC and particulate matters will be less discharged, because ester compounds in biodiesel contains oxygen promoting clean burning. Nitrogen oxide emission are slightly increased if the engine management remains unchanged. However, this can be optimized using special software and biodiesel sensor. Soy biodiesel reduces carbon dioxide by 78% on a life cycle basis. It was also found out that diesel engine exhaust from biodiesel had lower mutagenic potential than that of conventional diesel fuels. It is believed to result from a lower content of polycyclic aromatic hydrocarbon in the particulate emission of biodiesel [1].

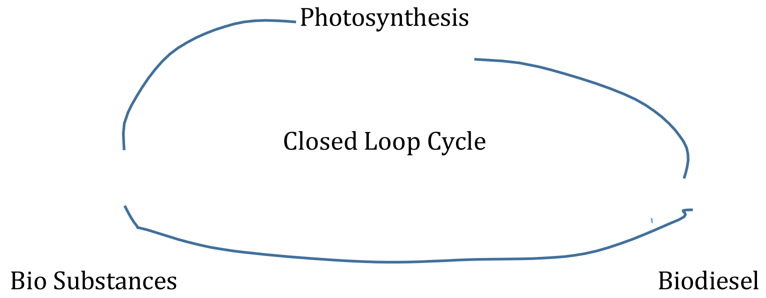

Figure 1: Carbon cycle of Biodiesel

The Flammability of biodiesel is better than that of diesel oil because of its high cetane number. Also, the flash point of biodiesel is also higher then diesel which enables it to be transported more safely. It also has good lubrication which can lower the water rate of injection pump, cylinder and engine connecting, thereby extending the life span of engine. The combustion performance of biodiesel is similar to diesel oil and thus can be widely sold using restore and sales network of diesel oil [1].

V. PROPERTIES AND CHARACTERISTICS OF NON-EDIBLE BIODIESEL

1) Cloud Point and pour point

The cloud point is defined as temperature at which cloud of wax crystals first become visible when fuel is cooled under controlled conditions and pour point is the temperature at which amount of wax form of a solution is sufficient to gel the fuel and is lowest temperature at which fuel can flow. In general, biodiesel has higher cloud and pour point than diesel and varies significantly with feedstock depending on fatty acids composition [3].

2) Flash point

It is the temperature at which fuel will ignite when exposed to flame or spark. Biodiesel has a high flash point and is usually more than 423K while conventional diesel fuel has flash point of 323- 338K [3].

3) Viscosity

It is defined as resistance of liquid to flow. It is most important property of biodiesel since it affects the operation of fuel injection equipment. High viscosity may lead to formation of soot and engine deposits due to insufficient fuel atomization [3].

4) Cetane number

It is the measure of ignition quality of diesel fuel during combustion ignition. High cetane number signifies short ignition delay. Cetane number of biodiesel is usually higher than diesel fuels [3].

5) Iodine number

It is an index of the number of double bonds in biodiesel which determines the degree of unsaturation of biodiesel. This property can greatly influence the oxidation stability and polymerization of glycerides. This can lead to formation of deposits in diesel engine injectors. Iodine value is also somewhat directly correlated to biodiesel viscosity, cetane number and cold flow characteristics [3].

VI. EFFECT OF FATTY ACIDS ON PROPERTIES OF BIODIESEL

The Trans-esterification reaction of an oil or fat produces biodiesel fuel corresponding to the fatty acid profile of its parent oil or fat (as biodiesel is mixture of fatty ester with each ester component contributing to the properties of fuel). Properties of biodiesel are strongly influenced by the structure of its component fatty esters and nature of its minor components. The properties of different vegetable oils and biodiesel are given in table 1

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below [2].

Table 1. Physiochemical properties of fuels

Properties and Parent Oil	Density at 298K (g/cm3)	Kinematic Viscosity at 313K (centistokes)	Iodine value	Cetane number	Calorific value (kJ/g)	Flash point (K)	Pour point (K)	Acid number mg KOH/g
Animal Fat	0.92	45	-	40	39.770	-	-	-
Cotton seed Oil	0.876	34	-	38	39.47	507	274.7	-
Palm oil	0.86	45	59	49	40.14	466	280.2	-
Sunflower oil	0.91	62.1	126.3	36.7	39.6	505	266.3	-
Jatropha methyl ester	0.884	4.12	100	57	39.594	435	269	0.149
Balanites oil methyl ester	0.86	3.98	-	-	39.65	348	-	0.34
Diesel	0.83	5.80	11	48	46.22	320	261	0.06

Cetane number of biodiesel increases with increasing chain length and decreases with increasing unsaturation. Alcohol utilized in producing biodiesel will also affect the cetane number. The cold flow properties of biodiesel fuel like pour point and cloud point depends on the feedstock from which they are made and are a strong function of level of saturated fat. Unsaturated esters acts as a solvent, with saturated esters dissolved in it as unsaturated esters have low melting point. Thus, when we decrease the temperature, saturated fatty components crystallize earlier than unsaturated compounds. This is the reason, biodiesel with significant amounts of saturated fatty components exhibits higher cloud and pour point. Iodine number is a measure of the degree of unsaturation of the fuel. It is shown in literature that increase in unsaturation will increase the number of double which in turn increases the iodine number. Higher iodine number will lead to deposit formation and storage stability problems with fuels i.e. Auto-Oxidation, which can adversely alter fuel quality by affecting properties such as kinematic viscosity, acid value etc. the presence of polyunsaturated fatty ester is the cause of oxidative stability problems with biodiesel. Any attempt to further correlate the properties of biodiesel with fatty acid profile is full of difficulties due to complex nature of natural fats and oil. Still certain trends can be drawn, which is evident from the data presented in Table above [2].

VII. EFFECT OF BIODIESEL ON ENGINE PERFORMANCE AND EMISSION

It is also reported by some authors that there was no significant difference in engine power between biodiesel and diesel engines. The reason behind is that engine delivers fuel on volumetric basis and as biodiesel density is higher than that of diesel, engine supplies more biodiesel to compensate the lower heating value. In addition, in built oxygen of biodiesel also benefits the combustion process. This is the reason for increase in engine power. Also, more saturated biodiesel have higher calorific value as shown in table and are expected to produce more power than less saturated biodiesel. Moreover, higher viscosity reduces leakage and high cetane number reduces ignition time delay [2].

For the biodiesel, the CO emission were less than for the diesel fuel. Some literature indicate 4- 18.4% reduction in CO emission. This is due to oxygen content of biodiesel and its blends. Some of the literature reported less NOx emission with the utilization of biodiesel i.e. between 4-38.4%. Explanations given are higher cetane number and lower flash point of biodiesel as compared to diesel. The literature review shows that PM emissions were generally reduced with the use of biodiesel as compared to diesel, due to oxygen contained in the biodiesel molecules, the low levels of sulphur content and higher cetane number. High cetane number also resulted in shorter ignition delay and longer combustion duration and hence low particulate emissions. Diesel contains sulphur which results in sulphates that are absorbed on soot particles and thus increase the PM emitted and as biodiesel is free from sulphur, it has advantage over diesel [2].

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VIII. EFFECT OF BLENDING BIODIESEL ON ENGINE PERFORMANCE AND EMISSIONS

Saravanan et al. studied the combustion and emission characteristics of crude rice bran methyl ester blend with no 2 diesel oil (20/80 on volume basis) as a fuel. He found similar combustion characteristics as diesel with reduced smoke intensity. Anand et al. investigated combustion, performance and emission characteristics of neat karanji biodiesel and its methanol blend in a diesel engine. Results showed that unburnt HC and carbon emissions were slightly higher for methanol biodiesel blend compared to neat biodiesel at low load conditions. However at high load conditions unburnt HC emission are comparable for the two fuels and Co emission and exhaust gas temperature decrease significantly to a maximum of 46.5% at full load condition. Prasad et al studied the possibility of NOx reduction in the exhaust gas of diesel engine fueled with Mahua Methyl ester (MME) along with exhaust gas recirculation (EGR). After analysis of the results, authors concluded that 5% EGR is preferable along with MME as it gives low HC, NOx and CO as well as improvement in thermal efficiency than pure petroleum diesel operation. Usta investigated the effect of tobacco seed oil methyl ester substitution for diesel fuels. He found that brake power and thermal efficiency have increased slightly. Moreover, the addition of tobacco seed oil methyl ester to diesel fuel reduced CO and SO2 emissions while causing slightly higher NOx emissions without any engine modification and preheating of the blends [3].

IX. CHALLENGES OF BIODIESEL INDUSTRY DEVELOPMENT

Due to increase in demand for vegetable oil as a biodiesel feedstock, it has altered the world's agricultural landscapes and the ecosystem services they provide. This may highlight a number of negative effects associated with its use. Many countries biodiesel industry development has been motivated by their climate change mitigation target, as the biodiesel produced from biomass have the potential to be carbon neutral over their life cycle and their combustion returns to atmosphere the carbon dioxide absorbed from air by feedstock crops through photosynthesis. But in order to grow the oil crops necessary to produce biodiesel, additional land is to be brought under production. This is leading to rainforests being cleared for sake of monoculture plantation. It was also observed that landscapes with high levels of oil crops had a low habitat diversity and significantly reduced bio control services in these fields [1].

On the other hand, growing use of food crops as a feedstock of biodiesel has caused negative impacts like reduced food availability and associated price effects. One major problem observed was diversion of traditional food and feed crops to biodiesel production, as returns to biofuel production are often greater than returns a farmer might get were the same crop sold for food or for non-biofuel crop. Such practices can reduce food availability and may allot food and feed production to less productive land, thus reducing yields and food security, and raising food prices [1].

X. THE BIODIESEL POLICY

In recent years, incentives exist within energy-, climate- and agricultural policies in several countries to promote further progress in the use of biodiesel. The policy and government incentives will directly influence development of biodiesel industry. The local government play an essential role in determining the course, and crucially, the scale, of biodiesel development, in particular by means of the proper incentives such as exemption in taxes, control in prices, targets and direct subsidies. There are many incentives that can be offered by a government to spur the development of biodiesel industry and to maintain its sustainability, some are given below.

1. Crops required for biodiesel, if possible to be done in abandoned and fallowed agricultural land
2. Implementation of carbon tax
3. Exemption from the oil tax
4. Mandatory biodiesel blend use in gas station
5. Subsidizing the cultivation of non-food crops
6. Usage of waste oil as feedstocks.

While governments are focusing on the ways to improve biodiesel production and consumption, they should give enough attention to unresolved issues like food price increase and rainforest depletion. Without taking into account these, their policies might have detrimental effects on climate changes [1].

XI. CURRENT AND FUTURE DEVELOPMENTS

Despite many years of R&D, no real breakthroughs have been made with respect to large scale use of biodiesel in transportation sector. The basic path forward will generally rely on consolidation of the diverse processing steps, both in engineering and biological sense. E.g. microbial cells will be expected to conduct multiple conversion reaction with high efficiency and to remain robust to process conditions. Several studies have been made to optimize biodiesel production from sunflower oil including ultrasonic irradiation. It was seen that ultrasonic irradiation was better than using only mechanical stir. A Romanian team used the lipase for conversion and purification of biodiesel and confirmed that use of enzymes in biodiesel production ensures high productivity, several possibilities of reuse and low reaction time [4]. Therefore, the industrial improvements of enzymatic production of biodiesel can be a viable option in the future. Maintaining fuel quality during long term storage is a concern for biodiesel producers, marketers and consumers. Most cost effective means for improving oxidative stability of biodiesel is treatment with antioxidant additives. The cost of biodiesel, however is the major hurdle to its commercialization in comparison to diesel as use of edible oil as biodiesel feedstock costs about 60-70% of raw material cost and is not feasible in view of big gap in demand and supply of such oils in the producing countries for dietary consumption [1]. One way of reducing this is to use less expensive feedstocks containing fatty acids such as non-edible oils, animal fats, recycled or waste oil etc.

XII. CONCLUSION

In conclusion, biodiesel production may see a drastic rise in future. Biodiesel offers the promise of numerous benefits related to reduction of pollutant emission, energy security, economics and expansion of agricultural sector. It is rich in vast raw materials, excellent in dynamic properties, has received attention from many countries and is environment friendly. All of these evidences indicate that developing biodiesel industry is bound to gain support from the governments. Not many countries are working to subsidize the biodiesel industry through fiscal and tax policy and set up national standards for production process, product quality and production safety in order to standardize the manufacturing. If these issues mentioned above could be resolved properly, it would be reasonable to believe that in the near future, biodiesel will be widely applied in the automotive industry and bring us more convenience.

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