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## Biodiesel: An Alternate to Conventional Fuel for Diesel Engines

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**ABSTRACT:** To increase the alertness of the exhaustion of fossil fuel reserves and ecological issues with rapidly increasing need and ambiguity in their availability and also sudden hike in petroleum prices, has thrown a challenge to come up with alternates of Conventional Diesel Fuel. Condition is scary and we have to rush in finding new alternatives so as to meet our demands by reducing dependency on diesel fuel and should be environmentally sustainable thereby increasing our currency level across the globe. Biodiesel is pretty promising and very important area of research because of ecological issues and rising of petroleum prices. This paper reviews the history and recent developments of Biodiesel, including the different types of biodiesel, the characteristics, processing and economics of Biodiesel industry. The application of biodiesel in automobile industry, the challenges of biodiesel industry development are discussed as well.

**KEYWORDS:** Biodiesel, Transesterification, Emission, Energy & Economics.

### I. INTRODUCTION

Energy is one of the most important resources for mankind and its sustainable development. Today, the energy crisis becomes one of the global issues confronting us. Fuels are of great importance because they can be burned to produce significant amounts of energy. Many aspects of everyday life rely on fuels, in particular the transport of goods and people. Main energy resources come from fossil fuels such as petrol oil, coal and natural gas. Fossil fuel contributes 80% of the world's energy needs. Most industries use diesel machines for the production process. In the transportation sector, private vehicles, buses, trucks, and ships also consume significant amounts of diesel and gasoline. This situation leads to a strong dependence of everyday life on fossil fuels. However, the growth of the population is not covered by domestic crude oil production [5-6]. Fossil oils are fuels which come from ancient animals and microorganisms. Fossil fuel formation requires millions of years. Thus, fossil oils belong to non-renewable energy sources. An increase of the oil price often leads to economic recessions, as well as global and international conflicts. Especially in some developing countries, the great development in the economy in fossil fuel resources will be consumed in only 65 more years. In addition the emission produced by the combustion of fossil fuels also contributes to the air pollution and global warming [1-4]. Most countries also experience more and more international pressure on global warming issues. [7-9]. Hence, renewable and clean alternative fuels have received increasing attention for current and future utilization. Biodiesel as one promising alternative to fossil fuel for diesel engines has become increasingly important due to environmental consequences of petroleum-fuelled diesel engines and the decreasing petroleum resources. Biodiesel can be produced by chemically combining any natural oil or fat with an alcohol such as methanol or ethanol. Methanol has been the most commonly used alcohol in the commercial production of biodiesel. Lots of researches on biodiesel have shown that the fuel made by vegetable oil can be used properly on diesel engines [10-13]. In fact the energy density of biodiesel is quite close to regular diesel. Biodiesel can be produced by soybean and methanol via transesterification in the presence of acid catalysts. Similarities between the combustion properties (Table 1) of biodiesel and petroleum-derived diesel have made the former one of the most promising renewable and sustainable fuels for the automobile [14].

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Fuel Properties	Biodiesel	Diesel
Density at 15°C, g/cm <sup>3</sup>	0.8834	0.8340
Viscosity at 40°C, mm <sup>2</sup> /s	4.47	2.83
Sulfur content, %	< 0.005	0.034
Carbon, %	76.1	86.2
Hydrogen, %	11.8	13.8
Oxygen, %	12.1	---
Flash point, °C	178	62
Cetane Number	56	47
Net Calorie value, kJ/kg	37,243	42,588

Table 1 Properties of Diesel and Biodiesel [14]

## II. THE TYPE OF BIODIESEL AND ITS SERVICE CONDITION

Feedstocks for biodiesel can be divided into oil crops, including soybean, rapeseed and so on; oil trees including Chinese pistachio and palm oil; and other animal fat, waste oil food. Due to its outstanding environmental and renewable characters, fatty acid methyl ester (FAME) is of particular importance. One of the advantages of this fuel is that the raw materials used for production are natural and renewable. All these types of oils come from vegetables or animal fat, making it biodegradable and nontoxic. The typical chemical properties of vegetable oils are given in Table 2 [15].

Vegetable oil	Fatty acid composition % by weight									Acid value	Phos (ppm)	Peroxide value
	16:1	18:0	20:0	22:0	24:0	18:1	22:1	18:2	18:3			
Corn	11.67	1.85	0.24	0.00	0.00	25.61	0.00	60.60	0.48	0.11	7	18.4
Cottonseed	28.33	0.89	0.00	0.00	0.00	13.27	0.00	57.51	0.00	0.07	8	64.8
Crambe	20.7	0.70	2.09	0.80	1.12	18.86	58.51	9.00	6.85	0.36	12	26.5
Peanut	11.38	2.39	1.32	2.52	1.23	48.28	0.00	31.95	0.93	0.20	9	82.7
Rapeseed	3.49	0.85	0.00	0.00	0.00	64.4	0.00	22.30	8.23	1.14	18	30.3
Soybean	11.75	3.15	0.00	0.00	0.00	23.26	0.00	55.53	6.31	0.20	32	44.5
Sunflower	6.08	3.26	0.00	0.00	0.00	16.93	0.00	73.73	0.00	0.15	15	10.7

Table 2 Typical chemical properties of vegetable oils [15]

Fatty acid	Soybean	Cottonseed	Palm	Lard	Tallow	Coconut	Peanut	Rice bran	Sesame	Olive
Lauric	0.1	0.1	0.1	0.1	0.1	46.5	0.1	0.2	0.1	0
Myristic	0.1	0.7	1	1.4	2.8	19.2	0.3	0	0.3	0
Palmitic	10.2	20.1	42.8	23.6	23.3	9.8	12.3	11.2	9.2	18.5
Stearic	3.7	2.6	4.5	14.2	19.4	3	4.6	1.6	4.8	4.5
Oleic	22.8	19.2	40.5	44.2	42.4	6.9	53.6	46.5	43.6	65.2
Linoleic	53.7	55.2	10.1	10.7	2.9	2.2	29	40	41.9	11.2
Linolenic	8.6	0.6	0.2	0.4	0.9	0	0.1	0.5	0.1	0.6

Table 3 Typical fractions of fatty acids in different vegetable oils [16, 17]

The typical fractions of fatty acids in different vegetable oils are given in Table 3 [16, 17]. Some fuel properties of biodiesel from different oils are shown in Table 4 [18].

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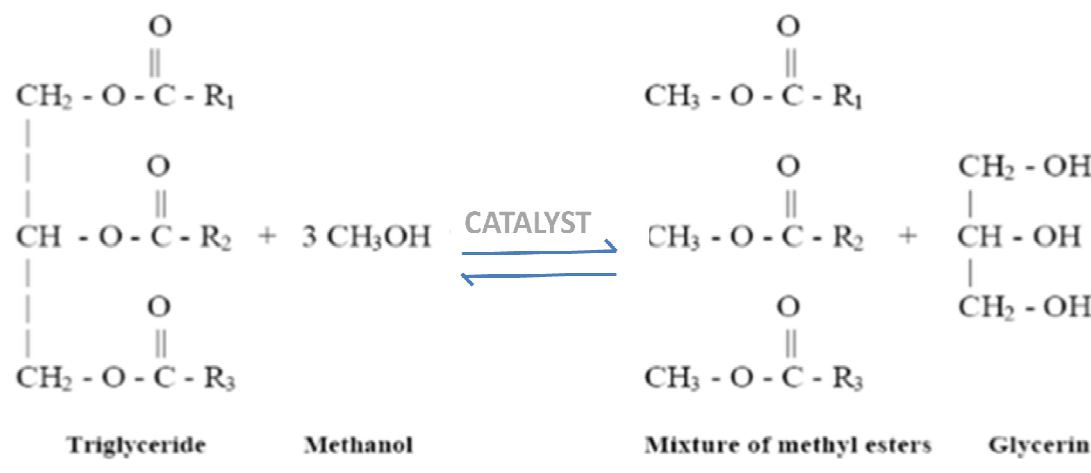
Vegetable oil	Kinematics Viscosity (mm <sup>2</sup> /s)	Cetane number	Cloud point (°C)	Pour point (°C)	Flash point (°C)	Density (kg/l)	Lower Heating value (MJ/kg)
Peanut	4.9	54	5	---	176	0.883	33.6
Soya bean	4.5	45	1	-7	178	0.885	33.5
Babassu	3.5	63	4	---	127	0.875	31.8
Palm	5.7	62	13	---	164	0.880	33.5
Sunflower	4.6	49	1	---	183	0.870	33.5
Tallow	---	---	12	9	96	---	---
Diesel	3.06	50	---	-16	76	0.855	43.8
20% biodiesel blend	3.2	51	---	-16	128	0.859	43.2

Table 4 Some fuel properties of biodiesel from different vegetable oils [18]

The feedstock of biodiesel depends greatly on climate and local soil conditions, consequently different regions are focusing their efforts on different types of oil. Like in the United States soybean oil is mainly used as raw material, whereas Germany uses mainly rapeseed oil which even set up a special economic sector in order develop biodiesel. Currently, biodiesel has already emerged in 1,500 German gas stations. In the US, biodiesel is specified by ASTM D6751, an authoritative body in 1996 and in 2000 published standards [19, 20 & 21].

## III. BIODIESEL CONVERSION TECHNOLOGIES

Conventional methods of the application of vegetable oil in diesel engines are [22] direct mixing and micro emulsion. These two physical methods can lower the viscosity of vegetable oil, but they cannot solve the problem of carbon deposits and lube pollution, and the high temperature pyrolysis cracking is hard to be controlled by its reactant at high temperature. The most relevant process parameters in these kinds of operation are reaction temperature, ratio of alcohol to vegetable oil, amount of catalyst, mixing intensity (RPM), catalyst, and the raw oils used [23]. In contrast, ester exchange is a more advanced method. The triglyceride can be transformed into monoester. Due to the transesterification in the ester exchange process, the viscosity of vegetable oil is reduced and heat values maintained. The Cetane number increases because the molecular chain is cut into 1/3. Transesterification is the chemical reaction between triglycerides and short-chain alcohol in the presence of a catalyst to produce mono-esters. The long- and branched-chain triglyceride molecules are transformed to mono-esters and glycerine [24]. Commonly-used short-chain alcohols are methanol, ethanol, propanol and butanol. Methanol is used commercially because of its low price [25]. The overall transesterification reaction can be shown by the reaction equation given in Fig. 2 [24-26].



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Because this process is a reversible reaction, the output of biodiesel will be directly influenced by the proportion of reactants, the type and the dosage of the activator, and the reaction conditions. From the principle of reversible reaction, it follows that a higher usage of carbinol leads to a higher output of biodiesel. However, the higher density of carbinol can cause a polycondensation reaction; as a result, it will reduce the effective concentration of carbinol, and cause difficulties for the separation of biodiesel. Furthermore, more carbinol is associated with higher costs. In the process of batch reaction or continuous reaction activated by an alkalescence catalyst, a 6:1 mol ratio has been used widely [27-30]. There are three common kinds of catalysts in the ester reaction: lipase catalysts, acid catalysts, and alkali catalysts. Each catalyst has its own advantages and disadvantages in the whole reaction process. As the catalyst, enzyme is restricted to rigorous reaction condition and activity lose of lipase etc, it can't be used on the large commercial production until now. Most of the commercial biodiesel is produced from plant oils using very effective homogeneous alkali catalysts such as sodium or potassium hydroxides, carbonates or alkoxides. [31-34]. Basic type of catalyst & comparison between homogeneous and heterogeneous catalysis is summarized in Table 5 [34].

Factors	Homogeneous catalysis	Heterogeneous catalysis
Reaction rate	Fast and high conversion	Moderate conversion
Post-treatment	Catalyst cannot be recovered, must be neutralized leading to waste chemical production	Catalyst can be recovered
Processing methodology	Limited used of	Continuous fix bed continuous methodology operation possible
Presence of water/ free fatty acids	Sensitive	Not sensitive
Catalyst reuse	Not possible	Possible
Cost	Comparatively costly	Potentially cheaper

Table 5 Comparison of homogeneously and heterogeneously catalyzed transesterification [34]

## IV. ADVANTAGES OF EMISSIONS PRODUCED BY BIODIESEL

Biodiesel can replace fossil fuel as a "clean energy source". It can protect the environment by reducing CO<sub>2</sub>, SO<sub>2</sub>, CO, HC. Plants absorb CO<sub>2</sub>, which is more than those discharged by the biodiesel combustion process. Thus, using biodiesel can more effectively reduce the emission of CO<sub>2</sub>, protect the natural environment and maintain the ecological balance, compared to the use of fossil fuel [35]. The emission of SO<sub>2</sub> in the combustion process of biodiesel is much lower than normal diesel oil because of the low sulfur content in it [36]. Thus, the use of biodiesel instead of normal diesel oil will effectively reduce acid rain, which represents a serious threat to the environment and human infrastructure in forms of acidification of soil, surface and ground water forest and vegetation damage, and increased corrosion of buildings and historical monuments made from calcium containing stones. Furthermore, CO, HC and particulate matters will be less discharged, because ester compounds in biodiesel contains oxygen promoting clean burning. Using biodiesel can also reduce air pollution. The use of biodiesel in a conventional diesel engine results in a substantial reduction of hydrocarbons, aromatic hydrocarbons, carbon monoxide, alkenes, aldehydes, ketones, and particulate matter [37]. Nitrogen oxide emissions are slightly increased if the engine management remains unchanged. However, this can be optimized using special software [38] and biodiesel sensors [39]. Using biodiesel decreases solid carbon fraction particulate matter and eliminates the sulphate fraction. Increasing the percentage of biodiesel blended with petroleum diesel fuel progressively eliminates sulphates. Biodiesel works well with new technologies such as catalysts, particulate traps, and exhaust gas recirculation. Soy biodiesel reduces carbon dioxide by 78 percent on a life cycle basis. In addition, diesel engine exhaust from biodiesel was found to have a lower mutagenic potential than that from conventional diesel fuel [37, 40]. This effect is believed to result from a lower content of polycyclic aromatic hydrocarbons in the particle emission of biodiesel [37], Biodiesel is the first alternative fuel that has fully completed the health effects testing requirements of the Clean Air Act.3

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## V. DYNAMIC PROPERTY ON DIESEL ENGINES

The flammability of biodiesel is better than that of diesel oil because of its high cetane number which is an index of flammability. It also can be transported conveniently and more safely than diesel oil, due to its high flash point which enables it to be identified as safe goods. Biodiesel has a high viscosity and is composed of fatty acid methyl ester of high unsaturation [41]. It has a good lubrication which can lower the water rate of injection pump, cylinder and engine connecting, and extend the use-life-span of the engine. Using unmodified vegetable oils in diesel engines can cause excessive carbon build up in combustion chambers and reluctance to start. Biodiesel burns more cleanly than petroleum diesel and is a better lubricant and detergent.

## VI. CHALLENGES OF BIODIESEL INDUSTRY DEVELOPMENT

Increased demand for vegetable oil as a biodiesel feedstock is altering world agricultural landscapes and the ecosystem services they provide, which will highlight a number of negative effects associated with its use. Many countries' biodiesel industry development has been motivated by their climate change mitigation target. Because biodiesel produced from biomass have the potential to be "carbon-neutral" over their life cycles as their combustion only returns to the atmosphere the carbon dioxide absorbed from the air by feedstock crops through photosynthesis. However, in order to grow the oil crops necessary to produce biodiesel, additional land must be brought into production. This has led to pristine rainforests being cleared for the sake of monoculture plantations. Worldwide, deforestation accounts for an estimated 20 percent of greenhouse gas emissions. And much of the forest now being cleared for palm oil is peat land, with marshy soils that are crucial holders of methane, a greenhouse gas even more potent than carbon dioxide. At the same time, landscapes with high levels of oil crops had low habitat diversity and significantly reduced bio-control services in these fields [43, 44]. On the other hand, the growing use of food crops as a feedstock of biodiesel has caused negative impacts on health and sanitation and reduced food availability and associated price effects. One major problem is diversion of traditional food and feed crops to biofuel production, as returns to biofuel production are often greater than the returns a farmer might get were the same crops sold for food, or for non-biofuel crops. Such practices can reduce food availability and may consign food and feed production to less productive land, thus reducing yields and food security, and raising food prices [45, 46].

## VII. THE PROSPECT OF THE APPLICATION OF BIODIESEL

In conclusion, biodiesel production is set to rise drastically in the coming years. Biodiesel offers the promise of numerous benefits related to energy security, economics, and expansion of the agriculture sector and reduction of pollutant emission. Despite its many advantages as a renewable alternative fuel, biodiesel presents a number of problems that must be resolved before it will be more attractive as an alternative to petroleum diesel.

1) These problems include improving the relatively poor low-temperature properties of biodiesel as well as monitoring and maintaining biodiesel quality against degradation during long-term storage (due to its unstable double bond). Maintaining fuel quality during long-term storage is a concern for biodiesel producers, marketers, and consumers. The most cost-effective means for improving oxidative stability of biodiesel is the treatment with antioxidant additives, e.g. The combination with hydrogen to reduce the double bond [24].

2) In spite of the impressive technological advances that have been made over the last decade in the field of biodiesel, a great deal of research remains to be accomplished to fully address technical deficiencies inherent in biodiesel. For example, biodiesel generally has higher density, viscosity, cloud point and cetane number, and lower volatility and heating value compared to commercial grades of diesel fuel. Long-run engine testing have shown that its fatty colloid will plug the fuel oil filter. The high viscosity will lead to a blocking of the fuel injector, and its unburned hydrocarbon also will deteriorate the tube when it leaks into crankcase. Furthermore, Biodiesel generally contains about 10 wt.% of oxygen and thus can be considered as a of oxygenated fuel. The high oxygen content in biodiesel results in the improvement of its burning efficiency, reduction of PM, CO and other gaseous pollutants, but at the same time produces larger NO<sub>x</sub> formation, particularly under a high temperature burning environment. Previous studies have shown that these drawback of biodiesel will be solved by mixing with diesel or ethanol. Research also has revealed that



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fuel blends are stable well below 0°C, and reduce the viscosity as well as NO<sub>x</sub> emissions. Fuel blends have shown equal or superior fuel properties to regular diesel fuel. [47-53] As mentioned above, the primary market for biodiesel in the near to long-term future is likely to be as a blend component in petroleum diesel.

3) The cost of biodiesel, however, is the major hurdle to its commercialization in comparison to petroleum diesel (use of edible oil as biodiesel feedstock costs about 60–70% of raw material cost [54]). The high value of soybean oil or canola oil as a food product makes production of a cost-effective fuel very challenging. Use of such edible oil to produce biodiesel is not feasible in view of a big gap in the demand and supply of such oils in the producing countries for dietary consumption. In addition, food prices are expected to continue to rise over the next decade in response to biofuel consumption targets adopted in the world. Therefore, development of alternative feedstocks for biodiesel production is another important area of current and future research [55]. One way of reducing the biodiesel production costs is to use the less expensive feedstocks containing fatty acids such as non-edible oils, animal fats and oils, recycled or waste oil and byproducts of the refining vegetable oils, microalgae. These oils have great potential for supplementing other conventional feedstock. [25, 26, 56-63]. In addition, non-edible plants that contain oil can be cultivated on marginal lands where other crops, such as soybean, rape, palm, peanut and sunflower cannot be grown well. By this means, it would not only improve the utilization ratio of marginal lands. Now many countries are working to subsidize the biodiesel industry through fiscal and tax policy and set up national standards for the production process, product quality, and production safety in order to standardize the manufacturing. In the near future, biodiesel will be widely applied in automobile industry, and bring us more convenience.

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