International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 1, July 2014)

Feedstocks, Production, Properties and Blending Effect of Biodiesel: A Review

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Abstract— **Demands for energy have been increasing day by day which has led to the depletion of global fossil fuel reserves at an exponentially increasing rate. Alternative fuels like biodiesel seem to be favorable solutions for near future. Renewable diesel fuel, termed as biodiesel, is produced from various edible and non-edible feedstocks. Various methods for production of biodiesel have been used out of which transesterification method, has been reported mostly in many literatures. Despite its many advantages, biodiesel possesses some serious negative features for which blending of biodiesel with petroleum diesel fuels becomes necessary to make it more compatible as conventional fuel. Decrease in the emission of hydrocarbons is remarkable with biodiesel blending that could be observed along with enhanced thermal efficiency of the engine. This paper is an attempt to review various sources for biodiesel production, properties, and use of biodiesel by blending as substitute of the diesel fuel.**

Keywords—**Biodiesel, renewable, biodiesel blending**

I. INTRODUCTION

Due to the depletion of the world's petroleum reserves and the increasing environmental concerns, there is a great demand for alternative sources of petroleum-based fuel, including diesel and gasoline fuels [1]. Biofuel, a clean renewable fuel is offering many priorities, including sustainability, reduction of greenhouse gas emissions, regional development, social structure, agriculture and security of supply, and so biodiesel is the probable fuel of the future.

Developing countries have a comparative advantage for biofuel production because of greater availability of land, favourable climatic conditions for agriculture and lower labour costs. In developed countries, there is a growing trend towards employing modern technologies and efficient bioenergy conversion using a range of biofuels, which are becoming cost-wise competitive with fossil fuels [2]. In recent years researchers have focused in producing biofuels from various edible and non-edible feedstocks. Several biodiesel production methods have been developed, among which transesterification using alkali catalyst gives high level of conversion of triglycerides to their corresponding methyl ester in short reaction time [3].

II. BIODIESEL FEEDSTOCKS

Biodiesels can be produced from various sources of edible and non-edible vegetable oils, animal fats, used frying oils and waste cooking oils which have similar characteristics to petroleum-derived diesel fuel. The source for biodiesel production is chosen according to the availability in each region or country, physico-chemical properties, production cost and transportation. Commonly accepted biodiesel raw materials are given in the TABLE I.

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TABLE I
REPORTED BIODIESEL FEEDSTOCK WITH THEIR OIL CONTENTS [4]

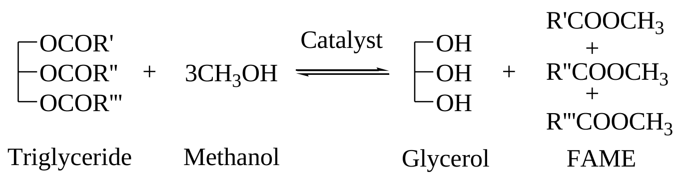
Name	Oil content (wt.%)
Jatropha curcas	30-50
Rubber (*Hevea brasiliensis*)	40-50
Rocket (*Eruca sativa* Mill.)	34
Terminalia belerica Robx.	43
Zanthoxylum bungeanum Maxim	24-28
Field pennycress	29
Croton megalocarpus	32
Moringa oleifera	35
Coriander (*Coriandrum sativum* L.)	26-29
Hemp (*Cannabis sativa* L.)	26-38
Stillingia (*Sapium sebiferum* Roxb)	32
Guindilla (*Guindilia trinervis*)	28-29
Pistacia chinensis	40
Roselle (*Hibiscus sabdariffa* L.)	18
Hazelnut oil	60
Calophyllum inophyllum L.	75
Syagrus coronata (Mart.) Becc.	39
Osage orange (*Maclura pomifera*)	32
Camelina (*Camelina sativa* L.)	30
Perah (*Elateriospermum tapos*)	38
Schizochytrium limacinum	50
Mahua (*Madhuca Indica*)	30-40
Yellow oleander (*Thevetia peruviana*) [5]	60-65
Nahar (*Mesua ferrea*) [5]	70-75
Pongamia glabra [5]	30-40
Citrus maxima [6]	50
Cucurbita moschata [6]	44
Meyna spinosa [6]	22

III. BIODIESEL PRODUCTION

Various methods for biodiesel production are (a) direct use and blending with diesel fuel, (b) microemulsions with solvents such as methanol, ethanol and/or other alcohols, (c) thermal cracking (pyrolysis) by means of heat or by heat with the aid of a catalyst and (d) transesterification. Transesterification is the most commonly used method as the properties of biodiesel obtained in this process are very close to those of diesel fuel, and the process is relatively simple. Transesterification or alcoholysis is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except that alcohol is used instead of water (Scheme 1). In the production of biodiesel, oils and fats are transesterified with methanol in the presence of an acid, base, or enzyme (lipase) catalyst to afford fatty acid methyl esters (FAME) and glycerol as a byproduct (Scheme 2) [7].

$$\underset{\text{Ester}}{RCOOR'} + \underset{\text{Alcohol}}{R''OH} \xrightleftharpoons{\text{Catalyst}} \underset{\text{Ester}}{RCOOR''} + \underset{\text{Alcohol}}{R'OH}$$

Scheme 1: General equation of transesterification.



Scheme 2: General equation for transesterification of a triglyceride.

Generally, alcohols used in the transesterification are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are utilized most frequently, especially methanol because of its low cost and its physical and chemical advantages. This process has been widely used to reduce the high viscosity of triglycerides, thereby enhancing the physical properties of renewable fuels to improve engine performance [7].

Transesterification is a reversible reaction and proceeds essentially by mixing the reactants. The stoichiometric reaction requires 1 mol of a triglyceride and 3 mol of the alcohol. However, an excess of the alcohol is used to increase the yields of the alkyl esters and to allow its phase separation from the glycerol formed. Transesterification consists of a number of consecutive and reversible reactions. The first step is the conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides, and of monoglycerides to glycerol, yielding one methyl ester molecule per mole of glyceride at each step (Scheme 3).

$$\text{Triglyceride} + \text{ROH} \rightleftharpoons \text{Diglyceride} + \text{R'COOR}$$
$$\text{Diglyceride} + \text{ROH} \rightleftharpoons \text{Monoglyceride} + \text{R''COOR}$$
$$\text{Monoglyceride} + \text{ROH} \rightleftharpoons \text{Glycerol} + \text{R'''COOR}$$

Scheme 3: The transesterification reactions of vegetable oil (Triglyceride) with alcohol to esters and glycerol.

The reactions are reversible, although the equilibrium lies towards the production of fatty acid esters and glycerol. The step wise reactions are reversible and a little excess of alcohol is used to shift the equilibrium towards the formation of esters. In presence of excess alcohol, the forward reaction is pseudo-first order and the reverse reaction is found to be second order. It was also observed that transesterification is faster when catalyzed by alkali [7].

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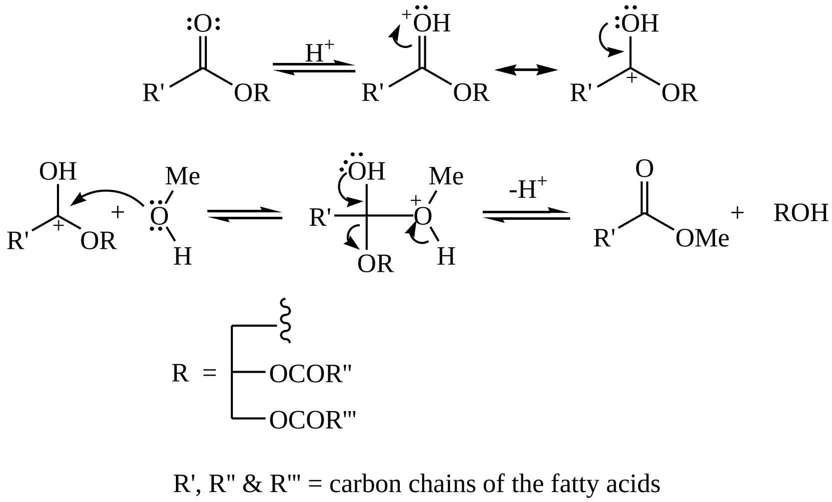
The mechanism of the acid and base-catalyzed transesterification of vegetable oils for a triglyceride is shown in Scheme 4 & 5 respectively [7]. However, diglycerides and monoglycerides are also converted by the same mechanism to a mixture of alkyl esters and glycerol.

Heterogeneous catalysts are receiving more importance for production of biodiesel. They are reusable, environmentally benign, could give high quality of products, and more effective than acid catalysts and enzymes.

Recently, heterogeneous catalysts derived from both waste industrial and biological resources have attracted interest for biodiesel synthesis as these heterogeneous catalysts are biodegradable, environmentally benign and their large scale use pose no disposal problem [8].



Scheme 4: Mechanism of acid-catalyzed transesterification of a triglyceride (vegetable oil) with methanol. Transformation of the three ester functionalities may proceed simultaneously or one after another.

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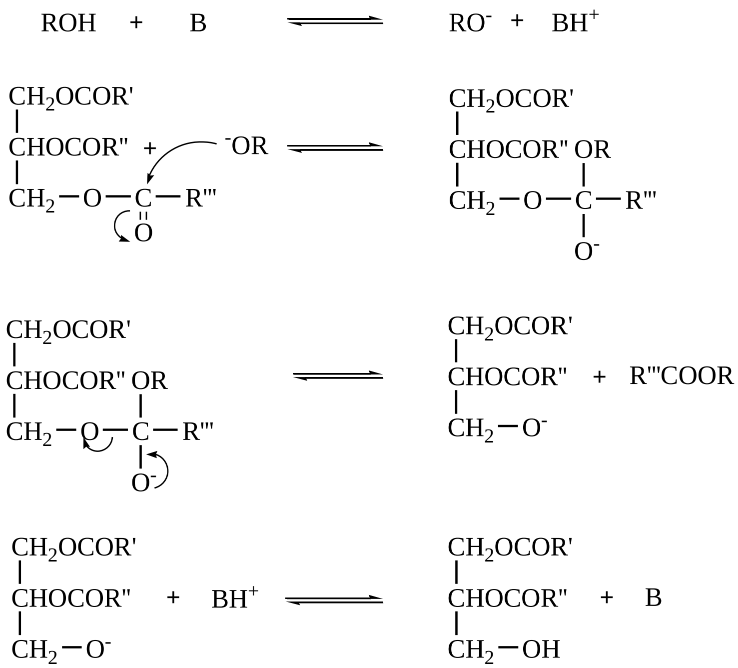

Scheme 5: Mechanism of base-catalyzed transesterification of vegetable oil (triglyceride).

IV. Properties Of Biodiesel

The characteristics of biodiesel are found to be close to diesel fuels, so it becomes a strong source to replace the diesel fuels. Biodiesel, formally known as either methyl-ester or ethyl ester, is derived from naturally occurring vegetable oils or animal fats that have been chemically modified to run in a diesel engine. Biodiesel has viscosity close to diesel fuels. These esters contain 10–11% oxygen by weight, which may encourage more combustion than hydrocarbon-based diesel fuels in an engine. The cetane number of biodiesel is around 50 [9]. The unrefined biodiesels showed higher lubricity properties than refined biodiesel. Biodiesel is considered clean fuel. It has no sulphur, no aromatics and has about 10% built in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel. The hydrocarbons present in the diesel fuels include paraffins, naphthenes, olefins and aromatics. Carbon numbers of these hydrocarbons ranges from 12 to 18.

V. Blending Of Biodiesel

To minimize the carbon deposition in combustion chamber [10], premature engine failure [11], piston ring deposits [12] biodiesel is the only alternative fuel so that low concentration biodiesel–diesel blends run on conventional unmodified engines [13]. The biodiesel can be blended in any percentage. Biodiesel blends from 2% to 20% can be used in most diesel equipment with no or minor modifications. The properties of the blend change with the amount of fuel blended with the biodiesel [14]. Liu *et al*. observed the combination of alcohol-biodiesel blends with intake charge dilution that could reduce the NOx emission and maintains particulate mass concentration at a relatively low level where the intake CO_2 concentration increased from 2% to 5.6% and particulate mass concentration of the alcohol-biodiesel blends remained almost unchanged [15]. A blend of 20% vegetable oil and 80% diesel fuel was also successfully reported [16] which improves the viscosities of the vegetable oils.

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VI. Use And Feasibility Of Biodiesel

Biodiesel's advantages compared to petroleum diesel include its renewable nature, superior emission properties like higher combustion efficiency, lower sulfur and aromatic content, higher cetane number and higher biodegradable [10], support for domestic agriculture, compatibility with existing engines, and distribution infrastructure, and ease of manufacture [17]. 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 [18]. Both good and bad biofuels exist depending on energy balance as well as economical and social sustainability and future deployments [19]. Usage of agricultural land to cultivate bioenergy crops may displace food crops and other ecosystem services that could be threatened. The interest to produce biodiesel is due to its less polluting and renewable nature, compared to conventional petroleum-based diesel fuel. The increasing development of biodiesel opens new challenges to the scientific community, including the production of renewable energy respecting natural ecosystems [20].

VII. Conclusion

Biodiesel is a clean-burning diesel fuel. Biodiesel is derived from varied range of edible and non-edible biomass sources. It attributes to lesser emission of CO, hydrocarbons, biodegradable and renewable. Biodiesel is said to be carbon neutral as more of carbon dioxide is absorbed by the biodiesel yielding plants than what is added to the atmosphere when used as fuel. Despites many processes of biodiesel production, transesterification is the method for biodiesel production which is successfully employed to reduce the viscosity of biodiesel and other characteristics. Another advantage of biodiesel is that blending of biodiesel along with diesel fuel gives positive effect. The emission composition of biodiesel is much lesser than petroleum based fuels which have gained attention. Therefore, continuous development and improvement of biodiesel is needed in producing cleaner emissions with less impact on the environment at a lower cost.

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