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Biodiesel production from renewable feedstocks: Status and opportunities

Venu Babu Borugadda, Vaibhav V. Goud *

Department of Chemical Engineering, Indian Institute of Technology Guwahati, Guwahati 781039, Assam, India

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ABSTRACT

The increased demand for energy, climate change, and energy security concerns has driven the research interest for the development of alternative fuel from plant origin. Biodiesel derived from plant oils, which include edible and non-edible oil have gained interest for the last two decades as alternative for diesel around the world. Among these plant origin oils more than 95% of biodiesel production feedstocks come from edible oils, because they are readily available in many regions. The major advantage of these feedstocks is the properties of biodiesel produced from them are suitable to be used as diesel fuel substitute. But the consequence is the increase demand of the feedstock for food as well as fuel. A sustainable alternative fuel should be derived from renewable non-food biomass sources. The main objective of this review is to give an overview on the synthesis of biodiesel through esterification and transesterification using non-edible oil resources which are available in India, and available processes for synthesis of biodiesel (acid-, base-catalyzed transesterification reactions (homogeneous and heterogeneous), their importance, and which is the commercial process also discussed here.

Contents

* Corresponding author. Tel.: +91 361 2582272; fax: +91 361 2582291.
E-mail address: vvgoud@iitg.ac.in (V.V. Goud).

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1. Introduction

Fuels are playing a major role in the economy of every country of this world and majority of the world energy needs are supplied by the petrochemical resources, coal and natural gases, with the exception of hydroelectricity and nuclear energy [1,2]. Among these mineral oils, petroleum plays a major role in the development of industrial growth, transportation, agricultural sector and to meet many other basic needs of human being [3]. Since 1970s mineral-based fuel oil (i.e. petroleum, diesel, kerosene, natural gas, etc.) prices are increasing day by day due to depletion of fossil fuel reserves and rapid consumption of mineral oils. The main reason that caused the fast diminishing of energy resources is due to rapid population and industrialization growth globally [4]. Moreover petroleum-based fuels are creating negative impact on the ecosystem and burning of these fuels leads to emission of pollutant gases like CO_2, HC, NOx, SOx [5]. Due to the above and following reasons like rapidly increasing prices, uncertainties concerning petroleum availability, increased environmental concern and effect of green house gases from industries have stimulated the search for alternative sources for petroleum-based fuel including diesel fuel [6].

As a result, biodiesel and ethanol has been known as bio-fuel to substitute petroleum derived cetane and octane fuel, respectively. These fuels have been attracted the attention, since use of these oxygenated fuels in the engines clearly reducing the exhaust emission of green house gases, particulate matters, unburned hydrocarbons, poly-aromatics and oxides of sulfur [7].

Biodiesel a processed fuel derived from the vegetable oils and animal fats through the esterification and transesterification reactions of free fatty acids (FFAs) and triglycerides, respectively, that occur naturally in renewable biological sources [8]. In other words we can define biodiesel is mixture of alkyl esters of long chain fatty acids, which are synthesized through esterification and transesterification of free fatty acids (FFAs) and triglycerides (TG) [2,8,9]. The major feedstocks available for biodiesel are rapeseed, palm, canola and soybean oils, though the process to grow non-food grade oil is under process in the developing nations in tropic and sub-tropics. Many bio-diesel industries have been set in the last decades worldwide, whereas most of these are not operational throughout the year due to the scarcity of cheap vegetable oils as feedstock for economic production of biodiesel.

In the production of biodiesel more than 95% of feed stocks come from edible oils since they are mainly produced in many regions of the world and the properties of biodiesel produced from these oils are much suitable to be used as diesel fuel substitute. Use of such edible oil to produce biodiesel is not feasible in view of a big gap in demand and supply of such oils as food and they are far expensive to be used at present and obviously, the use of non-edible vegetable oils compared to edible oils is very significant. Moreover biodiesel does not contain any compounds like sulfur or aromatic compounds and burning of biodiesel results in lower emission of hydrocarbons, carbon monoxides and particulate matters [10,11]. Since the cost of raw materials accounts about 60–80% of the total cost of biodiesel production, so choosing a right feed stock is very important and properties of biodiesel produced from different feed stocks would be quite different [2]. However, it may cause some problems such as the competition with the edible oil market, which increases both the cost of edible oils and biodiesel; moreover it will cause deforestation in some countries because more and more forests have been felled for plantation purposes. In order to overcome these disadvantages, many researchers, scientists, technologists as well as industrialists are interested in non-edible oil source which are not suitable for human consumption because of the presence of some toxic components in the oils. Furthermore, non-edible oil crops can be grown in wastelands that are not suitable for food crops and the cost of cultivation is much lower because these crops can still sustain reasonably high yield without intensive care [2,6,12]. However, most non-edible oils contain high free fatty acids. Thus they may require multiple chemical steps or alternate approaches to produce biodiesel, which will increase the production cost, and may lower the ester yield of biodiesel below the standards.

In recent days a number of methods are available and have been adopted for the production of biodiesel. There are four primary ways to produce biodiesel such as direct use and blending of raw oils, micro-emulsions, thermal cracking and transesterification [2]. The purpose of transesterification process is to lower the viscosity of the oil. The transesterification is the process of removing the glycerides and combining oil esters of vegetable oil with alcohol. The process reduces the viscosity to a value comparable to that of diesel and hence improves combustion [3]. This chemical process converts the triglycerides into fatty acid methyl esters (FAMEs), by releasing glycerol as a by-product. Currently the main synthetic approaches used for biodiesel production includes base-catalyzed transesterification, acid-catalyzed transesterification (with simultaneous esterification of free fatty acids), non-catalytic conversion via transesterification and esterification under super critical alcohol conditions, microwave and ultrasound [8]. Recently heterogeneous base-catalyzed transesterification gaining more interest due to its great advantages towards product separation, reusability of catalyst and reaction conditions. Above all each catalytic and non-catalytic process has its own importance and advantages towards esterification and transesterification reactions. Furthermore, in both acid- and base-catalyzed approaches, conversion efficiency is highly dependent upon the water and free fatty acid content of the feedstocks. Therefore, in this paper attempt has been made to give an overview on the synthesis of biodiesel through esterification and transesterification using non-edible resources which are available in India, and available processes for synthesis of biodiesel (homogeneous and heterogeneous), their importance, and which is the commercial process also we discussed here [4,13–19].

2. Feedstock's for biodiesel

Since last few years many biodiesel production plants have been identified in India. These plants are operational as per the availability of feedstock, price of crude vegetable oils. The common feed stock for the production of biodiesel in India is palm oil, which is being imported from Malaysia and Indonesia. As palm oil is being used for edible purpose, the price of the crude palm oil fluctuates in the international market. Apart from that some other feedstocks are also being used (i.e. fish oil, used cooking oil) but to a very less extent. Even though the consumption of edible oils in some countries like India is high, the availability of used cooking oil is very small as it is used till the end. Hence, focus needs to be