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Trends in catalytic production of biodiesel from various feedstocks

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ABSTRACT

Biodiesel offers to be one of the renewable fuel that is in great demand due to hike in price and exploitation of various conventional resources. Biodiesel has gained wide attention as it emits less carbon monoxide and other pollutants. Biodiesel is known as mono-alkyl esters of long fatty acid, produced by transesterification in the presence of triglycerides and alcohol. The choice of catalyst and feedstock are the most important criteria for effective production of biodiesel. Catalyst and raw material selection play a significant role in the cost of biodiesel production. The heterogeneous catalyst offers a wide option for the catalytic selection because of its high selectivity and reusability characteristics. Recent advances in the field of catalytic technology for biodiesel production using nanosized catalyst is because of high stability over the repeated use. Nanocatalyst solves various bottleneck problem associated in the production of biodiesel. The present review is focused on various technologies and challenges linked to the production process, including some important aspects of feedstock selection. Thus the present review is maily focused on various catalytic technology used for biodiesel production using different production methods and potential feedstocks.

Contents

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1. Introduction

Due to the depletion of conventional resources for fuels, researchers started to explore alternative sources to meet the energy demand for present and future. The impending challenges and the environmental implications has created a wide attention to find notable alternative fuels [1]. The crucial energy demand has accounted as a result of the rapid industrial establishment around the 19th century. It was reported that the transport sector occupies second position on high-energy consumption. The usage of oil in transportation sectors accounts to be 97.6% indicating the importance of oil resource for the production of energy. Although conventional sources of oil recorded to be the main source of energy consumption, it is expected to decline to 30% by 2035 [2]. Energy is reported to be inevitable for the existence of human life on earth. The main reason for finding an alternative source of energy is due to fluctuations over the price of crude oil and limited resources around the countries [3]. Biodiesel is one of the fuel that showed an appreciable result in the reduction of greenhouse gas and noted as a blended component in the transportation sector [4]. The establishment of liquid biofuel industries has increased in developed countries to reduce its dependence over the foreign oil resources [5].

Biodiesel has remained as a good substitute for automobile engines and recognized as global fuel in recent days. The physical and chemical properties of biodiesel are similar to the conventional diesel as it has a higher flash point and lubricating efficiency. These properties paved way for the commercialization of biodiesel with traces of sulfur and aromatic contents. Biodiesel is considered as safe for the environment as it showed insignificant contribution of carbon dioxide and other particulate emissions [6]. Chemically biodiesel is known as mixture of fatty acid methyl esters derived from either edible or non-edible oils. Production of biodiesel offers to be a great challenge to researchers, as the main criteria lies in minimizing the production cost. Selection of the feedstocks and catalyst plays an important role as these requires 75% of the total investment. It has been reported that biodiesel production is mostly from non-edible and waste oils, which eliminates the competition over food consumption. Various sources like algal oil, microalgae, jatropha and grease were reported to reduce the cost by 60–90% [7].

The new generation biodiesel intends to utilize raw materials from renewable feedstocks, providing sustainability and maintaining the availability of biodiesel at timely needs [8]. Evaluation of the feedstock with respect to life cycle analysis is important in the production of biodiesel as percentage of oil and yield are essential criteria in quality of biodiesel [9]. The different sources for the production of biodiesel and their respective oil percentage are given in Table 1. The Table 1 shows that the algal biomass possess high oil content when compared to the non-edible seeds. Irrespective to feedstock used, the presence of a catalyst is essential for the reaction to be completed [10]. Transesterification of triglyceride is conventionally carried out by acid and base catalyzed reaction. Though, the reaction time is shorter in homogeneous catalysts they possess certain constraints which are rectified by the use of heterogeneous catalysts.

Heterogeneous catalyst has several advantages over the traditional homogeneous catalyst such that they can be easily recovered and reused for next successive cycles [11]. The other catalyst reported for the production of biodiesel are biocatalyst and nanocatalyst. In the case of enzymatic transesterification, thermal stability and activation of catalyst makes it effective, whereas the cost of enzyme make it to be inefficient [12]. Recent advances in the field of nanocatalyst shows improvement in the surface area for its effective binding of the reactant. Also the lifetime of the nanocatalyst used in the reaction increases with respect to their surface binding efficiency [13]. This review summarizes the outline of different raw materials and the catalyst used for the biodiesel production and scale-up. Notably, importance of algal biomass and the blooming nanosized catalyst are indexed in this review. As transesterification is greatly affected by various parameters, knowledge on parameters optimization is necessary. The effect of catalyst concentration, oil to methanol ratio, temperature and time plays a crucial role in the biodiesel production process. The major objective of the present review is to consolidate the trends in development of various catalyst for biodiesel production.

2. Strategies of transesterification reaction

Transesterification is one of the commercial method to produce biodiesel with the help of alcohol having 1–8 carbon atoms. The transesterification reaction is facilitated by the presence of the catalyst [3,14]. Methanol is most widely used owing to its low price and availability [15]. During the transesterfication of triglycerides to fatty acid alkyl esters, three reversible reactions take place consecutively in which diglycerides and monoglycerides are the major intermediate products [16]. The stoichiometric molar ratio of alcohol to oil is three moles of alcohol and one mole of oil indicating that excess alcohol is required to shift the equilibrium favoring the formation of methyl esters [17]. Production of biodiesel has been reported with batch and continuous reactors with a drawback of batch operations [18].

3. Potential feedstock's for biodiesel production

The barrier in commercialization of biodiesel production is the cost of feedstock. The use of edible oils sparks with the issue of energy security while non-edible oils require additional pretreatment steps. In concern to these matters, exploration of waste or used oils has gained attention due to the effective elimination of disposal oils [19]. The utilization of waste or non-edible oils has several advantages such that, they are inexpensive and does not posses any threat to the environment. It was reported that million

Table 1
Main feedstock used for biodiesel production with their respective oil % [94–98].

Type of oil	Feedstock	Oil content % (w/w)
Edible	Soybean	15–20
	Rapeseed	38–46
	Sunflower	25–35
	Peanut oil	45–55
	Coconut	63–65
	Palm	30–60
Non-Edible	Jatrropha seed	35–40
	Pongamia pinnata	27–39
	Neem oil	20–30
	Castor	53
Other sources	Rubber seed	40–50
	Sea mango	54
	Cotton seed	18–25
	Microalagae	30–70