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A review on recent advancement in catalytic materials for biodiesel production

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ABSTRACT

Biodiesel, which could be derived from plant oils and animal fats, is considered as a promising substitute for petroleum diesel fuel because of its advantages, such as renewability, biodegradability, less environmental toxicity, and superior combustion efficiency. The feedstock used for biodiesel production primarily include edible oils, non-edible oils, waste oils, and animal fats. Consistent scientific investigations are performed to locate innovative oil resources and minimize the utilization of expensive food-grade oils for biodiesel production. The extensive research information is available on the determination of physico-chemical properties of different plant oils. This review will present a general information related to the existing varieties of oil feedstocks, their lipid content, and fatty acid composition.

This article further discusses different methods employed to enable the usage of plant oils as biofuel, such as its direct use, blending, thermal cracking, microemulsion, and alcoholysis process. Among the possible methodologies for biodiesel production, alcoholysis process, in the presence or absence of a catalytic material, have been frequently employed. The benefits and limitations of using homogeneous, heterogeneous, enzyme catalysts, and supercritical method for the alcoholysis process are comprehensively discussed. In the current article, efforts have been made to review the recent inventions in homogeneous and heterogeneous catalytic materials utilized for biodiesel production. The present study shall provide a tool for the selection of an optimal catalyst for a large-scale biodiesel production.

Contents

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1. Introduction

Energy is a basic requirement for human existence. Due to a continuous growth in human population, the majority of the world total energy is utilized for the industrial applications, transportation, and for the power generation sector. According to the International Energy Outlook 2013 set by the U.S Energy Information Administration [1], the total energy consumed in 2010 was 5.5282×10^{20} J, which further is predicted to rise to 8.6510×10^{20} J by 2040. Accordingly, the total world energy consumption will grow by 56% between 2010 and 2040; this can be seen in Fig. 1.

Transportation is currently the second largest energy consuming sector and is increasing by an average of 1.1% per year [1]. In the current situation, the foremost amount of energy is supplied by the conventional fossil fuel resources, such as gasoline, liquefied petroleum gas, diesel fuel, and natural gas. However, the use of fossil fuels has several carcinogenic influences on the ecosystem, such as large greenhouse gas emissions, acid rain, and also global warming. In addition to serious environmental issues, dwindling reserves of crude oil, oscillating petroleum fuel prices, and the overconsumption of liquid fuels, especially for the transportation purposes, have made today's necessity to find an alternate "green" sources of energy which are sustainable, environmentally tolerable, economically competitive, and easily available. The numerous modes of renewable energy resources are anticipated to play a significant role in resolving the world's future power situation; therefore, over the past few years, researchers have driven their attention towards finding an appropriate replacement for fossil fuels. Renewable energy resources, such as solar energy, wind energy, hydro-energy, and biofuels (biodiesel, bioethanol, biogas, and biomass) have been considered as a potential alternative to reduce the entire dependency on the use of fossil fuels [2–4].

Amongst others, biodiesel is consistently gaining attention as a viable substitute for petroleum diesel in a near future due to its remarkable characteristics. Biodiesel production is persistently winning relevance and market due to its benefits, such as biodegradability, renewability, environmentally less toxicity, high combustion efficiency, high cetane number, high flash point, lower sulfur content, better lubrication, among others [5–6]. Furthermore, biodiesel, ensuring a flashpoint of 423 K, is a non-flammable and non-explosive fuel in contrast to petroleum diesel having flashpoint of 337 K. Consequently, handling, storage, and transportation of biodiesel becomes relatively easy and safe [7]. Additionally, biodiesel production could also provide an opportunity to improve the domestic oil market in developing countries, and enhance farm incomes and agricultural industries [6,8].

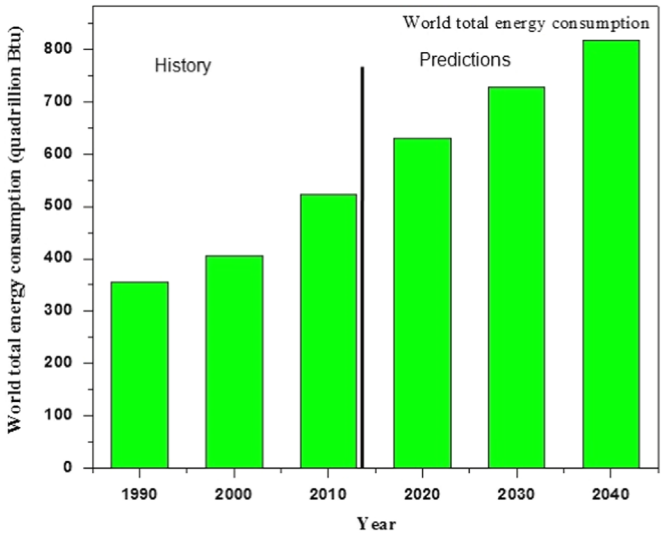

Fig. 1. World total energy consumption; history and projection.

In order to achieve the objective of understanding the valuable importance of biodiesel, the recent available literature were thoroughly reviewed to determine the current state-of-the-art and identify different oil sources, methodologies, and catalytic materials employed for biodiesel production. The current article will highlight the latest catalytic materials utilized for biodiesel production.

2. Biodiesel

According to the American Society for Testing and Materials (ASTM), biodiesel is defined as a mono-alkyl esters derived from lipid feedstocks, such as vegetable oils or animal fats [9]. The major components of plant oils and animal fats are triacylglycerol (TAGs); the esters of fatty acids and glycerol. The TAGs, also known as triglycerides, consists of different fatty acid composition which influences both physical and chemical properties of plant oils and animal fats; correspondingly also deciding the quality of biodiesel. There are two kinds of fatty acids: saturated fatty acids containing carbon-carbon single bond, and unsaturated fatty acids which include one or more carbon-carbon double bond. The most common fatty acids found in the lipid feedstocks are palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1), linoleic acid (18:2), and linolenic acid (18:3). The other fatty acids which are also present in several plant oils include myristic acid (14:0), palmitoleic acid (16:1), arachidic acid (20:0), and erucic acid (22:1). Besides the presence of fatty acids, additional components, such as phospholipids, carotenes, tocopherols, sulphur compounds, and water might also be present in plant oils [5,10].

2.1. Different types of oils

The satisfactory replacement of petroleum diesel with biodiesel is feasible only if it encounters two basic requirements: first is its easy availability and environmentally acceptability, and second being economically reasonable. In current scenarios, cost of plant oils used accounts for about 60–80% of the total production cost of biodiesel [11–13]. Thus, wide ranges of feedstocks have been assessed for biodiesel production and could be divided into different categories, such as edible oils, non-edible oils, waste oils, animal fats, and algal lipids. The different forms of plant oils, animal fats, and other sources used for producing biodiesel are