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A review on novel processes of biodiesel production from waste cooking oil

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ABSTRACT

Fossil fuel depletion, environmental concerns, and steep hikes in the price of fossil fuels are driving scientists to search for alternative fuels. The characteristics of biodiesel have made the pursuit of high quality biodiesel production attractive. Utilization of waste cooking oil is a key component in reducing biodiesel production costs up to 60–90%. Researchers have used various types of homogeneous and heterogeneous catalyzed transesterification reaction for biodiesel production. Meanwhile, the effect of novel processes such as membrane reactor, reactive distillation column, reactive absorption, ultrasonic and microwave irradiation significantly influenced the final conversion, yield and in particular, the quality of product. This article attempts to cover all possible techniques in production of biodiesel from waste cooking oil.

Contents

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1. Introduction

Energy consumption is inevitable for human existence. There are various reasons for the search of an alternative fuel that is technically feasible, environmentally acceptable, economically competitive, and readily available. The first foremost reason is the increasing demand for fossil fuels in all sectors of human life, be it transportation, power generation, industrial processes, and residential consumption [1]. This increasing demand gives rise to environmental concerns such as larger CO_2 and greenhouse gas emissions, and also global warming. World energy consumption doubled between 1971 and 2001 and the world energy demand will increase 53% by the year 2030. For instance, petroleum consumption will rise from 84.4 to 116 million barrels per day in USA until year 2030 [2,3]. The second reason is that fossil-fuel resources are non-renewable, and they will be exhausted in the near future [4]. Some reports claimed that oil and gas reserves will be depleted in 41 and 63 years, respectively, if the consumption pace remains constant [5]. The last reason is the price instability of fuels such as crude oil, which is a serious threat for countries with limited resources [6]. Several alternatives such as wind, solar, hydro, nuclear, biofuel, and biodiesel have been suggested but all of them are still in the research and development stage.

The inventor of biodiesel engines, Rudolf Christian Karl Diesel (1858–1913) demonstrated the use of vegetable oils as a substitute for diesel fuel in the 19th century [7]. He believed the utilization of biomass fuel will become a reality as future versions of his engine are designed and developed. Biodiesel is a mono alkyl ester of fatty acids produced from vegetable oils or animal fats [8,9]. In other words, when a vegetable oil or animal fat chemically reacts with an alcohol, it can produce Fatty Acid Methyl Ester (FAME), a vegetable oil which can be used in diesel engines after some adjustments and modifications. Vegetable oils contain saturated hydrocarbons (triglycerides) which consist of glycerol and esters of fatty acids. In addition, fatty acids have different numbers of bonds and carbon chain lengths. There are different kinds of modification methods, such as dilution, thermal cracking (pyrolysis), transesterification, and microemulsification. However, transesterification is the best method for producing higher quality biodiesel [10–14].

All fatty acid sources such as animal fats or plant lipids (more than 300 types of them) can be used in biodiesel production [15–19]. The utilization of these types of sources has given rise to certain concerns as some of them are important food chain materials [20,21]. In other words, the production of biofuels from human nutrition sources can cause a food crisis. Therefore, the majority of researchers have focused on non-edible oils or waste cooking oils as feedstock for biodiesel production such as algae oil [22–24], microalgae [25–29], jatropha oil [30], and grease oil [31]. Table 1 shows various feedstocks in biodiesel production [32]. The most important obstacle in biodiesel industrialization and commercialization is production costs [33,34]. Therefore, the usage of waste edible oils can reduce biodiesel production costs by 60–90% [35–39]. In an effort to produce higher quality biodiesel at lower costs, researchers are using various novel processes to decrease the reaction time, amount of alcohol, catalyst, and particularly reaction temperature.

In this paper, an attempt has been made to review all possible methods in the production of biodiesel from waste cooking oil with emphasis on some processes in separation, purification and analysis of product quality. The downstream of biodiesel, performance of engine fuels and characterization of biodiesel exhaust have been reviewed in previous studies [40,41].

2. Biodiesel

The utilization of biofuels or vegetable oil in internal combustion engines was reported during 1920–1930 and Second World War from all around the world. Germany, Argentina, Japan, Belgium, Italy, France, the United Kingdom, Portugal, and China have tested and used different types of biofuels. However, petroleum fuel production costs were cheaper than alternative fuels causing to slow down production of biofuel infrastructures. Recent concerns of environmental degradation and fossil fuel depletion have again jumpstarted the production of biodiesel, because it seems to be the most feasible solution for this situation [29].

The investigation of vegetable oils as fuel started in 1978 and 1981 in the United States and South Africa, respectively. In 1982, methyl ester was produced in Germany and Austria from rapeseed oil, and a small pilot plant was built in Austria at 1985. Commercial production of methyl ester first began in Europe in 1990. More than 2.7 million tones biodiesel was produced in Europe in 2003, but their target is around 20% total diesel market in 2020. In addition, the USA future plan for biodiesel production is around 3.3 million tones in 2016 [42].

Biodiesel has significant influences in reducing engine emissions such as unburned hydrocarbons (68%), particulars (40%), carbon monoxide (44%), sulfur oxide (100%), and polycyclic aromatic hydrocarbons (PAHs) (80–90%) [43,44]. Meanwhile, it is safer to

Table 1
Different feedstocks for production of biodiesel.

Conventional feedstock		Non-conventional feedstock
Mahua	Soybean	Lard
Nile tilapia	Rapeseed	Tallow
Palm	Canola	Poultry fat
Poultry	Babassu	Fish oil
Tobacco seed	Brassica carinata	Bacteria
Rubber plant	Brassica napus	Algae
Rice bran	Copra	Fungi
Sesame	Groundnut	Micro-algae
Sunflower	Cynara cardunculus	Tarpenes
Barley	Cottonseed	Latexes
Coconut	Pumpkin	Pongamina pinnata
Corn	Jojoba oil	Palanga
Used cooking oil	Camelina	*Jatropha curcas*
Linseed	Peanut	Sea mango
Mustard	Olive	Okra