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Recent insights into continuous-flow biodiesel production via catalytic and non-catalytic transesterification processes

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HIGHLIGHTS

- Biodiesel can be produced via catalytic and non-catalytic processes.
- Mass production of biodiesel with continuous-flow reactors is reviewed.
- Continuous process assisted with ultrasound, microwave, supercritical method.
- New techniques developed to improve mass transfer and biodiesel conversion.
- Continuous-flow conversion of microalgal oil is intensively reviewed.

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ABSTRACT

Biodiesel has been receiving considerable attention as an alternative energy source over the last decade. Conventionally, biodiesel is produced by transesterification of lipid and alcohol, with or without the aid of catalysts. Due to the presence of multiple phases during the catalytic reaction, the mass transfer between reactants and catalysts, as well as the type of catalyst used are the two major factors that should be considered during the design of the reactor applied for the targeted conversion. Most efforts in this area focused on the selection of effective catalysts (e.g., homogeneous catalysts, heterogeneous catalysts, enzymes) for biodiesel conversion via transesterification. The tests are regularly conducted on batch mode and the optimization of the operating conditions was done. However, to scale up the biodiesel production, many researchers utilized continuous-flow regime to continuously convert lipids to biodiesel with preferable process design to solve the problems encountered during continuous operation. This review is aimed at providing the knowledge and updated information on recent advances of the continuous-flow biodiesel production technology. This article presents and critically discusses the advantages and limitations of using catalyzed and non-catalyzed transesterification in conventional continuous-flow reactors and those assisted by supercritical conditions, membrane reactors, ultrasound, microwave, and other special techniques. Several newly developed processes, such as oscillatory flow reactor (OFR), microchannel reactors, laminar flow reactor-separator, liquid-liquid film reactor, which could minimize mass transfer resistance and improve biodiesel conversion are also presented. Finally, updates on conversion technologies for lipids from oleaginous microalgae (potential third-generation oil feedstock) to biodiesel and reviews on commercial continuous-flow biodiesel conversion technologies are provided.

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Contents

1. Introduction

The over exploitation of fossil fuels and the unsustainable nature of their resources has led to the current energy crisis and environmental issues. The world is now operating in an unsustainable mode. Thus, the search for greener fuels which supports sustainable growth of industry and economy is critical [1]. Biodiesel is being considered as a very promising alternative due to its many advantages, mainly (a) the sustainable nature of their sources compared to petrochemical or fossil fuel based fuels, and (b) its clean burning properties without the net emission of greenhouse gases (GHGs) [2–5]. Biodiesel is reported to have a similar cetane number as fossil-refined diesel and it can be used as original fuel or as a blend with conventional diesel in current vehicle infrastructure without any modification [6].

Conventionally, biodiesel is mainly produced via transesterification of triglycerides with alcohol. The source of triglycerides for transesterification can vary widely, including animal fats [7], vegetable oils [8–11], waste cooking oil [5,12,13], microalgae oil [4,14,15] and fungal oil [16]. Transesterification reactions can be non-catalytic [7] or catalytic processes [17] using homogeneous catalysts [9,13], heterogeneous catalysts [12,18–20], biocatalysts [21,22], and ionic liquids [23,24]. The batch production is typically carried out to investigate the effect of reaction parameters (i.e., temperature, stirring rate, catalyst loading, etc.) on the conversion of fatty acid esters (biodiesel) and determine the optimal operating condition for the reactions [19,21,25,26]. In continuous mode, the experiment is conducted to investigate the effect of reaction parameters on the conversion of products (biodiesel) and to determine the optimal conditions for scale up in mass production [27,28]. To improve biodiesel conversion, the efficiency of mass transfer should be enhanced between triglyceride and alcohol with catalysts, which can be assisted with microwave [15], ultrasound [9,18], or supercritical conditions [14].

The principle of the reactions for biodiesel production from triglycerides (vegetable oils, animal fats, etc.) is shown in Fig. 1. There are three consecutive reversible reactions involved in the reaction and the yield of biodiesel highly depends on the properties of reactants (purity, structure, etc.) and the catalysts used. The original characteristics of reactant sources would aid in the design and optimization of the type of catalyst used, while the original property of catalyst would be the determining factor on the choice of a suitable reactor. In contrast, once a reactor is specified, the catalyst can be designed to obtain the targeted conversion of products in the particular reactor and the operating mode could be adjusted to achieve the optimal biodiesel conversion. Continuous reactor technology could enhance the reaction rate, reduce energy input and molar ratio of alcohol to oil by intensification of mass and heat transfer and *in situ* product separation. This technology is also easy to scale up, thus possessing high commercial potential [29].

This article focuses on reviewing the current advances of using continuous-flow technology for the production of biodiesel.