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Advances in solid-catalytic and non-catalytic technologies for biodiesel production

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ABSTRACT

The insecure supply of fossil fuel coerces the scientific society to keep a vision to boost investments in the renewable energy sector. Among the many renewable fuels currently available around the world, biodiesel offers an immediate impact in our energy. In fact, a huge interest in related research indicates a promising future for the biodiesel technology. Heterogeneous catalyzed production of biodiesel has emerged as a preferred route as it is environmentally benign needs no water washing and product separation is much easier. The number of well-defined catalyst complexes that are able to catalyze transesterification reactions efficiently has been significantly expanded in recent years. The activity of catalysts, specifically in application to solid acid/base catalyst in transesterification reaction depends on their structure, strength of basicity/acidity, surface area as well as the stability of catalyst. There are various process intensification technologies based on the use of alternate energy sources such as ultrasound and microwave. The latest advances in research and development related to biodiesel production is represented by non-catalytic supercritical method and focussed exclusively on these processes as forthcoming transesterification processes. The latest developments in this field featuring highly active catalyst complexes are outlined in this review. The knowledge of more extensive research on advances in biofuels will allow a deeper insight into the mechanism of these technologies toward meeting the critical energy challenges in future.

1. Introduction

Today's struggle for existence is the struggle for sustainable energy. Considering the economic development and therefore high consumption, the present demand of earth's energy (14 terawatt (TW)/y) will increase to 28–30 TW/y by 2050 [1]. The known petroleum reserves are limited and will eventually run out. In consequence, the inadequacy of fossil fuel and the increase in demand of energy are the driving force concerning the future energy security around the world. Fossil fuel consumption causes the emission of carbon dioxide into the atmosphere, resulting in collapse of balance between the carbon dioxide released to environment and the gas absorbed by plants. According to world climate report [2], the ongoing trend of using traditional energy sources aid to increase the carbon dioxide levels from 8600 to 13,000 million metric tons of carbon by 2050. Hence, researches have been directed toward the development of renewable, non-toxic and carbon–neutral alternative fuels. The efficient production of clean energy is the vital breakthrough of modern science to keep up-to-date on *cutting-edge* research. It was reported that [3]:

> *"Scientists have the moral duty to inform the general public of the urgency and complexity of the energy problem."*

An update on the advances production technique can reinforce the biodiesel as an *alternative clean fuel.* Biodiesel refers to the lower alkyl esters of long chain fatty acids, which are synthesized either by transesterification with lower alcohols or by esterification of fatty acids [4] shown in Fig. 1. The transesterification can be carried out either using catalytic (homogeneous or heterogeneous) or non-catalytic process. Presently, most of the commercial production of biodiesel worldwide uses homogeneous base or acid

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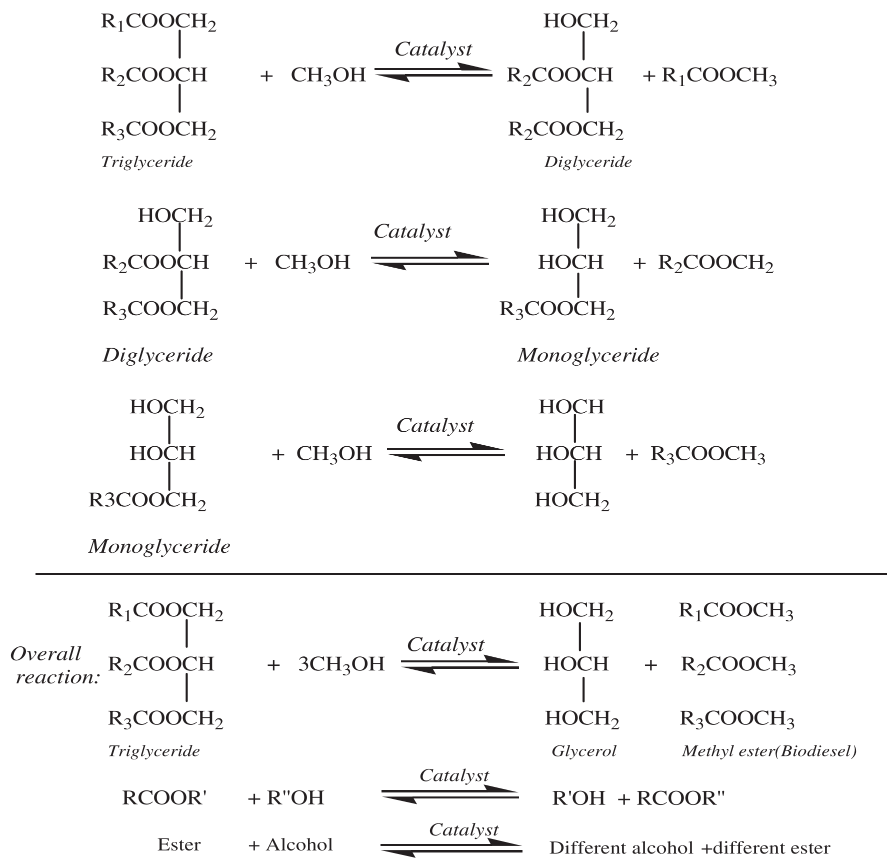
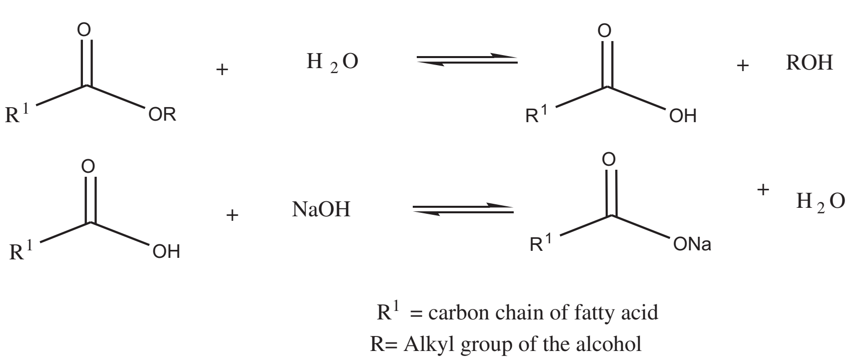


Fig. 1. Overall transesterification reaction.

catalysts. Homogeneous catalyst dispersed in a solution of reactants, has many potential advantages over solid phase and could be designed rationally to be selective and highly active. However, the main problem of this process is the undesirable production of soap which requires energy intensive separation operations [5].



It was reported by King [6] that separation processes represent more than half of the total investment in equipment for the fuel industries. Therefore, it is reasonable to state that the separation costs are a decisive factor in the final analysis of a new process. In addition, the production process is fairly corrosive and cannot be reused [7]. Hence, a great effort has been *placed toward* the development of solid catalysts aiming to make a cost efficient process.

From a process perspective, the heterogeneous catalysts in contrast to the homogeneous catalysts have the benefit of the elimination of several steps of washing of biodiesel, ensuring thereby, higher efficiency and profitability of the process. For the classification of various types of heterogeneous catalysts, it is convenient to divide them into two broad categories, soild-acid and solid-basic catalyst (Fig. 2). In particular, layered double hydroxides (LDHs) have attracted much interest as solid base catalysts for vegetable oil transesterification [8,9]. LDHs have showed efficient catalysts for esterification reaction due to its high basic properties; however, the catalyst works rarely for the transesterification reaction [10]. Thus, most of the secondary feedstocks such as waste oil and most other non-food feedstocks containing high FFA are more desirable in acid catalyzed reaction than basic-catalyzed reaction [11]. Several recent studies have reported on technical and economical feasibility for biodiesel production through heterogeneous acid-catalyzed transesterification [12,13]. Consequently, the acid catalytic reaction is of particularly interest for biodiesel production; however, the acid catalysts show lower catalytic activity in