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# Lipase-catalyzed process for biodiesel production: Enzyme immobilization, process simulation and optimization

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ABSTRACT

Transesterification of oil feedstocks using immobilized lipase (IL) is a promising process for biodiesel production. However, the running cost of this process is still higher than that of conversional chemical-catalyzed approaches. To address this challenge, both upstream and downstream processes have to be optimized. This review provides an overview of recent progresses in improving IL-catalyzed biodiesel production, focusing on mid- and down-stream processing such as immobilization of lipase, bioreactors development, process optimization, simulation and techno-economic evaluation. The immobilization of lipase is a costly process. Most of the commercial ILs are prepared by adsorption of free lipase on polymeric materials. However, to further reduce cost, works should be focused on developing cheap carriers and strengthening the interaction between enzyme and carrier but without significant loss of lipase activity. Running cost of lipase also can be reduced by improving its lifetime during transesterification. To achieve this goal, solvents can be used to prevent lipase leaching and eliminate the inhibitive effects of alcohol (usually methanol) and glycerol. Downstream processing includes important units to purify biodiesel products. In this part, works should be focused on minimizing energy consumption and waste effluents. A global process integration and optimization with economic evaluation also should be figured out to improve the economic feasibility of Il-catalyzed production of biodiesel.



**Contents**



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## 1. Introduction

Lipase-catalyzed transesterification of oil feedstocks has been considered as one of the most promising techniques for producing biodiesel, a mixture of fatty acid alkyl esters (FAAE). This process has become a research hot-spot in academic community during last 10 years. An increasing number of scientific publications including articles, review papers, book chapters, patents and conference abstracts have been published (Fig. 1). However, conventional biodiesel plants adopt transesterification processes using chemical catalysts such as alkalis and acids. Only a few plants have employed enzymatic process for industrial productions of biodiesel [1,2]. This is mainly because that the catalyst (lipase) used in the enzymatic process is much more expensive than chemical catalysts, such as NaOH and $H_2SO_4$. Various lipases have been used for biodiesel production, among which immobilized-lipase (IL) shows great potential for industrial application since ILs are more tolerant to organic solvents, heat and shearing force, and much easier to recover than free lipases (FLs).

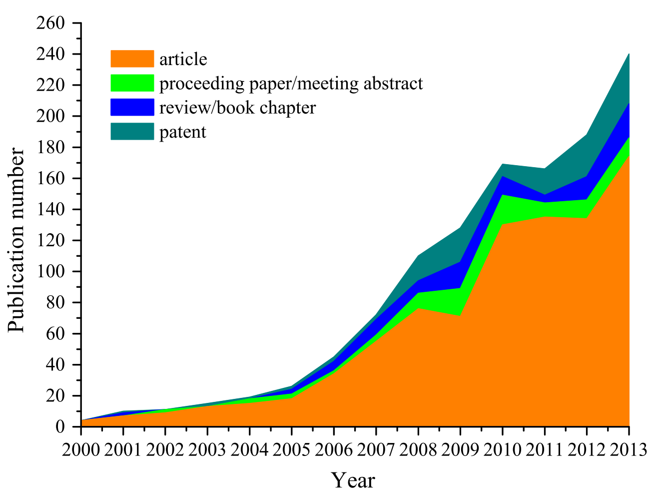


**Fig. 1.** Publications in years of 2000–2013 found in Web of Science ™ database by the term "biodiesel and lipase" separated by document types.

To reduce the production cost of enzymatic transesterification, strategies can be made in up-, mid- and down-stream processings (Fig. 2). Specifically, in up-stream processing the catalytic stability and activity of lipase can be improved by protein engineering, strain optimization and metabolic engineering techniques as reviewed in our previous paper [3]. In addition, further reduction of running cost of the enzyme-catalyzed biodiesel production can be achieved by process intensification strategies, for example by improving the immobilization as well as process design and optimization. Immobilization of lipase enzymes has been studied for many years, and various carriers have been used. However, only a few types of carrier and immobilization process have been commercialized. Nevertheless, these commercialized ILs are still too expensive to be used for biodiesel production. Some newly developed immobilization technologies by using magnetic and nano-particles have been reported, but they are still far away from industrial application. One of the solutions to the high cost of lipase for biodiesel production is to increase its lifetime in transesterification. At this point, reaction media, operation parameters as well as reactor development should be considered. For example, the stability of ILs in conventional aqueous system is usually poor due to the leaching of enzyme from carriers and the inhibitive effects of methanol and glycerol. However, by introducing novel solvent, e.g. *tert*-butanol, as reaction media, the stability of lipase can be greatly improved [1]. Reactor design is important for scale-up of IL-catalyzed production of biodiesel, but the development of high-efficiency reactor for IL-catalyzed production of biodiesel goes slowly. Commonly used reactors are stirred tank reactor (STR), packed-bed reactor (PBR) or their combination. However, much improvement is still needed for intensifying mass

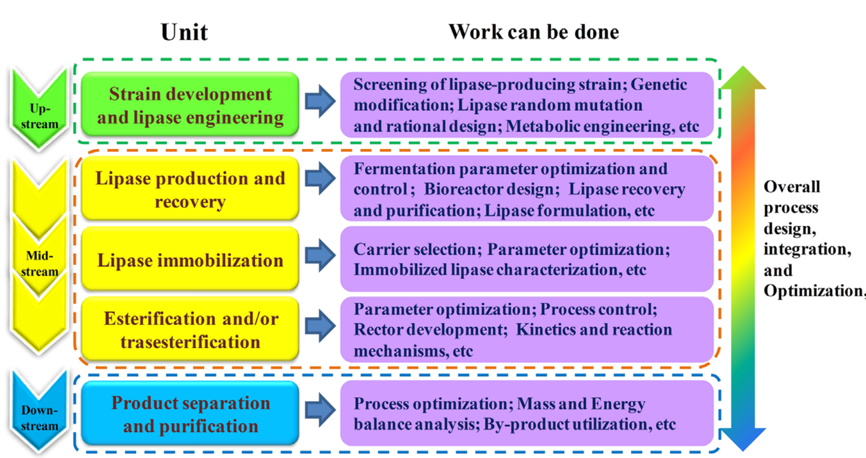


**Fig. 2.** Unit operations and corresponding works that can be done to reduce the cost of lipase-catalyzed biodiesel production.