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ENHANCING LIPID EXTRACTION AND TRANSESTERIFICATION EFFICIENCY TO OPTIMISE MICROALGAL BIODIESEL

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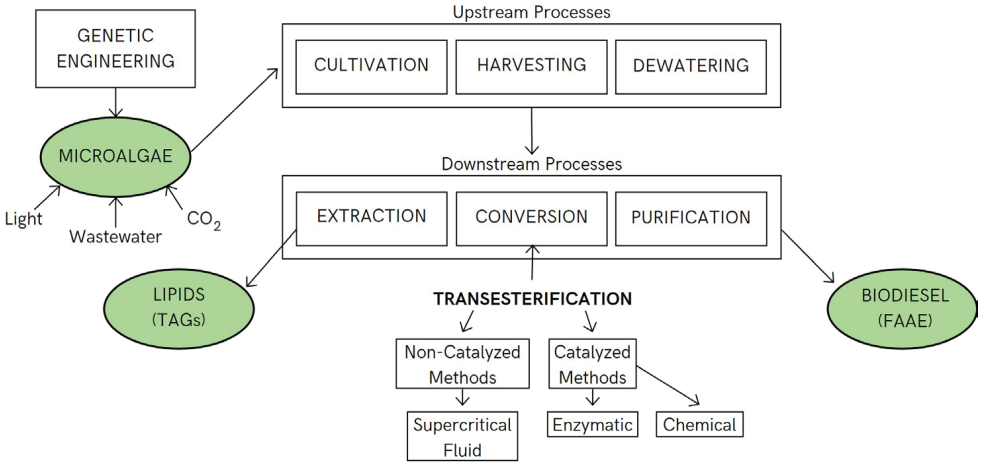
Abstract – The global quest for sustainable energy solutions has intensified as the adverse effects of fossil fuel consumption become increasingly evident. Rising energy demand underscores the need for biofuels derived from biological sources to reduce reliance on fossil fuels. Among various biomass sources, microalgae have emerged as promising biodiesel feedstock due to minimal resource requirements, rapid growth, and superior carbon fixation efficiency compared to terrestrial crops. In this contribution a review on the microalgae-derived biodiesel is presented, with particular attention to the role of lipid extraction and transesterification processes. Advancements in upstream processes – cultivation methods such as phototrophic, heterotrophic, and mixotrophic systems, harvesting, and dewatering – and downstream processes, including lipid extraction, conversion, and purification are critically discussed. A scheme of the key steps is represented in the figure. The review focuses on the role of chemical and enzymatic catalysts in enhancing transesterification efficiency, achieving yields of up to 94 %. Homogeneous catalysts, including base and acid types, are highlighted for the high activity, with base catalysts excelling under mild conditions and acid catalysts proving more effectiveness for high free fatty acid content. Heterogeneous catalysts are emphasized for the reusability, non-corrosiveness, and reduced environmental impact, although challenges like limited mass transfer and catalyst deactivation persist. Enzymatic systems, especially those enhanced with magnetic nanoparticles, are shown to achieve up to 93 % fatty acid ethyl ester yields while mitigating issues such as saponification and high energy demands of traditional methods. Additionally, emerging non-catalytic approaches, such as supercritical fluid technology, are highlighted for the ability to achieve single-step conversion of algal lipids to biodiesel, with yields exceeding 85 %. Finally, this contribution explores the potential of genetic and biochemical engineering to boost lipid productivity and metabolic efficiency, advancing toward fourth-generation biofuels. Indeed, recent results underscore the viability of microalgae as keystone in the global transition to sustainable energy. However, economic and technical barriers, such as high production costs and energy requirements, currently hinder large-scale implementation of microalgae-based biodiesel. Current interdisciplinary research prioritize cost-effective cultivation systems, innovative reactor designs, and strategies for co-product utilization within algal biorefineries to achieve scalable and sustainable biodiesel production.

Keywords – Biofuel; catalyst efficiency; fatty acid ethyl ester; genetic engineering; lipid extraction; microalgae



Key steps in the mechanism of microalgae biodiesel production