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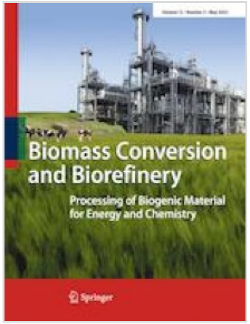

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Abstract

The rising global population and the environmental impact of fossil-fuel dependency have intensified the need for cleaner and renewable energy alternatives. Biodiesel, among biofuels, has gained significant attention as a key contender due to its sustainability and compatibility with existing energy infrastructure. Researchers worldwide are continuously exploring cost-effective, scalable, and sustainable production methods to meet this growing energy need. Waste cooking oil (WCO) and other feedstocks are commonly used for biodiesel production due to their economic advantages and waste reduction potential. To overcome these hurdles, a two-step transesterification or hybrid approach has been adopted for commercial-scale biodiesel production, offering an efficient and environmentally friendly solution for the biofuel industry. In this review, emergence of biocatalysts and hybrid catalytic approaches has been investigated as revolutionary solutions in sustainable biodiesel synthesis. Additionally, economic feasibility, industrial challenges, and potential breakthroughs have been discussed that can drive biodiesel production toward a more sustainable and commercially viable future. By embracing these green innovations, the biofuel industry moves closer to an era of clean, efficient, and cost-effective energy solutions. This study advances sustainable biodiesel production through innovative catalytic approaches, supporting clean energy (sustainable development goal (SDG) 7), waste valorization (SDG 12), and climate action (SDG 13).

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