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Emerging approaches in lignocellulosic biomass pretreatment and anaerobic bioprocesses for sustainable biofuels production

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ABSTRACT

The development of advanced biofuels from waste organic matter, such as lignocellulosic biomass, is critical for global sustainable waste management and to delay climate change by reducing greenhouse gas emissions *via* partial replacement of fossil fuels. However, the inherent recalcitrance of lignocellulosic biomass due to the presence of inhibitory components, mainly lignin, limits the hydrolysis of its carbohydrate content, representing a key hurdle augmenting biofuel production. Therefore, pretreatment of lignocellulosic biomass is crucial to promote its fragmentation, increase its surface area and solubility, and lower the cellulose crystallinity and lignin content for sustainable biorefinery. Conventional pretreatment processes have several drawbacks, including high operational costs, corrosion of equipment, and generation of toxic effluents and by-products. To offset the negative impacts of these limitations on biofuel production, here, we have discussed and critically compared various eco-friendly approaches for the efficient conversion of biomass to ensure high yields of biofuels as a commercial solution. Moreover, a range of microbes and enzymes have been highlighted that effectively utilize lignocellulosic biomass to obtain energy and convert its complex polymeric structure into a biodegradable one, facilitating its subsequent valorization. Furthermore, the importance of multi-omics approaches was discussed to gain functional insights into the lignocellulolytic microbial communities and their interspecies symbiosis during the hydrolysis of organic biomass. Finally, the limitations of previous studies, challenges, industrial perspectives, and future outlooks for the development of economical, energy-saving, and eco-friendly strategies toward the sustainable valorization of lignocellulosic biomass were summarized.

1. Introduction

The bioeconomy of the 21st century has encouraged the development of novel economic models to curtail the utilization of natural resources for economic prosperity and ecological survival (Hassan et al., 2018; Kumar et al., 2020a). Global warming and climate change, environmental deterioration, and consequent increase in pollution-related health hazards are significant threats due to the ever-growing demand and consumption of fossil fuels (Kazemi Shariat Panahi et al., 2019). Intense efforts are being made to channelize sustainable energy from the largest renewable carbon source, the lignocellulosic biomass (LCB), which is an attractive feedstock for anaerobic bioprocessing (Cheng et al., 2020). This will help to meet the global energy demand, reduce the dependence on fossil fuels, and reduce greenhouse gas (GHG) emissions by 20–70%, thereby encouraging sustainable green growth (Xu et al., 2016).

Biorefineries can be used to produce energy, value-added chemicals, bioplastics, and fuels using renewable and non-edible feedstocks, such as LCB and food waste biomass, to drive society towards a sustainable economy (Sriariyanun et al., 2021). However, numerous challenges, such as the presence of inhibitory molecules and the structural complexity of LCB due to cross-linking between polysaccharides (cellulose and hemicellulose) and phenolic polymers (lignin), critically

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