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Editorial: Emerging Feedstocks & Clean Technologies for Lignocellulosic Biofuel

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Editorial on the Research Topic

Emerging Feedstocks & Clean Technologies for Lignocellulosic Biofuel

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The United Nations Sustainable Development Goals (SDGs) include the availability of affordable and clean energy (Goal 7) for attaining peace and prosperity for all (Sustainable Development Goals, 2022). The other SDGs "Sustainable Cities and Communities" (Goal 11), "Responsible Consumption and Production" (Goal 12), and "Climate Action" (Goal 13) also warrant the search for sustainable feedstock and clean technologies for the production of renewable fuel. Lignocellulosic biomass is one of the prominent and emerging feedstocks being investigated as a source for biofuel production. The yearly global production of lignocellulosic biomass in nature is estimated to be 181.5 billion tons. Of this, just 8.2 billion tons of biomass is said to be currently utilized of which 7 billion tons originates from forest, agriculture and grasses and 1.2 billion tons is supplied from agricultural residues (Ashokkumar et al., 2022). The traditional utilization of such biomass is for cooking, heating, construction material, and production of paper, cardboard, and textiles. With the advancement in technologies and biomass management this valuable lignocellulosic biomass can be directed towards production of renewable biofuels. Moreover, the cellulose, hemicelluloses, and lignin material could be valorized to other useful industrial bioproducts and biochemicals (Ashokkumar et al., 2022).

Lignocellulosic biomass comprises of lignin, cellulose, and hemi-cellulose and is abundant globally. Cellulose is the most abundant organic material available in nature followed by lignin. The percent composition of cellulose, hemicellulose, and lignin vary in lignocellulosic materials such as softwood, hardwood, agricultural residues, and grasses. Lignocellulosic biomass comes from a wide variety of feedstocks such as sugar crops, starch crops, agricultural residues, herbaceous biomass, woody biomass, oilseeds, and microalgae (Yuan et al., 2018). Carbohydrate present in the cellulose and hemicellulose components of lignocellulosic biomass are considered suitable for the production of biofuels. However, the lignocellulosic material is recalcitrant as the lignin in the lignocellulosic biomass inhibits the saccharification and hydrolysis of carbohydrate present in the biomass and thus poses challenges in biofuel conversion. The major challenge in the conversion of polymer to monomer from the lignocellulosic biomass is attributed to the strong covalent and non-covalent bond in its structure, crystallinity, and lignin incrustation that needs to be overcome for its utilization as a material for biofuel production (Preethi et al., 2021). The recalcitrance nature of the lignocellulosic material is overcome by pre-treatment steps that disorders the lignin component in the biomass. Thereafter, the cellulose and hemi-cellulose could be subjected to enzymatic hydrolysis. The pre-treatment methods can be physical, chemical, physiochemical or biological. Pre-treatment leads to fragmentation of the lignocellulosic material, further enhancing its surface area and solubility, and lowering the crystallinity of cellulose and lignin content in the biomass (Hoang et al., 2021; Kumar et al., 2022). Feedstock selection, blending of feedstocks, efficient pretreatment methods, integration of saccharification and fermentation processes, enzyme sources and application technologies can alleviate the challenges of lignocellulosic biomass for its conversion to biofuel.

"*Emerging Feedstocks & Clean Technologies for Lignocellulosic Biofuel*" explores the novel feedstocks, recent advancements, and technological developments in lignocellulosic biofuels production. Globally, researchers are focusing on investigating the feasibility of locally grown or available lignocellulosic biomass to produce biofuel. This biomass includes energy crops, by-products from various production processes, and even waste materials. Adewuyi emphasized utilizing lignocellulosic wastes and developing efficient pretreatment methods most applicable to the biofuel demand of developing countries. In the review, the high production cost of biofuel is attributed to high cost of enzyme production; however, developing a relevant simultaneous saccharification and co-fermentation (SSCF) process and consolidated biomass processing (CBP) can alleviate this challenge. Developing countries needs to encourage biofuel and feedstock producers through policies. Using locally available lignocellulosic biomass can ensure energy security and waste management through energy recovery.

Feedstock is crucial for successful sustainable production of biofuel. Feedstock variability due to its growth and processing conditions also influence biofuel yield. Blending different feedstocks and developing efficient pre-treatment methods can improve biofuel yield. Li et al. conducted technoeconomic analyses of sugars produced from four feedstocks and two blends of these feedstocks using two different pre-treatment methods. They studied single-pass corn stover (SPCS), multi-pass corn stover (MPCS), switchgrass (SW), sorghum (SG), a 60/40 blend of MPCS and SPCS, and a 25/35/35/5 quad blend of MPCS/SPCS/SW/SG. These feedstocks were subjected to deacetylation and dilute acid pretreatment (DDA) or deacetylation and mechanical refining pretreatment (DMR). Pretreatment methods and processing of biomass for biofuel production greatly influence the yield and economics of biofuel. Pre-treatment methods can produce inhibitors that affect the enzymatic saccharification and microbial fermentation process. Some conditioning or processing after the pre-treatment of biomass can improve the saccharification and fermentation of feedstock biomass. Ilanidis et al. studied conditioning of steam pre-treated softwood using different industrial reducing agents and found improvement in fermentability with sodium sulfite conditioning. Integration of such processing steps can tackle the technological barriers and improve overall production capacity.

Hydrolysis of complex polysaccharides from lignocellulosic biomass and fermentation to ethanol is catalyzed by various enzymes. Researchers are focusing on exploring and developing enzyme cocktails and a microbial consortium that are capable of hydrolyzing complex lignocellulosic biomass and fermentation of sugars. Thermotolerant enzymes have shown promising conversion activities even at high temperatures in industrial bioreactors. Lepcha et al. investigated goat rumen content to develop a thermotolerant xylanolytic consortium for saccharification of alkali pre-treated rice straw and mushroom spent rise straw. More attention is required from researchers to develop more efficient and cost-effective enzyme cocktails for saccharification of complex lignocellulosic waste feedstocks for biofuel production.

Lignocellulosic-based biofuel is poised to play a major role in minimizing environmental pollution and generation of renewable energy. Research advancements need to focus on deriving sustainable and profitable forms of energy from lignocellulosic biomass. Techno-economic analysis and life cycle assessment of the biofuel derived from the lignocellulosic biomass will be the guide in evaluating the benefits and applicability of the fuel derived from it. Lignocellulosic biofuels have great potential to attain energy security and thus governments and policymakers' needs to encourage research, development and production activities in this field.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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