Editorial Corner

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From Waste to Wealth: Challenges in Producing Value-Added Biochemicals from Lignocellulose Biorefinery

Malinee Sriariyanun[1]* and Babu Dharmalingam[2]

[1]Biorefinery and Process Automation Engineering Center, Department of Chemical and Process Engineering, The Sirindhorn International Thai-German Graduate School of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

[2]Department of Mechanical Engineering, College of Engineering Guindy, Anna University, Chennai, Tamil Nadu, India

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***Corresponding Author:** malinee.s@tggs.kmutnb.ac.th

Lignocellulose biorefinery is a sustainable and integrated approach to convert lignocellulosic biomass into a variety of valuable products, including biofuels, biochemicals, platform chemicals, and biomaterials (Ruensodsai & Sriariyanun, 2022). Lignocellulosic biomass is composed of three main components: cellulose, hemicellulose, and lignin, which are tightly interconnected in the plant cell wall. These components are abundantly found in various renewable resources such as grass, wood, municipal wastes, agricultural residues, and dedicated energy crops. This concept supports the circular economy concept and the sustainable development goal (SDG), especially SDG 12, Responsible Consumption and Production. The main benefit of lignocellulose biorefinery is not only to gain the economic benefit of converting waste to products, it also reduces the release of waste and pollution to the environment (Panakkal & Sriariyanun, 2023).

Due to the recalcitrant structure and chemical properties of lignocellulose biomass, the biorefining process to convert biomass to a final product has low efficiency. The main bottleneck of this process is the hydrolysis of lignocellulose to monomers or oligomers of cellulose hemicellulose and lignin derivatives. Therefore, the main steps in lignocellulose biorefinery generally include pretreatment, hydrolysis, fermentation and product recovery (Figure 1) (Phakeenuya & Kitiborwornkul, 2024). Pretreatment methods are employed to break down the physical and chemical barriers, making cellulose, hemicellulose, and lignin more accessible for subsequent processing, e.g. hydrolysis. Various pretreatment methods have been developed from lab scale to industrial scale operation that are mainly categorized as chemical, physical, biological, and combined methods. During hydrolysis, enzymatic (such as cellulases and hemicellulases) or chemical hydrolysis is used to break down cellulose into glucose and hemicellulose into various sugars. The resulting sugars, as oligomers or monomers, serve as the building blocks for the production of biofuels, biochemical and other value-added products. Then microorganisms, such as bacteria or yeast, are employed to ferment the sugars obtained from hydrolysis into biofuels (such as ethanol) or high-value biochemicals. Finally, the produced biofuels or biochemicals are separated from the fermentation broth and purified by various separation techniques, such as distillation, chromatography, and membrane filtration.

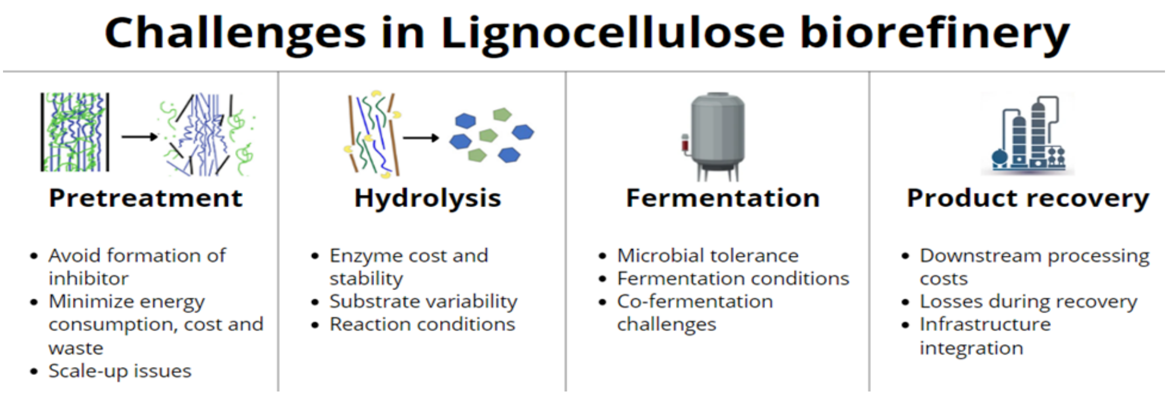

Figure 1 Challenges in lignocellulose biorefinery for the production of value-added biochemicals.

Based on this scenario, a biorefining process of lignocellulose is therefore multistep process, in which each step should support each other to promote the process efficiency. Therefore, the design of each step to optimize efficiency should not interfere with the downstream process. Ongoing research aims to improve efficiency, reduce costs, and expand the range of products obtained from lignocellulosic biomass and various challenges have been indicated. For example, some chemical pretreatment methods have a negative impact on enzymatic hydrolysis. The chemical residues of ionic liquid used in pretreatment impair cellulase activities. Furthermore, during harsh acid pretreatment, several byproducts, such as furfural, 5-HMF and acetic acid, are formed that suppress the activities of cellulases and microbes (Phusantisampan & Kitiborwornkul, 2022). In the case of enzymatic hydrolysis, it is challenging to formulate cellulase and hemicellulase to be compatible with various lignocellulose substrates. Currently, commercial enzymes for biorefinery are available, such as CelluClast 1.5L, CTec2, and Accellerase 1000 (Panakkal et al, 2023). To maximize the utilization of glucans and xylans obtained from cellulose and hemicellulose, co-fermentation is offered by using *Saccharomyces cerevisiae* and *Pichia kudriavzevii*, which are yeast strains that have strict preferences on glucans and xylans, respectively (Kirdponpattara et al, 2022). Furthermore, to make the product recovery step economically feasible, the process design should be done based on existing infrastructures, facilities and technologies to accelerate the commercialization. Addressing these challenges requires ongoing research, innovation, and collaboration across various disciplines to make lignocellulose biorefinery more efficient, economically viable, and environmentally sustainable.

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