บรรณาธิการปริทัศน์/Editorial Corner

การพัฒนากระบวนการผลิตเคมีภัณฑ์แพลตฟอร์มจากชีวมวลลิกโนเซลลูโลสอย่างยั่งยืน
Sustainable Development and Progress of Lignocellulose Conversion to Platform Chemicals

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ศูนย์วิจัยอุตสาหกรรมเคมีชีวภาพและวิศวกรรมกระบวนการแบบอัตโนมัติ สาขาวิชาวิศวกรรมเคมีและกระบวนการ บัณฑิตวิทยาลัยวิศวกรรมศาสตร์นานาชาติสิรินธร ไทย-เยอรมัน มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าพระนครเหนือ

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A biorefinery is analogous process of a petroleum refinery, with the type of raw material being the key difference. For petroleum refinery, crude fossil fuels are distilled into fuels and refined to petrochemicals. Biorefining is defined as "the sustainable conversion of biomass into a spectrum of marketable bio-based goods (chemicals, materials) and bioenergy (biofuels, power, heat)" by the International Energy Agency's Bioenergy Task 42 [1], [2]. Based on this definition, biomass can be converted into a wide array of chemicals and energy carriers in a biorefinery, and it can also contribute to the development of a circular economy [3]. This concept is based on the idea that lignocellulosic materials are reused, recycled and converted to bio-based products. Lignocellulose is composed of cellulose, hemicellulose and lignin and it is present in all plant species, and it is the most abundant biomass on earth. To achieve the circular economy concept, the agricultural wastes from industrial and agricultural activities, such as corncobs, bagasse, softwood sawdust and hardwood waste paper are utilized as raw materials for a biorefining process. Currently, lignocellulose waste is produced after harvesting seasons and mostly is combusted on the field without proper management that is become the main source of PM10 and PM 2.5 dust problem, a serious air pollution. Therefore, the lignocellulose biorefiney concept aligns with the United Nations Climate Change (UN COP26) mission that aims to a sustainable development goal (SDG) by using alternative materials to convert to energy, instead of using fossil fuels, to reduce the emission of toxic substances into the environment.

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Traditionally, lignocellulose biomass is digested anaerobically to produce biogas, and since the 2010s, it has been utilized as raw material for the production of the second generation ethanol. Both biogas and bioethanol are ready to be utilized in industrial and household uses due to their compatibility with the existing processes and infrastructures. However, due to competitiveness with the market prices of ethanol obtained from petroleum, along with the current efficiency of the process to produce the second generation ethanol that still needs more improvement, searching for alternative final products from lignocellulose biorefinery is necessary. Platform chemicals obtained from lignocellulose biomass are groups of potential products with higher market values and wide arrays of downstream processes. Platform chemicals include the small chemical molecules or monomers that are used as substrates in chemical, thermochemical and biochemical reactions to generate more complex chemical compounds or polymers. Several platform chemicals, such as diacid, acetone-butanol-ethanol (ABE), furan, lactic acid, gluconic acid, hydroxyl propionic acid (HPA), glycerol, polyols are demonstrated in the lab stage to be high potential chemicals to synthesize final products for different downstream industries e.g. polymers, constructions, foods, feeds, pharmaceutical, cosmetics and medicals (Figure 1) [4]–[7]. Furthermore, several products obtained from lignocellulose platform chemicals have been technologically upscaled and transferred to industrial productions, such as poly(ethylene succinate) (PES) and poly(butylene succinate) (PBS) [8]. These advanced products have potential to add up the values to the bioethanol

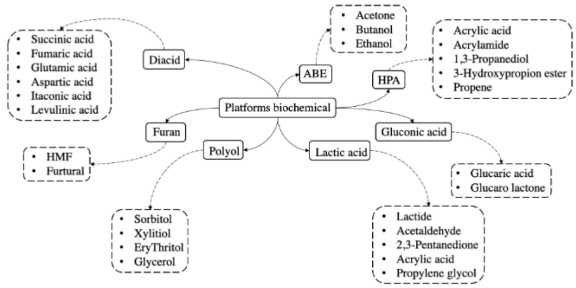

Figure 1 Platform chemicals and their destinations.

(0.9–1.1 USD) up to ten times for polymers (10–30 USD/kg) and this process concept could be considered to fit with the bioeconomy concept.

However, one major bottleneck of the production and manufacturing of lignocellulose-derived platform chemicals is their infeasible economics. In general, the biorefining process of lignocellulose is composed of 4 steps, including pretreatment, hydrolysis, conversion/fermentation and product recovery/purification. Pretreatment and hydrolysis have been demonstrated to be the major cost of the overall process (up to 70%) because the structures of lignocellulose are tough and resistant to breaking down into small molecules of monomers. Therefore, pretreatment with different methods to allow the modification of lignocellulose and make it more vulnerable to hydrolysis is developed. The mechanisms of pretreatment to promote biomass hydrolysis include the removal of the inhibitory byproducts, an increase of surface areas, modification of biomass molecular arrangements. Various pretreatment methods have been demonstrated for their pros and cons with different operational costs and process complexity. Some chemical pretreatments use hazardous chemicals and generate large amounts of wastewater. The green chemical pretreatments, such as ionic liquid (IL) and deep eutectic solvent (DES), have been proposed to be highly efficient methods with lower impact on environments, especially due to their recyclability [9]–[12]. Therefore, these methods could be also considered to fit with the green economy concept.

Platform chemicals from lignocellulose are gaining in demand worldwide because they are aligned with Bio, Circular and Green (BCG) economy concept for people who are concerned about sustainable development in industries and have awareness of the tremendous deterioration of the environment. Nevertheless, the production and manufacturing processes of platform chemicals are highly variable, which make them difficult to identify standard process designs. Ultimately, the conditioning process depends on the proposed application. Furthermore, any advice on suitable conditioning methods must be based on a thorough techno-economic assessment and Life-Cycle Assessment (LCA) analysis. Last but not least, the competitions in market positions and users with petroleum-derived platform chemicals are highly challenging due to the differences in scale of production aspect and user acceptance.

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