ISBN:
978-1-917892-15-5

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Selective Depolymerization of Lignin into High-Value Aromatic Monomers via Hydrothermal and Ionic Liquid-Assisted Approaches

Abstract: Lignin, the underutilized structural component of lignocellulosic biomass, represents a promising renewable feedstock for aromatic chemical production. This study demonstrates an efficient depolymerization strategy employing synergistic hydrothermal liquefaction and 1-butyl-3-methylimidazolium methyl sulfate ([Bmim][$MeSO_4$]) catalysis to convert diverse lignin feedstocks, including agricultural residues (sugarcane peel, corn stover) and commercial alkaline lignin, into high-value aromatic compounds. Systematic optimization of reaction parameters (80–180°C, pH, solvent systems) revealed temperature-dependent product distributions, with maximum vanillin yields achieved at 120°C under mild acidic conditions. Ethanol co-solvent significantly enhanced ketone formation while improving product stability, whereas the ionic liquid catalyst expanded product diversity at the expense of generating reactive intermediates requiring careful process control. Advanced analytical characterization (GC-MS) coupled with kinetic modeling (activation energies: 16.9–62.2 kJ/mol) provided mechanistic insights into the depolymerization pathways. The developed process demonstrates remarkable tunability, enabling selective production of target aromatics (vanillin, 2-methoxy-4-vinylphenol, 2,3-dihydrobenzofuran) while minimizing char formation, a critical advancement for industrial implementation. These findings establish a robust technical foundation for sustainable lignin valorization, offering a viable pathway to transform abundant biomass residues into renewable alternatives for flavor, fragrance, and biofuel applications. The work presents significant progress toward economically viable biorefinery operations by addressing key challenges in selectivity, energy efficiency, and scalability of lignin conversion technologies.

Keywords: Lignin valorization, Hydrothermal depolymerization, Ionic liquid catalysis, Renewable aromatics, Kinetic modeling

Biography: Dr. Shuguang Deng is a Professor of Chemical Engineering at Arizona State University. He earned his Ph.D. from the University of Cincinnati and specializes in nanomaterials, adsorption, carbon capture, and biomass conversion for sustainable energy and environmental applications. Recognized among the world's top 2% of scientists (Stanford University database), he has published over 370 peer-reviewed articles with more than 25,600 citations (H-index: 86) and holds multiple patents.