Journal of Industrial and Engineering Chemistry 137 (2024) 29–60

Contents lists available at ScienceDirect

Journal of Industrial and Engineering Chemistry

journal homepage: www.elsevier.com/locate/jiec

Review Article

Technological advancements in the pretreatment of lignocellulosic biomass for effective valorization: A review of challenges and prospects

Prasenjit Chakraborty [a,1], Ramesh Kumar [b,1], Sankha Chakrabortty [c], Shouvik Saha [d], Sujoy Chattaraj [e], Somagni Roy [c], Avishek Banerjee [a], Suraj K. Tripathy [c], Alak Kumar Ghosh [a,*], Byong-Hun Jeon [b,*]

[a] Department of Chemistry, The University of Burdwan, Burdwan 713104, West Bengal, India
[b] Department of Earth Resources & Environmental Engineering, Hanyang University, 222-Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea
[c] School of Chemical Technology, Kalinga Institute of Industrial Technology, Bhubaneswar 751024, Odisha, India
[d] Department of Biotechnology, Brainware University, Barasat, Kolkata 700125, West Bengal, India
[e] Department of Chemical Engineering, Indian Institute of Technology Madras, Chennai 600036, Tamil Nadu, India

ARTICLE INFO

Keywords:
Lignocellulosic biomass
Physicochemical method
Eco-friendly process
Valorization
Value-added product
Clean energy

ABSTRACT

Potential green energy systems can be explored using competent waste lignocellulosic (LC) biomass transformation to energy, a promising and sustainable substitute for energy resources. The intrinsic recalcitrance caused by inhibitory components, primarily lignin, significantly inhibits biofuel production from LC biomass. LC biomass pretreatment facilitates its disintegration via surface area solubility enhancement and reduction of lignin concentration and cellulose crystallinity. Various pretreatment techniques that promote sustainable LC biomass conversion to valuable organic chemicals and biofuels have been employed to rapidly disintegrate the components (lignin, cellulose, and hemicellulose). Herein, we elucidate recent biomass pretreatment strategies and optimum values of their operating parameters that effectively utilize LC biocomponents. Considering economic feasibility and scale-up possibilities, microwave-assisted deep-eutectic solvent pretreatment can be one of the sustainable schemes for delignification (~87 %) and biofuel production. This study offers insights into the selection of a highly effective and appropriate biomass pretreatment method for green and sustainable energy development.

Introduction

The escalating global utilization of fossil fuels as energy resources to meet societal needs has led to global warming through greenhouse gas (GHG) emissions and increased health hazards due to the formation of respirable particulate matter [1–3]. The global community must expedite the transition to renewable and clean bioenergy to mitigate environmental and societal concerns [4,5]. Harnessing sustainable bioenergy from the most abundant renewable resources, such as lignocellulosic (LC) biomass, has garnered significant interest as a promising method for biofuel production [6]. The LC biomass can also be used to fabricate bio-based materials to replace fossil-based goods, such as bio-based nanocomposites, graphene oxide, catalysts, biochar, and adsorbents, for developing energy-efficient and eco-friendly technologies for energy conversion, sensors fabrication, and environmental applications [7–9]. Implementing lignocellulose-based bioenergy production would effectively address environmental concerns (~70 % less GHG emissions) by decreasing fossil fuel dependence [10].

LC biomass is the chief constituent in forestry and agriculture [1]. Various agricultural wastes, such as rice straw (RS), corncob, potato haulm, corn and cereal straw, beech wood, paper industry residue, rice husk, sugarcane tops, and sugarcane bagasse, are significant sources of LC materials [12]. The exploitation of LC biomass-based fuels has garnered considerable interest in recent decades [13]. However, the

Abbreviations: AIDR, acid-genesis liquid digestate coupled with disc refining; DES, deep eutectic solvents; DP, degree of polymerization; GHG, greenhouse gas; LC, lignocellulosic; LHW, liquid hot water; MHP, Microwave heat propagation; ROD, reactive oxygen species; RS, rice straw; SE, steam explosion; TDES, ternary deep eutectic solvent; USEL, ultrasonic ethanol.

* Corresponding authors.
E-mail addresses: akghosh@chem.buruniv.ac.in (A. Kumar Ghosh), bhjeon@hanyang.ac.kr (B.-H. Jeon).

[1] These authors have contributed equally.

https://doi.org/10.1016/j.jiec.2024.03.025
Received 15 December 2023; Received in revised form 11 March 2024; Accepted 15 March 2024
Available online 22 March 2024
1226-086X/© 2024 The Korean Society of Industrial and Engineering Chemistry. Published by Elsevier B.V. All rights reserved.