Humic acid mediated valorization of sugarcane bagasse: A biorefinery approach

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By

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ABSTRACT

Lignocellulose, abundant biopolymer on the earth, suitable for producing bioethanol upon hydrolysis and fermentation. However, the recalcitrant nature of this biomass raises the techno-economic challenges that limit the effective utilization of biomass into fine chemicals, polymers, biofuels, etc. This is of tangible interest for the many biorefinery sectors to restructure the recalcitrant biomass in a disentangle form for its complete utilization in terms of a circular economy.

A green facile method was developed wherein humic acid (HA) acts as a catalyst and surfactant in the alkali pretreatment of sugarcane bagasse for the step reduction in lignin recovery scheme with phenomenal properties and enhanced enzymatic-hydrolysis. HA-assisted experiments were performed with and without calcium chloride ($CaCl_2$). Effective disintegration of lignocellulose by the cleavage of ß-O-4 moieties resulted in forming lignin and hydrolyzable biomaterial via two pathways. Possible covalent linkages between the HA and lignin resulted in the release of esters as a byproduct. Thus, the delignified biomass, the isolated lignin, and various esters could be valorised in various industrial applications. The biomass was characterized by XRD and SEM analysis. The isolated lignin was characterized using FTIR, NMR, GPC, SEM, and TGA – DTA studies. The yield of recovered pure lignin for the two processes was 90–100%, as measured by gravimetric analysis. The produced lignin was utilized as the dopant for the cellulase acetate (CA) in order to increase the hydrophobicity of CA, emphasizing the dielectric property and its application in high voltage transformers. The produced esters were confirmed using FTIR studies. Batch enzymatic hydrolysis was performed for the HA-assisted delignified bagasse (without $CaCl_2$), which demonstrated a 19% increase in glucose yield compared to the alkali-treated bagasse.

The newly schematized humic acid (HA)-assisted alkali pretreatment can upgrade the bagasse's characteristics for the pragmatic accessibility of the enzyme. After delignification, the upgraded biomass harnessed as solid support to immobilize the enzyme, ultimately reducing the cost and step for designing physical support for immobilization. HA, an active ligand, with its enriched functional moieties such as carboxyl, carbonyl, hydroxyl, and amide group, bind prior to the substrate (i.e., delignified bagasse) that immobilizes enzyme and hydrolyses cellulose portion. The interaction mechanisms of pretreated bagasse with enzyme were demonstrated through molecular docking using Auto Dock software and UV (Ultraviolet) Spectrophotometric analysis. The pretreatment efficiency was analyzed as a case study in a

large-scale reactor by subjecting pretreated bagasse to batch enzymatic hydrolysis with a low enzyme-loading rate of 14 FPU/g of cellulose. Cellulose conversion of 88% (i.e., 20.92 g/L of glucose) was achieved in 48 hours, respectively. Subsequently, the flat-sheet cross-flow ultrafiltration (UF) membrane-based continuous recycling unit was operated at a flux of 22.5 L/m2hr towards the purification of glucose (i.e., 15.75 g/L of glucose). The performance of PES10-UF membrane module chaperoning with hydrolysis reactor for the designed hydrolysis scheme was examined in light of critical flux, pure water permeability, and irreversible fouling studies. The flow rate of 300 LPH (L/hr) and the transmembrane membrane pressure (TMP) of 1.5 bar showed high antifouling performance.

The overall research outcome under the influence of humic acid spotlit the disintegrated lignocellulosic biomass valorization in many dimensions of industrial application without any chemical modifications like lignin as a dispersant; nanocomposites; adhesives; drug; drug carrier; thermal shield; stabilizer; carbon precursors; additives and so on. For instance, recovered lignin was utilized in our study as a dopant for cellulose acetate in dielectric application because of its good polydispersity, high solubility, and good temperature stability. In addition, the structural upgraded delignified bagasse could be the best source option for bioethanol production on an industrial scale.