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Pretreatment and enzymatic saccharification of sludge from a prehydrolysis kraft and kraft pulping mill

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Abstract

The South African pulp and paper industry generates an estimated 0.5 million tons of pulp and paper mill sludge (PPMS) annually. As PPMS is generated, it requires safe, efficient, and economical collection and disposal. However, PPMS is typically land-filled and subsequently emits nuisance odors, methane, and leaches toxins. Thus, PPMS is an environmental hazard and a potential pollutant of air, soil, and water systems. PPMS is primarily composed of cellulose and coupled with the prospect of biorefinery practices, a value-added product such as glucose-rich hydrolyzate can be derived from this lignocellulosic waste stream. The current study applied a Box-Behnken design to establish the appropriate conditions to obtain the highest possible yield of glucose from PPMS. The PPMS contained 6.89% ash and 64.21% cellulose. De-ashing using acidic pretreatment reduced the ash content by 51%, thereby increasing the amenability of the cellulose fibers to enzymatic hydrolysis. The optimized conditions for the model from the Box-Behnken design were: pH 4.89, 51 °C, hydrolysis time 22.9 h, 30 U/g β-glucosidase, and 60 U/g cellulase, and a substrate load of 6.4%. The model was validated using these conditions, and recovery of 0.48 g glucose per 1 g of fiber was attained. The hydrolyzate contained trace amounts of xylose and mannose. Pyrolysis gas chromatography-mass spectrometry elucidated that the hydrolyzate also contained low concentrations of toxins such as hemicellulose-derived acetic acid (0.25%), sugar-derived furans (1.06%), and lignin-derived phenols (0.58%). This study proposes a scheme that resulted in a 75% yield of glucose and validated the use of PPMS as a viable candidate for enzymatic saccharification. The glucose-rich hydrolyzate retrieved has potential capability as an inexpensive source of fermentable sugars in downstream applications.