Evaluation of Electrooxidation as a Pretreatment for Lignin Extracted from Sugarcane Bagasse for Application in Anaerobic Digestion

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Abstract

Lignin, a byproduct generated in large quantities during sugarcane bagasse processing, poses a challenge for the sugar-energy industry in achieving full utilization of the bagasse due to its recalcitrant structure, which limits its conversion into value-added products. This study investigated the application of electrooxidation (EO) as a pretreatment for lignin to enhance its biodegradability. Different current densities (CD: 20, 30, 40, 50, and 60 mA/cm²) were tested in a batch reactor equipped with stainless steel electrodes to determine the conditions that optimize biodegradability enhancement, assessed through biomethane production using the Biochemical Methane Potential (BMP) methodology.

Lignin was extracted from sugarcane bagasse via alkaline pretreatment, recovered by precipitation, and subsequently subjected to EO. The results demonstrated that current density significantly influenced process efficiency. At CD = 40 mA/cm², the highest reduction in total phenols (82.4%) and fixed solids (98.0%) was observed, indicating efficient depolymerization of lignin into more soluble compounds. Under these conditions, the chemical oxygen demand (COD) of the supernatant increased from 74.6 to 102.4 mg/L, suggesting the release of lower molecular weight organic molecules. In contrast, at CD = 60 mA/cm², a reduction of 78.4% in total phenols was achieved; however, partial mineralization (33.3% residual fixed solids) limited substrate availability for the biological stage.

In anaerobic digestion assays, biomethane production was directly influenced by the pretreatment. The condition with CD = 60 mA/cm² resulted in the highest cumulative methane production (343 mL in 20 days), with a daily peak of 91 mL on day 5, indicating accelerated hydrolysis of EO-released compounds. At CD = 40 mA/cm², production reached 275 mL, associated with balanced lignin degradation without excessive mineralization. Conversely, at CD = 20 mA/cm², a 10-day methane production latency was observed, attributed to the presence of undegraded residual lignin (88% of total solids), requiring prolonged microbial consortium adaptation.

HPLC analysis revealed that EO generated specific phenolic compounds, such as syringaldehyde (8.43 mg/L at CD = 20 mA/cm²) and vanillin (1.64 mg/L), which were preferentially degraded at higher CDs. The presence of acetic acid (0.055 g/L at CD = 50

mA/cm²) and arabinose in the assays suggested that EO facilitated the release of metabolic precursors for the acetoclastic pathway, the primary methane production route. However, high total phenol concentrations (>15 mg/L) at CD = 20 and 30 mA/cm² correlated with reduced methanogenic activity and a decrease in volatile solids in the biomass (from 85% to 61%), indicating inhibitory effects.
The results align with previous studies, such as Wang et al. (2015), which highlighted moderate CDs (~40 mA/cm²) as optimal for balancing depolymerization and energy costs. It is concluded that EO is a promising strategy for integrating lignin into biorefineries for biogas generation, provided it is optimized to avoid excessive mineralization (CD > 50 mA/cm²) or insufficient degradation (CD < 30 mA/cm²). Pilot-scale evaluation and economic analysis are recommended for industrial feasibility and complementary studies on synergies with biological treatments.
Keywords: Lignin, electrooxidation, anaerobic digestion, biomethane, sustainability.