Development of Bioelectrochemical Systems for Enhanced Energy Recovery from Organic Wastes

Abstract

The present study aims to develop different BES configurations viz. microbial fuel cells (MFC), microbial carbon capture cells (MCC) and microbial electrolysis cells (MEC) and assess their potentiality for energy recovery from the spent medium of anaerobic fermentation. A mixed electroactive consortia capable of electricity generation using VFA rich wastewater as substrate was enriched using fly ash-leachate. DGGE analysis revealed the dominance of *Arcobacter, Pseudomonas* and *Desulfobacter species*. Optimization of anodic influential parameters of MFC generated maximum power density of 6.20 W m^{-3} with an average COD removal efficiency of 75.25 % Nanostructured WO_3 and Pt/WO_3 electrocatalysts were synthesized and impregnated on carbon felts for anode modification in MFCs. 45% higher power densities were obtained with catalyzed electrodes as compared to uncatalyzed electrodes. The potential of *Chlorella* sp. based MCCs for simultaneous power generation, wastewater treatment and microalgal biomass production was evaluated. The maximum power density of 2.32 W m^{-3}, maximum microalgal dry cell mass of 812 mg L^{-1}, an overall COD removal efficiency of 92-95 % and energy recovery of 59 % were achieved using the developed MCCs. Single chamber tubular MEC was successfully developed for electrohydrogenesis. The maximum cumulative H_2 of 630 mL L^{-1} was obtained with an overall yield of 796 mL g^{-1} acetate. To further improve the performance of MECs, nanostructured WO_3, MnO_2 and their composites were synthesized and impregnated on carbon felt electrodes. The catalyzed electrodes resulted in 35% increase in hydrogen (H_2) production as compared to the uncatalyzed system and substrate conversion efficiency of 91±4.4 % was achieved. The maximum cumulative methane (CH_4) production 213 mL L^{-1} was obtained using a hybrid anaerobic digester-MEC with catalyzed electrodes. The integration of developed BESs with dark fermentation (DF) and anaerobic digestion (AD) process for enhanced energy recovery was evaluated using water hyacinth as model substrate. The maximum overall energy recovery of 38.35 %, 57.7 %, 47.8 %, 71 % and 76.9 were obtained using integrated DF-MFC, AD-MFC, DF-MEC, DF-ADMEC and DF-AD-MFC respectively. Thus, the thesis highlights the importance and necessity of strategic integration of bioenergy processes for sustainable development of bio-based economy in the near future.

Keywords: Bioelectrochemical systems; Microbial fuel cell, Microbial electrolysis cell, Microbial carbon capture, Anaerobic digestion, Dark fermentation, Volatile fatty acids, Biocatalysts, Electrocatalyst