Emerging Pretreatment Technologies for Enhanced Bioenergy Production from Organic Waste

Cigdem Eskicioglu, Ph.D, P.Eng.
Associate Professor
Leader, UBC Bioreactor Technology Group
University of British Columbia, Okanagan Campus
School of Engineering, 1137 Alumni Avenue, Kelowna, Canada, V1V 1V7
cigdem.eskicioglu@ubc.ca

Increasingly, energy sustainability concerns all around the world bring renewable energy sources to the forefront. Among renewable sources, the development of energy efficient biomass-to-biofuel processes can replace fossil fuel use and reduce greenhouse gas emissions. In particular, municipal and industrial wastewater treatment residues (waste sludge) and lignocellulosic agricultural crops waste have a very significant unutilized energy potential. When landfilled, waste sludge can decompose in an uncontrolled environment and can contribute to greenhouse gas emissions. Similarly, lignocellulosic biomass is abundant all year around and the remaining portion after used as animal feed is often burnt in open environment that can further cause environmental concerns [1, 2].

Bioreactor processes, such as anaerobic digestion and dark fermentation have been extensively studied for their ability to convert a wide variety of organic waste including waste sludge, animal manure and lignocellulosic biomass to methane [3] and biohydrogen [4]. The bottleneck of conventional anaerobic digestion is slow degradation of the municipal waste activated sludge (WAS), comprised of a mixture of different microbial cells, organic and inorganic compounds that adhere together with extracellular polymeric substances (EPS). This necessitates long retention time (20-30 days) requiring large digester volume which eventually leads to high capital cost [5]. Similarly, complex structure of lignocellulosic biomass, comprised of holocelluloses (cellulose, hemicelluloses) and lignin, allows for limited accessibility to the biodegradable organics (i.e. holocelluloses). Such limited accessibility causes methane/hydrogen yields significantly lower than the theoretical estimations based on biomass compositional/structural features [6, 7].

Therefore, research at UBC's Bioreactor Technology Group in the last 10 years has focused on various pretreatment technologies using mechanical, chemical, thermal (i.e. conductive, microwave, and radio frequency), and biological ways or combinations to disintegrate polymeric network of wastewater sludge and dissolve lignin (delignification) in lignocellulosic waste for better enzymatic hydrolysis/microbial degradation [8-10]. These pretreatment technologies applied prior to anaerobic digestion and/or dark fermentation can enhance the rate and the extent of biogas and/or biohydrogen production resulting in smaller bioreactors.

The primary focus of this keynote presentation will be the performance evaluation on the aforementioned pretreatment technologies applied on various organic waste for enhance bioenergy recovery and improved digestate (final product) for final disposal (i.e. land application as soil amendment). The secondary focus will be on fate and transformation of emerging micro- (i.e. hormones, antimicrobials, pharmaceuticals), and nano-contaminants (i.e. ZnO) in the conventional and advanced anaerobic sludge digesters incorporating these pretreatment technologies.

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