UNDERSTANDING THE IMPACT OF FLOW RATE AND RECYCLE ON THE CONVERSION OF A COMPLEX BIOREFINERY STREAM USING A FLOW-THROUGH MEC

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Integration of MECs into biorefineries may require development of continuous systems rather than batch systems to supply a steady stream of hydrogen for the hydrodeoxygenation reaction. Typical parameters studied for quantifying and understanding performance of continuous MECs include hydraulic retention time (HRT) and organic loading rate (OLR), which depend on flow rate and substrate concentration. However, the number of reports investigating these effects for complex substrates in continuous systems are limited and not well understood. Understanding the influence of these operational parameters in MECs treating complex substrates requires insights into the mechanistic details of the process. The contribution of exoelectrogenic vs. fermentative and other accompanying biochemical reactions occurring in the MEC, as well as the kinetics and mass transfer issues underlying the processes have to be evaluated to provide a better understanding of the effects on MEC performance.

In this study, we investigated the effect of flow rate, which defines HRT and OLR at a given substrate concentration. We examined the effect of these variables on MEC performance treating a complex, biomass-derived pyrolysis aqueous phase, but is applicable to any complex wastewater stream. A continuous MEC operation was investigated under one-pass and recycle conditions using the complex, biomass-derived, fermentable, mixed substrate feed at a constant concentration of 0.026 g/L, while testing flow rates ranging from 0.19 to 3.6 mL/min. This corresponds to an organic loading rate (OLR) of 0.54 to 10 g/L-day. Mass transfer issues observed at low flow rates were alleviated using high flow rates. Increasing the flow rate to 3.6 mL/min (3.7 min HRT) during one-pass operation increased the hydrogen productivity 3-fold, but anode conversion efficiency (ACE) decreased from 57.9% to 9.9%. Recycle of the anode liquid helped to alleviate kinetic limitations and the drop in ACE increasing it by 1.8-fold and the hydrogen productivity by 1.2-fold compared to the one-pass condition at the flow rate of 3.6 mL/min (10 g/L-d OLR). High COD removal was also achieved under recycle conditions, reaching 74.2 ±1.1%, with hydrogen production rate of 2.92 ± 0.51 L/L-day. This study demonstrates the advantages of combining faster flow rates with a recycle process to improve rate of hydrogen production from a switchgrass-derived stream in the biorefinery.