Electro-Enhanced Anaerobic Digestion to Increase Production of Volatile Fatty Acids

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Anaerobic digestion (AD) is a process where organic materials, such as waste residues, are broken down into carbon dioxide and methane through several sequential pathways, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. However, these gases are not only economically unviable as fuels but are also potent greenhouse gases. In contrast, volatile fatty acids (VFAs), intermediates in anaerobic digestion, show much more promise as they are precursors to sustainable aviation fuels and other industrially valuable products. Arresting acetogenesis and methanogenesis can increase yields of these valuable acid products. Moreover, since longer-chain VFAs are more desirable, shifting acid profiles towards these longer-chain VFAs is also of interest.

In pure cultures, electro-fermentation has been explored as a strategy to shift product profiles toward more reduced products by overcoming intracellular redox limitations. Applying this concept to mixed culture processes, such as anaerobic digestion, can similarly influence processes on both the cellular and community levels by affecting microbial community structure. In this context, electro-enhanced anaerobic digestion (Electro-AD) has shown that applied potentials can induce changes in microbial community composition, redox behavior, and product profiles.

Methodological challenges exist in differentiating the effects of direct electron transfer (DET) from background electrochemistry. Recognizing these challenges led us to identify experimental conditions to isolate DET from other reactions and investigate common pitfalls that lead to misinterpretations. For instance, the use of certain electrode materials can lead to anaerobic corrosion, which potentially influences metabolic processes through the release of iron and hydrogen evolution.

Overall, it was found that electro-enhancement in anaerobic digestion affects microbial community structure and product profiles. Electro-enhanced experiments at applied potentials between -300 and -750 mV vs. Ag/AgCl were performed, and metabolic, electrochemical, and taxonomic analyses were used to study the effects of DET and redox control on AD processes. Results indicated a maximal total VFA production at an applied potential of -600 mV vs. Ag/AgCl and a significant difference in microbial community structures between the control and biased reactors.