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Towards environmental biorefinery: upscaling of microbial electrosynthesis cell fueled with heterogeneous organic waste

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Abstract: Environmental biorefineries aim to produce biofuels and platform biomolecules from organic waste. To this end, microbial electrochemical technologies theoretically allow microbial electrosynthesis of multi-carbon organic molecules to be coupled to bioelectrochemical oxidation of waste organic matter. Here, we provide the proof of concept and upscaling strategies of a waste fueled microbial electrosynthesis cell (WF-MES) which could become a cornerstone technology for future environmental biorefineries.

Keywords: anaerobic process; microbial electrosynthesis; environmental biorefinery

Session: Bio-electrochemical systems

Introduction

Environmental biorefinery consists of transforming organic waste into resource by biological activities, especially those exercised by microorganisms. Anaerobic digestion (AD) is a well-established example of environmental biorefinery that can recover biowaste in the form of methane. It is however noteworthy that current success of this process majorly relies on its simplicity and high robustness, not on the value of its product (Moscoviz et al., 2018). Moreover, the prosperity of AD industry today partly depends on favorable conditions for biogas production established in many European countries (Grando et al., 2017). Certainly, the development of AD is a milestone towards circular economy of organic matter, but the profitability of environmental biorefinery industries could still be improved. The recent development of microbial electrochemical technologies (METs) has created new opportunities of waste valorization with the introduction of anode-breathing microbes (such as *Geobacters*) able to oxidize organic wastes to feed a cathode with an electron flow (Reguera et al., 2005). On the other hand, with the discovery of microbial electrosynthesis (MES) in 2010, a paradigm shift has happened in the domain of MET with the possibility of producing soluble small multi-carbons compounds on a cathode with high selectivity, high rate and with high energy efficiency, by using only electrons and CO₂ (Nevin et al., 2010). Thus bioanode-biocathode coupling could provide an efficient way to reduce the energy demand of MES by removing COD in a waste stream, which could lead to a new generation of profitable environmental biorefinery (Rabaey & Rozendal, 2010). In such a system however, an appropriate balance should be struck between anodic and cathodic conditions for proper functioning. In this work, we'd like to show the proof of concept of this technology with a 15L lab-scale reactor fed with organic waste and wastewater, as well as upscaling strategies resulting in better performance on optimized systems.

Material and Methods

Reactors were built with three compartments separated with ion exchange membranes. The anodic compartment enclosed two removable flat anodes made of stainless steel frames and

carbon felt. The cathodic compartment enclosed a removable massive cathode made of stainless steel baskets containing carbon granules. The intermembrane compartment was separated from the anodic and cathodic compartment by a cation and an anion exchange membrane, respectively. The reactor contained reference electrodes for anode and cathode potential real-time recording and automated systems for pH and pressure regulation.

All reactors were operated with a potential difference between 0.7V and 1.2V so that they could work normally without reference electrodes which are undesirable in industrial reactors. Value of the potential difference was regulated in function of substrate availability and H₂ concentration in the cathodic compartment.

The anodes were inoculated with a pre-enriched inoculum. The cathodes were inoculated with a mature culture of dark fermentation. Biowaste and wastewater were used as substrate for the bioanodes.

Results and Conclusions

The 15 liter laboratory scale reactor (Figure 1A) was built and operated for 16 months. Biowaste from an industrial treatment platform was used as substrate for bioanode. With an enriched anodic inoculum, the COD removal rate reached 0.83 g per day per liter of anolyte; anodic coulombic efficiency reached 98.6%. Acetate was produced at cathode with a rate of 0.53 g per day per liter of catholyte, and with a cathodic coulombic efficiency of 63.7%. Its maximum concentration reached 9.7 g per liter (Figure 2). During the operation, a potential difference of 1.2V was applied between the bioanode and biocathode, obtaining a current density as high as 6.7 A/m². Based on these results, an optimized parallelepiped reactor was built by reducing the distance between electrodes and increasing the surface/volume ratio (Figure 1B). A cylinder reactor (Figure 1C) was built with larger anodic surface. Both new configurations showed better performances. Coupling a bioanode with a biocathode enabled a two to four-fold reduction in energy consumption compared to conventional microbial electrosynthesis (MES) thereby opening new doors for the industrial development of microbial electrochemical technologies.

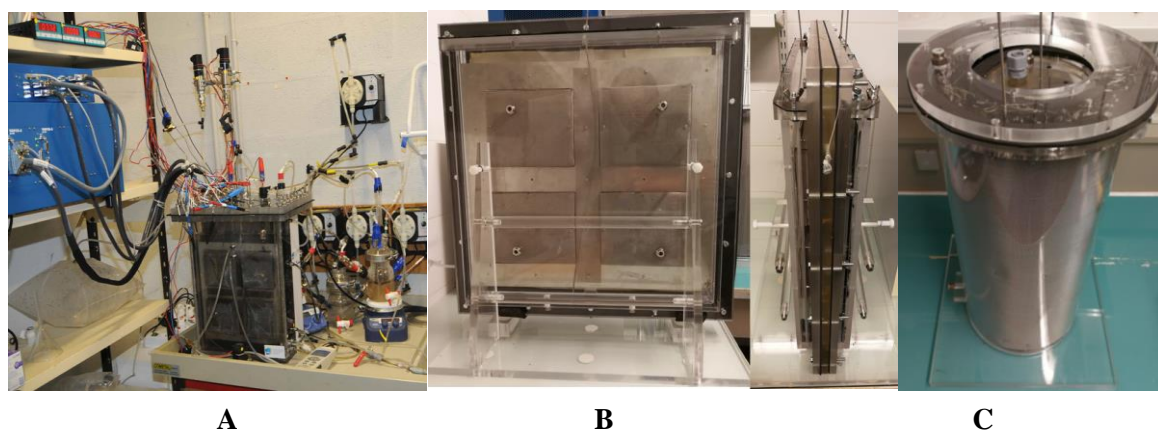


Figure 1. Reactors used in this study.

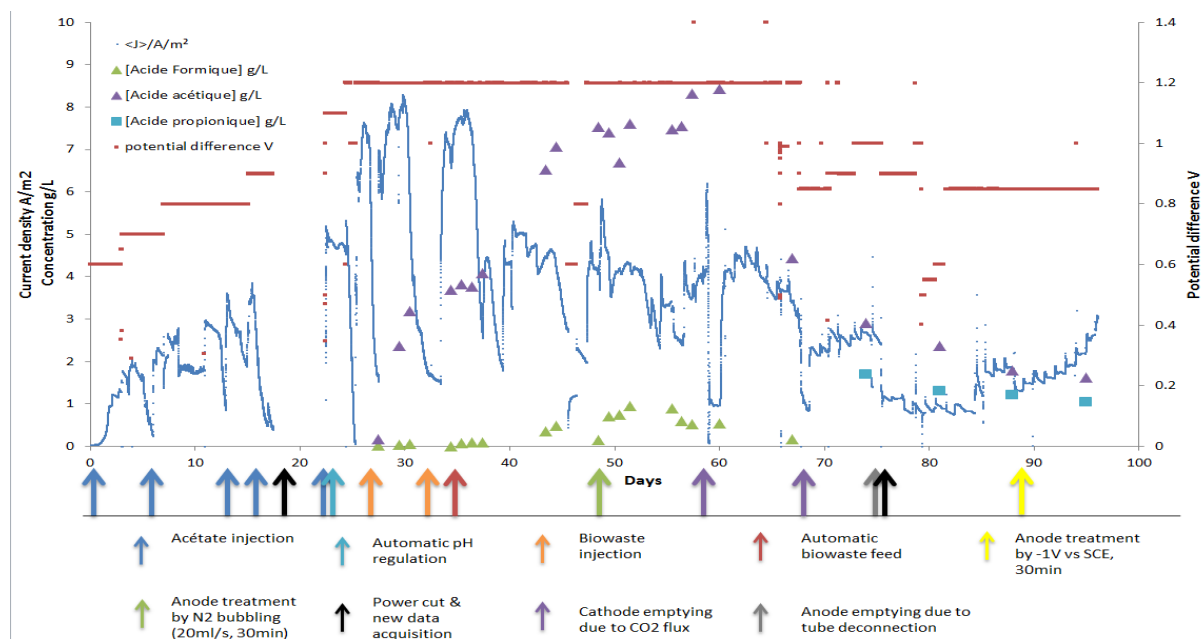


Figure 2. Performance of the proof of concept WF-MES reactor in the first 100 days of continuous operation.

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