frontiers in Energy Research

EDITORIAL
published: 18 September 2019
doi: 10.3389/fenrg.2019.00104

Editorial: Microbial Electrochemical Technologies for Renewable Energy Production From Waste Streams

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Keywords: microbial electrochemical technologies (MET), waste valorization, bioelectrochemical systems (BES), energy carriers, energy efficiency

Editorial on the Research Topic

Microbial Electrochemical Technologies for Renewable Energy Production From Waste Streams

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Specialty section:
This article was submitted to Bioenergy and Biofuels, a section of the journal Frontiers in Energy Research

Received: *25 July 2019*
Accepted: *04 September 2019*
Published: *18 September 2019*

Citation:
Escapa A, Morán A, Tartakovsky B and Heidrich ES (2019) Editorial: Microbial Electrochemical Technologies for Renewable Energy Production From Waste Streams. Front. Energy Res. 7:104. doi: 10.3389/fenrg.2019.00104

The world is facing the challenge of ever increasing energy demand along with growing environmental pressure, which can be resolved by reducing energy consumption. As population increase and urbanization accelerates, city services are not only expected to grow, but also continuously improve. This growth must be achieved whilst reducing their energy footprint and providing benefits for the economy. Although such polarized demands rarely align, novel approaches for treating organic wastes and wastewater offer a distinct opportunity. Many types of organic wastes have a significant energy content. This energy remains untapped in conventional waste management technologies, which typically use relatively large amounts of energy for treatment. The treatment of 1 m^3 of municipal wastewaters (at 300 mg/L COD) requires between 0.21 and 0.6 kWh of energy (Pant et al., 2011), yet the wastewater itself contains 1.35 kWh of chemical energy (Dai et al., 2019), with additional potential for nutrients recovery. A wide range of technologies intended for energy valorization of wastes do exist. Most are mature technologies [e.g., combustion and anaerobic digestion (AD)] that have widely proved their economic and technical feasibility. However, they are very often too rigid with energy recovery being limited to only one product and the waste feedstocks required to meet strict specifications. In particular, low concentration of organic materials in municipal wastewater renders these techniques unsuitable. For example, AD requires the treatment temperature to be at around 35°C, which implies that 1 m^3 of wastewater (assuming a starting temperature of 10°C) would require 35 kWh of energy to heat, exceeding by 26 times the amount of recoverable energy. Combustion is even less suitable, as wastewater typically has 99% water content.

Microbial electrochemical technologies (MET) have greatly evolved in the past 15 years (Butti et al., 2016), becoming a promising and more flexible alternative with respect both to the organic wastes feedstock (valorization of solid, liquid, and gas waste streams at varied dilutions) and the produced energy carriers (electricity, liquid, or gaseous fuels). However, these complex and diverse technologies have yet to prove their economic and technical feasibility. All the articles in this issue offer useful insight into how METs can be applied to real life applications.

The success of future MET implementations will depend largely on the development of suitable electrodes that can provide large current densities, be biologically, physically, and chemically stable, economically viable and feature high specific surface area and conductivity. The first article of this special issue (Bian et al.) aims at developing novel anode designs that can meet several of these requirements. Here, we learn that copper does not constitute an ideal anodic material, yet the use of 3D printing was highly successful in creating an anodic material base with the desired porosity to maximize microbial activity. The authors propose to control the anode potential as means of avoiding copper corrosion and thus benefiting from its high conductivity.

In microbial fuel cells (MFC), maximum attainable current density is usually limited by the sluggishness of the oxygen reduction reaction, thus, suitable catalysts are frequently required to limit the cathode overpotentials. However, substrate crossover from the anode can induce the formation of a biofilm layer, which usually results in an obstruction of oxygen and OH^- transfer causing a drastic decline of the MFC performance. Chen et al. studied the effect of substrate crossover on a MFC equipped with a rotating 3D air cathode. The authors observed that very low concentrations of acetate on the catholyte can limit significantly the current densities because of the biofouling. However, they found that by a short pulse of high speed rotation up to 85% of the initial cathode performance can be recovered.

Understanding the routes of carbon source conversion and the complex bioelectrochemical transformations that take place in METs is useful for optimizing the performance of these systems. Kubannek et al. looked not only at the electrogenic metabolic step within a MET, but also at the stages higher up the food chain, developing a new method for examining the degradation pathways and rate constants for different carbon sources, without interrupting the continuous operation of a biological electrochemical system (BES). The authors apply this method to identify the reaction pathways of glycerol degradation in a continuously-fed BES, obtaining detailed information on conversion efficiencies and rate constants. The results were validated by community analysis showing and confirming the existence of different roles played by the planktonic phase and the biofilm.

Regarding the optimization of BES performance, Fonseca et al. touched upon a fourth important topic: the optimization of the biocatalysts (i.e., the electroactive microorganisms). In direct electron transfer, a chain of redox proteins controls the rate at which electrons are transferred across the cytoplasmic membrane to the cell surface and from there to the electrode surface. The authors point to a different optimization approach whereby microorganisms will be genetically modified to enhance electron transfer. Importantly, their work suggests that such modifications across the microbe-electrode interface is unlikely to adversely affect the electron-transfer performance of the remainder trans-periplasmic redox chain.

Another strategy to improve the biocatalytic processes in BESs consists of developing microbial communities specifically adapted to the substrates being fed. This is precisely what Brunner et al. were dealing with in the last article included in this Research Topic. The approach followed by the authors relays firstly on selecting ferric iron reducing microorganisms from real wastewater samples and then transferring these isolates to the anodic compartment of a BES. When the BES was operated with isolates co-cultivated with *Geobacter sulfurreducens* in a continuous mode, the system was able to produce current densities of up to 1.37 A m^{-2}.

In summary, we believe that the collection of articles included in this Research Topic can help to move METs forward. Important questions such as the manipulation of microbial electron transfer mechanisms, the division of metabolic steps and adaptation at the microbial community level, or the development of new possibilities for BES designs will indeed be of interest to researchers and engineers working in the field of BESs and to all those interested in bringing this technologies toward practical applications.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.