Microbial Electrolysis Cells integration in anaerobic digesters for biogas upgrading

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Keywords: anaerobic digestion, biomethane, bioelectrochemical systems, biogenic carbon dioxide, carbon capture and ultilization
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Introduction

Anaerobic digestion stands out as a promising technology for simultaneous waste treatment and bioenergy production. However, it faces challenges such as prolonged start-up times, low methane content, and susceptibility to environmental fluctuations (Khanal, 2008). Addressing these bottlenecks is crucial for advancing the field. The integration of Microbial Electrolysis Cells (MECs) into anaerobic digestion (AD) systems emerges as an innovative approach for sustainable waste treatment and renewable energy production, offering solutions to conventional anaerobic digestion challenges (Kanellos *et al*, 2024; Wang *et al*, 2022).

A notable advantage of incorporating MECs in anaerobic digestion is their capacity to reduce start-up times by creating micro-aerobic conditions. This facilitates an accelerated hydrolysis rate, thereby minimizing start-up durations (Wang *et al*, 2022). Beyond expediting start-up, micro-aerobic conditions enhance organic matter removal by augmenting the hydrolysis rate (Tartakovsky *et al*, 2011). Additionally, MECs play a pivotal role in generating hydrogen, improving both the combustibility of biogas and its methane content through hydrogenotrophic methanogenesis (Zeppilli *et al*, 2020). Furthermore, MECs have the potential to enhance anaerobic digestion performance at low temperatures by promoting hydrogenotrophic methanogenesis, an alternative to the rate-limiting acetoclastic methanogenesis (Liu *et al*, 2016). Addressing a common challenge in anaerobic digestion systems, MECs offer a solution to inhibitory compounds by electrochemically removing them (Rago *et al*, 2015). This not only contributes to effective waste treatment but also broadens the scope for digesting a wider range of feedstocks.

However, despite these promising aspects, challenges persist in the realm of MECs. The optimization of MEC design and operation, improvement in material durability, and enhancing overall cost-effectiveness are areas that require focused attention. Overcoming these hurdles is paramount for the widespread adoption of MECs in AD systems as research progresses. Therefore, the objective of this work is to determine the optimal applied potential at different electrode configurations, aiming to contribute valuable insights to the advancement and integration of MECs in anaerobic digestion systems.

Material & methods

A polyvinyl chloride (PVC) reactor was designed and constructed, in which applied potentials of 0.3, 0.5, 0.7, 0.9, 1.1, 1,3 and 1,5 V were tested with glucose as substrate. Two different electrode configurations were investigated, a graphite plate anode and cathode configuration, and a graphite brush anode and cathode configuration. Figure 1 shows the experimental set-up.

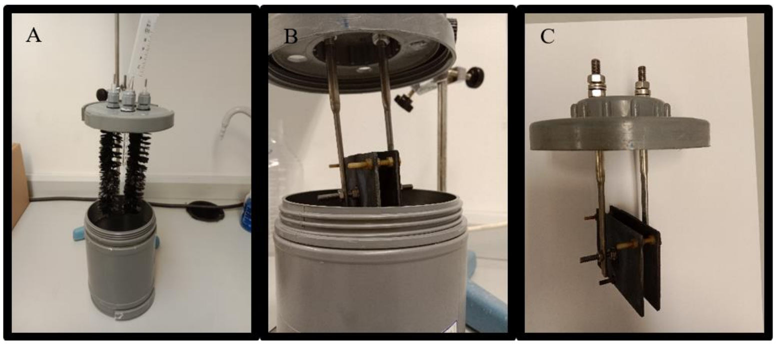

Figure 1. Impression of the set-up, with A) the graphite brush anode and cathode, and B&C) the graphite plate anode and cathode.

To determine the effect on the biogas, production and composition were measured. The production was determined by using the water displacement method. To determine the effect on the composition the concentration of methane, carbon dioxide and hydrogen were measured. Samples were collected in Tedlar bags and measured using a Varian CP-4900 Micro-GC chromatograph with a thermal conductivity detector. The relative increase in methane content was calculated by taking the difference between the AD-MEC and the AD and dividing this by the percentage of methane measured in the AD set-up.

Results & Discussion

The relative methane content of the biogas produced by the AD-MEC set-up increased when the applied potential was augmented from 0.9 V up to 1.5 V. The relative methane content increased from – 1.4% at an applied potential of 0.9 V to 8.8% at an applied potential of 1.5 V, as showed in Figure 2. It is highly likely that this can be attributed to accelerated formation of hydrogen at 1.5V compared to 0.9 V. The accelerated hydrogen formation results in an enhanced availability of hydrogen for hydrogenotrophic methanogenesis and stimulates biological carbon dioxide methanation, in agreement with Zeppilli *et al*, (2020).

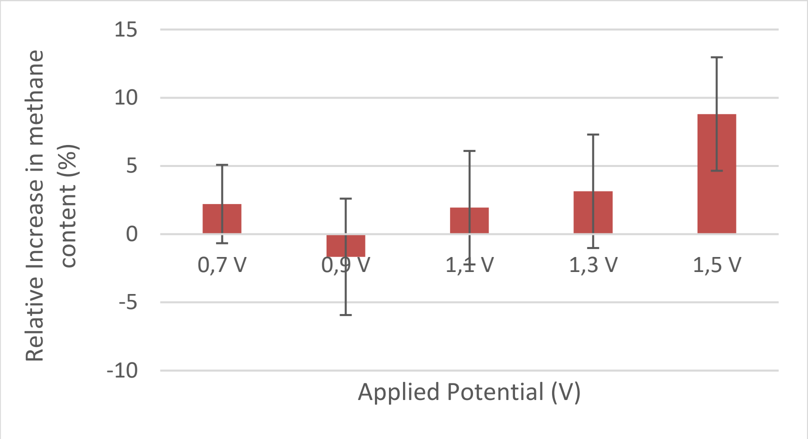

Figure 2. The relative increase in methane content (%).

Conclusion

An applied potential of 1.5 V results in a relative increase in methane content of 8.8%. This result shows that integration of a MEC can increase the methane content of the produced biogas. And, therefore confirms the promise MEC integration in AD for performance enhancement.

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