ABSTRACT

With the advent of industrialization and rapid global population bloom, the atmospheric CO_2 concentration has skyrocketed recently eliciting environmental problems like global warming and climate change. Furthermore, this has also increased the stress on the natural resources due to the proliferation in the energy demand imperative towards global urbanisation. Therefore, there lies enormous scope of developing novel technologies/strategies exemplifying carbon capture/sequestration and with concomitant energy or valuable recovery. One such technology in microbial electrosynthesis (MES), which works on the principles of bioelectrochemistry by heralding electrotrophic microbes as biocatalysts to sequester carbon dioxide for the production of organic chemicals like acetic acid. In the present research, efforts were directed to improve the efficacy of MES by employing efficient cathode catalysts, novel modular setup, and optimization of operational parameters, which would expedite the commercialization of this innovative technology.

The application of Rh or TiO_2 as cathode catalyst in MES demonstrated an acetate production rate of 2.15 ± 0.15 g L^{-1}.day and 1.06 ± 0.08 g L^{-1}.day, respectively; thus, exemplifying an improved performance of MES, due to the application of these materials as cathode catalysts. However, TiO_2 was more efficient in illustrating a performant MES mainly due to the formation of a stable biofilm on the cathode surface coated with TiO_2 and reduced overpotential of hydrogen evolution reaction leading to the transfer of more electrons to the planktonic cells mediated through hydrogen. In the subsequent part, the operating parameters, namely mode of operation, catholyte pH and imposed potential was optimized and their effect on the performance of MES was investigated. It was found that the production rate of acetate (55.61 ± 4.14 mM m^{-2}.day^{-1}) was improved by 31%, when the MES was operated in batch mode in comparison to the continuous mode of operation. This can be accredited to the higher retention of CO_2, the feedstock and hydrogen in the cathodic chamber of MES operated in batch mode led to its enhanced performance in comparison to the continuous mode of operation.

A novel modular three chamber circular MES was also designed and operated for the simultaneous production and separation of acetic acid. This setup produced 81.35 ± 1.15 g m^{-2}.day and 104.26 ± 1.75 g m^{-2}.day of acetic acid in the cathodic and extraction chambers, respectively, thus demonstrated the successful extraction of acetic acid from the cathodic chamber. Based on results obtained from these investigations, a pilot-scale MES was designed and operated, which was able to produce acetic acid at the rate of 6.31 ± 0.31 mM day^{-1} at optimized conditions, which was around four times higher than that produced by lab-scale MES, thus exemplifying successful scaling-up of this technology. Therefore, the present results will abet the budding researchers in developing highly performant MES setups by alleviating the bottlenecks associated with this technology thus expediting the commercialization of this technology.

Keywords: Acetic acid; Bioelectrochemical system; Biofuel; Carbon sequestration; Microbial electrosynthesis.