Title:	Design and optimization of a single-chambered membrane-less reactor for microbial electrosynthesis (MES) of acetic acid from CO 2
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Abstract:	Microbial electrosynthesis (MES) is an exciting and dynamic research area at the nexus of microbiology, electrochemistry, material sciences, reactor engineering, and environmental sciences. In MES, microbes having the ability to fix CO 2 via the Wood-Ljungdahl pathway are used as biocatalysts for the electricity-driven conversion of CO 2 into chemical compounds (e.g. acetic acid, methane, butyric acid, etc.). Considerable advancements have occurred in MES technology through intense research focus on microbial catalysts, electrode materials, and process control variables. However, it is still far from practical application due to high ohmic losses, high cost, low gas-liquid mass transfer, high over-potential, and operational complexities associated with its routinely used two-chambered reactor design. In traditional two-chambered 'H-type' reactors, anode and cathode chambers are separated by a proton-exchange membrane (PEM). PEM allows the passage of protons and minimizes O 2 transfer to the cathode chamber. As microbes present in the cathode chamber are anaerobic, O 2 contamination can adversely affect their growth. However, PEM is expensive, sensitive, and requires pretreatment, thus hindering the scaling up of the technology. Also, due to its complexities, expert handling is required for long-term operation. Moreover, PEM restricts the free flow of protons between the electrodes, which adds to the ohmic losses. The distance between electrodes in a two-chambered reactor is more, which is another cause of higher ohmic losses. Hence, to pave the way for MES to industrial application, there is a need to investigate improved reactor designs that cater to both biological and electrochemical requirements. My thesis work focused on designing and testing a single-chambered membrane-less reactor with a unique cathode and anode placement strategy to address some of the issues associated with conventional two-chambered MES reactors. We demonstrate MES of acetic acid from CO 2 in a proof-of-concept customized design using a mixed microbial inoculum source dominated by Acetobacterium sp. At an applied cathode potential of -1.2 V vs. Ag/AgCl, about 0.6 ± 0.4 g/L acetic acid was produced at volumetric and cathode surface area-based production rates of 0.06 ± 0.04 g/L/d and 20.0 ± 14. g/m 2 /d, respectively. About 84 ± 34% electrons were recovered in acetic acid. The O 2 produced at the anode was flushed out of the reactor by continuous N 2 sparging at 25ml/min to maintain anaerobic conditions. The E cell was -2.6 V vs Ag/AgCl, which is lower than the conventional two-chambered MES reactors (mostly > -3 V vs Ag/AgCl). The bioproduction at a low applied voltage means a low energy input and high energy efficiency. This study demonstrates that the bio-conversion of CO 2 into acetate via MES can be achieved by developing and optimizing a single-chambered membrane-less reactor. Some operational issues need to be addressed through further work. For instance, the trace amount of O 2 was detected in the headspace of the reactor. It reduces production efficiency as the microbes used for biocatalysis are anaerobic. Hence, by further upgradation like narrow anode opening and better N 2 sparger, O 2 contamination can be avoided. Pressurizing headspace with excess CO 2 will reduce O 2 diffusion from the anode chamber to the headspace. A high acetic acid production rate with higher coulombic efficiency can be achieved by optimizing operational parameters like electrode potential, electrode material and size, and improved CO 2 solubility.
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