Title:
Enhancing Methanogenesis Performance in the Power-to-Methane process: Addressing H2 and CO2 Intermittency

Authors:
Jie Xue, Wenyu Gu

Institution(s):
EPFL, ENAC, IIE, MICROBE

Abstract (300 words maximum): :
Aims: Power-to-Methane (PtM) technology stands at the forefront as a promising solution for the storage of surplus renewable energy aligned with CO2 reduction. In the biological PtM process, methanogens utilize H2 generated from water electrolysis powered by renewable energy and CO2 from industrial waste gas to produce CH4, namely methanogenesis. Our work aims to enhance the robustness of PtM processes by optimizing this methanogenesis step, addressing challenges related to intermittent gas feeding.
Methods: The model strain Methanococcus maripaludis MM901 was cultured in batch cultures to study its starvation-revival dynamics under H2- vs. CO2- starvation by monitoring OD600nm and specific CH4 production rate. To obtain mechanistic understanding of the observed difference, we also (1) measured NAD+ and NADH in the cells during starvation using bioluminescent assays, as well as (2) performed oxygen exposure experiments, where cultures were exposed to air for 1h during starvation followed by monitoring their revival dynamics after O2 removal.
Results: M. maripaludis MM901 exhibited a shorter lag time and higher metabolic activity after H2 starvation compared to CO2 starvation, and an increase in starvation time amplified the difference. We hypothesize that cells experience a reductive stress under CO2 starvation. We measured NAD+ and NADH in cells during starvation and observed significantly higher NADH/NAD+ ratio in CO2 starved cells indicating accumulation of reducing equivalence. O2 exposure also exerts greater inhibition on the revival of CO2-starved cultures over H2-starved cultures shown by a significantly longer lag phase.
Conclusions: In CO2-starved cells where there is H2 leftover, it is possible that O2 reacts with accumulated reducing equivalence, resulting in the production of highly oxidative reactive oxygen species, and subsequently damaged enzymes and DNA in cells. To ensure the process stability and gas product quality, where H2 leftover is preferred over CO2 leftover, further efforts are needed to adapt methanogens to starvation under CO2 limitation.