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Production of formate from CO2 gas: towards flow through enzymatic reactors

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PURPOSE OF THE ABSTRACT

As mentioned in the last IPCC report, a drastic reduction of anthropogenic CO2 emissions is mandatory to follow pathways that limit global warming to 1.5°C above pre-industrial levels in 2100.[1] To achieve this objective, global CO2 emission must reach net zero in the foreseeable future (2040 to 2055). In this context, the carbon capture, utilization and recycling appears as a key challenge. CO2 should not be seen anymore as a waste but as an alternative carbon feedstock to produce platform chemicals and energy carriers.[2, 3] However, the production of platform molecules from CO2, such as methanol or formate, presents some drawbacks. CO2 is thermodynamically stable and its difficult chemical activation has incited the scientific community to develop new heterogeneous catalysts. A promising alternative lies in biocatalytic processes, as they run on relatively mild conditions, are ecologically-friendly and highly selective.[4, 5]

Few biocatalysts including enzymes and bacteria have been studied for the conversion of CO2. Amongst them, formate dehydrogenases (FDHs) have been widely used, especially the commercial one from Candida Boidinii (CbFDH). However, besides the low solubility of CO2 in aqueous solutions, the use of FDHs presents two major limitations. The first limitation lies in the fact that most FDHs, including CbFDH, exhibit low CO2-reducing activities. Few oxygen-stable FDHs have demonstrated superior CO2-reducing properties including FDH from Methylobacterium extorquens AM1 (MeFDH).[6] The second limitation lies in the fact that FDHs require the loosely bound cofactor nicotinamide adenine dinucleotide (NAD) in its active reduced form, 1,4-NADH. As NAD is relatively unstable and expensive, it has to be regenerated in situ. In the last years, various strategies have been developed to selectively reduce NAD+ to 1,4-NADH.[7] However, most of those strategies are nonselective, inefficient, complex (by-products generation) and/or expensive. Amongst them, the enzymatic regeneration using phosphite dehydrogenases (PtDH) is highly selective and rather clean (no additional by-products).[5]

Recently, we could produce formate from CO2 gas in a flow through biocatalytic reactor via the co-immobilization of these two enzymes (PtDH and MeFDH) together with the cofactor NAD+ within porous carbon monoliths (Figure 1).[8, 9] Polyethylene glycol-based cross-linkers were employed to overcome the low solubility of CO2 and immobilize both enzymes and cofactors. We could produce 4 mmol formate per mg of MeFDH during 3 days, which is the highest formate productivity reported to date regarding biocatalytic processes. In this communication, we will present and discuss our latest results regarding the enzymatic production of formate from CO2 gas.

FIGURES

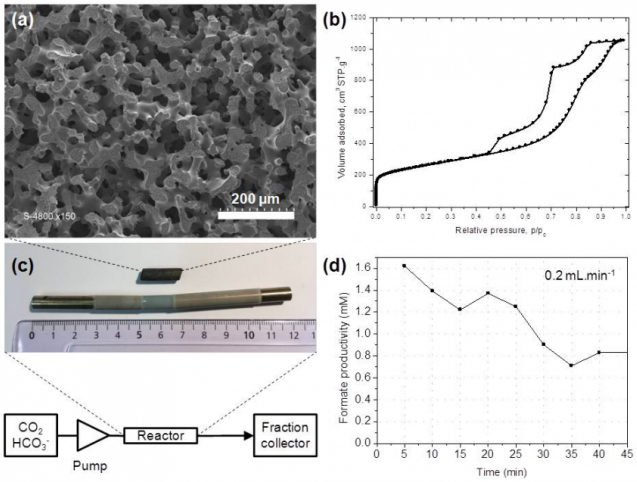

FIGURE 1

Flow through bioreactor

(a) SEM micrograph and (b) N2 sorption isotherm at 77K of the carbon monolith employed for the preparation of the bioreactor. (c) Schematic representation of the flow through reactor. (d) Formate productivity over time.

FIGURE 2

KEYWORDS

CO2 conversion | Biocatalysis | Flow-through reactor | Porous monolith

BIBLIOGRAPHY

[1] http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

[2] G. A. Olah et al. Chem. Soc. Rev. 43, 2014, 7995

[3] F. Kapteijn et al. Chem. Rev. 117, 2017, 9804

[4] Z. Jiang et al. Chem. Soc. Rev. 44, 2015, 5981

[5] R. Cazelles et al. New J. Chem. 37, 2013, 3721

[6] M. Laukel et al. Eur. J. Biochem. 270, 2003, 325; K. Kano et al. Sensing and Bio-Sensing Research 5, 2015, 90

[7] H. Wu et al. Green Chem. 15, 2013, 1773

[8] N. Brun et al. Carbon 61, 2013, 245

[9] M. Baccour, PhD Thesis, 2018, ENSCM, Montpellier, France