Use of nano-biocatalysts for the conversion CO_2 to formic acid

C. Gakis[1], A. Karaiskou[1,2], R. Fotiadou[1], M. Patila[1], K. Spyrou[2], A. C. Polydera[1], D. Gournis[2] and H. Stamatis*

[1] Biotechnology Laboratory, Department of Biological Applications and Technologies, University of Ioannina, 45110 Ioannina, Greece

[2] Department of Materials Science & Engineering, University of Ioannina, 45110 Ioannina, Greece

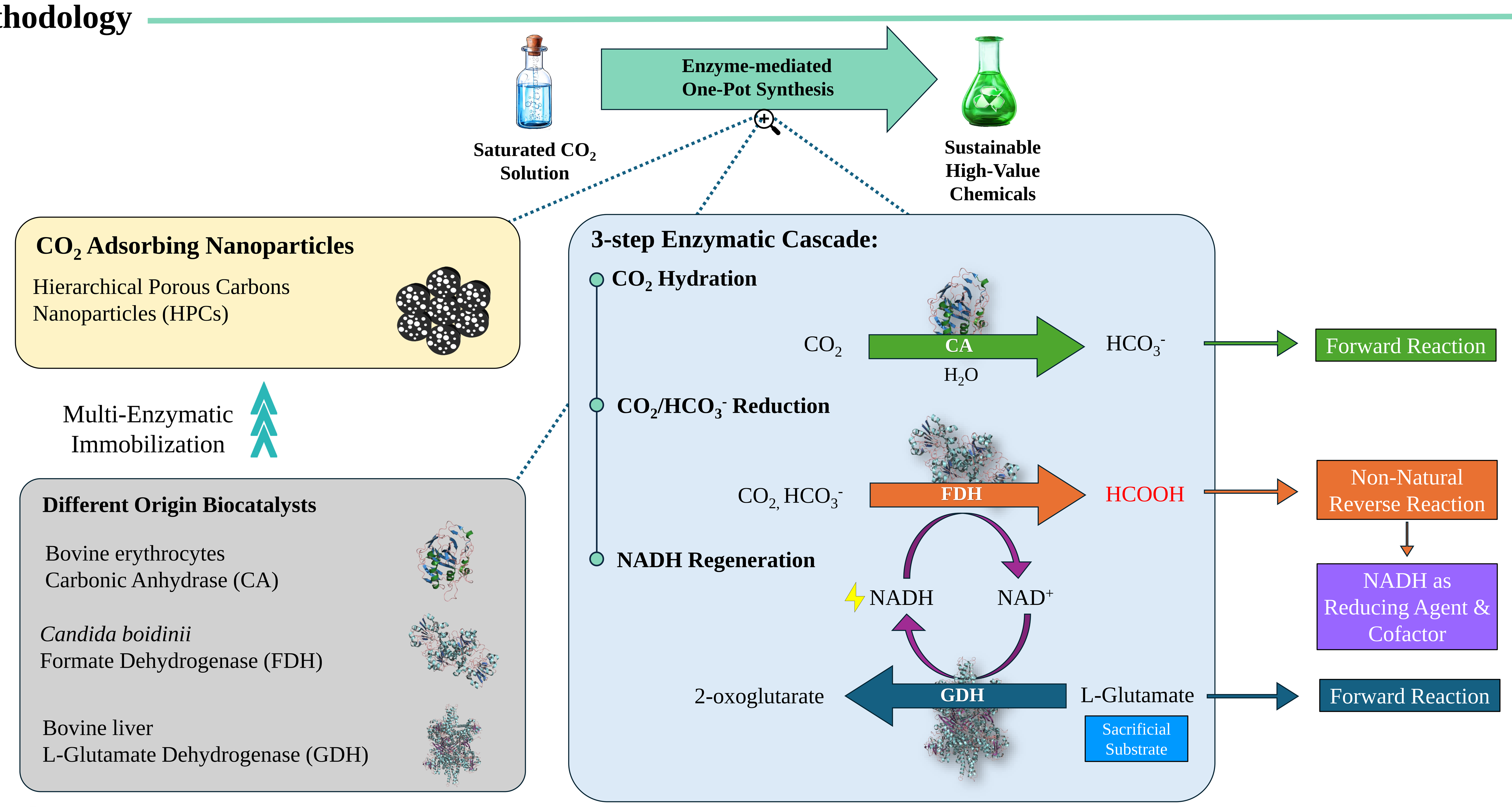
Introduction

- Low solubility of CO_2 in aqueous media is a crucial limitation for biocatalysis
- Development of a multi-enzymatic nano-biocatalyst to capture and utilize CO_2 into formic acid:
  - Incorporation of Carbonic Anhydrase (CA) to increase the solubilization of gaseous CO_2
  - Addition of CO_2 adsorbing nanoparticles namely Hierarchical Porous Carbons (HPCs)
  - Simultaneous immobilization of CA, Formate Dehydrogenase (FDH), Glutamate dehydrogenase (GDH)

Formic Acid:

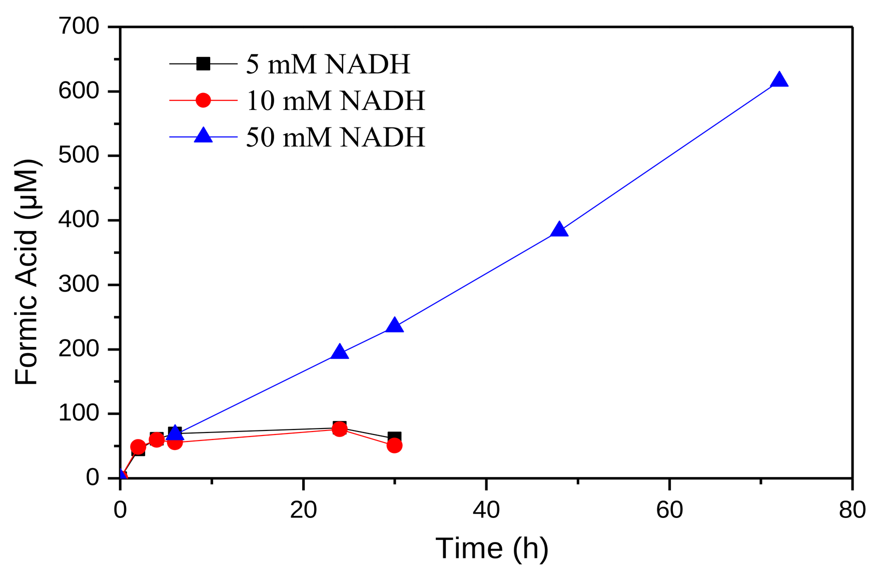
- ✓ Raw material for chemical Industry
- ✓ Hydrogen Storage
- ✓ Essential intermediate for the enzymatic production of Formaldehyde and Methanol

Methodology



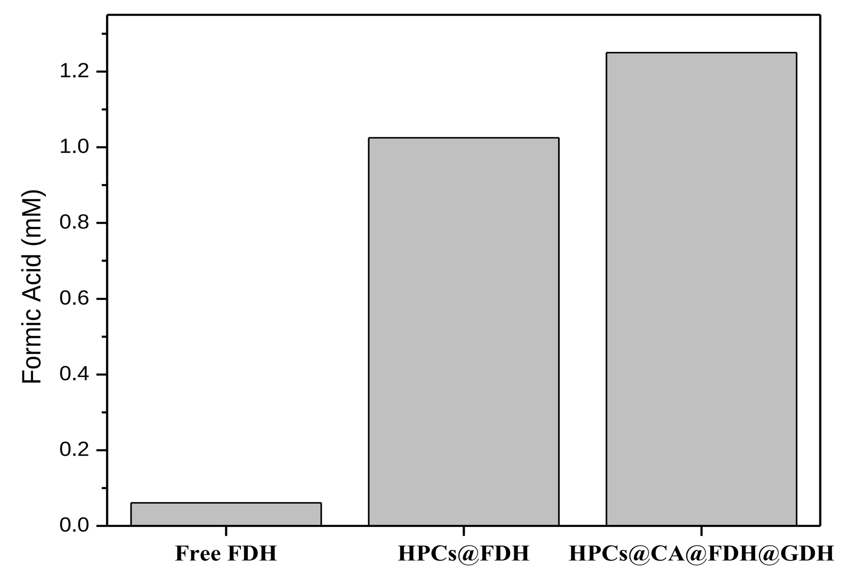
Results

1 Investigation of potency of free FDH reverse reaction (pH 7.0, 30°C)



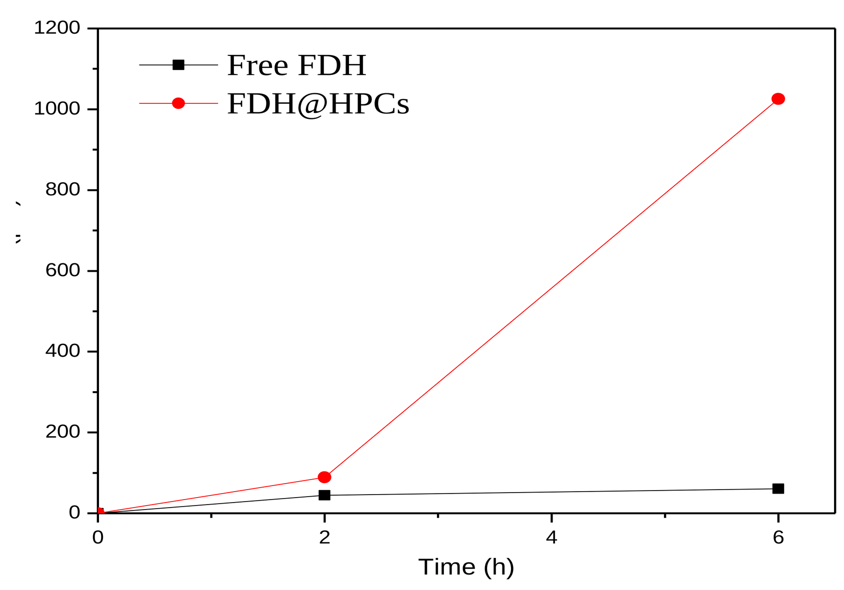
- The presence of the reduced cofactor NADH is in major importance to drive the reaction towards formic acid
- Accumulation of NAD^+ leads to reaction shift towards CO_2

3 Comparison of nano-biocatalytic systems for formic acid production



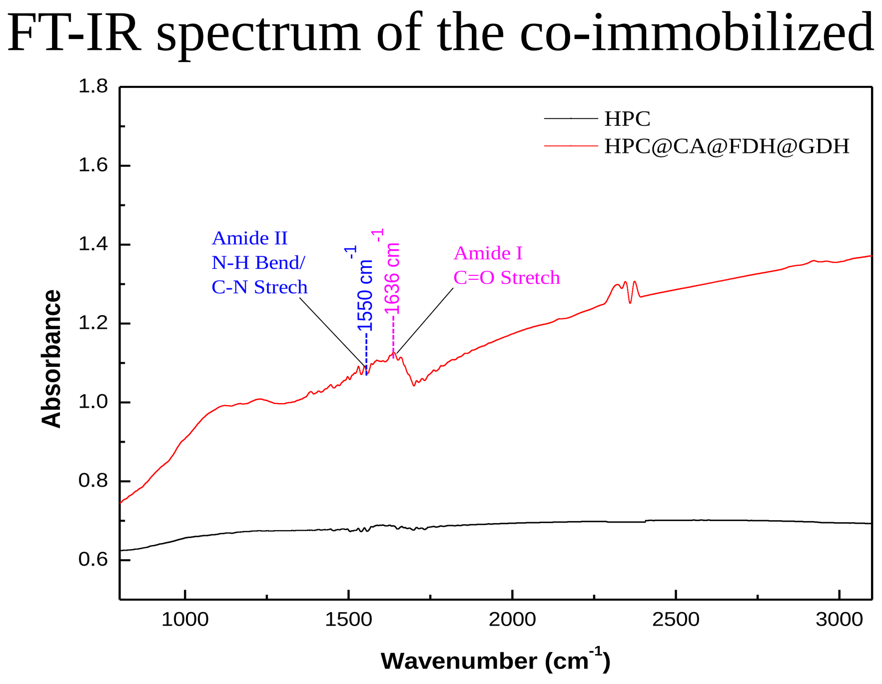
- The nano-biocatalytic systems achieve faster reaction rates of CO_2 reduction
- Multi-enzymatic system exhibits enhanced production of formic acid
- The synergy of CA. FDH and GDH should be investigated more deeply

2 Investigation of catalytic potency of immobilized FDH (FDH@HPCs)



- At equivalent amounts of FDH the presence of the HPCs leads to 17-fold increase of the reaction yield
- HPCs increase the reaction yield probably by bringing the adsorbed CO_2 into proximity with the FDH

4 FT-IR spectrum of the co-immobilized enzyme system



- The presence of amide I and amide II bands confirm the successful immobilization of enzymes

Conclusions

- High excess of NADH is crucial to preserve the CO_2 reduction
- Immobilized systems exhibit superior performance compared to the free FDH system
- 1.25 mM of formic acid was achieved with multi-enzymatic nano-biocatalyst

Future Work

- Investigation of optimized immobilization system
- Investigation of formic acid yields with lower NADH concentrations
- Investigation of catalytical properties in CO_2-adsorbing mediums

Acknowledgements

We acknowledge the support for this work provided by the project "Advanced Nanostructured Materials for Sustainable Growth: Green Energy Production/Storage, Energy Saving and Environmental Remediation" (TAEDR-0535821), which was implemented under the action "Flagship actions in interdisciplinary scientific fields with a special focus on the productive fabric" (ID 16618), Greece 2.0—National Recovery and Resilience Fund and funded by the European Union NextGenerationEU.

Greece 2.0 NATIONAL RECOVERY AND RESILIENCE PLAN
Funded by the European Union NextGenerationEU