Multienzymatic cascades for environmentally sustainable processes

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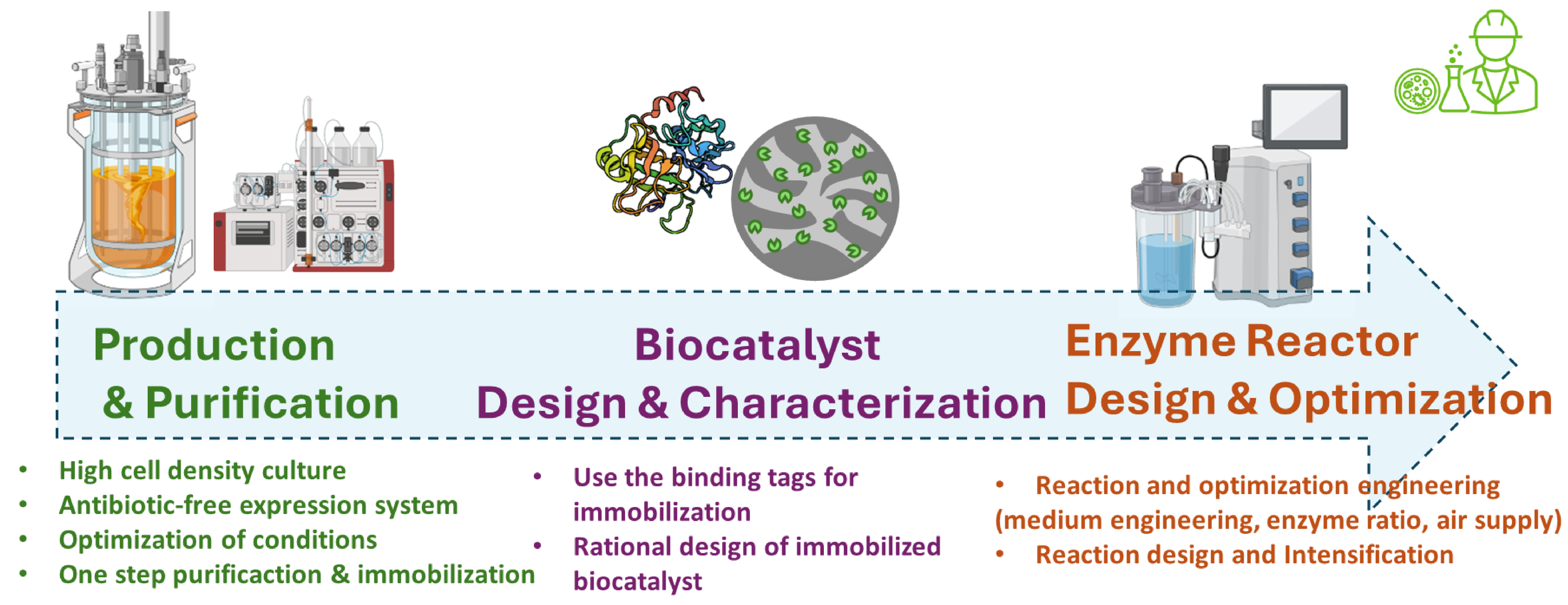
INTRODUCTION

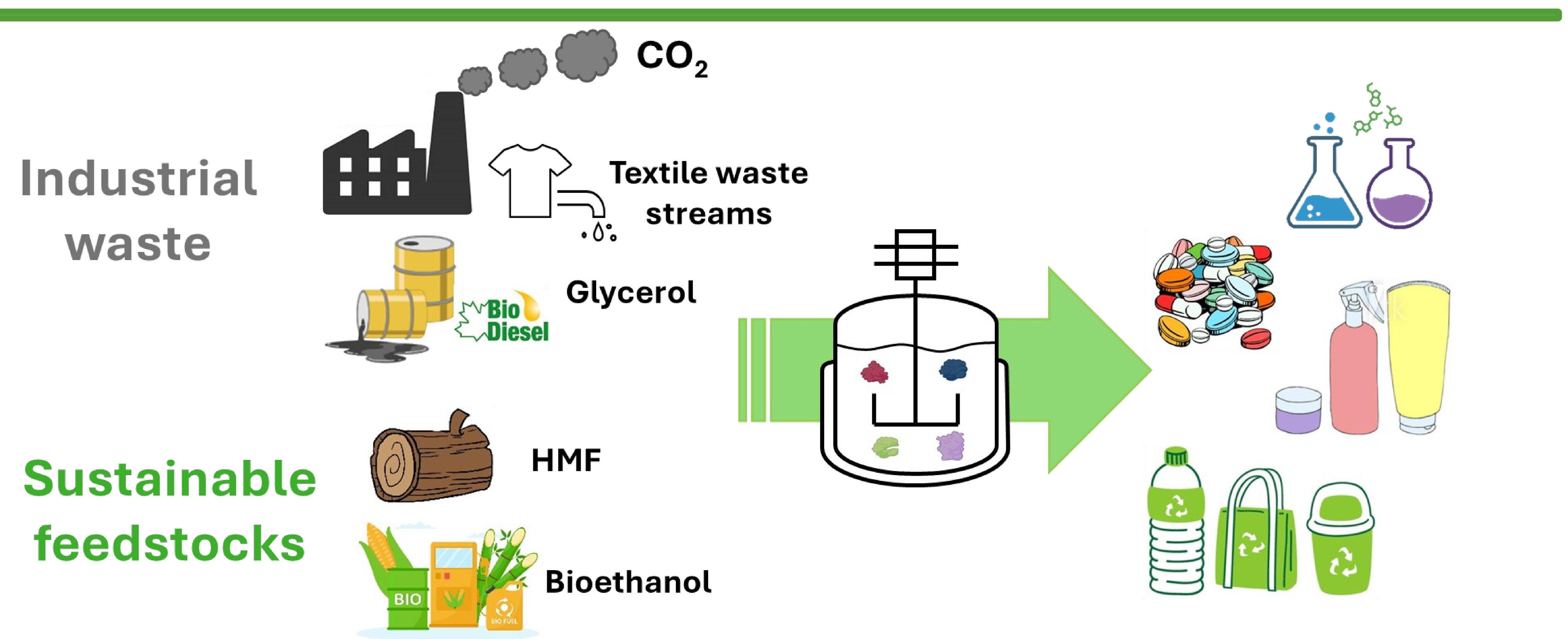
The design and implementation of sustainable processes, which are not dependent on fossil fuels, represents a significant challenge in the coming years [1]. However, biocatalytic processes based on one enzymatic step limit the potential range of molecules that can be produced. A clear trend is emerging towards the development of new and sophisticated biocatalytic cascades, which will replace single-step enzymatic transformations, allowing a cost-effective production of complex molecules while expanding the range of compounds that can be enzymatically obtained. However, further progress is required to industrially implement these systems such as improvements in process metrics, robustness and flexibility. In addition, a reduction in the biocatalysts production costs is also required to enhance the techno-economic feasibility of the processes.

The group of **Bioprocess Engineering and Applied Biocatalysis** aims to address these challenges through the economic and sustainability-oriented design, preparation, and implementation of biocatalysts. This goal is achieved through the implementation of an integrated and multidisciplinary approach, involving the production, the purification/immobilization of enzymes in a single step [2], as well as the design of self-sufficient biocatalysts for their use in enzymatic reactors.

Integral Perspective from a Bioprocess Engineering



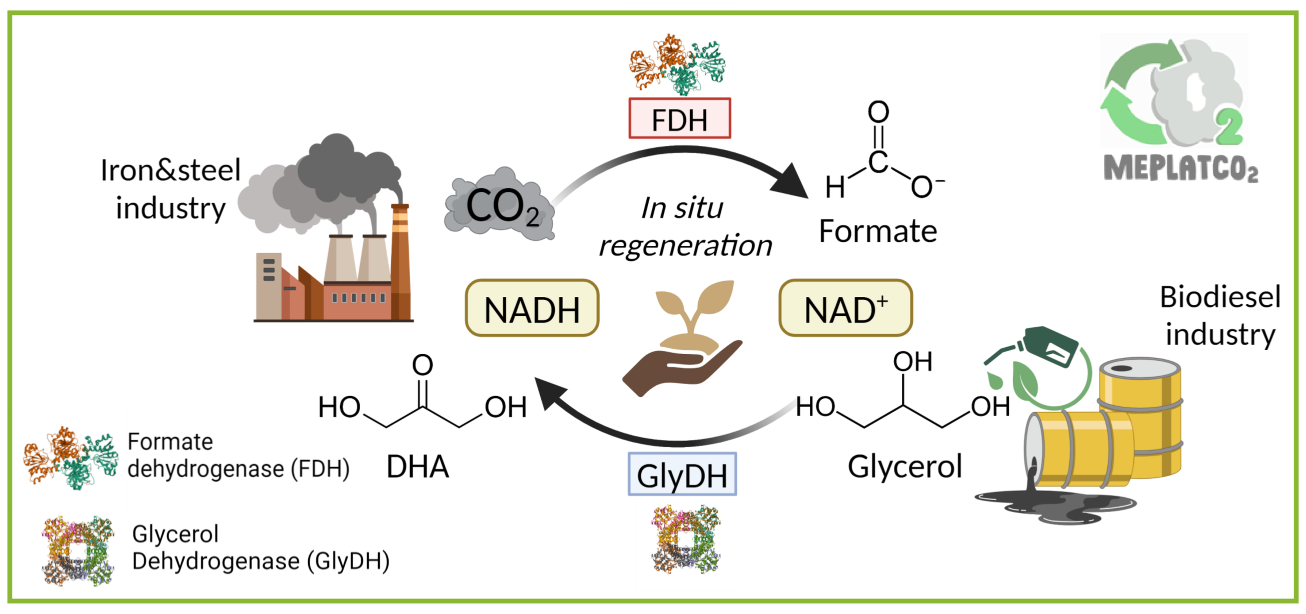
Development of multienzymatic cascades for environmentally sustainable processes from two aproaches:



ONGOING PROYECTS

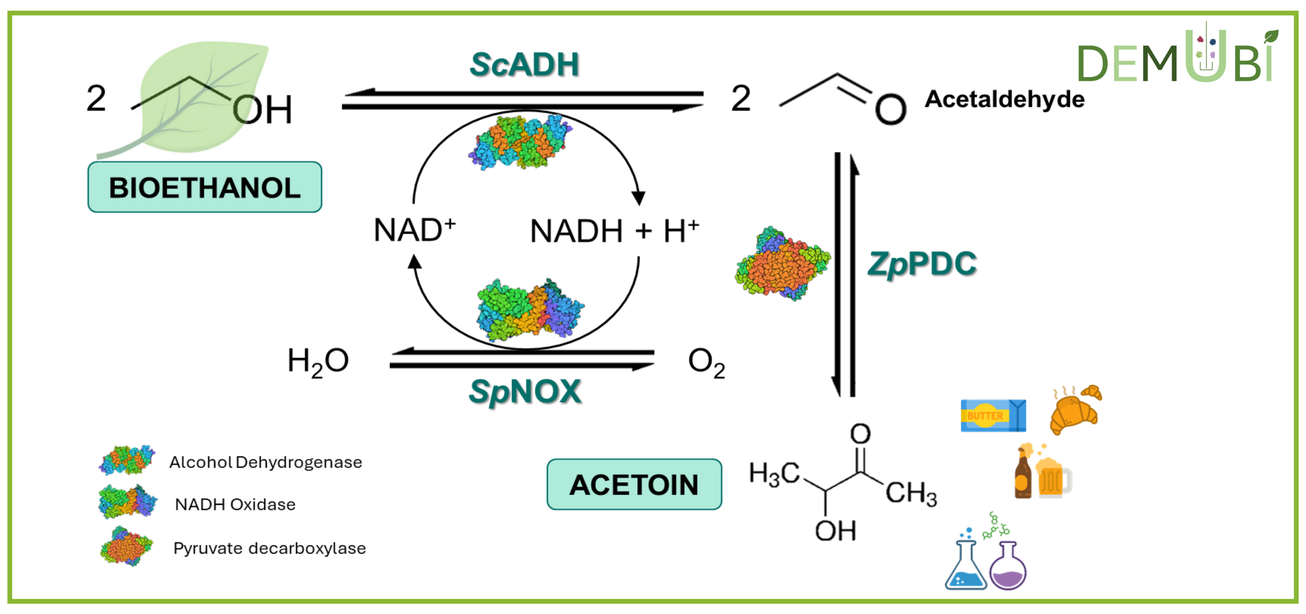
Multi-enzymatic Carbon Capture and Utilization (CCU)

- **CCU technologies** play a crucial role in industries where limited alternatives exist to mitigate the combustion of fossil fuels, being a promising alternative to produce **high-value chemicals from CO_2**.
- The multi-enzymatic system, based on the **circular economy principles**, will allow **coupling a CCU strategy** to a **waste valorization**, producing two compounds of industrial interest (**DHA and formate**) from CO_2 and glycerol.
- The optimized multi-enzymatic system achieved an impressive **92.3% CO_2 conversion**, facilitated by efficient NADH regeneration.
- Furthermore, the system was validated under **industrial relevant environment** [3], using a synthetic gas mixture mimicking the composition of the **iron&steel** industry off-gases and a **crude glycerol**.



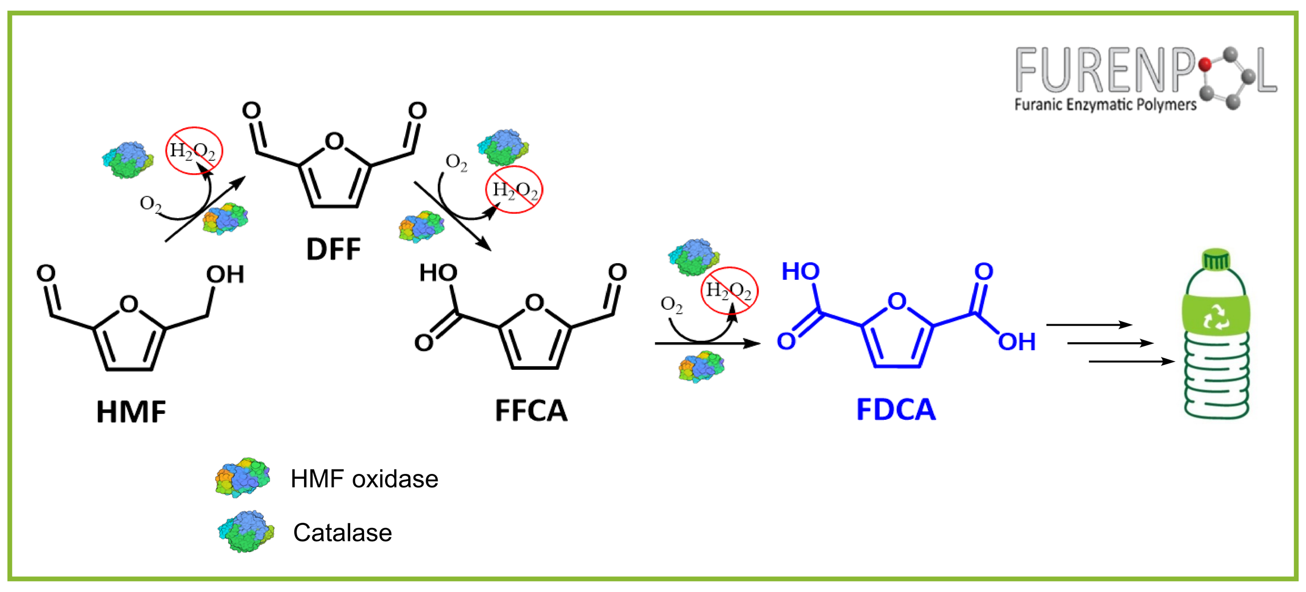
Synthesis of acetoin from Bioethanol in a one-pot reactor

- **Acetoin (3-hydroxy-2-butanone)** is designated as one of top 30 sugar-derived chemicals building block and used as **flavor** in food and beverage industry [4].
- **Novel multi-enzymatic synthesis**, more **environmentally friendly** compared to conventional chemical synthesis. In addition, acetoin produces could be **labelled as natural.**
- **Excellent metrics,** obtaining a yield of 87.9% with a productivity of 261.2 $mg_{acetoin} \cdot L^{-1} \cdot h^{-1}$
- **Intensification** of the multi-enzymatic and further **optimization** is currently ongoing.



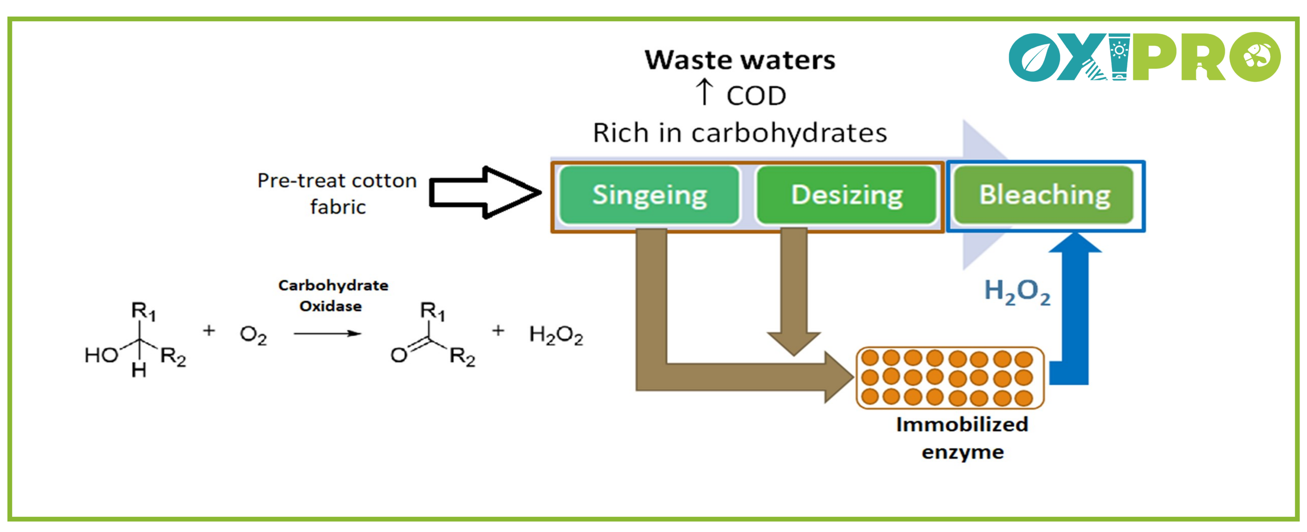
Intensification of the producction of furandicarboxilic acid (FDCA) for new biobased plastics

- **HMF** has been identified as a **versatile chemical platform** from renewable resources, and can be transformed into **FDCA**, a key **building block** for renewable materials such as **PEF** and specialty polymers.
- **HMF oxidase (HMFO)** from *Methylovorus sp*. is able to catalyse the three oxidative steps [5].
- **Intensification** by one-step purification&immobilization strategy into cellulose support was carried out using a CBM-fused HMFO, obtained high immobilization yield (98%) and protein loading ($59 mg_{protein}/g_{support}$).
- **Optimization** of the biocatalyst and the **reaction condition** has allowed to increase the **yield** and **productivity** up to 66% and 40.1 $mg_{FDCA} \cdot L^{-1} \cdot h^{-1}$, respectively.



Transition towards environment-friendly consumer products by co-creation of an oxidoreductase foundry

- **Carbohydrate oxidases** are used to develop a **circular cotton-textile biobleaching** process for reduction of energy, water and chemical consumption.
- Carbohydrate rich wastewaters from previous steps of cotton processing are using as feedstock to **generate H_2O_2 for the bleaching process.**



TO TAKE HOME

- Design and implementation of **green, sustainable and fossil-fuel independent processes** is crucial to face the challenges and goals that the next decades will bring.
- **Biocatalysis** will contribute to **boost key technologies** and solutions underpinning policies and **sustainable development goals.**
- **Economically** & **green** driven biocatalyst design and preparation.
- **Integral** & **multidisciplinary** approach for process development

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