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CO2 valorisation: Multienzymatic synthesis of lactic acid using CO2

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PURPOSE OF THE ABSTRACT

Carbon dioxide has the highest residence time in the atmosphere, making it the most impactful greenhouse gas to the global warming. For that reason, efforts should be focused on reducing its emissions. The EU has set the objective to reduce CO2 emissions in the EU by 80% in 2050. Technological innovations are needed to reach this goal, leading to successful CCU (Carbon Capture and Utilization) technologies.
The CO2 molecule is very stable, due to the highest valence state of carbon (+4), with a C=O bond breakage energy of 749 kJ mol-1. Hence, it requires high amounts of energy to transform it into added-value compounds. Biocatalysis presents a green approach for the development of CCU strategies, because the use of enzymes complies with 10 of the 12 principles of green chemistry. They can catalyze reactions under mild conditions of pressure, temperature and pH.
A number of enzymatic systems for utilizing CO2 have already been reported in the literature. For example, formate dehydrogenase (FDH) catalyzes the transformation of CO2 into formic acid. But most of them are single-enzyme systems, which limits the variability of products that can be obtained. In addition, the majority require cofactors such as NADH/NAD+ for catalysis. Therefore, multi-enzymatic systems can tackle these limitations by widening the range of products obtained and allowing regeneration of cofactor in-situ.
In this study, a multi-enzyme system for the synthesis of lactic acid using CO2 and ethanol, with a 100% atom economy, was studied. The system involves three enzymes: alcohol dehydrogenase which oxidizes ethanol into acetaldehyde consuming one NAD+ molecule, pyruvate decarboxylase which carboxylates acetaldehyde into pyruvic acid using a CO2 molecule, and lactate dehydrogenase which reduces pyruvic acid into lactic acid, using one NADH molecule, and regenerating the NAD+ needed for the first reaction. Firstly, each reaction was studied individually, revealing that PDC catalyzes an undesired secondary reaction which is highly favored. Therefore, two PDCs were studied to find which one produces less byproduct. Finally, by means of reaction medium engineering and enzyme ratio optimization, the lactic acid yield of the system could be increased, reaching 250 µM under the best conditions. So far, this is the highest concentration of lactic acid achieved using this multi-enzymatic system.

FIGURES

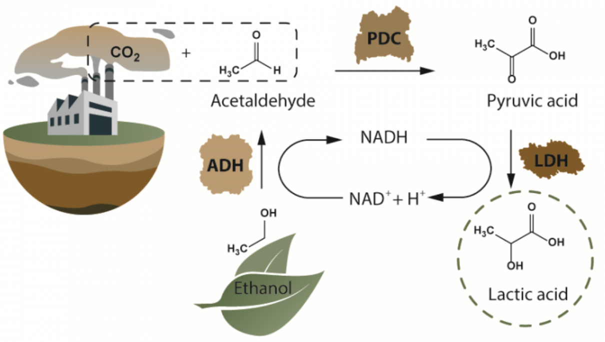

FIGURE 1

Multienzymatic synthesis of Lactic Acid

ADH: Alcohol dehydrogenase

PDC: Pyruvate decarboxylase

LDH: Lactate dehydrogenase

FIGURE 2

KEYWORDS

multienzymatic system | cofactor regeneration | Carbon dioxide | pyruvate decarboxylase

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BIBLIOGRAPHY

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