Isopropyl Alcohol Production from CO2 with a new Direct Air Carbon Capture and Fixation (CCF) approach: results from early *proof-of-concept* investigation

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Energy transition demands a reduction in CO_2 emission that should be *almost total, effective and extremely sharp.* Carbon Capture and Utilization (CCU) is a fundamental tool for hard-to-electrify sectors to obtain renewable chemicals and fuels. This work aimed to convert air-derived CO_2 into renewable isopropyl alcohol (IPA), serving as a versatile fuel, energy carrier, hydrogen carrier, or commodity chemical. To achieve a reliable system, the approach of this study uses microbial mixed culture (MMC, consisting of anaerobic homoacetogens) supported on a peculiar Char-Based sparger Reactor to reduce bicarbonate with renewable hydrogen, thus obtaining high concentration (>60 g/L) acetate, which is ketonized and hydrogenated to isopropyl alcohol (IPA). The key aspect of the process concept, hereafter named Carbon Capture and Fixation (CCF), is the fact that it exploits the increase in pH determined by the chemolithotrophy to obtain CO_2 from a diluted source, through a peculiar Air Capture Device. This system consists in a wet tertiary amine resin (a commercial anion exchange material) used to trap CO2 in the form of chemically bound bicarbonate, which is regenerated through washing with the alkaline solution produced from homoacetogenesis. Such approach allows to overcome the CO_2 thermal desorption step which consume most of energy in DAC, thus avoiding any thermal degradation of tertiary amine. Aim of this work was to test and validate this concept by evaluating the long-term performance of the entire CCF system, as well as purity of isopropanol finally obtained. Tests were performed by means of micro scale reactors, consisting in 50 mL CBSR reactor coupled with 30 mL carbon capture system, which was operated continuously for 9 months. First 4 months test was performed with a simplified carbon capture device (dual fixed bed) it was possible to demonstrate the conversion of captured CO2 into 40-60 g/L sodium acetate with stable performance. The performance and physicochemical properties of tertiary amine resin were not significantly affected by actual CCF operations. CCF derived Sodium acetate was then obtained through simple evaporation of the broth, obtaining trihydrate crystals with 98% purity. These were dried and subjected to bench scale pyrolysis, showing that pyrolysis of CCF-derived sodium acetate yields, along with residual reaction water, an organic liquid which consisted of 98% purity acetone. The overall selectivity of pyrolysis reaction was 88±5% which can be considered fairly good for a still not optimised reaction. Overall, it is possible to state that coupling MMC with an innovative carbon capture approach and sequence of well-known chemical and thermochemical steps it is possible to perform carbon fixation directly from air and without the use of an axenic environment. Although preliminary, such findings open up new perspectives, especially for small-scale contexts, for distributed production of C3 chemicals from CO_2.

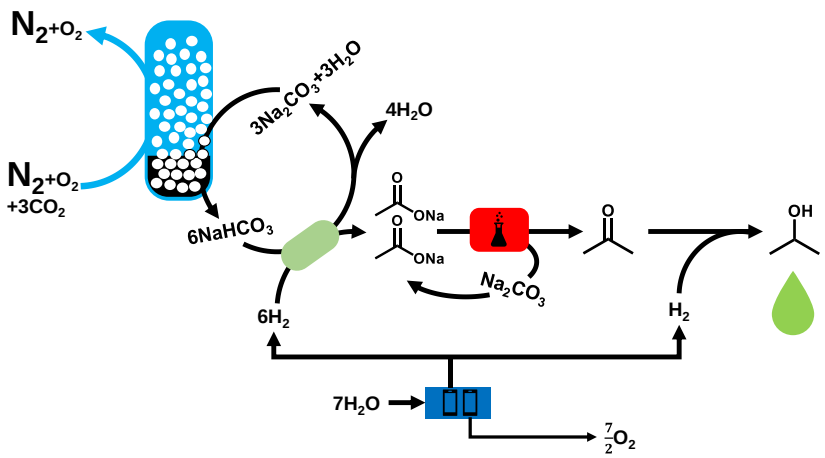

Figure 1: chemical pathway investigated in this work.