Carbon Capture Using Carbonic Anhydrase-Displaying *Escherichia coli* in Biologically Active Foams

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Abstract

In recent years, global warming as the result of greenhouse gas emissions, especially that of CO_2, has become of great concern. Many technologies have been proposed and employed to capture post-combustion CO_2 as governments worldwide have recognized the need to do so. Conventional methods such as absorption and adsorption have the problems of regeneration of spent solvents and media requiring additional energy input and expensive operating costs. For these reasons, the carbonic anhydrase enzyme (CA), which quickly catalyzes the conversion of CO_2 into bicarbonate ion and a proton, has been studied for use in carbon capture and sequestration (CCS) technologies. This process would solve the limitations of current carbon capture technologies because it readily converts CO_2 into environmentally friendly products at mild conditions. Furthermore, upon CO_2 removal, the aqueous bicarbonate can be precipitated and separated as calcium carbonate (bio-mineral) as a value-added product. However, current CA-driven carbon capture remains problematic: the purified enzyme itself costs in the range of thousands of dollars per gram; the enzyme works best in slightly alkaline conditions, so some buffering capacity is necessary to combat the protons it generates; and CA must be replaced over time as it gradually loses its activity. The major goals of this project are to employ genetically modified *E. coli* to continuously produce and display CA on their cell membranes and to use these bacteria in the Foam Bioreactor to capture and sequester CO_2. The bacteria incubated in auto inducible media (AIM) have shown successful growth and enzyme expression as well as high activity and foaming capacity in the Foam Bioreactor. Because of the huge gas-to-liquid surface area in the Foam Bioreactor, the CO_2 in gas phase was quickly transferred to many CA-displaying bacteria, allowing the CA to convert CO_2 to bicarbonate ions and protons. Under *ex situ* pH control and an inlet stream of 2% CO_2 at a cell concentration of 2.0 g/L, varying gas flow rates showed an optimum of 1 L/m with a removal efficiency (RE) of 50% and corresponding elimination capacity (EC) of 1,980 gCO_2/m^3h. Investigations on cell concentration effects at fixed gas flow rate of 1 L/m and inlet CO_2 showed increasing RE and EC as cell concentration increased from 0.015 g/L to 2.0 g/L, with an RE of 13 – 68%, respectively, and an EC of 660 – 2,860 gCO_2/m^3h, respectively. Studies combining the cells with the tertiary amine solution, MDEA, indicate the potential to combine this method of carbon capture as a means to refresh the solution, rather than via conventional, energy-intensive methods. Furthermore, preliminary studies with in-line bicarbonate product removal show even higher removal of 90% and long-lasting steady states.