Multi-pronged approach to improving carbon utilization by cyanobacterial cultures

Arizona State University, Wim Vermaas (PI)

Carbon dioxide (CO_2) is emitted as a waste byproduct from numerous process industries, notably including energy generation and bioethanol production. At the same time, CO_2 is also a key feedstock for advanced biofuel production by photosynthetic microbes, including genetically tractable cyanobacteria. Use of waste gas CO_2 for advanced biofuel production presents an attractive mechanism for reducing CO_2 emissions while simultaneously producing sustainable biofuels and bioproducts, examples of which are laurate (a fatty acid biofuel precursor) and methyl laurate (a drop-in biodiesel fuel). Despite the promise of this approach, poor rates and efficiencies of CO_2 absorption into the culture medium along with sub-optimal biological CO_2 assimilation and fixation rates currently limit overall performance. To address this, we will first increase rates of aqueous CO_2 absorption by addition of biocompatible amine solvents and a nanobubble gas delivery system. Amine solvents will react with CO_2 as it enters the liquid, increasing its net solubility and thereby providing a significantly greater driving force for its absorption. Nanobubbles, meanwhile, will reduce mass transfer resistance by greatly increasing the area for gas-liquid contact, as well as contact time between gases and liquids, supporting both faster and more complete transfer from gas to liquid. Rates of cellular uptake of dissolved inorganic carbon will be increased through engineering of bicarbonate transport proteins for increased activity, while carbon fixation rates will be increased by genetically ‘rewiring’ cellular metabolism to increase the amount of CO_2 utilized during both day and night. Actual fermentation effluent gases derived from both a bioethanol plant and a cidery will be tested as real CO_2 feedstocks and performance in large-scale growth systems under outdoor conditions will be demonstrated. Integrated technoeconomic and life-cycle analyses will be used to guide our approach and assess its viability. Overall, the outcomes of this research will demonstrate at least a 50% increase in CO_2 utilization efficiency with improved advanced biofuel production under industrially relevant conditions. Outside the immediate scope of this project, the biomass may be converted to additional advanced biofuel by hydrothermal liquefaction, while valuable co-products (natural or introduced) may also be extracted or synthesized to aid the overall economic viability of the process. This research will be performed at Arizona State University by researchers on both the Tempe and Polytechnic (AzCATI) campuses, at Colorado State University, and at Nano Gas, Inc.