Conversion of CO₂ and Carbonates to Methane and (bio) Isoprene

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Abstract

We propose a biotechnology to simultaneously convert anthropogenic CO₂ or carbonate minerals from energy generation facilities into a biofuel (methane), and a bioplastic (isoprene) using microbial consortia. Carbon Capture and Utilization Strategies (CCUS) are critical to minimize emissions or remove anthropogenic CO₂ from the atmosphere. Yet, green technologies converting CO₂ to value-added products in addition to biofuels is lagging. To date, 30–40% of emitted CO₂ results from coastal fixed power plants and technologies have been tested to remove CO₂ from emissions. One of these technologies is the production of carbonate minerals such as calcium carbonate. Methane-producing microbial species in pure culture and in microbial consortia have been used to produce isoprene, which they incorporate into branched alkylate lipids that constitute cell membranes. Isoprene is a valuable chemical commodity used in production of polyisoprene rubber (the major component of automotive tires), in pharmaceutical, and as a synthetic intermediate for a wide range of specialty chemicals (cosmetics, vitamins, flavorings, etc.). Microbially-derived isoprene is chemically identical to petroleum-derived isoprene, but can be extracted in higher yield and purity. This technology will be developed in two objectives: (Objective 1) quantify conversion of CO₂ and carbonates to methane and isoprene and (Objective 2) engineer methane-producing microbes to overproduce isoprene. These experimental objectives will be initiated in Year One as an effort to augment natural isoprene production in new and existing methane-producing microbial isolates or consortia. This technology will result in an inexpensive, economically feasible method to convert anthropogenic CO₂ and carbonates into an energy source and a commodity with increasing worldwide demand. Successful implementation will also result in a market for carbonates captured by power plants.

References
5. Deutscher, B. et al. Methane production in anaerobic bioreactors amended with CO₂ or CaCO₃ relative to a control where inorganic carbon was omitted. Values represent averages of triplicate reactors. Standard error of measure is denoted by error bars. Error bars not visible are smaller than the symbol.

Implications

Introduction

Methanogens

- Obligate anaerobes found in digestive tracts of animals, rice paddies, and sediments.
- Produce all bio-methane worldwide
- Isoprenoid-based membrane produced via Mevalonate Pathway
- Methanogens lipids used in pharmaceuticals, pharmaceutics, synthetic intermediates, and as a plastic intermediate

Carbonates

- Methanogenesis pathways
- Calcium carbonate dissolution
- Future Directions

Table 1: Uses of Isoprene

<table>
<thead>
<tr>
<th>Industry</th>
<th>Use</th>
<th>Market Size</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tires, tubes</td>
<td>31,000 mton/yr</td>
<td>$110 M</td>
<td></td>
</tr>
<tr>
<td>Butyl rubber</td>
<td>1,500 mton/yr</td>
<td>$50 M</td>
<td></td>
</tr>
<tr>
<td>Isoprene</td>
<td>520,000 mton/yr</td>
<td>$1.7 B</td>
<td></td>
</tr>
<tr>
<td>RUBBER</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Carbonate Utilization Strategies (CCUS)

- Critical to minimize emissions or remove anthropogenic CO₂ from the atmosphere

Future Directions

Gene A

- Methane Rate Assay
- Quantitative Liquid Profile analysis using HPLC
- Full characterization of enzymatic activity

Gene B

- Optimal stable transformants
- Characterization of promoter systems utilizing Western blots
- Characterization of pyrrolysine control using Western blots

Carbonates

- Single-cell genome sequencing
- Metagenomics
- Meta-transcriptomics
- Mechanism of carbonate dissolution

Acknowledgments

This project is funded by: 
- NCEER-Cycle 8 Award
- WERF NTRY1401