Project title: Calcium Carbonate Production by Coccolithophorid Algae in Long Term, Carbon Dioxide Sequestration

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Abstract

Predictions of increasing levels of anthropogenic carbon dioxide (CO_2) and the specter of global warming have intensified research efforts to identify ways to sequester carbon. A number of novel avenues of research are being considered, including bioprocessing methods to promote and accelerate biosequestration of CO_2 from the environment through the growth of organisms such as coccolithophorids, which are capable of sequestering CO_2 relatively permanently.

Calcium and magnesium carbonates are currently the only proven, long-term storage reservoirs for carbon. Whereas organic carbon is readily oxidized and releases CO_2 through microbial decomposition on land and in the sea, carbonates can sequester carbon over geologic time scales. This proposal investigates the use of coccolithophorids — single-celled, marine algae that are the major global producers of calcium carbonate — to sequester CO_2 emissions from power plants. Cultivation of coccolithophorids for calcium carbonate ($CaCO_3$) precipitation is environmentally benign and results in a stable product with potential commercial value. Because this method of carbon sequestration does not impact natural ecosystem dynamics, it avoids controversial issues of public acceptability and legality associated with other options such as direct injection of CO_2 into the sea and ocean fertilization. Consequently, cultivation of coccolithophorids could be carried out immediately and the amount of carbon sequestered as $CaCO_3$ could be readily quantified. The significant advantages of this approach warrant its serious investigation. The major goals of the proposed research are to identify the growth conditions that will result in the maximum amount of CO_2 sequestration through coccolithophorid calcite production and to evaluate the costs/benefits of using coccolithophorid cultivation ponds to abate CO_2 emissions from power plants.

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Introduction

The objective of this project is to determine the efficacy of using coccolithophorid $CaCO_3$ production in CO_2 removal technology. This project will determine the methods and biological and chemical conditions needed to optimize the native ability of coccolithophorid algae to sequester CO_2 in the form of $CaCO_3$. This project will identify the parameters necessary to produce coccolithophorid blooms and the factors required to obtain maximum calcification rates. The information gained in this study can be incorporated into the design and construction of future algal ponds or bioreactors in follow-up research (not a part of this project) on CO_2 sequestration by coccolithophorids. The initial task of the research is to identify the species, cell strain and the specific growth conditions (e.g., temperature, light intensity, nutrient concentrations) that maximize population growth rates and rates of calcification. The second task of the project is to quantify the amount of CO_2 sequestration by coccolithophorids when cells are grown under high-calcifying conditions in a custom-manufactured experimental vessel.

In this quarterly review period, we investigated whether the growth rates, maximize yield of coccolithophorids, and inorganic carbon uptake could be increased by growing cells in two different growth media – K media (Keller et al., 1987) and F/50 (Guillard, 1975) — which contain different sources and levels of nitrogen, phosphate, trace metals, and chelator.

Experimental

To determine if the production rate and maximum yield of coccolithophorids could be increased from our earlier results, we conducted two closed vessel experiments. In the first closed vessel, we inoculated 7 liters of F/50 media with a very small volume of *Emiliania huxleyi* cell strain CCMP 371 to give an initial cell density of 4×10^2 cells ml^{-1}. The culture was stirred continuously to keep cells uniformly suspended. This vessel was placed in a temperature and light-controlled environmental chamber. The temperature during the experiment was 18.5 $^{\circ}C$ and the light/dark cycle was 16 hours light/8hours dark. Subsamples were taken for cell densities and measurement of total alkalinity (TA) and dissolved inorganic carbon (DIC). Total alkalinity (TA) was determined using our own software. Total dissolved inorganic carbon in duplicate samples was measured using coulometry (Dickson and Goyet, 1994). Cell densities were determined daily by direct count.

In the second closed chamber experiment, we inoculated 7 liters of K media with a very small volume of *Emiliania huxleyi* cell strain CCMP 371 to give an initial cell density of 4×10^2 cells ml^{-1}. Subsamples and measurements were completed as described above.

Results and Discussion

Results of the 12-day experiments are graphically illustrated in Figure 1. Population cell growth showed the expected exponential growth curve including logarithmic and stationary phases. In both experimental chambers, maximum cell densities reached more than 10^7 cells ml^{-1}. Cells in the K media reached 10^7 cells ml^{-1} in 10 days, whereas cells in the F/50 media reached this density in 11 days. Our results suggest that there were no significant differences in growth rates or maximum yield between the two media. As shown by the decrease in DIC, cultures in both experimental media took up inorganic carbon at similar rates and were probably carbon-limited by day 12.

We hypothesize that introducing additional dissolved CO_2 at day 12 could possibly lead to greater cell growth and CO_2 sequestration, assuming nutrients were still abundant. This is supported by our previous experimental results (summarized in annual report #2 submitted in October 2003) in which increased nitrate loadings (from 1.5 to 3 times the nitrogen concentration in F/50 and K media) did not increase cell density relative to normal F/50 and K media.

Conclusion

The results of these experiments suggest that there are no substantial differences in cell growth rates, maximum cell density, or changes in DIC uptake when the coccolithophorid *Emiliani huxleyi* cell strain CCMP 371 is grown in K media versus F/50 media. Therefore, there is no advantage in using K media, which is more complex and expensive to make than F/50 media, to grow coccolithophorids for CO_2 sequestration. We plan to repeat this experiment to confirm our results. Assuming the outcome is the same, we will then begin to investigate coccolithophorid growth as a function of increased total dissolved CO_2.

References

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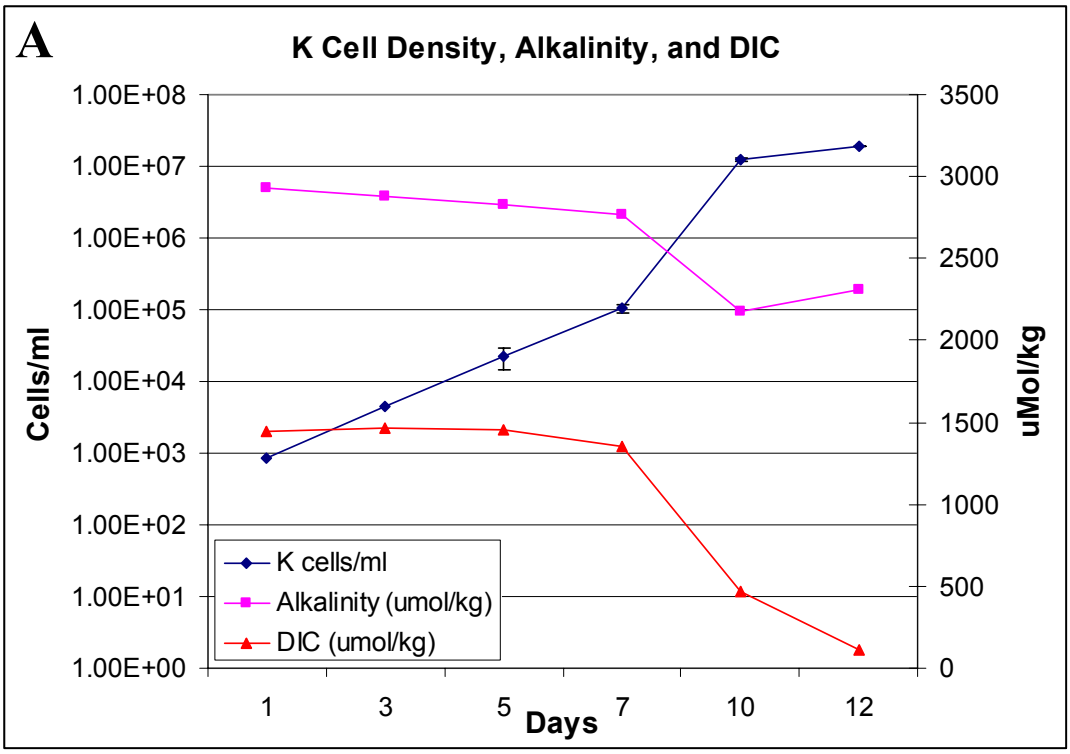

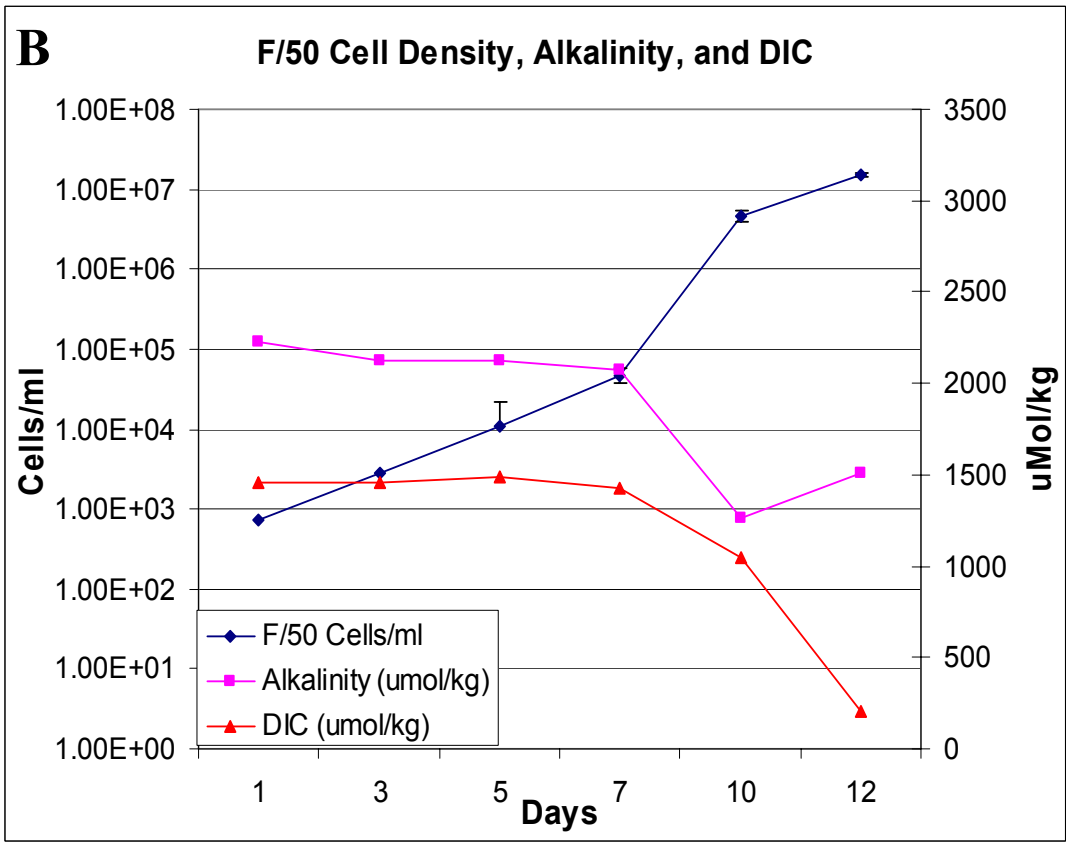

Fig 1. Changes in cell density (blue diamonds), total alkalinity (pink squares), and total dissolved inorganic carbon (DIC; red triangles) in closed vessel experiments with *Emiliania huxleyi* cell strain CCMP 371. (A) Cells grown in unmodified K media. (B) Cells grown in F/50 media.