When CO_2 increases, how does *Helicosphaera carteri* respond?

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Beginning in the 1960s, human activities have led to an increase in atmospheric CO_2 concentration 100 times faster than with previous natural increases. Approximately 30% of anthropogenic CO_2 is absorbed by the oceans, leading to changes in ocean chemistry termed ocean acidification (OA). Several studies have focused on the effects of increasing CO_2 on calcifying organisms, including coccolithophores. Responses of coccolithophores to OA appear to be species specific, but only a few species (from approximately 250 living species) have been studied, which warrants further studies. *Helicosphaera carteri* is a common coccolithophore species. It is considered a major contributor to carbon uptake and $CaCO_3$ storage in deep-sea sediments due to its large size and higher rates of organic carbon fixation and calcite production compared to smaller species. Despite its important role, only a few studies have been conducted on living *H. carteri* under experimental conditions, and none have considered the effects of rising CO_2.

In this work, we study for the first time the response of *H. carteri* (Strain RCC1323, Roscoff Culture Collection) to varying CO_2 (295, 444, 600 ppm) by analyzing its variations in morphology, growth rate, and particulate organic carbon (POC) and inorganic carbon (PIC) production. Our results show that *H. carteri* is not very sensitive to pH/CO_2 variations. From a morphological point of view, there is only a 10% increase in slightly malformed coccoliths and <1% of collapsed coccospheres when CO_2 amounts are increased from 295 to 600 ppm.

A preliminary comparison of malformed coccoliths of *H. carteri* with another heavily calcified species, *Calcidiscus leptoporus*, (grown under experimentally controlled conditions at CO_2 levels close to 600 ppm), shows that the percentage of malformed coccoliths in *C. leptoporus* is higher than that in our *H. carteri* experiments, and with a greater amount of malformation (Langer et al., 2006; Diner et al., 2015). This indicates that *H. carteri* has a greater resilience than *C. leptoporus* to CO_2 variation. However, there was a decrease in PIC production (-26%) and the PIC:POC ratio (-29.6%) with increasing CO_2 levels, showing that *H. carteri* is sensitive to ocean acidification.

Moreover, a decrease in *H. carteri* growth rate (μ) occurred at the lowest (295 ppm; 0.36 μ/day, decrease of 18%) and highest (600 ppm; 0.40 μ/day, decrease of 9%) CO_2 concentrations compared to the control culture (444 ppm; 0.44 μ/day), indicating a possible influence of CO_2 limitation (295 ppm) and H^+ inhibition (600 ppm), respectively. However, this decrease is not related to a decrease in POC production, as previously was observed by other authors in association to these two limiting factors (e.g., Bach et al., 2011). Indeed, POC production does not change significantly from 295 to 444 ppm, and contrary to the growth rate, it increases from the intermediate CO_2 level to the highest. Our results highlight the complexity of coccolithophore responses to increased CO_2 and underscore the need to collect extensive data from different species.

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