XXI Brazilian Meeting on Inorganic Chemistry
X Brazilian Meeting on Rare Earths
III Workshop on Theoretical Bioinorganic Chemistry
Belo Horizonte, September 12 - 15th 2024

The effect of alginate-iron controlled release systems on the thermal resistance of *Fugacium kawagutii*

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Thematic Area: Biological Inorganic Chemistry

Keywords: alginate, iron, bleaching

Increased sea temperatures may lead to bleaching events worldwide.[1] Recent studies confirm that iron (Fe) and its complexes promote significant recovery of *Symbiodiniaceae* after thermal stress events, particularly in *Fugacium kawagutii*.[1,2,3] Desferrioxamine (DFO) and histidine (His) can act as iron chelators and scavengers of reactive oxygen species, attenuating damage that could contribute to coral bleaching.[1] *Symbiodiniaceae* have demonstrated enhanced growth rates with FeDFO treatment.[2] However, the controlled release of metal complexes in marine ecosystems is challenging, as they disperse rapidly and may be assimilated by competing organisms. Therefore, controlled release systems for well-defined chemical species of Fe are required.[4,5] In this study, we developed alginate (Alg)-based beads crosslinked with Ca^{2+} as a controlled release system for Fe, FeHis, and FeDFO to assess their impact on the growth of *F. kawagutii* (strain BMAK 214) under thermal stress. The lyophilized beads were characterized using FTIR-ATR, TGA, CNH, and ICP-OES. The leaching of the beads in seawater was followed by GF-AAS over 24 hours. *F. kawagutii* inocula were seeded in Guillard F/2 culture medium and maintained at 20°C under 80 µE m^{-2} s^{-1} illumination with a 12:12 hour photoperiod. Alg-based beads (0.37 mg mL^{-1}) were added for treatments; inoculation involved 10^4 cells mL^{-1} from a mother culture in borosilicate tubes with Guillard F/2 without added Fe. Incubation occurred at 25°C and 30°C under the same light conditions. Regular Guillard F/2 (with free iron) served as the biological control, while AlgCa was used as a supplementation control. Cell densities were monitored on days 1, 2, 3, 7, 15, and 22 using a hemocytometer, and growth rates were evaluated during the exponential growth phase. At 25°C, total algal yield indicated equivalence among all treatments and regular F/2 (98.0±0.6%), demonstrating Fe-release, with AlgFe (97,5±0.6%), and AlgFeHis (97.8±0.7%) marginally standing out. At 30°C, however, AlgFeHis (96.2±2.1%) and AlgFeDFO (96.2±0,6%), but not AlgFe(90.5±2.1%) proved sufficient to mitigate the impacts of iron depletion in the medium (94.4±1.6%), as evidenced by total algal yield. Thus, alginate-based beads loaded with Fe, FeHis, or FeDFO improved total yield even under iron-depleted conditions, and the nature of the iron source in the bead was relevant for the temperature dependence of its efficiency. AlgFeHis proved relevant at both temperatures. Aiding growth even at 30°C, an unfavorable condition.

Acknowledgments: CNPq and FAPESP (financial support)

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