Change in element composition of microalgal cells under iron-deficient conditions: basic study on homeostasis of element utilization

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Abstract

In microalgae iron plays very important roles in the regulation of cellular metabolism as an essential element. It is already known that Fe-deficiency suppresses the growth of cells and reduces chlorophyll contents in photosynthetic organisms. This effect is mainly due to the inactivation of photosynthetic and respiratory electron transport chains since Fe is a cofactor of cytochromes. Under such Fe-deficient conditions it is also known that microalgae induce ferric reductase on the plasma membrane to reduce Fe^{3+} to Fe^{2+} for the supply of usable form of iron to be absorbed by cells. Thus, Fe-deficiency induces various physiological effects. In this study we focused on studying how elemental composition of cells is affected by Fe-deficiency in order to know whether some homeostatic mechanism functions to rescue the cells from severe damage, or not. For this purpose multi-element analysis using a bio-particle-induced X-ray Emission (Bio-PIXE) analysis is a desirable method. Unicellular green alga Chlamydomonas reinhardtii, a model organism for photosynthesis research, was selected as a material. Cellular content and composition of various elements was determined by Bio-PIXE after growing cells under Fe-sufficient and –deficient conditions in the medium of HSM containing or not-containing 0.105 mM $FeSO_4$, respectively. The content of Mn was strongly decreased because of the stimulating of the release of Mn into the medium under Fe-deficient conditions, while that of other elements such as P, Mg, Ca, Zn and K was only slightly reduced and S was decreased by 50% finally. The decrease in the intracellular concentration of Fe and Mn was quickly initiated after the transfer of cells to Fe-deficient conditions but the decrease in chlorophyll content and the suppression of cell growth appeared later than that of Fe and Mn contents. The decrease in both Fe and Mn is expected to inhibit strongly the generation of electron by the water splitting enzyme and its subsequent transport in the photosystems. The results suggest that a close relationship between Fe and Mn in this photosynthetic organism and some rescue system may function to delay the negative effect of Fe-limitation that triggers severe damage of cells.