Development of novel silica hydrogels for the encapsulation of photosynthetic microalgae

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In microalgae research slow cell growth, costly downstream processing and low benefits have so far hindered the implementation of production processes[1]. Studies have shown that immobilisation in hydrogels can support algal growth and allow continuous production of extracellular compounds[2]. Compared to the conventional calcium alginate silica hydrogels are advantageous due to their improved transparency and physicochemical stability in presence of cations and grazers[3].

This doctoral research within the BMBF project COMBINE aims to develop novel silica hydrogels for microalgae encapsulation to achieve high growth rates and biomass loading. Previous results showed that photoautotrophic growth of the marine diatom *P. tricornutum* and green freshwater microalga *C. reinhardtii* in sodium silica hydrogels was reduced by approximately 55% and 30%, respectively, compared to conventional calcium alginate. A novel indicator-based method for the determination of dissolved CO_2 diffusion into hydrogels revealed that the CO_2 diffusion rate in silica hydrogels is reduced by approximately 60% compared to calcium alginate, indicating a CO_2 limitation, which contributes to the weak photoautotrophic growth of the silica-encapsulated microalgae. Reduction of silica concentration and particle volume increased cell growth and CO_2 diffusion rates, which further indicates a diffusion limitation. Additionally, transparency analyses show that although fresh sodium silica hydrogels are more transparent than calcium alginate hydrogels, the initial transparency decreases during incubation in water, probably as a result of gel densification. The resulting light and space limitations present another problem for photoautotrophic cell growth.

To overcome these diffusion, light and space limitations, novel hydrogels from various functional silica precursors were investigated. Charged functional groups were observed to increase the CO_2 diffusion, prevent the reduction of transparency and gel densification over time and result in a soft yet stable gel consistency. The dissolved CO_2 diffusion rate in these modified silica gels was increased up to 2-fold compared to the sodium silica control. The maximum OD_{750} value of encapsulated *C. reinhardtii* grown photoautotrophically with 5% CO_2 supply in the novel hydrogels was increased up to 2.3-fold while the photosynthetic yield was stabilised. However, the maximum increase in OD_{750} for *P. tricornutum* was only 10%, hinting towards additional factors limiting the growth of this marine species such as generally low growth rates, lack of CO_2 in saltwater, the absence of carbonic anhydrases, nutrient deficiencies, a fragile cell shape or an unsuitable cultivation system.

We will present our recent findings together with further investigations towards the growth of other microalgae species in the novel silica hydrogels as well as strategies to improve the diatom growth. We will also show structural hydrogel analyses and an adapted cultivation system to overcome current limitations and shed more light into immobilisation materials facilitating the profitable production of high-value extracellular algal products.

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