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Improvement of Greenhouse Gases Bio-Fixation by Microalgae Using a "Plasmon-Enhanced Photobioreactor"

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Abstract : Light is a growth-limiting factor in microalgae cultivation, where factors like spectral components, intensity, and duration, often characterized by its wavelength, are well-reported to have a substantial impact on cell growth rates and, consequently, photosynthetic performance and mitigation of CO2, one of the most significant greenhouse gases (GHGs). Photobioreactors (PBRs) are commonly used to grow microalgae under controlled conditions, but they often fail to provide an even light distribution to the cultures. For this reason, there is a pressing need for innovations aiming at enhancing the efficient utilization of light. So, one potential approach to address this issue is by implementing plasmonic films, such as the localized surface plasmon resonance (LSPR). LSPR is an optical phenomenon connected to the interaction of light with metallic nanostructures. LSPR excitation is characterized by the oscillation of unbound conduction electrons of the nanoparticles coupled with the electromagnetic field from incident light. As a result of this excitation, highly energetic electrons and a strong electromagnetic field are generated. These effects lead to an amplification of light scattering, absorption, and extinction of specific wavelengths, contingent on the nature of the employed nanoparticle. Thus, microalgae might benefit from this biotechnology as it enables the selective filtration of inhibitory wavelengths and harnesses the electromagnetic fields produced, which could lead to enhancements in both biomass and metabolite productivity. This study aimed at implementing and evaluating a "plasmon-enhanced PBR". The goal was to utilize LSPR thin films to enhance the growth and CO2 bio-fixation rate of Chlorella vulgaris. The internal/external walls of the PBRs were coated with a TiO2 matrix containing different nanoparticles (Au, Ag, and Au-Ag) in order to evaluate the impact of this approach on microalgae's performance. Plasmonic films with distinct compositions resulted in different Chlorella vulgaris growth, ranging from 4.85 to 6.13 g.L-1. The highest cell concentrations were obtained with the metallic Ag films, demonstrating a 14% increase compared to the control condition. Moreover, it appeared to be no differences in growth between PBRs with inner and outer wall coatings. In terms of CO2 bio-fixation, distinct rates were obtained depending on the coating applied, ranging from 0.42 to 0.53 gCO2L-1d-1. Ag coating was demonstrated to be the most effective condition for carbon fixation by C. vulgaris. The impact of LSPR films on the biochemical characteristics of biomass (e.g., proteins, lipids, pigments) was analysed as well. Interestingly, Au coating yielded the most significant enhancements in protein content and total pigments, with increments of 15 % and 173 %, respectively, when compared to the PBR without any coating (control condition). Overall, the incorporation of plasmonic films in PBRs seems to have the potential to improve the performance and efficiency of microalgae cultivation, thereby representing an interesting approach to increase both biomass production and GHGs bio-mitigation.

Keywords : CO_2 bio-fixation, plasmonic effect, photobioreactor, photosynthetic microalgae
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