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A Diurnal Light Based CO_2 Elevation Strategy for Up-Scaling Chlorella sp. Production by Minimizing Oxygen Accumulation

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Abstract : Achieving high cell densities of microalgae under obligatory light-limiting and high light conditions of diurnal (low-high-low variations of daylight intensity) sunlight are further limited by CO_2 supply and dissolved oxygen (DO) accumulation in large-scale photobioreactors. High DO levels cause low growth due to photoinhibition and/or photorespiration. Hence, scalable elevated CO_2 levels (% in air) and their effect on DO accumulation in a 10 L cylindrical membrane photobioreactor (a vertical tubular type) are studied in the present study. The CO_2 elevation strategies; biomass-based, pH control based (types II & I) and diurnal light based, were explored to study the growth of Chlorella sp. FC2 IITG under single-sided LED lighting in the laboratory, mimicking diurnal sunlight. All the experiments were conducted in fed-batch mode by maintaining N and P sources at least 50% of initial concentrations of the optimized BG-11 medium. It was observed that biomass-based (2% - 1st day, 2.5% - 2nd day and 3% - thereafter) and well-known pH control based, type-I (5.8 pH throughout) strategies were found lethal for FC2 growth. In both strategies, the highest peak DO accumulation of 150% air saturation was resulted due to high photosynthetic activity caused by higher CO_2 levels. In the pH control based type-I strategy, automatically resulted CO_2 levels for pH control were recorded so high (beyond the inhibition range, 5%). However, pH control based type-II strategy (5.8 – 2 days, 6.3 – 3 days, 6.7 – thereafter) showed final biomass titer up to 4.45 ± 0.05 g L^{-1} with peak DO of 122% air saturation; high CO_2 levels beyond 5% (in air) were recorded thereafter. Thus, it became sustainable for obtaining high biomass. Finally, a diurnal light based (2% - low light, 2.5 % - medium light and 3% - high light) strategy was applied on the basis of increasing/decreasing photosynthesis due to increase/decrease in diurnal light intensity. It has resulted in maximum final biomass titer of 5.33 ± 0.12 g L^{-1}, with total biomass productivity of 0.59 ± 0.01 g L^{-1} day^{-1}. The values are remarkably higher than constant 2% CO_2 level (final biomass titer: 4.26 ± 0.09 g L^{-1}; biomass productivity: 0.27 ± 0.005 g L^{-1} day^{-1}). However, 135% air saturation of peak DO was observed. Thus, the diurnal light based elevation should be further improved by using CO_2 enriched N_2 instead of air. To the best of knowledge, the light-based CO_2 elevation strategy is not reported elsewhere.

Keywords : Chlorella sp., CO_2 elevation strategy, dissolved oxygen accumulation, diurnal light based CO_2 elevation, high cell density, microalgae, scale-up
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