Poster Title

‘Co-optimization of Growth Parameters in Glycerol-mediated Mixotrophic Cultivation of Microalgae in Bubble Column Photobioreactors: quantifying the synergy between autotrophy and heterotrophy’ by Sreyashi Ghosh, & Saikat Chakraborty*, *Department of Chemical Engineering, Indian Institute of Technology Kharagpur, India.* (*corresponding author)

Abstract

Microalga is a primary source for third generation biofuels due to its high photosynthetic ability, which can be exploited to produce bioethanol, biodiesel, biohydrogen, as well as value-added co-products such as proteins, carbohydrate, vitamin, omega fats, carotenoids etc. Using glycerol (a primary by-product of biodiesel industry) for mixotrophic algal cultivation can improve the economic and environmental sustainability of the biodiesel industry.

Chlorella sorokiniana is cultured mixotrophically in modified TAP media using glycerol as the sole organic carbon source and atmospheric CO₂ as the inorganic carbon source in a 1 L bubble column PBR with photoperiod of 18h :6h (Light:Dark). This study shows how the co-optimization of reactor scale parameters augments biomass yield at the cellular level by enhancing the synergy between autotrophic and heterotrophic pathways in the molecular level. A heterotrophic parameter (initial glycerol loading) and an autotrophic parameter (reactor illumination) are employed to engineer the mixotrophic algal cultivation process. The operating range of reactor illumination and initial glycerol loading are 3500-14000 Lux and 0.6-2.2 mL/L, respectively.

As the reactor illumination is increased from 3500 Lux (extremely light-limited) through 7500 Lux (moderately light-limited) to 10500 Lux (light-saturated), the glycerol uptake by the alga increases from 0.6 mL/L through 1mL/L to 1.4 mL/L, with a corresponding increase in algal biomass yield from 0.58 g/L through 1.02 g/L to 1.4 g/L, respectively. However, further increase of light intensity to 14000 lux (photo-inhibited regime) reduces the biomass yield to 1.2 g/L by affecting the glycerol uptake mechanism and damaging the photosynthetic receptors due to the formation of Reactive oxygen species. Since the metabolic pathways for autotrophy and heterotrophy are interconnected, the optimization of light intensity requires co-optimization of the organic carbon input. At the light-sufficient condition of 10500 Lux, the organic carbon input for heterotrophic uptake operates – as in the case of light input for autotrophic growth – in three different regimes, namely: substrate-limited regime (<1.2mL/L), substrate-sufficient regime (1.2-1.6 mL/L), and substrate inhibited regime (>1.8 mL/L), which produce algal biomass yields of 1.1 g/L, 1.4 g/L, 0.6 g/L, respectively.

Increasing the reactor illumination (below photo-inhibition) results in increased electron flux in the autotrophic and the photo-heterotrophic pathways, which, in turn, increases the metabolic flux in chemo-heterotrophic pathway and augments biomass, ATP and macromolecular yields. When atmospheric CO₂ (0.04%) is provided as inorganic carbon source, it enters into the cells via the energy-intensive Carbon Concentrating Mechanism (CCM) as CO₂ is transported against concentration gradient. Therefore, synergized heterotrophic pathway supports the CCM mechanism by supplying extra energy to the photosynthetic pathway, thus enhancing not only the chemo-heterotrophic growth but also the phototrophic synthesis.

We quantify this synergy between autotrophy and heterotrophy by plotting the autotrophic parameter (reactor illumination) against the heterotrophic parameter (optimum glycerol loading) in Figure 1. We show that a Michaelis-Menten type empirical equation quantifies the synergy between autotrophy and heterotrophy in mixotrophic algal cultivation ($R^2=0.98$), wherein the heterotrophic parameter increases monotonically with the autotrophic parameter but saturates on attaining photo-inhibition.

Figure

Figure 1: Michaelis-Menten type equation quantifies the synergy between optimum glycerol loading (heterotrophic parameter) and reactor illumination (autotrophic) [Reactor operating conditions: atmospheric CO₂ concentration (0.04%), 0.5 LPM air flowrate, 18h:6h(Light:Dark) Photoperiod, 1L bubble column PBR; $R^2=0.98$]