Light attenuation in photobioreactors and algal pigmentation under different growth conditions – Model identification and complexity assessment

Microalgae are photosynthetic organisms, and thus one of the most important factors affecting their growth is light. Yet, effective design and operation of algal cultivation systems still lacks robust numerical tools. Here, a comprehensive and mathematically consistent simulation model is presented in the ASM-A framework that can accurately predict light availability and its impact on microalgae growth in photobioreactors (PBR). Three cylindrical column reactors, mimicking typical open pond reactors, with different diameters were used to conduct experiments where the light distribution was monitored inside the reactor. A batch experiment was conducted where the effect of nutrients and light availability on the pigmentation of the microalgae and light distribution was monitored. The effect of reactor size and cultivation conditions on the light distribution in PBRs was evaluated. Moreover, we assessed the effect of using different simulation model structures on the model prediction accuracy and uncertainty propagation. Results obtained show that light scattering can have a significant effect on light distribution in reactors with narrow diameter (typical to panel-type PBRs) and under cultivation conditions that promote low pigmentation or low biomass concentration. The light attenuation coefficient was estimated using the Lambert-Beer equation and it was compared to Schuster's law. The light attenuation was found to be dependent on biomass concentration and microalgae pigmentation. Using a discretized layer model to describe the light distribution in PBRs resulted in the most accurate prediction of microalgal growth and lowest uncertainty on model predictions. Due to model complexity a trade-off needs to be made between accuracy of the prediction and simulation time.

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