The Effect Of Light On Mixed Green Micro-Algal Growth: Experimental Assessment And Modelling

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Micro-algal growth in photobioreactors (PhBRs) is highly dependent on the availability of light that is an essential component in the photosynthetic synthesis of carbohydrates. Light is heterogeneously distributed inside the PhBRs which makes mathematical model prediction and reactor design optimization more challenging for photosynthetic systems. The rate of photosynthesis will increase with increasing light intensities until a saturation level is reached (Richmond, 2004). Increasing the light intensity above the saturation level might potentially lead to photoinhibition. Dense cultures can result in self-shading, limiting algal growth. Therefore, light distribution in the algae cultures is a crucial factor to be accounted for in PhBR design and optimization.

The attenuation of light through a cultivation system can be described by the Lambert-Beer equation, predicting an exponential decline in the light intensity over the culture depth. Different equations have been proposed to describe the effect of available light on algae growth rate within the culture: Steele equation, Platt and Jasby equation, Poetters and Eilers equation, Smith’s function, Poisson single-light model and Monod type equation (Bouterfas et al., 2002; Ambrose et al., 2006; Stijlbrak et al., 2012).

Objectives:

i) to assess the light distribution in PhBRs with different reactor geometry, biomass concentration and biomass pigmentation

ii) to assess the light limitation on algae growth in microbatch experiments and

iii) to assess the different mathematical expressions that have been proposed to describe the effect of available light on algae growth rate within the culture.

Assessment of the light distribution in PhBRs

Table 1: Different mathematical expressions assessed in the study

<table>
<thead>
<tr>
<th>Expression</th>
<th>Description</th>
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<tbody>
<tr>
<td>Normal type equation</td>
<td>$a = a_0$ if light intensity is limited</td>
</tr>
<tr>
<td>Steele equation</td>
<td>$a = a_0 + a_1\exp(-a_2K_a)$</td>
</tr>
<tr>
<td>Platt and Jasby equation</td>
<td>$a = a_0 + a_1\exp(-a_2K_a)$</td>
</tr>
<tr>
<td>Poetters and Eilers equation</td>
<td>$a = a_0 + a_1\exp(-a_2K_a)$</td>
</tr>
<tr>
<td>Smith’s function</td>
<td>$a = a_0 + a_1\exp(-a_2K_a)$</td>
</tr>
<tr>
<td>Poisson single-light model</td>
<td>$a = a_0 + a_1\exp(-a_2K_a)$</td>
</tr>
</tbody>
</table>

Light distribution in PhBR

Figure 4 suggests that there is an impact of the change in biomass concentration on the attenuation coefficient ($K_a$). No clear relation between the reactor diameter and $K_a$ was found. Moreover, no impact of the airflow or the bubble size was found on the $K_a$ results shown in Wagner et al. (2014).

There is a clear impact of substrate availability and growth conditions of the micro-algae on the pigmentation and the $K_a$ as shown in Figure 5.

Effect of TSS with different reactor diameters

Results obtained in micro-batch experiments

The effect of light on the specific growth rate of micro-algae assessed in microbatch experiments

The Steele equation accounts for the attenuation of light at high light intensities, however the measurement data is not conclusive in this region.

The attenuation coefficients estimated for each of the measurements can be found in Wagner et al. (2014). The relation between $k_{ss}$ and $TSS$ was obtained under both nutrient limited and nutrients in excess cultivating conditions and the relation is presented in Wagner et al. (2014).

The light intensity was estimated in the reactors using the two different relations obtained for $k_a$. As shown in Figure 6 and Figure 7 both the $k_a$ estimated in nutrient limited conditions results in an overestimation of the measurement data. The $k_a$ estimated with optimal nutrient conditions gives a considerably better fit.

The effect of light on the growth of the micro-algal community can be best described by the Steele equation.

5. SIMULATIONS

The attenuation coefficient ($K_a$) is estimated by the Steele equation and the attenuation coefficient was calibrated.

It was found that the $K_a$ is affected by the biomass concentration.

The reactor diameter, aeration and bubble size does not have an effect on the $K_a$.

Simulations results obtained suggest that the culturing conditions can have a significant impact on the model calibration. If was found that parameters obtained under nutrient limited conditions that might be linked to pigmentation result in a poor simulation results. It was suggested thus to calibrate the model under environmentally representative conditions.

References:


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1. INTRODUCTION

2. METHODS

3. RESULTS I

4. RESULTS II

5. CONCLUSIONS

6. CONCLUSIONS