Light distribution model and lumostatic operation of a photobioreactor

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In the field of bioprocess engineering, the supplying method and distribution of light energy has not been rigorously investigated despite the importance of light energy in the growth of photosynthetic microorganisms. Light energy is readily absorbed, and cannot be stored in the photobioreactor. The amount of light energy can also affect the microalgal cell growth and productivity. Any light energy not absorbed or not used for photosynthesis will be wasted into thermal energy[1]. This study focuses on the development of a mathematical model for light distribution inside a photobioreactor. Particular attention was also paid to the construction of a new internally radiating photobioreactor and its lumostatic operation method.

A mathematical model of light distribution is proposed for internally radiating photobioreactors by applying the concept of parallel translation[2]. To test the feasibility of the proposed model, a new type of internally radiating photobioreactor was constructed. This novel photobioreactor combines the advantages of an air-lift bioreactor and an internally radiating system[3]. For a model photosynthetic microorganism, *Synechococcus* sp. PCC 6301 was cultivated in an internally radiating air-lift photobioreactor.

Three model parameters (ε_m, K_X, and K_r) were determined from separate experiments in order to investigate the light attenuation phenomena in a photobioreactor caused by high cell density and long light path-length. The light condition inside the photobioreactor was characterized by the light distribution profile and the average light intensity, which were calculated from the light distribution model. And the effects of cell density, the number of radiators, and radiator positions were investigated through photograph analysis and model simulation studies. The predicted light intensity values were found to be very close to actual light intensities measured from the experiment. This suggests that the proposed model can accurately interpret the light conditions inside the photobioreactor system. Due to the robustness of the light distribution model, it was possible to apply the model to other photobioreactors, including optical-fiber photobioreactors and pond-type photobioreactors.

Furthermore, the proposed model, which was originally developed for an internally radiating photobioreactor, was expanded to an externally radiating photobioreactor with appropriate modification of the model equations. Light attenuation phenomena in externally radiating photobioreactors were expressed by using three model parameters, and these empirical parameters were evaluated by following the same procedure for internal radiators. The efficiency of internally and/or externally radiating methods was investigated based on both average light intensity and light distribution profiles. What the present study makes clear is that the quantitative analysis of internally and/or externally radiating methods can be made on the same mathematical background.

The lumostatic approach was also investigated to develop an efficient way of supplying light energy into the photobioreactor during cell cultivation. Since excessive light energy induced photoinhibition at the early growth stage, the strategy of lumostatic operation was developed in order to maintain the light condition at an appropriate level during cell cultivation. Based on the calculation results of the light distribution model, the average light intensity was regulated at 30, 60, or 90 μmol m^{-2} s^{-1} by increasing the number of light radiators. The model-based control of irradiating level enabled us to harvest a larger amount of cells without showing the photoinhibited growth. Other favorable results included the reduction of cultivation time and lower consumption of irradiating power.

The model-based study in this work is a preliminary work on optimizing the light transfer efficiency for efficient photobioreactor design. And this model-based study will offer helpful tools to bioengineers for optimal design and efficient operating method of a photobioreactor. It is expected that the proposed model can play an important role in comparative and quantitative study of light supplying methods in various photobioreactor designs.

<u>*References*</u>

[1] Prokop A, Erickson LE. 1995. Photobioreactors. *In*: Asenjo JA, Merchuk, JC, editors. *Bioreactor System Design*. New York : Marcel Dekker. p. 441–477.

[2] Suh IS, Lee SB. A light distribution model for an internally radiating photobioreactor. *Biotechnol Bioeng* (submitted).

[3] Suh IS, Lee SB. 2001. Cultivation of cyanobacterium in an internally radiating air-lift photobioreactor. *J Appl Phycol* **13**: 381-388.