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DOE Grant #: DE-FG22-93PC93212

BIOLOGICAL DETERMINANTS OF PHOTOBIOREACTOR DESIGN

3rd Quarterly Report: Period - March 1, 1994 - May 31, 1994

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Abstract:

Proper mixing is very important for achieving high concentration photosynthetic cultures. Good mixing can keep the cells in suspension, eliminate thermal stratification, help nutrient distribution, and improve gas exchange. We have tested various configurations of photobioreactors and found a PBR with a vertical rectangular slab-shaped illumination chamber to be the best. This shape meets all the criteria of a successful photobioreactor and could support *Chlorella vulgaris* up to 10^8 cells/mL.

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EFFECTS OF MIXING ON MICROALGAL PRODUCTION

Introduction

Good fluid mixing is important for achieving high cell concentration in a PBR. Good mixing can keep the cells in suspension, eliminate thermal stratification, help nutrient distribution, and improve gas exchange. Since the algae cells are so efficient in absorbing the light, only the top layer of the cell will see the light and go through the photosynthesis once cells are settled down. Furthermore, mixing can reduce the degree of mutual shading and lower the probability of photoinhibition. The last reason is perhaps the most important one for requiring the right extent of mixing to achieve a successful PBR. Proper mixing will significantly reduce the mutual shading and thus increase the portion of the cells exposed to the light. This mixing will also move the cells close to the illuminated surface into the center of the PBR, which will give these photon-saturated cells the opportunity to use up all the absorbed light energy for photosynthesis before they are exposed to the light again. This mixing, in turn, will also provide the same opportunity to the cells in the center (that have already used up the absorbed photons) to "see" the light. As a result, proper mixing may significantly improve overall light utilization efficiency.

Materials and Methods

Several different types of prototype photobioreactors were designed and tested with different recycling rate to see the effect of mixing and transit time on microalgal production.

Conical shape photobioreactor, PBRc (Figure 1)

Cylindrical shape photobioreactor with magnetic stirrer, PBRs (Figure 2)

Rectangular slab shape photobioreactor with external gas exchanger, PBRe (Figure 3)

	Volume	Flow rates
PBRc	10 mL	40 - 150 mL/min
PBRs	14.5 mL	0 - 80 mL/min
PBRe	66 mL	66 - 1000 mL/min

Results and Discussion

For the first generation prototypes (PBRc), no matter what the flow rate was, the cells settled on the bottom of the reactor. The cell concentration curves were non-smooth due

to the settling of the cells inside the reactor. Further, the cell concentration 2 days after the inoculation was always lower than the inoculum concentration. However, a sample withdrawn after vigorous shaking of the PBR gave a higher cell concentration than the inocula. This became clear when we opened the reactor as we could see the cells settled on the surface at the bottom. This happened over a wide range of recirculation rate (40-150 mL/min in 40 mL working volume reactor).

To achieve better mixing, we introduced a magnetic stirrer into the PBR (PBRs). Nonetheless, similar results with PBRc were obtained

This implied that more efficient mixing is definitely required for the PBR system. Thus a PBR with a totally different geometry was designed. The inner shape of the reactor was a vertical rectangular slab. With this shape, cell settling could be prevented since the flow direction was directly against gravity, which causes cell settling. With this design, a very high flow rate damaged the cells due to the accompanying high shear stress. Around 1 vvm of recirculation was found to be enough to support high cell densities. One of the growth curves from a PBRe run is shown in Figure 4.

Conclusion

From a series of simple preliminary experiments using various configurations, a PBR with a vertical rectangular slab-shaped illumination chamber was found to be the most suitable. This shape meets all the criteria such as good light distribution, proper mixing without damaging the cells by shear stress, and minimization of wall growth. Further, this configuration made the resulting PBR less sensitive to transit times.

Figure 1. Schematic diagram of PBRc.

Figure 2. Schematic diagram of PBRs.

Figure 3. Schematic diagram of PBRe.

Figure 4. Typical growth curve in PBRe.

Schematic Diagram of the Second Photobioreactor (PBR_c)

Variation of the First Photobioreactor (PBRs)

Variation of the Third Photobioreactor (PBR_e)

Fig. 4.

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