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Influence of Carbon Dioxide Concentration on Microalgal Growth in a Bubble Column Photobioreactor

Shuwen Li[1,2,3 a], Shengjun Luo[1,b], Rongbo Guo[1,c*]

[1] Qingdao Institute of Bioenergy and Bioprocess Technology, Key Laboratory of Biofuels, Chinese Academy of Sciences, Qingdao 266101, P.R. China

[2]College of Life Sciences, Qingdao Agricultural University, Qingdao 266109;

[3] Graduate University of Chinese Academy of Sciences, Beijing 100049, P.R. China

[a]email:lisw@qibebt.ac.cn, [b]email:luosj@qibebt.ac.cn, [c*]email:guorb@qibebt.ac.cn

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Abstract. The CO_2 sequestration by microalgae is thought to be one of the most sustainable strategies to relieve global warming. To produce 1 ton of microalgal dry biomass, 2 ton of CO_2 is required. However, insufficient supply of CO_2 will limit microalgal growth, and excessive CO_2 both means wasting and inhibits microalgal growth. In the present study, the dissolved CO_2 concentration in culture limiting and inhibiting microalgal growth (*Chlorella vulgaris*) in a bubble column photobioreactor was studied. The experimental results showed that the dissolved CO_2 concentration ranging from 107μmol/L to 1500 μmol/L could meet microalgal growth's need, which provides the guidance for microalgal CO_2 biofixation with high efficiency.

Introduction

CO_2 emissions have increased from 3 metric tons in 1751 to 8230 metric tons in 2006 according to the report of carbon dioxide information analysis center [1], and the rise of CO_2 concentration in atmosphere has become a worldwide environmental and economic problem because of its leading to global warming. In order to reduce the impact of CO_2 on the change in environment, effective removal of CO_2 from point source should be paid more attention. Among all the sequestration methods of CO_2, microalgal CO_2 biofixation may be a promising alternative as microalgae have a higher CO_2 fixation ability and produce biodiesel and bio-products through their biomass [2-4]. The bubble column photobioreactor is low-cost, easy to operate, good mixing with low energy consumption; it has high potentials for scalability, and reduces photo-inhibition and photo-oxidation for degassing. The effects of CO_2 concentration on microalgal growth in various designs and scales of bubble column photobioreactors have been examined [5-10]. Their experimental results simply showed the influence of supplied CO_2 concentration on microalgal growth, but the effect of dissolved carbon dioxide in culture on microalgal growth did not be investigated. Microalgae can tolerate CO_2 only up to a certain level, above which it becomes detrimental for the growth of cells, and CO_2 should not drop below the minimum concentration that limits microalgal growth [11, 12]. In the present study, the inhibition and limitation concentrations of dissolved CO_2 in culture for strain *Chlorella vulgaris* were investigated, which provides the reference for CO_2 sequestration by microalgal cultivation with high efficicency.

Materials and Methods

Bubble Column Photobioreactor. The bubble column photobioreactor was a cylindrical vessel and was made of polymethyl methacrylate, and consisted of a 100 cm high vertical tube of 11 cm diameter. The bioreactor had a culture volume of 8 L, and the enriched CO_2 gas was injected into the column using a porous stone at the bottom of the column. The cool white fluorescent lights placed to one side of the reactor. The culture temperature was controlled by air conditioning. pH and dissolved oxygen probes were installed in photobioreactor and connected to a data acquisition system for on-line record of measurement.

Microalgal Cultivation. Strain *Chlorella vulgaris* was obtained from College of Marine Life Sciences, Ocean University of China. Algal cells were cultivated in the following medium(per liter), containing 1000 mg KNO_3, 237 mg KH_2PO_4, 88 mg $CaCl_2 \cdot 2H_2O$, 40 mg EDTA, 30 mg $FeSO_4 \cdot 7H_2O$, 204 mg $MgSO_4 \cdot 7H_2O$, and 1 mL of trace metal solution. The trace metal solution (per liter) includes 0.83 g H_3BO_3, 0.17 g $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$, 0.51 g $CoCl_2 \cdot 6H_2O$, 3.3 g $MnCl_2 \cdot 4H_2O$, 0.95 g $CuSO_4 \cdot 5H_2O$, 2.7 g $ZnSO_4 \cdot 7H_2O$. Culture was aerated continuously with 2% or 8% CO_2 (nitrogen balance) with different aeration rate, and the rate of CO_2 supply was measured using a rotor flow meter (LZB-3, Yinhuan, China). The microalgae cells were incubated at 24±1°C under the light intensity of 100 μmol/m^2s with a 24:0 h light-dark cycle, and the light intensity was determined using a light meter (Hansatech Instruments Quantitherm light meter thermometer, Norfolk, England). The culture pH values were measured using a pH meter (PB-10, Sartorius, Germany) and the concentrations of dissolved oxygen in culture were determined using a DO meter (M700, Mettler Toledo, Switzerland). The dissolved CO_2 concentration in media was determined by a carbon dioxide meter (FC-200, Shanghai su park information technology Co. Ltd., China) and was recorded every eight hours.

Calculation of Microalgal Dry Weight and Productivity. Culture suspension with a volume of 30 mL was filtered through pre-dried and pre-weighted 2μm membrane filters, after filtration the filters were rinsed with distilled water, and the filters with microalgal cells were dried at 105 °C for 12 h and reweighted, then the dry weights of microalgal cells were calculated. The biomass productivity (P, g /hL) of microalgae was calculated from the variation in biomass density (X, g/L) according to the equation $P=(X_t- X_0)/(t-t_0)$, where X_0 was the initial biomass density at time t_0 and X_t was the biomass density at any time t subsequent to t_0.

Results and Discussion

Microalgal Growth. The effect of gas flow rate and CO_2 concentration on microalgal biomass is shown in Fig.1. After cultivation for 24 h, for the gas flow rates of 40 mL/min and 120 mL/min, microalgal biomass supplied by 2% CO_2 and 8% CO_2 began to be different, especially from 32 h to 56 h. For the gas flow rate of 40 mL/min, microalgal productivity of 2% CO_2 (0.0033 g/hL) was lower than that of 8% CO_2 (0.0050 g/hL) during 56 h cultivation period, and for the aeration of 120 mL/min, microalgal productivity of 2% CO_2 (0.0061 g/hL)was higher than that of 8% CO_2(0.0047 g/hL), and for the gas flow rate of 80 mL/min, their microalgal productivity were almost equal(2%:0.0051 g/(hL);8%:0.0052 g/(hL). The reason of productivity difference may be caused by different dissolved CO_2 concentration in culture. The variation processes of dissolved CO_2 concentration in culture supplied by 2% CO_2 and 8% CO_2 were roughly same. The time course of dissolved CO_2 concentration was characterized by a sharply increasing during process start-up and decreasing in the mid-growth phase and maintaining stability in the last stages of cultivation from 32 h to 56 h. However, the dissolved CO_2 concentration in culture supplied by 2% CO_2 and 8% CO_2 was significantly different with the same aeration rate. The average dissolved CO_2 concentration in culture aerated with 2% CO_2 and 8% CO_2 from 32 h to 56 h with the gas flow rate of 40 mL/min was 78 μmol/L and 1420 μmol/L, respectively, which indicated that the low microalgal productivity of 2% CO_2 was caused by insufficient dissolved CO_2. Weissman et al. observed that CO_2 concentration in bulk liquid of at least 65 μmol/L was required for optimal productivity of some microalgae [13], which was little lower than the present experimental result. For the aeration of 120 mL/min, the average dissolved CO_2 concentration in culture aerated with 2% CO_2 and 8% CO_2 was 139 μmol/L and 1800 μmol/L, respectively, which may concluded that the low microalgal productivity of 8% CO_2 was the reason that excessive dissolved CO_2 inhibited microalgal growth. Lee et al. suggested that when the dissolved CO_2 concentration in culture was higher than 2800 μmol/L, the microalgal growth for *Chlorella pyrenoidosa* would be inhibited [14]. This inhibition concentration was significantly higher than ours. The reason may be that the inhibition concentration varies from one species to another. For the gas flow rate of 80 mL/min, the average dissolved CO_2 concentration in culture aerated with 2%

CO_2 and 8% CO_2 was 107 μmol/L and 1500 μmol/L, respectively, and their microalgal productivity was the same and higher than that in column photobioreactor aerated with 8% CO_2 and 120 mL/min of gas flow rate, which showed that the dissolved CO_2 concentration ranging from 107 μmol/L to 1500 μmol/L was enough and had no restrain on microalgal growth.

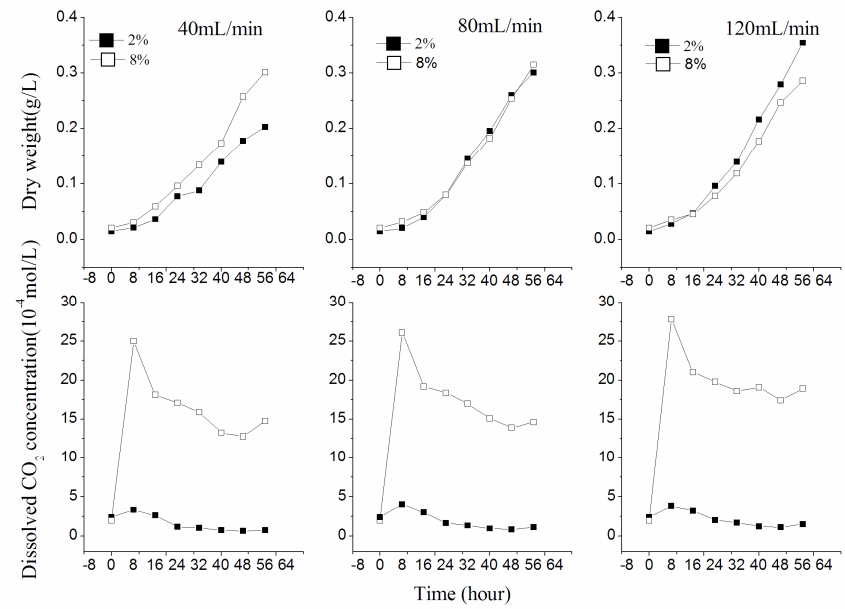

Fig.1 Microalgal biomass and dissolved CO_2 concentration in culture

pH Value and Dissolved Oxygen Concentration. Fig.2 gives pH values and dissolved oxygen concentrations of culture in bubble column photobioreactors aerated with different gas flow rates and CO_2 concentration. As shown in Fig.2, the pH value of culture aerated with 8% CO_2 was lower than that of culture aerated with 2% CO_2, which showed that much more CO_2 dissolved in culture aerated with 8%, and ranged from 6.98 to 5.29. The pH value of culture aerated with 2% CO_2 ranged between 6.16 and 7.20. The variation of pH values of culture aerated with 2% CO_2 and 8% CO_2 did not inhibit microalgal growth[15]. Oxygen generates from microalgal photosynthesis and the excessively accumulated dissolved oxygen will lead to photorespiration and photooxidation with high levels of irradiance [16, 17]. In the preasent study, the dissovled oxygen concentration of culture in bubble column photobioreactors ranged from 4.289 mg/L to 10.741 mg/L, which had no inhibition effects on microalgal growth [18].

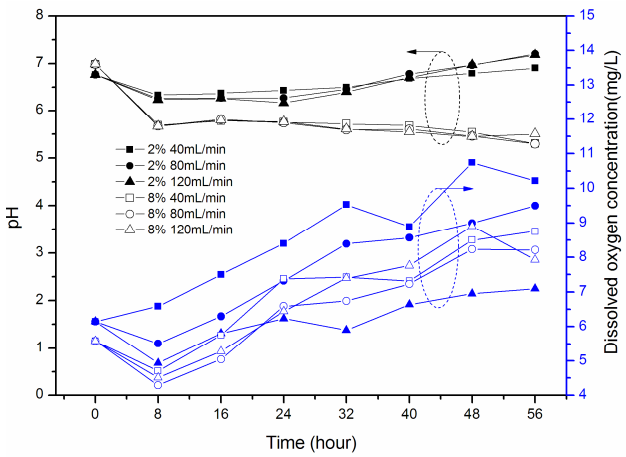

Fig. 2 pH and dissolved oxygen concentration in culture

Conclusions

The present research examined the influence of high concentration of CO_2 on microalgal growth in a bubble column photobioreactor. The range of pH values and dissolved oxygen of culture aerated with 2% CO_2 and 8% CO_2 did not inhibit microalgal growth. The difference of microalgal productivity in a bubble column photobioreactor supplied by 2% CO_2 and 8% CO_2 was caused by dissolved CO_2 concentration. In this work, the dissolved CO_2 concentration in culture between 107 μmol/L and 1500 μmol/L was fit for microalgal growth.

Acknowledgements

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References

[1] K. Kumar, C.N. Dasgupta, B. Nayak, P. Lindblad, D. Das: Bioresource technology (2011).

[2] C. Yoo, S.Y. Jun, J.Y. Lee, C.Y. Ahn, H.M. Oh: Bioresource technology (2010).

[3] T.M. Mata, A.A. Martins, N.S. Caetano: Renewable and Sustainable Energy Reviews (2010).

[4] S.W. Li, S.J. Luo, X.L. Fan, Z.M. Yang, J.S. Yin, R.B. Guo: Advanced Materials Research (2012).

[5] C.U. Ugwu, H. Aoyagi, H. Uchiyama: Bioresource technology (2008).

[6] S.Y. Chiu, C.Y. Kao, C.H. Chen, T.C. Kuan, S.C. Ong, C.S. Lin: Bioresource technology (2008).

[7] M.G. de Morais, J.A. Costa: Biotechnology letters (2007).

[8] E. Jacob-Lopes, C.H.G. Scoparo, T.T. Franco: Chemical Engineering and Processing: Process Intensification (2008).

[9] M.G. de Morais, J.A. Costa: J Biotechnol (2007).

[10] C.J. Hulatt, D.N. Thomas: Bioresource technology (2011).

[11] S. Rados, B. Vaclav, D. Frantisek: Arch Hydrobiol Suppl (1975).

[12] T.M. Sobczuk, F.G. Camacho, F.C. Rubio, F. Fernández, E.M. Grima: Biotechnology and bioengineering (2000).

[13] J.C. Weissman, R.P. Goebel, J.R. Benemann: Biotechnology and bioengineering (1988).

[14] Y.K. Lee, H.S. Tay: Journal of applied phycology (1991).

[15] G. Hodaifa, M.E. Martínez, S. Sánchez: Biotechnology and Bioprocess Engineering (2010).

[16] I. Douskova, J. Doucha, K. Livansky, J. Machat, P. Novak, D. Umysova, V. Zachleder, M. Vitova: Applied microbiology and biotechnology (2009).

[17] A.S. Miron, A.C. Gomez, F.G. Camacho, E.M. Grima, Y. Chisti: Journal of Biotechnology (1999).

[18] S. Aiba: Microbial Reactions (1982).