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MICROALGAE AND POTENTIAL APPLICATION IN SEQUENSTRATION CO_2

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ABSTRACT

In this work, an isolated strain *Chlorella* sp. was used to study its capability in sequestration of CO_2 in laboratory scale. Results indicated that the *Chlorella* sp. grew well under a wide range of CO_2 concentration from 0.04% to 15% with maximum growth was achieved under CO_2 aeration of 15%. In a single photobioreactor (PBR) with 10 min empty bed residence time (EBRT), the *Chlorella* sp. only achieved CO_2 fixation efficiency of 4.9%. Increasing number of PBRs to 15 and connected in a sequence enhancing CO_2 fixation efficiency up to 67.78% under inlet CO_2 concentration of 15%. Moreover, the CO_2 fixation efficiency was stable in the range of 69.67 to 78.34% in the 10 following days of cultivation. The obtained data demonstrated that the *Chlorella* sp. strain is a promising microalgae for further research on CO_2 mitigation via CO_2 sequestration from flue gas.

Keywords: Carbon dioxide, *Chlorella* sp., Photobioreactors, Sequestration.

1. INTRODUCTION

Global warming caused by accumulation of billion tons of CO_2 in the atmosphere. Hence, the reduction of emissions of CO_2 is an urgently demand. Numerous technologies such as chemical adsorption, chemical absorption and storage have been applied for the purpose of treatment of CO_2 mainly discharging from industrial plants [1]. However, most of the developed technologies are costly and unsustainable. Biological method of capture CO_2 using microalgae have been considering as a promising technology [2]. Microalgae mostly grow via photosynthesis by consuming CO_2 and using solar energy at a rate of ten times greater than terrestrial plants with higher daily growth rate. Capturing CO_2 by microalgae can be simultaneously integrated with wastewater treatment for nutrient removal while producing high-added value biomass which is promising feedstock for energy-related and bioproducts-related industries [3].

Various factors must be considered to successfully apply CO_2 sequestration using microalgae in industrial plants. The most important factor is the microalgal strain, which is need to be screened to find an excellent one based on main criteria such as highly adaptable to high concentration of CO_2, high growth, highly resistance to toxics (SO_x, NO_x, micro and nano dust), nutrient composition, light, pH, as well as reactor type [4].

In this work, a newly isolated *Chlorella* sp. strain was used to test its capability in growing and fixation efficiency of CO_2 under a range of CO_2 concentration of 0.04 to 20% in a single photobioreactor. Moreover, a sequence of fifteen photobioreactors was also constructed to evaluate stable growth and efficiency of CO_2 removal of the algal from mixture of air and industrial CO_2.

2. METHODS

2.1. Strains and media

Chlorella sp. used in this study was obtained from microalga collection of Department of Applied Analysis, Institute of Chemistry, Vietnam Academy of Science and Technology, Vietnam. The strain was isolated from wastewater of a Cam Pha's coal-fired power plant in Quang Ninh

province, Vietnam. The strain was maintained on algal containing BG-11 medium [5] under continuous light intensity of 60 µmol/m^2·s at 25 ^oC. The seed *Chlorella* sp. culture was made by transferring solid algal on agar plate into 100 mL flask containing 50 mL sterilized BG-11 medium (5-7 days), then further growth in in 250 mL flaks containing 150 mL BG-11 medium under shaking rate of 150 rpm, continuous light intensity 60 µmol/m^2·s at 25 ^oC for several days to reach optical density (OD) of 0.5 for CO_2 sequestration experiments.

2.2. Experiments of fixation of CO_2 under different CO_2 concentrations in single and a sequence of fifteen photobioreactors

All experiments were performed under irradiation of LED system (light intensity of 60 µmol/m^2·s) at 27-28 ^oC. Duran glass bottles (D × H = 182 mm × 330 mm, 5 L**)** containing 4L BG-11 were used as photobioreactors (PBRs) which were inoculated with 150 mL of *Chlorella* sp.'s seed culture.

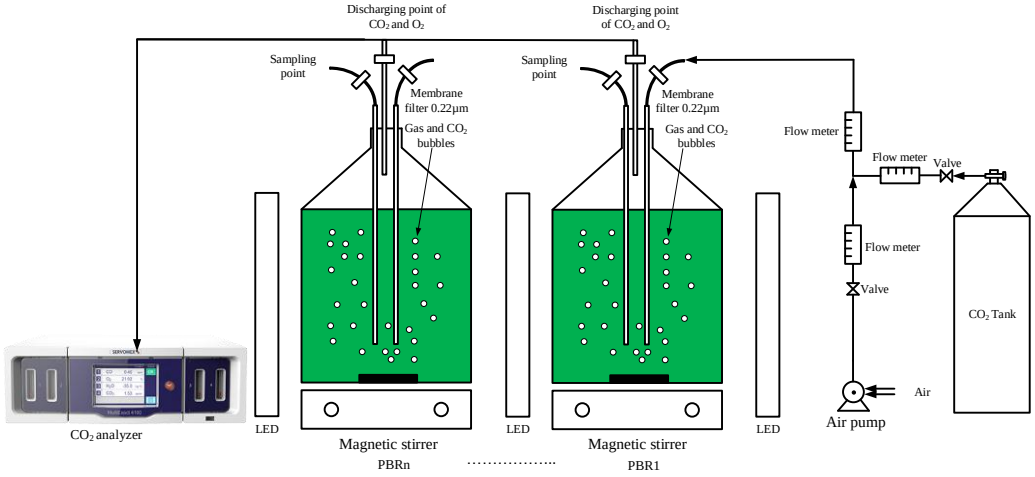

Fig. 1. Schematic diagram of CO_2 sequestration using Chlorella sp. in a serial of photobioreactors (PBRs).The bioreactors were connected with industrial CO_2 tank (99,99% CO_2) and air pump via a long stainless steel pipe (450 mm × ϕ3 mm) to the bottom for gas bubbling in.

Carbon dioxide and air flow was controlled by flow meters to yield different concentration of CO_2 aerating the PBRs. Exactly 400 mL/min of different CO_2 was continuously aerated into the inlet of the PBR and flow out into an infrared online CO_2 analyzer (SERVOMEX4100, UK) to monitor CO_2 concentration for measurement of CO_2 sequestration efficiency (Fig. 1).

2.3. Analysis of algal growth and CO_2 fixation efficiency

Biomass growth (g/L) was determined every day by gravimetric method after drying sample under in a thermal oven at 105 ^oC for 24 h. The concentration of CO_2 was monitored at inlet and outlet of the PBRs, which was then used to calculated CO_2 removal efficiency according to the following equation.

$$E_{CO_2} = \left(1 - \frac{CO_{2outlet}}{CO_{2inlet}}\right) \times 100\%$$

Where CO_{2inlet} and $CO_{2outlet}$ are the CO_2 concentration measured at inlet and outlet point of the PBRs.

3. RESULTS AND DISCUSSION

3.1. Effect of CO_2 concentration aeration on the algal growth in single PBR

It is observed that *Chlorella* sp. adapted well under CO_2 concentration range of 0.04 - 20%. The increasing biomass concentration was recorded when CO_2 concentration increased from 0.04 to 15%. Particularly, maximum CO_2 concentration of 2.04±0.21 g/L was achieved at day 7^{th} when 15% CO_2 was applied. Further increased CO_2 concentration to 20% resulted in decreasing of

biomass concentration (**Fig. 2A**). Thus, it was concluded that optimal CO_2 concentration for the *Chlorella* sp. growth is 15%, which is a popular proportion of CO_2 in flue gas.

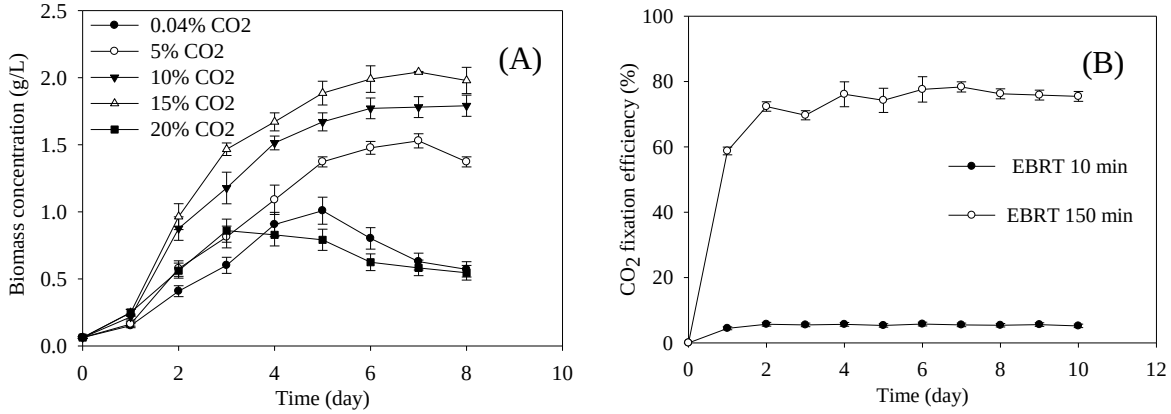

Fig. 2. Biomass concentration trend under different CO_2 concentration aeration measured in single PBR (A) and effect of empty bed residence time (EBRT) on CO_2 fixation efficiency of Chlorella sp. (B).

3.3. CO_2 fixation efficiency in single and sequential photobioreactors

The *Chlorella* sp. strain was cultured in BG-11 medium and continuously aerated with 400 mL/min (0.1 vvm) of 15% CO_2 to determine its biomass productivity and CO_2 removal capability in a single and a sequential of 15 photobioreactors. The empty bed residence time (EBRT) of single bioreactor and sequential 15 bioreactors are 10 and 150 min, respectively. Similar mixing of the culture caused by gas bubbles resulted in the same biomass productivities for each bioreactor in the multi-stage sequential bioreactor.

Maximum biomass concentrations determined for single PBR and sequential PBRs were 2.89 and 2.53 g/L on day 10, respectively, reaching the maximum growth rate of *Chlorella* sp. of 0.29 and 0.25 g/L·day, respectively (**Table 1**). The CO_2 concentration in single PBR and 15 sequential PBRs were measured at 11-13% and 4-5%, respectively, supporting excellent growth of the microalgal. The obtained data indicates that the most appropriate CO_2 concentration range for *Chlorella* sp. is about 4-13% which demonstrating wide adaptability of the microalgal in industrial CO_2 sequestration. The amount of CO_2 fixation exhibited a linearly proportional with cultivation time. The peak CO_2 fixation rate was increased from 0.56 g/day (EBRT = 10 min) to 10.15 g/day (EBRT = 150 min) (**Table 1**).

CO_2 fixation efficiency by *Chlorella* sp. cultured with an EBRT of 10 min increased from 4.45 to 6.67% within first 5 days, and then stabilized at 5.34 to 5.75% within the following 10 days, and the average CO_2 fixation efficiency was calculated as 4.9%. When cultured with 150 min in 15 sequential bioreactors, the CO_2 fixation efficiency of 58.74% was achieved within 24 h and then stabilized at 69.67 to 78.34% in the 10 following days (**Fig. 2B**).

Table 1. Biomass productivity and CO_2 fixation efficiency of Chlorella sp. in single and 15 sequential bioreactors under aeration of 15% CO_2.

EBRT (min)	Biomass concentration (g/L)	Maximum biomass growth rate (g/L·day)	Maximum CO_2 fixation rate (g/day)	CO_2 fixation efficiency (%)
10	2.89±0.12	0.29±0.03	0.56±0.09	4.9±0.38
150	2.53±0.27	0.25±0.02	10.15±1.64	66.78±5.75

4. CONCLUSION

The culture of a newly isolated microalgal *Chlorella* sp. was grown well in BG-11 medium under aeration of CO_2 5-15% and biomass production was peaked at 2.04 g/L at CO_2 concentration of 15% within 8 days of cultivation. Increasing of EBRT from 10 min to 150 min considerably

enhanced CO_2 fixation efficiency by 4.9 to 66.78%. Biomass growth rate measured in sequential PBRs system was 0.25 g/L·day, which was similar to that of single PBR (0.29 g/L·day). The *Chlorella* sp. was stably grown under CO_2 15% with CO_2 fixation efficiency of 69.67 to 78.34% in the 10 following days, demonstrating that the *Chlorella* sp. is a highly promising algal strain for application in industrial CO_2 sequestration.

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