MICROALGAE AND POTENTIAL APPLICATION
IN SEQUESTRATION CO₂

Thi Cam Van Do¹, Dang Thuan Tran²*, Quang Tung Nguyen¹

¹Faculty of Chemical Technology, Hanoi University of Industry, docamvan85@gmail.com; quangtungdhcnhn@gmail.com
²Institute of Chemistry, Vietnam Academy of Science and Technology, tdangthuan@gmail.com

ABSTRACT

In this work, an isolated strain Chlorella sp. was used to study its capability in sequestration of CO₂ in laboratory scale. Results indicated that the Chlorella sp. grew well under a wide range of CO₂ concentration from 0.04% to 15% with maximum growth was achieved under CO₂ aeration of 15%. In a single photobioreactor (PBR) with 10 min empty bed residence time (EBRT), the Chlorella sp. only achieved CO₂ fixation efficiency of 4.9%. Increasing number of PBRs to 15 and connected in a sequence enhancing CO₂ fixation efficiency up to 67.78% under inlet CO₂ concentration of 15%. Moreover, the CO₂ 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 CO₂ mitigation via CO₂ sequestration from flue gas.

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

1. INTRODUCTION

Global warming caused by accumulation of billion tons of CO₂ in the atmosphere. Hence, the reduction of emissions of CO₂ is an urgently demand. Numerous technologies such as chemical adsorption, chemical absorption and storage have been applied for the purpose of treatment of CO₂ mainly discharging from industrial plants [1]. However, most of the developed technologies are costly and unsustainable. Biological method of capture CO₂ using microalgae have been considering as a promising technology [2]. Microalgae mostly grow via photosynthesis by consuming CO₂ and using solar energy at a rate of ten times greater than terrestrial plants with higher daily growth rate. Capturing CO₂ 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 CO₂ 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 CO₂, high growth, highly resistance to toxics (SOₓ, NOₓ, 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 CO₂ under a range of CO₂ 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 CO₂ removal of the algal from mixture of air and industrial CO₂.

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 under continuous light intensity of 60 µmol/m²·s at 25 °C. 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 flasks containing 150 mL BG-11 medium under shaking rate of 150 rpm, continuous light intensity 60 µmol/m²·s at 25 °C for several days to reach optical density (OD) of 0.5 for CO₂ sequestration experiments.

2.2. Experiments of fixation of CO₂ under different CO₂ concentrations in single and a sequence of fifteen photobioreactors

All experiments were performed under irradiation of LED system (light intensity of 60 µmol/m²·s) at 27-28 °C. 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 CO₂ sequestration using Chlorella sp. in a serial of photobioreactors (PBRs).](image)

The bioreactors were connected with industrial CO₂ tank (99.99% CO₂) 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 CO₂ aerating the PBRs. Exactly 400 mL/min of different CO₂ was continuously aerated into the inlet of the PBR and flow out into an infrared online CO₂ analyzer (SERVOMEX4100, UK) to monitor CO₂ concentration for measurement of CO₂ sequestration efficiency (Fig. 1).

2.3. Analysis of algal growth and CO₂ fixation efficiency

Biomass growth (g/L) was determined every day by gravimetric method after drying sample under in a thermal oven at 105 °C for 24 h. The concentration of CO₂ was monitored at inlet and outlet of the PBRs, which was then used to calculated CO₂ removal efficiency according to the following equation.

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

Where CO₂inlet and CO₂outlet are the CO₂ concentration measured at inlet and outlet point of the PBRs.

3. RESULTS AND DISCUSSION

3.1. Effect of CO₂ concentration aeration on the algal growth in single PBR

It is observed that Chlorella sp. adapted well under CO₂ concentration range of 0.04 - 20%. The increasing biomass concentration was recorded when CO₂ concentration increased from 0.04 to 15%. Particularly, maximum CO₂ concentration of 2.04±0.21 g/L was achieved at day 7th when 15% CO₂ was applied. Further increased CO₂ concentration to 20% resulted in decreasing of
biomass concentration (Fig. 2A). Thus, it was concluded that optimal CO₂ concentration for the Chlorella sp. growth is 15%, which is a popular proportion of CO₂ in flue gas.

![Graph showing biomass concentration trend under different CO₂ concentration aeration measured in single PBR (A) and effect of empty bed residence time (EBRT) on CO₂ fixation efficiency of Chlorella sp. (B).]

### 3.3. CO₂ 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% CO₂ to determine its biomass productivity and CO₂ 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 CO₂ 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 CO₂ concentration range for Chlorella sp. is about 4-13% which demonstrating wide adaptability of the microalgal in industrial CO₂ sequestration. The amount of CO₂ fixation exhibited a linearly proportional with cultivation time. The peak CO₂ fixation rate was increased from 0.56 g/day (EBRT = 10 min) to 10.15 g/day (EBRT = 150 min) (Table 1).

CO₂ 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 CO₂ fixation efficiency was calculated as 4.9%. When cultured with 150 min in 15 sequential bioreactors, the CO₂ 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 CO₂ fixation efficiency of Chlorella sp. in single and 15 sequential bioreactors under aeration of 15% CO₂.

<table>
<thead>
<tr>
<th>EBRT (min)</th>
<th>Biomass concentration (g/L)</th>
<th>Maximum biomass growth rate (g/L/day)</th>
<th>Maximum CO₂ fixation rate (g/day)</th>
<th>CO₂ fixation efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.89±0.12</td>
<td>0.29±0.03</td>
<td>0.56±0.09</td>
<td>4.9±0.38</td>
</tr>
<tr>
<td>150</td>
<td>2.53±0.27</td>
<td>0.25±0.02</td>
<td>10.15±1.64</td>
<td>66.78±5.75</td>
</tr>
</tbody>
</table>

### 4. CONCLUSION

The culture of a newly isolated microalgal Chlorella sp. was grown well in BG-11 medium under aeration of CO₂ 5-15% and biomass production was peaked at 2.04 g/L at CO₂ concentration of 15% within 8 days of cultivation. Increasing of EBRT from 10 min to 150 min considerably
enhanced CO₂ 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 CO₂ 15% with CO₂ 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 CO₂ sequestration.

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**REFERENCES**


