

EFFECTS OF GAS FLOW RATE OF CO₂-ENRICHED AIR, HIGH CO₂ CONCENTRATION, AND ANAEROBIC ATMOSPHERE ON THE GROWTH OF BLUE-GREEN ALGA *ANACYSTIS NIDULANS*

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Introduction

Carbon dioxide fixation by utilizing micro-algae is one of the most promising approaches to reducing the greenhouse effect.⁵⁾ In our previous paper, a chemometrics approach was applied to the analysis of the combined effects of temperature, light intensity and CO₂ concentration on the growth rate of the blue-green alga *Anacystis nidulans*.⁶⁾ The evaluation of other factors such as the bubbling gas flow rate, light quality (wave length), O₂ concentration and cell physiology for achieving rigorous growth would also be required to assess the actual utilization of micro-algae. The exhaust gases from most steam electric plants contain about 10 to 20% CO₂, so a test of the effect on growth of bubbling gas with such a high CO₂ content would be useful from a practical viewpoint.

The purpose of the present study is twofold: (i) to test the effects of the gas flow rate of CO₂-enriched air on the photosynthetic growth of *A. nidulans*; (ii) to obtain a knowledge of the capability of algal growth under flushing with gases having extreme compositions: 20% CO₂ in air and 3% CO₂ in N₂. Little work has been reported on these points using micro-algae.

1. Experimental

A. nidulans IAM M-6 was obtained from the Algal Culture Collection in the Institute of Applied Microbiology, University of Tokyo. Details of our experimental apparatus have been given in the previous paper⁶⁾. For anaerobic cultivation a system for supplying nitrogen gas is newly added. Growth of cultures in modified Detmer medium⁸⁾ was followed by measuring optical density at 600 nm. The $k_L a'$ values for CO₂ in the cultures was measured, adjusting pH=3.5 in the same way as in the previous work³⁾, by using a CO₂ electrode. Experiments were performed using oblong flat flasks (37 mm thickness,

115 mm width and 380 mm vertical length) containing 500 ml of cell suspension cultures at previously determined optimum temperature (40°C) and light intensity (8 k lux) on the inside wall of the flat surface of the flask⁶⁾. CO₂-enriched air and CO₂-enriched N₂ are flushed into the flask by a single nozzle.

2. Results and Discussion

In a bubbling culture, high growth rate requires an adequate supply of CO₂. A volumetric gas flow rate of more than 360 l/d is usually considered to be needed for vigorous growth.⁷⁾ A marked increase in growth rate of *A. nidulans* was observed qualitatively with increasing aeration rate and decreasing bubble size.²⁾

The effects of the gas flow rate Q_G , changing from 72 to 720 l/d (at 298 K), on the specific growth rate μ at the optimum growth condition ($T=40^\circ\text{C}$, $I=8.0$ klux, $y_{\text{CO}_2}=3.0\%$)⁶⁾ are shown in Fig. 1. When Q_G is less than 540 l/d, the μ value increases with increasing Q_G . No dependence of the gas flow rate on μ is observed as the values of Q_G become greater than or equal to 540 l/d. The relation between Q_G and $k_L a'$ in fresh medium at 40°C is shown in Fig. 2. The $k_L a'$ value increases with increasing Q_G when Q_G is less than 540 l/d, and then keeps a constant value of ca.

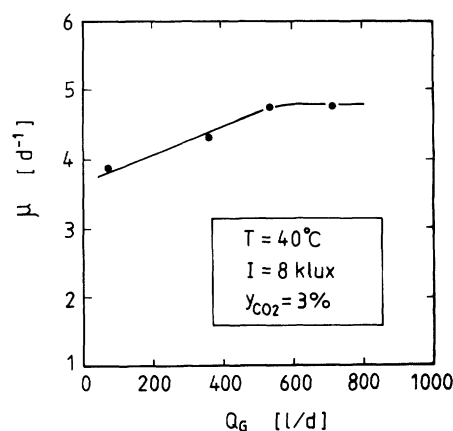


Fig. 1. Effects of gas flow rate on the specific growth rate of *A. nidulans*

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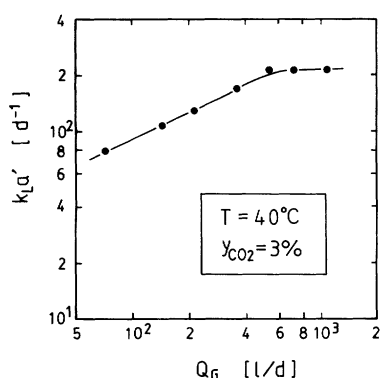


Fig. 2. Effects of gas flow rate on the k_La' value of CO_2 in the medium solution

210 d^{-1} in the range of $Q_G \geq 540 \text{ l/d}$. This tendency is qualitatively in accord with the dependence of μ on Q_G in Fig. 1. From these results it turns out that our previous works ($Q_G = 720 \text{ l/d}$)⁶⁾ were carried out at a gas flow rate providing a relatively high k_La' value.

A CO_2 concentration in air in the range of 1 to 5% has been found to be adequate for the cultivation of micro-algae and is widely used in laboratory experiments. Higher CO_2 concentrations are thought to be toxic to algae. However, no such effect was reported by Geoghegan with *Chlorella vulgaris* var. *viridis* using 20% CO_2 -enriched air¹⁾. There has been little effort to cultivate *A. nidulans* at such high gaseous CO_2 concentration.

Figure 3 shows the growth curves of *A. nidulans* obtained by flushing with 3% CO_2 -enriched air, 20% CO_2 -enriched air, and 3% CO_2 -enriched N_2 . The photosynthetic activity of *A. nidulans* is reduced significantly in aeration of 20% CO_2 -enriched air, but the cell growth is evident in this figure. In this case pH was controlled at 7.0 during cultivation. The μ value of cells in this condition is about 1/25 of that in optimal condition, but we could continue this cultivation for 30 h. After that time, we observed a change of cell color to yellow and the arrest of cell growth. As for the effects of oxygen concentration, the broken line shows that an oxygen content of 0% in the inlet gas has no effect on the photosynthetic growth of *A. nidulans*. There are reports in the literature of inhibition of photosynthesis in *A. nidulans* by flushing with high O_2 content (60% and 100%) gas.⁴⁾ Therefore, it is evident that the use of gas with low O_2 content is adjustable for the growth of *A. nidulans*.

Conclusion

The effects of the flow rate of CO_2 -enriched air, high CO_2 concentration, and anaerobic atmosphere on the photosynthetic growth of *A. nidulans* were

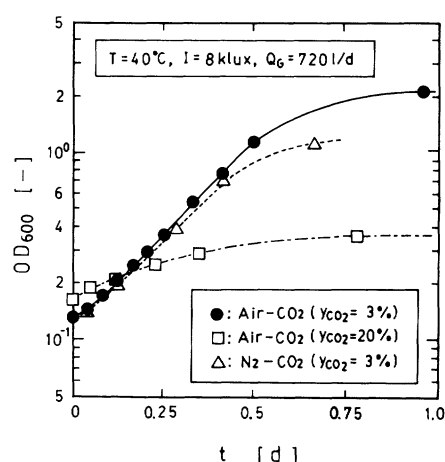


Fig. 3. Growth of *A. nidulans* with sparging gases of various compositions

studied. The results showed that (1) a gas flow rate more than 540 l/d (0.75 vvm) is required for vigorous growth of *A. nidulans*, (2) the photosynthetic growth of *A. nidulans* is possible under flushing with 20% CO_2 enriched air, and (3) anaerobic cultivation has no effect on the growth of *A. nidulans*.

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Nomenclature

I	= light intensity	[klux]
k_La'	= volumetric mass transfer coefficient of CO_2 into the culture	$[\text{d}^{-1}]$
Q_G	= gas flow rate at 298 K	$[\text{l/d}]$
T	= culture temperature	$[\text{°C}]$
t	= time	$[\text{d}]$
y_{CO_2}	= mole fraction of CO_2 in the gas	$[\%]$
μ	= specific growth rate	$[\text{d}^{-1}]$

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