

Influence of SO₂, NO and soot dust in fuel gas on microalgae ZY-1 Growth

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Abstract. The ZY-1 strain, a fresh water microalgae isolated in our former work, was viewed as a possible means of CO₂ fixation from fuel gas. In order to confirm the possibility, the influence of SO₂, NO and dissolved components of the soot dust in fuel gas on its growth was investigated. The results were showed. SO₂ gas itself did not influence the its growth. However, when SO₂ concentration was high, the pH of the medium decreased and the productivity was lowed. The presence of NO did not influence the growth of ZY-1, however, NO absorbed in the medium was changed to NO₂⁻ and utilized as a nitrogen source. When the dissolved concentrations of Ni and V in the medium exceeded more than 1 and 0.1ppm, respectively, the ZY-1 productivity decreased, however, under actual conditions, their concentrations are normally lower than these values. The above results obtained in a small test using a simulated gas were confirmed in a field test using a raceway-type reactor with actual flue gas.

Introduction

Increase in the concentration of greenhouse effect gases in the atmosphere has caused concern about potential global climate change. Biological methods, in particular using microalgae photosynthesis, have merits for the further disposal of CO₂ [1]. Direct use of fuel gas reduces the cost of pretreatment but imposes extreme conditions on microalgae. Most strains are known to be critically inhibited by air containing only 50ppm SO_x[2]. Though physico—chemical means may be used to removed the toxic compounds from fuel gases, the gases fed for microalgae cultivation could maintain up to 100% (v/v) CO₂ with a trace of toxic compounds. However, concentrations of CO₂ above 5% (v/v) influence the growth of microalgae[3,4]. So, strains that grew fast in as high CO₂ as possible would be required. In our former work, a fresh water microalgae ZY-1, with high CO₂ tolerance, has been isolated and its cultural characteristics have been investigated[5]. The ZY-1 was identified as genus Chlorella. It showed maximum growth at 10% (v/v) CO₂, and showed a good growth rate in a broad range of conditions. In this paper, in order to confirm the possibility, the influence of SO₂, NO and dissolved components of the soot dust in fuel gas on microalgae ZY-1 Productivity was investigated.

Material and Methods

Microalgae Strain. ZY-1 isolated has been selected as the algal strain. ZY-1 stain was maintained by transferring monthly on a Detmer agar plate. A modified M4N medium was used to culture the microalgae. The inoculum for each experiment was obtained from an air flow culture at 25°C and 10000 Lux. The inoculum, with dry weighs of approximately 100mg, was inoculated into 1L of media. Samples were collected daily from the vessels to determine the algal growth and pH of the medium.

Apparatus. The apparatus used in the small scale test is shown In Fig.1., A 1L Roux bottle was used as the cultivator and placed. The gas flow rate was measured using a mass flow controller. The concentration of CO₂ was monitored by an on-line CO₂ analyzer. The SO₂ gas concentration was measured by gas chromatography and NO gas concentration by NO_x meter. Gas flow meters were used to regulate the supply rate of each gas into the culture vessel. The average light intensity was measured by a photometer. In the small scale test, a model stack gas was used, its components and concentrations were confirmed according to the data that were supplied by Shenyang environmental protection agency (CO₂,15%; O₂,1.3%; NO and SO₂,50-70ppm). Basic cultural conditions were as

follows: 25°C, 0.25l/min, initial pH6.0. The test apparatus with a raceway-type reactor used in the large scale test is shown in fig.2.

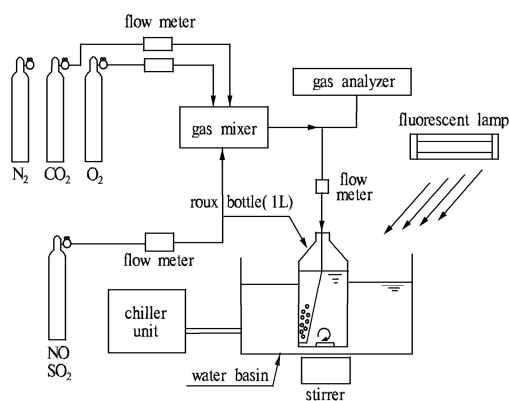


Fig.1. The apparatus in the small scale test

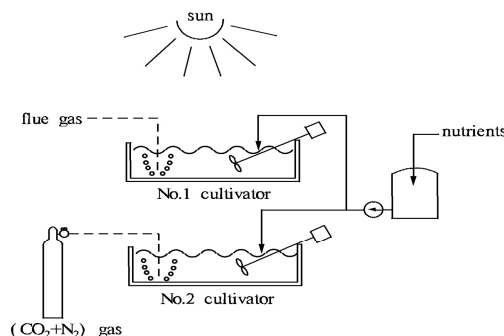


Fig.2. The apparatus used in the large scale test

Determination of cell concentration and calculation of its growth rate. The initial special growth rates were determined during the exponential growth phase of batch cultures in 200mL conical flasks. The exponential growth phase was confirmed by plotting the cell dry weights. The algal growth was determined by measuring the absorbance at 680nm using a spectrophotometer which was converted into dry cell weight, a conversion factor of 0.874g was multiplied to the number of absorbance units. The conversion factor was, r , which is defined by the following equation, and the soot dust concentration is shown as $r=q_A/q_B$. Here, q_A is miroalgae ZY-1 productivity with soot dust, q_B is miroalgae ZY-1 productivity without soot dust.

Results and Discussion

Influence of SO₂. As shown in fig.3, at a 50ppm SO₂ gas concentration, the productivity is not practically influenced, although the pH of the medium decreased from 6.0 to 4.7 after 50h. At 0ppm and 50ppm SO₂, cell concentrations were 1.82 and 1.79g/l respectively after 50h culture. However, when the SO₂ concentration was 400ppm, the pH of the medium became lower than 4 after 20h from the start and the productivity of ZY-1 gradually decreased. However, even in this case, when the pH is maintained at 6 using NaOH, the productivity did not decrease. In a parallel experiment that did not contain microalgae cells that the absorbed SO₂ was oxidized to sulfate SO₄²⁻, even at an actual level of 1% O₂ in the fuel gas. Therefore, it was considered that ZY-1 growth was not affected by SO₂ directly and the cause of the productivity decreased without pH adjustment is accumulation of sulfate and the resulting drop of pH of the medium caused by SO₂. So, SO₂ would have to be previously eliminated or the pH of the medium would have to be controlled all the time if the microalgae ZY-1 growth is to be satisfactory when it is used to fix CO₂ in flue gas.

Influence of NO. The influence of NO on ZY-1 was investigated shown in fig.4. When the model fuel gas with 100 or 300ppm NO was supplied at the cell concentration lower than 1.5g dry weight/l, cell growth was completely suppressed. Cells were thus cultivated in the absence of NO until halfway through the liner growth phase, when the cell concentration was about 1.5g dry weight/l. At this point (4 d after inoculation), the culture was aerated with the model flue gas. When the culture was aerated with the model fuel gas with 300ppm NO, NO is absorbed in the medium and part of it was changed to NO₂⁻ and accumulated in the medium. When the O₂ concentration was increased from 1.8 to 16.2%, accumulation of NO₂⁻ in the medium increases and the productivity decreased during the early stages of cultivation, but significantly increased later on. Nitrogen source of the medium was changed from NaNO₃ to NaNO₂. The productivity decreased during the early stages of the cultivation, and then it significantly increased. It was confirmed that NO was not an impediment but could be used as a nitrogen source for ZY-1.

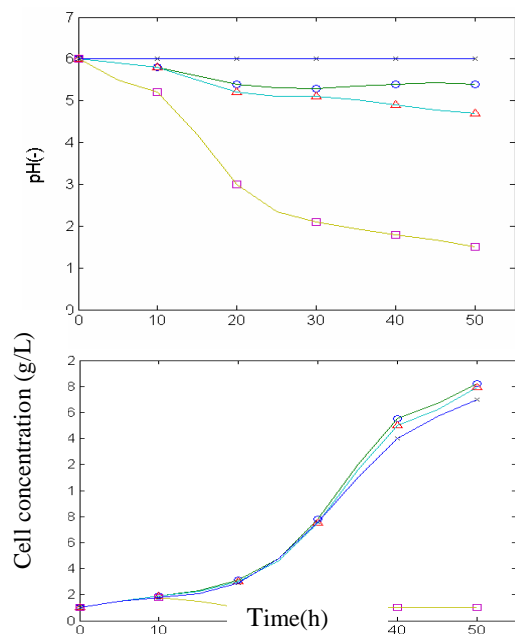


Fig.3. Influence of SO₂ gas and pH change

- 0ppm SO₂ ; △ —50ppm SO₂
 □—400ppm SO₂ ; ×—400ppm SO₂ (pH=6.0)
 □—300ppm NO (16.2 %O₂ , NaNO₃ is N source)

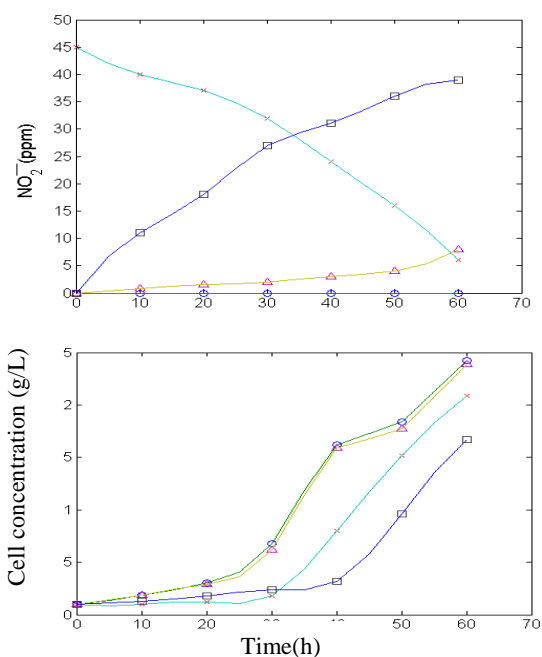


Fig.4. Influence of NO gas on microalgae cultivation

- 0ppm NO (1.8 % O₂ , NaNO₃ is N source)
 ×—0ppm NO (1.8 % O₂ , NaNO₂ is N source)
 □—300ppm NO (1.8 % O₂ , NaNO₃ is N source)

Influence of soot dust. Leaching tests of the coal ash using medium as a solvent indicated that N₁, V and Al ions were less than 0.1ppm. Therefore, the actual heavy oil ash, with V₂O₅, N₁O, Fe₂O₃, Al₂O₃, and CaO, was used as a sample of the soot dust. The test results were shown in fig.5 and fig.6.

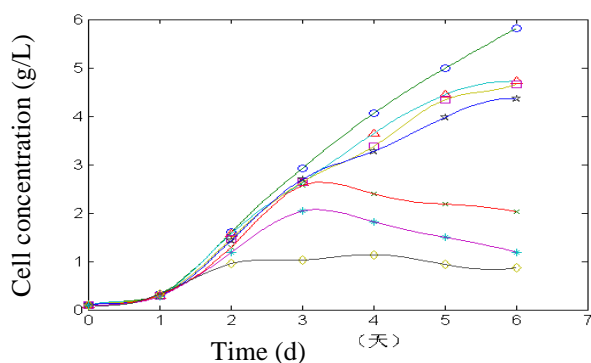


Fig. 5 Effect of soot dust on the growth of ZY-1

- 0g·L⁻¹ ; □—0.1g·L⁻¹ ; □—0.2g·L⁻¹ ;
 ☆—0.25 g·L⁻¹ ×—0.5g·L⁻¹
 *—1.0g·L⁻¹ □—5.0g·L⁻¹

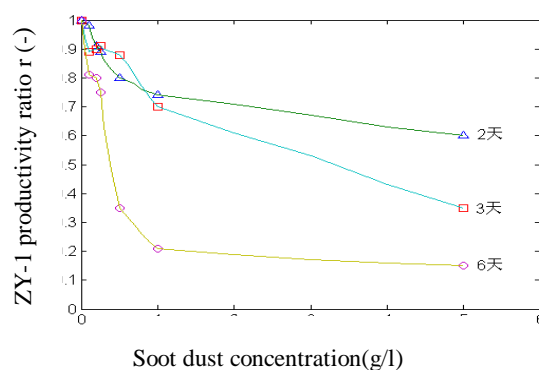


Fig. 6 Effect of soot dust under different time

- △ —after 2 days culture
 □—after 3 days culture
 ○—after 6 days culture

When the soot dust concentration was higher than 0.2g/l (Ni=1ppm, V=0.1ppm), ZY-1 productivity was influenced. Since the soot dust concentration in a discharged gas is at most 50mg/m³, it is probably only in very rare cases that the soot dust concentration becomes higher than 0.2g/l.

Large scale test. The influence of the actual flues gas was investigated by conducting a reference test at the same time using a cylinder mixed gas containing CO₂ and N₂. Test results were shown in fig.7. The time courses of the cell concentration and the productivity, which was calculated using the cell concentration increase for one day and the liquid volume, indicated the same tendency as that obtained with the cylinder gases. So, it was confirmed that cultivation of ZY-1 can be performed using actual flue gas. Also, the ZY-1 cell concentration in the large scale test with actual exhaust gas was

6.872g dry weight/l in the case of fine weather, and it was almost the same value (about 6.943 g dry weight/l) as that with model gas.

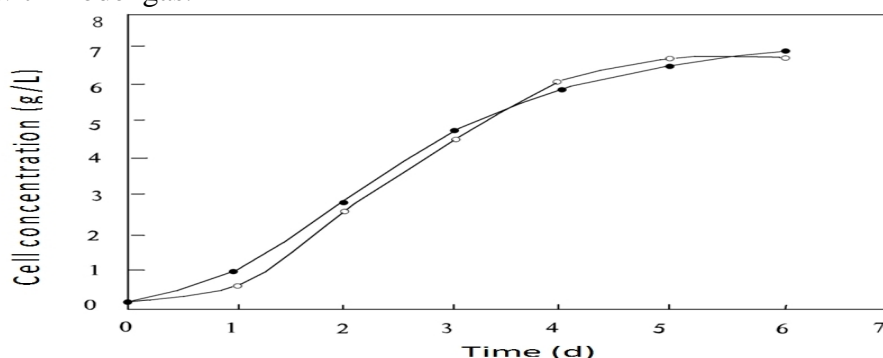


Fig.7 Test results in raceway culture (○—with actual exhaust gas;●—with model gas)

Conclusion

A fresh water microalgae, which has high CO₂ tolerance, has been isolated and its cultural characteristics have been investigated in our former work. In order to confirm the possibility as means of CO₂ fixation from fuel gas, the influence of the compositions of the thermal power plant fuel gas on ZY-1 productivity was investigated. ZY-1 growth was not affected by SO₂ itself. However, when the SO₂ concentration was high, the pH of the medium decreases and the productivity of the microalgae ZY-1 was lowered. So, SO₂ would have to be previously eliminated or the pH of the medium would have to be controlled to be satisfactory. NO did not influence the ZY-1 growth. NO absorbed in the medium is changed to NO₂⁻ and may be utilized as a nitrogen source. When the dissolved concentrations of Ni and V in the soot dust exceed 1 and 0.1ppm, respectively, ZY-1 productivity decreased, however, under actual conditions, their dissolved concentrations are normally lower than these values. The above results obtained in the small scale test using a simulated gas were confirmed in a field test using a raceway- type reactor with actual flue gas.

Acknowledgments

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References

- [1] Y. Watanabe, H Saiki, *Energy Conversion and Management*, 36 (2005) 713-716.
- [2] H. Matsumoto, A. Hamasaki, N. Sioji, *Journal of Chemical Engineering of Japan*, 30(2001) 620-623.
- [3] S. Nielsen, *Physiologia Plantarum*, 8 (2005) 317-335.
- [4] H. J. Silva, S.J. Pirt, *Journal of General Microbiology*, 30 (2004) 2833-2838.
- [5] L.H. Yue, W.G. Chen, *Energy Conversion and Management*, 46(2005) 1868-1876.