Nitrogen removal from wastewaters without carbon sources using microalgae

Kwangyong Lee and Choul-Gyun Lee
Department of Biological Engineering, Inha University, Inchon 402-751
이광용, 이철균
인하대학교 생물공학과
전화 (032) 865-7518, FAX (032) 872-4046

Abstract
Possibility of biological nitrogen treatment was tested in wastewaters with low C/N ratio. *Chlorella kessleri* was inoculated at 10^6 cell/mL of initial density in two different artificial wastewaters: one that contained glucose for organic carbon source and the other without carbon source. Nitrate could be successfully reduced below 10 mg NO_3/mL from initial nitrate concentration of 560 mg NO_3/mL in 10 days even in the wastewater without carbon source, This 98% removal of nitrate without extra organic carbon source lights up the future of biological wastewater treatment, where the insufficient ability of nitrogen removal is a major problem.

Introduction

Microalgae have a great potential in treating wastewaters. They can fix carbon dioxide by photosynthesis and remove excess nutrient efficiently at a minimal cost.[1] Besides, photosynthetically produced oxygen can relieve BOD in wastewaters. Microalgae also have abilities to absorb heavy metals, nitrogen and phosphorus.[2,3] They can use various organic compounds especially eutrophic compounds containing nitrogen and phosphorus for their carbon sources. Furthermore, the algae can serve as feeds for animals and fishes after the treatment.[4]

One characteristic of the wastewaters in Korea is a low C/N ratio. As a result, typical biological wastewater treatment system cannot remove the nitrogen below the effluent criteria. Microalgae can be the most potential, economical and attractive method in treating nitrogen-rich wastewater and in solving many serious environmental problems at the same time. Furthermore, biological waste

treatment is much friendlier to environment than physical/chemical treatments.

Material and methods

Microorganism and Media

Chlorella kessleri (UTEX 398), a green eukaryotic photoautotrophic microorganism from the UTEX (The culture collection of algae at the University of Texas at Austin) was grown in N8 media. The media contains nitrate and phosphate but no organic carbon. Nitrogen and other eutrophic compounds removal rates were compared in N8 media and in modified N8 media supplemented with organic carbon source. Cultures were maintained in N8 media in 100 mL flask under 30°C, 200 rpm.

Cell Concentration and Cell Size Distribution

Cell concentration and size distribution were measured by Coulter Counter (Model Z2, Coulter Electronics, Inc., Hialeath, FL, U.S.A.). The Coulter method of sizing and counting particles is based on measurable changes in electrical resistance produced by nonconductive particles suspended in an electrolyte which is ISOTON II (Coulter Electronics, Ltd., Hongkong, China).

Bubble Column Photobioreactor

Column was made of Pyrex (650 mm of height, 35 mm of internal diameter) that penetrate light. Fluorescent light tubes (FL20D, OSRAM, Korea) were used to illuminate the photobioreactor. Two fluorescent lamps were placed at a distance of 20 mm from photobioreacor columns.

Air was introduced into the bottom of the column at various air flow rates.

Analysis

The concentrations of phosphate, nitrogen and TOC were measured after removing algal by centrifugation at 3000 rpm for 10 minute.

Phosphate content was measured by vanadomolybdophosphoric acid colorimetric method. In a dilute orthophosphate solution, ammonium molybdate reacts under acid conditions to form a heteropoly acid, molybdophosphoric acid. In the presence of vanadium, yellow vanadomolybdophosphoric acid is formed. The intensity of the yellow color is proportional to phosphate concentration in samples. Spectrophotometer was used at 400 nm for quantification of phosphate.

Nitrate and ammonium concentration was measured with ion selective electrodes (Phoenix Electrode Co, Huston, TX, U. S. A.) through a ion meter(model 750P, ISTEK, Korea). Samples were diluted to within calibration curve range.

Results and discussion

Microalgae need carbon, nitrogen, phosphorus and other micronutrients to grow. They can fix carbon dioxide from air through photosynthesis and they will take nitrogen and phosphorus up from wastewater. Microalgae were cultured in 100 mL flasks in shaking incubator with 30℃, 200 rpm. Fig. 1. showed that cell growth under various nitrogen concentration. Initial nitrogen concentration was 138, 69, 13.8 mg/L respectively. Although initial nitrogen concentrations were different, the final cell concentrations were about the same, to about 2×10^7 cell/mL. Assuming the nitrogen contents of algae is 9.2% of dry cell weight, 2×10^7 cell/mL requires 11.5 mg/L of nitrogen. Nitrate concentration in wastewater measured with nitrate ion electrode. Fig. 2. presented the removal efficiency of nitrate. The amounts of nitrogen removal were 12.74, 11.62, 5.32 mg-N/L, respectively, whose range was close enough to the calculated value. The ion selective electrode used did not work very well at low nitrogen concentration, and the measurement of the last flask that originally contained 13.8 mg/L of nitrogen had large errors and thus giving the low nitrogen removal.

Since the mass transfer rates in flasks were not enough, bubble column photobioreactors were constructed. Flow rate and resident time were important parameters in photobioreactor experiments. As shown in Fig. 3, final cell density was a function of air flow rate. Final cell density was 1.6×10^7 cell/mL under higher air flow rate of 0.4 and 0.8 vvm that increased over 100 times from inoculation cell density. In contrast, cell growths under lower air flow rate of 0.1 and 0.2 vvm were only about 40% of those under higher air flow rate. This results proved that microalgae could successfully remove nitrogen from wastewater with no carbon source as long as the carbon dioxide transfer rate was high enough.

In a high density photobioreactor experiment, over 98% of initial 560 mg NO_3/L was removed at the end in 10 days (Fig. 4). The final cell concentration was 6.4×10^7 cell/mL.

Microalgal nitrogen removal appeares to be a promising method in treating high nitrogen content wastewater with low C/N ratio. More detailed experiments are

necessary to make this process economical.

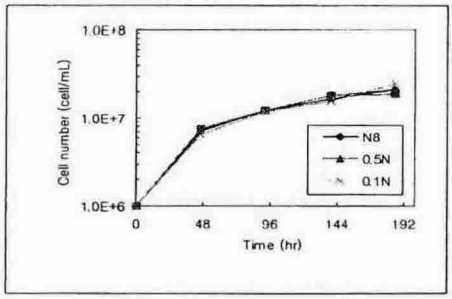

Fig. 1. Cell growth in flask under 30℃, 200 rpm. N8, 490 mg NO_3/mL; 0.5N, NO_3 concentration is 50% of N8; 0.1N, NO_3 concentration is 10% of N8

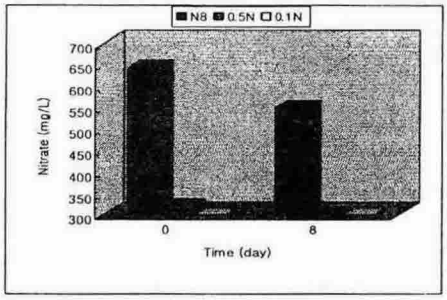

Fig. 2. Removal of nitrate in flask under 30℃, 200 rpm. N8, 490 mg NO_3/mL; 0.5N, NO_3 concentration is 50% of N8; 0.1N, NO_3 concentration is 10% of N8

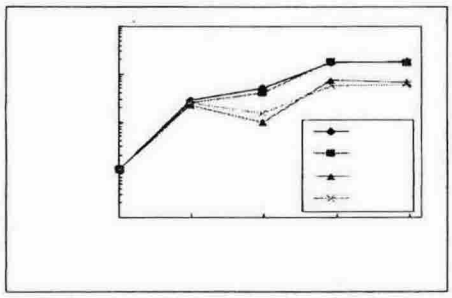

Fig. 3. Cell growth in bubble column photobioreactor with various air flow rate.

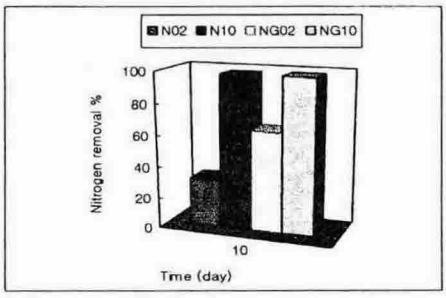

Fig. 4. Nitrogen removal in bubble column photobioreactor at 10 day, N02, N8 with 0.2 vvm; N10, N8 with 1.0 vvm; NG02, Add organic carbon in N8 with 0.2 vvm; NG10, Add organic carbon in N8 with 1.0 vvm.

Reference

1. Negoro, M., Kamasaki, A., Ikuta, Y., Makita, T., Hirayama, K. and Suzuki, S. *Appl. Biochem. Biotechnol.*, 39/40:643-653, 1993.

2. Vilchez, C., I. Garbayo, et al. Microalgae-mediated chemicals production and wastes removal. *Emzyme. Microb. Technol.* 20: 562-571, 1997.

3. Borowitzka, M. A. and L. J. Borowitzka. Micro-algal Biotechnology. Cambridge University Press, Cambridge, U. K., 1988.

4. Becker, E. W. Microalgae, Cambridge University Press, Cambridge, U. K., 1994.

5. APHA, AWWA, and WEF. Standard Methods for the Examination of Water and Wastewater. 19th ed. Baltimore, U.S.A., 1995.