Application of Photosynthetic Bacteria Treatment System for Recovery of Organic Carbon from Noodle Processing Wastewater

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Abstract

This paper presents a case study on application of photosynthetic bacteria wastewater treatment system to recover organic carbon in wastewater in the form of photosynthetic bacterial cells. In noodle production process, the wastewater was mainly produced during rice soaking and rinsing processes containing starch as its main constituent. For carbon recovery purpose, wastewater was applied to laboratory photosynthetic wastewater treatment system where carbon could be transformed into protein in purple non-sulfur or purple sulfur bacterial cells. The system has shown to be effective for the treatment of starch wastewater and cultivation of photosynthetic bacteria when operated at hydraulic retention time of 6 and 10 days.

1. Introduction

The application of photosynthetic bacteria to wastewater treatment is one of the attractive methods since the microorganisms are widely available in nature and capable of removing organic substances even under high organic load (Hiraishi et al., 1989) especially in sunlight intensive area like tropical countries. The treatment will require minimum additional energy apart from natural sunlight and the treatment cost can be substantially reduced. They are applicable to organic compounds (Madigan et al., 2000) and wastewater from various industries (Noparatnaraporn et al., 1986). By introducing this system, it might be possible to develop a high-efficiency treatment process without odorous gas production. The proposed system (Figure 1) consists of two ponds connected in series. In the first pond, it is expected that acidogenic bacteria consume organic matter in wastewater and photosynthetic bacteria grow with their metabolite. Then the following aerobic fishpond is expected to have a high fish yield. Moreover the by-product of the treatment, the photosynthetic bacteria cells, has high nutrition such as protein and vitamin (Kobayashi and Tchan, 1973; Getha et al., 1998; Banjaree et al., 2000) which is a good alternative for fish feed.

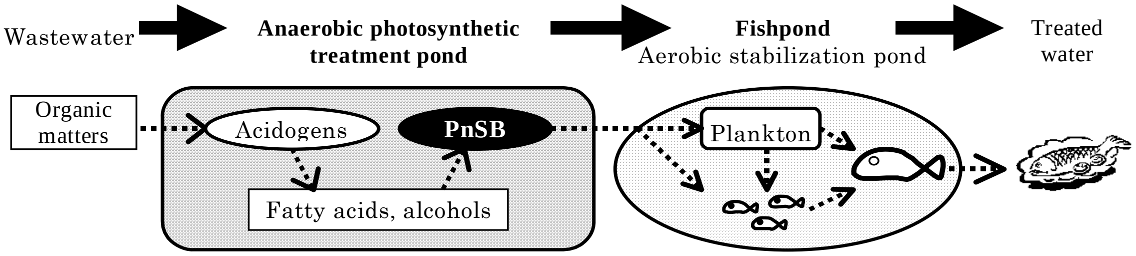


Figure 1. Process flow of photosynthetic bacteria pond treatment system.

2. Wastewater from noodle production

Typical production of rice noodle includes broken rice and water as two main raw materials for production of unfermented rice noodles. It involves washing and soaking of rice, pasting the rice and making the starch slurry. For thick noodle processing, the slurry is then used in sheeting prior to cooking and drying step. For thin noodle processing, the sheeted slurry is cooked and dried in an oven before cutting process. The processing of vermicelli noodle is slightly different from thick and thin noodle. The starch slurry is passed through a filter press, yielding semi-dry starch solids. The starch solids are steamed before being extruded to form vermicelli noodles. The production of rice noodles produces wastes at various stage, i.e. raw material preparation, production, packaging and process line cleaning. Among these, wastewater is mainly produced during rice soaking/rinsing and cleaning of pasting tank. It contains starch as main constituents with high BOD and suspended solids.

3. Experimental system

Laboratory scale reactors (3-L working volume) simulating photosynthetic bacteria ponds were used (Figure 2). The reactor was illuminated for 12 hours per day by two 60 W incandescent lamps from both side. The bioreactor was operated as single pass complete mixed reactor by providing magnetic stirrer mixing. During the experiments, intermittent aeration was supplied to prevent permanent drop in oxidation-reduction potential (ORP). Feeding of wastewater and withdraw of reactor effluent was done once a day. Enriched photosynthetic bacteria (wild strains) were used as seeding in the photo-bioreactor. The organic loading to the system was varied between 0.16 and 0.35 kgCOD/m^3.d respectively. Microbial population in the system was studied by determining bacterio-chlorophyll-a (Bchl.a) for photosynthetic bacteria and chrolophyll-a for microalgae. Purple non-sulfur bacteria (PnSB) were also quantified by fluorescent in-situ hybridization (FISH) technique. The populations of sulfate reducing bacteria (SRB) and purple sulfur bacteria (PSB) were quantified by conventional plate count methods. Crude protein content of sludge withdrawn from the photo-bioreactor was also analyzed.

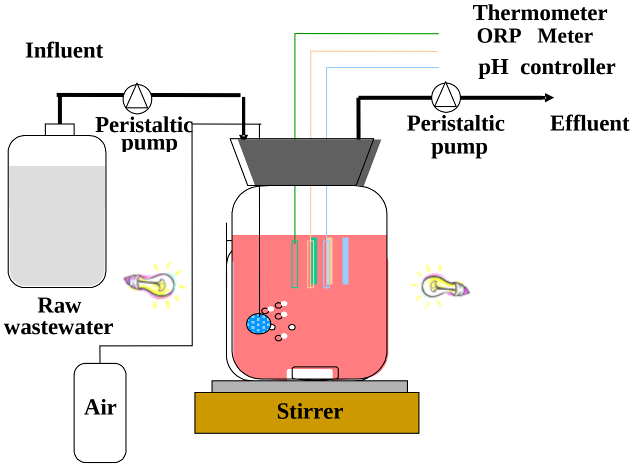


Figure 2. Schematic of laboratory scale photosynthetic bacteria pond system

4. Organic carbon conversion in the system

The photo-bioreactors were operated either with or without infrared transmitting filter. The main purpose of filter installation is to prevent the growth of microalgae in the system. It was found that high COD removal rate of more than 90% was achieved under the organic loading rate of 0.1 to 0.3 kg/m^3.d. High COD removal was obtained when the HRT in the system was operated between 3 and 10 days even though occasional fluctuations on the removal efficiency were observed at low HRT case. The removal of organic substance is mainly accomplished by PnSB which utilized organic substrates in the presence of light from wastewater as photosynthetic electron donor and carbon sources. In addition, sulfate reduction can also help eliminating some fraction of organic substances. The treatment performance in the photo-bioreactor with and without infrared transmitting filter was comparable to each other.

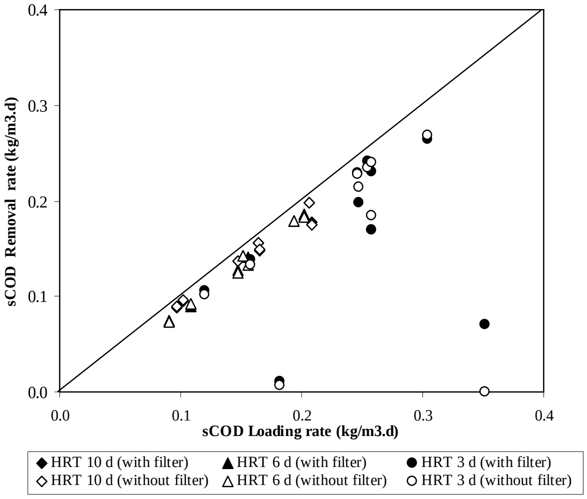


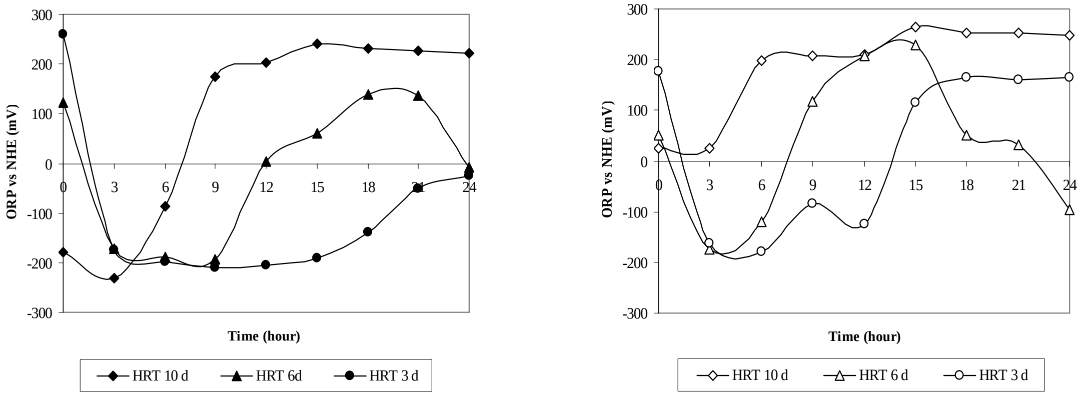
Figure 3 Relationship between organic loading and removal rate in photo-bioreactor

The reduction of HRT did not only increase organic substance but also raised sulfur compound loading to the system. As a result, they produce sulfide which is inhibitory compound for PnSB. Sulfite concentration in effluent was kept below 20 mg/l while sulfate concentrations in effluent was increasing. This was mainly due to the oxidation of incoming sodium metabisulfite which has been used for bleaching and antioxidant purposes. Nevertheless, sulfate concentration was found gradually declined towards the end of the operation due to the development of sulfate reduction in the system.

Figure 4 shows the variation of ORP in a feeding cycle. In photo-bioreactor without infrared transmitting filter, ORP increased much higher than those in photo-bioreactor with infrared transmitting filter after feeding because oxygen was produced from the photosynthesis of microalgae in the presence of light. Higher organic loading and the use of infrared transmitting filter could control the ORP mostly in the negative range. Microanaerobic condition is preferable to the growth of PnSB as compared to microalgae but too low ORP might also promote the SRB activities.

5. Bacteria community in the system

Photosynthetic bacterium cultivated from natural mixed culture consists of at least two species of PnSB; Rps. palustis and Rba. blasticus. There was a decreasing trend of Bchl.a and PnSB in the system. The growth of SRB was found significant in the latter stage. The opposite trend of PnSB and SRB suggested that there was a competitive relationship among them. The growth of PSB associated with SRB was also observed at high organic loading rate as PSB could utilize sulfide produced from SRB activities for their growth. Chl.a was found abundant in the photo-bioreactor without infrared transmitting filter since visible wavelength could be easily absorbed by microalgae during photosynthesis. The use of infrared transmitting filter was found effective for suppression of microalgae growth.



(a) (b)

Figure 4 Variation of ORP within a feeding cycle (24 hours) in the photo-bioreactor a) with infrared transmitting filter and b) without infrared transmitting filter

6. Single cell protein (SCP) production

Crude protein content in the sludge obtained from the photo-bioreactor with infrared transmitting filter at all HRT was found more than 50% (Table 1), sufficiently high to be utilized as SCP. Sludge from the system with infrared transmitting filter had higher protein content than that without infrared transmitting filter as the photosynthetic bacteria cell contain higher protein than microalgae.

Table 1. Production of SCP from photosynthetic bacteria at different HRT.

Run	HRT (d)	Light	Organic-N (mg/l)	Crude protein (mg/l)	SS (mg/l)	Crude protein content (g/g-dry weight)
A-1	10	with filter	38	234	437	0.54
A-2		w/o filter	33	208	529	0.39
B-1	6	with filter	46	287	430	0.67
B-2		w/o filter	52	326	541	0.60
C-1	3	with filter	35	181	343	0.53
C-2		w/o filter	41	254	458	0.55

7. Conclusions

High organic removal of more than 90% was achieved in photosynthetic bacteria treatment system operated at HRT of 6 and 10 days. Infrared transmitting filter was effective in suppressing the growth of microalgae and allow purple non-sulfur to grow. Two species of purple non-sulfur bacteria were identified, i.e. Rps. Palustis and Rba. Blasticus. The growth of purple sulfur bacteria associated with sulfate reducing bacteria was observed. The sludge withdrawn from the system contained high protein content of more than 50% which to be utilized as single cell protein.

8. References

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