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Photohydrogen Production from Thermophilic Aerobic Digestion Effluent and Distillery Wastewater by Photosynthetic Bacterium *Rhodopseudomonas palustris* WP 3-5

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1 Introduction

Based on the reserved limitation and environmental consequences of fossil fuel, hydrogen is considered to be one of the most promising clean fuels for the future [1], and can be produced using biological system through exploiting fermentative bacteria, algae, cyanobacteria, and anoxygenic photosynthetic bacteria [2]. Among these hydrogen microproducers, purple nonsulfur photosynthetic bacteria can utilize VFAs as the substrates for growing and producing hydrogen [3]. Thermophilic aerobic digestion (TAD) is a dynamic, new waste-processing technique which uses the heat generated during microbial aerobic metabolism to raise the temperature of waste undergoing treatment in an insulated system to thermophilic levels (45°C). As a relatively new process, it is increasingly being accepted for waste treatment, either in stand-alone processes, or as part of an integrated two-stage process [4]. It was mentioned that when TAD process was modified to be operated under microaerobic condition for sludge digestion, the accumulation of volatile fatty acid (VFAs) was expected [5]. Thus, combining the modified TAD process with photohydrogen production process shall make sludge removal and energy recycle possible. The aim of this research was to investigate the feasibility of biohydrogen production by purple nonsulfur photosynthetic bacterium, strain *Rhodopseudomonas palustris* WP 3-5, using TAD process effluent.

2 Methods

Before photohydrogen production using TAD process effluent, several strategies were applied to realize optimum operated condition of the TAD process for maximum VFAs accumulation. Moreover, other possible hydrogen production wastewater such as distillery wastewater was also examined. Figure 1 shows the experimental flowchart.

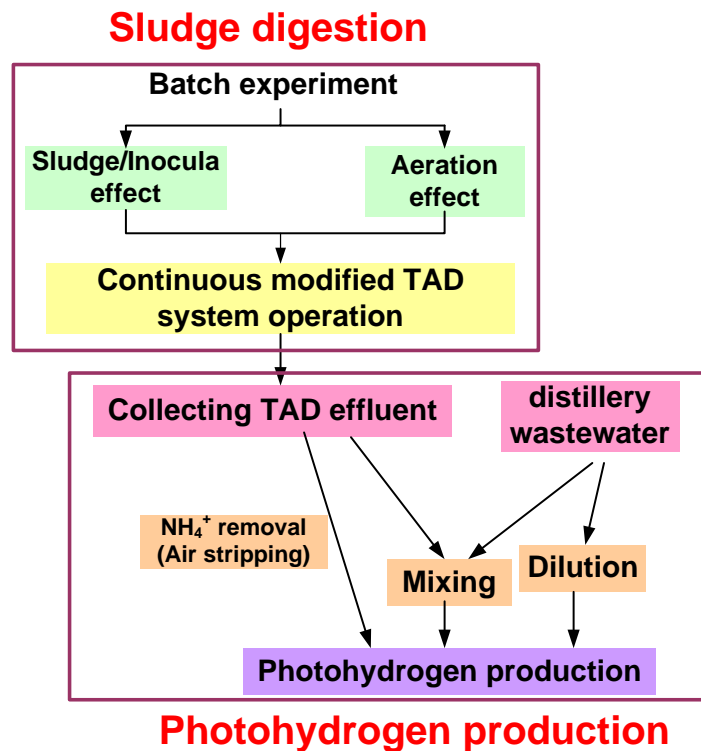


Figure 1: The experimental flowchart.

3 Results

The optimum strategies for maximum VFAs production with TAD process were to inoculate supplementary sludge digestion bacterium *Geobacillus thermocatenulatus* S2 isolated from the sludge produced during the textile industrial wastewater treatment process and control the initial sludge loading concentration: inoculum concentration to 20:1. Moreover, slight aeration (0.25 vvm) caused lower NH_4^+ accumulation and benefited the followed photohydrogen production. The optimum HRT for better VFAs accumulation was 24 hr, and the continuous TAD process could be maintained at least for 120 hr.

Although the optimum operated conditions of the TAD process were found out, the $\text{NH}_4^+\text{-N}$ concentration in the TAD effluent was still too high to inhibit photohydrogen production. In the previous research, photohydrogen production occurred only when the NH_4^+ concentration was below 17 mg- $\text{NH}_4^+\text{/L}$ [6]. Thus, $\text{NH}_4^+\text{-N}$ in the TAD effluent was eliminated by pH adjustment and air stripping. When pH value was adjusted to 12.0, $\text{NH}_4^+\text{-N}$ concentration could decrease under detection limitation within 17 hr after air stripping. The pretreated TAD effluent was then utilized for photohydrogen production using photosynthetic bacterium *R. palustris* WP 3-5. The results demonstrated that the highest accumulated hydrogen volume was 25.8 mL (the headspace was 50 mL). Based on high VFAs content but low $\text{NH}_4^+\text{-N}$ concentration in the distillery wastewater, we also mixed the distillery wastewater with the TAD effluent for hydrogen production.

The results revealed that the best distillery wastewater:TAD effluent mixed ratio for photohydrogen production was 2:5, and the highest accumulated hydrogen volume and hydrogen production rate (HPR) was 263.9 mL and 12.4 mL H₂/L-culture/hr, respectively.

Moreover, the diluted distillery wastewater was also applied for hydrogen production. When distillery wastewater diluted ratio was 0.4x, the highest accumulated hydrogen volume and HPR were 278.3 mL and 13.06 mL H₂/L-culture/hr, respectively.

4 Conclusion

Comparing the hydrogen producing efficiency of mixed wastewater and diluted distillery wastewater, it was observed that the diluted distillery had better HPR, but the mixed wastewater had higher total accumulated hydrogen volume.

References

- [1] Rupperecht, J., B. Hankamer, J.H. Mussnug, G. Ananyev, C. Dismukes, and O. Kruse, "Perspectives and advances of biological H₂ production in microorganisms," *Applied Microbiology and Biotechnology*, Vol. 72, No. 3, pp. 442-449 (2006).
- [2] Zabut, B., K. El-Kahlout, M. Yücel, U. Gündüz, L. Türker, and İ. Eroğlu, "Hydrogen gas production by combined systems of *Rhodobacter sphaeroides* O.U.001 and *Halobacterium salinarum* in a photobioreactor," *International Journal of Hydrogen Energy*, Vol. 31, No. 11, pp. 1553-1562 (2006).
- [3] Lee, C.M., P.C. Chen, C.C. Wang, and Y.C. Tung, "Photohydrogen production using purple nonsulfur bacteria with hydrogen fermentation reactor effluent," *International Journal of Hydrogen Energy*, Vol. 27, No. 11-12, pp. 1309-1313 (2002).
- [4] Ugwuanyi, J.O., L.M. Harvey, and B. McNeil, (2004) "Protease and xylanase activities and thermophilic populations as potential process monitoring tools during thermophilic aerobic digestion," *Journal of Chemical Technology & Biotechnology* Vol. 79, No. 1, pp. 30-38 (2004).
- [5] Chu, A., D.S. Mavinic, W.D. Ramey, and H.G. Kelly, "A biochemical model describing volatile fatty acid metabolism in thermophilic aerobic design of wastewater sludge," *Water Research*, Vol. 30, pp. 1759-1770 (1996).
- [6] Lee, C.M., K.M. Yu, and P.C. Chen, Limiting factors of photo-hydrogen production by *Rhodospseudomonas palustris* WP3-5, In: Antonio Mendez-Vilas (Ed.), *Modern Multidisciplinary Applied Microbiology*. Wiley-VCH, Weinheim, pp. 236-240 (2006).