Anaerobic granular sludge formation in a UASB reactor using polyvinyl alcohol gel beads as bio-carrier

Tran Phuong Thao[1), 2)], Dang Minh Hang[1)], Vu Thi Hoa[1)], Nguyen Thi Thanh[1)], Takahiro Watari[2)], Masashi Hatamoto[2)], Takashi Yamaguchi[2)], Nguyen Lan Huong[1)]*

[1)] School of Biotechnology and Food Technology, Hanoi University of Science and Technology, Hanoi, Vietnam

[2)] Department of Civil and Environmental Engineering, Nagaoka University of Technology, Nagaoka, Japan

** Corresponding author's email address: huong.nguyenlan@hust.edu.vn*

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Introduction

Currently, anaerobic digestion is popularly used for treating high-strength organic wastewater. One of the most notable anaerobic high-rate reactors is up-flow anaerobic sludge blanket (UASB) reactor with low energy requirement and high methane recovery. However, granular sludge is a key factor for stable and high performance of UASB reactor. Granular sludge formation is based on the microbial adhesion itself, or enhanced by addition of bio-carriers for microbial attachment (Hulshoff et al., 2004). The use of bio-carriers is preferred due to its advantage over the former way, such as shorten the formation period, controllable and less dependent from wastewater's characteristics. There have been many types of inert materials investigated, such as polyvinyl alcohol (PVA), polypropylene, polyurethane, alginate, chitosan, etc. Among them, PVA gel bead has been received growing attention. This bead has large specific surface area and porous structure supporting the microbial retention onto the surface, as well as into the inner-sphere complex. Besides, it has mechanical stability, non-toxicity, non-biodegradability, higher specific gravity and low price. Therefore, PVA gel bead was chosen in this study to support anaerobic granular sludge formation in a UASB reactor.

The objectives of this research is immobilize the anaerobic sludge on PVA gel beads, then compare the performance of the immobilized PVA gel bead and anaerobic sludge separately in two UASB reactors.

Material and Methods

The PVA gel beads were made in laboratory by crosslinking between 8% PVA solution and saturated boric acid solution. The dispersed sludge was collected from a household biogas system treating livestock manure in Thanh Tri, Vietnam. In the first period, the PVA gel beads and the anaerobic sludge were mixed with a ratio of 1:1, in a UASB reactor (total solid volume of 10L and working volume of 20L). The raw natural rubber processing wastewater was diluted and fed continuously to reactor at flow rate of 24L/day, temperature was maintained in 35^{o}C. The COD influent was gradually increased from 600 mg/L to 2000 mg/L. After 104 days, the sludge and the

PVA beads were separated and used to run in two 10L-UASB reactors, UASB1 and UASB2, respectively. They were run with flow rate of 25L/day, 35^{o}C and COD influent was adjusted from 1000 to 6000 mg/L in order to confirm the performance (the second period).

The immobilization was determined by specific methanogenic activity (SMA) of PVA beads during 104 days. COD concentration of influent and effluent was determined using a HACH water quality analyzer (DR-2800, HACH). Total suspended solid (TSS) was measured using standard methods (APHA, 2005). The specific methanogenic activity of PVA beads was determined in anaerobic serum vials at 35°C using a modified method according to that proposed by Tsuyoshi Imai (1997). The chemical composition of anaerobic medium was same as that reported by Dolfing and Bloemen (1985). Biogas composition was analyzed using a gas chromatograph equipped with a thermal conductivity detector (GC-8A, Shimadzu). SMA was calculated based on methane production rate and VSS content in each vial and expressed as g-COD/(gVSS·day). A factor of 350 ml CH_4/gCOD under standard temperature and pressure (273°K, 1atm.) condition was used for this calculation.

Results and Conclusions

After 104-days immobilization, the 20L UASB reached COD removal efficiency of over 85%. The colour of beads changed from white to brown and some were black (**Figure 1**). In addition, the SMA of immobilized PVA bead was 0.342 gCOD/(gVSS·day), corresponding to 41.7% of the SMA of dispersed sludge (data not shown). These results indicate that biomass was immobilized in PVA bead.

In the second period, both reactors rapidly reached COD removal efficiency of over 90% under organic loading rate (OLR) of 3.55 – 4.51 kgCOD/(m3·day) after 7 days operation. The UASB2 with PVA gel bead was keep operating well with COD removal efficiency of 94,5% under OLR of 13.5 kgCOD/(m3·day), meanwhile the UASB1 with dispersed sludge was observed sludge wash-out under OLR of only 7.26 kgCOD/(m3·day) (**Figure 2**). At this time, the biogas and methane production of UASB2 with PVA bead were 22.6 L/day and 16.6 L/day, respectively. The biogas and methane production of UASB1 were 12.6 L/day and 11.7 L/day, respectively (**Figure 3**). The PVA bead is likely to enhance the performance of UASB reactor under high rate operation.

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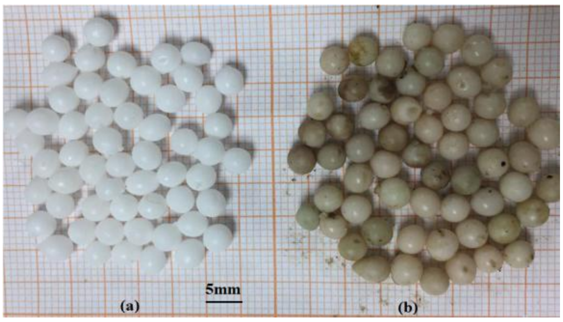

Figure 1. The color change of PVA gel bead during immobilization period. (a)-Before immobilization, (b)-After 104 days immobilization.

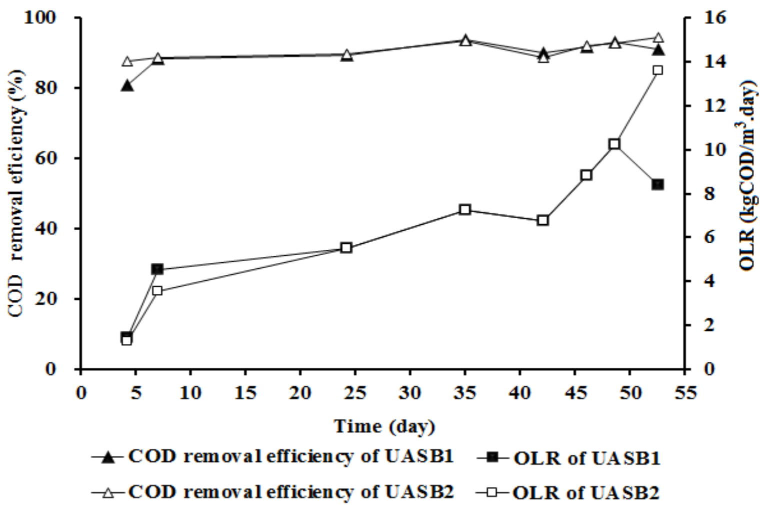

Figure 2. Time series data for COD removal efficiency and OLR in two UASB reactors during the second period.

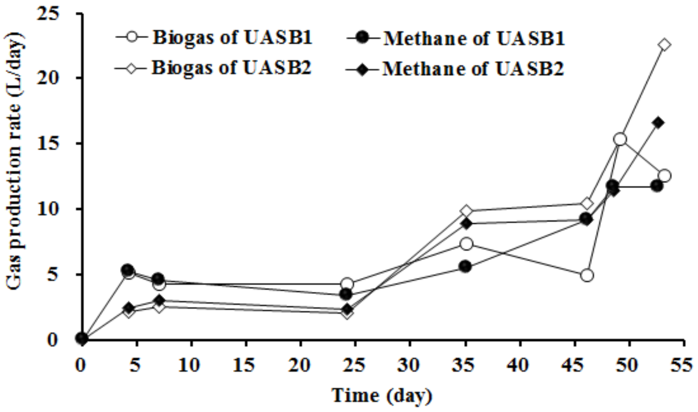

Figure 3. Time series data of biogas and methane production in two UASB reactors during the second period.