導電性材料を介した DIET によるメタン生成の保進

Promotion of Methane Production Using DIET via Conductive Materials

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1. Introduction

Anaerobic digestion (AD), a cost-effective technology that can convert wastes such as wastewater sludge into biogas through process called methane fermentation. This process is a biochemical reaction in which organic matter is decomposed by anaerobic microorganisms that then produce CH_4 and CO_2 through methanogens phase.

The limiting factor of this process is the slow growth rate of anaerobic bacteria especially syntrophs. Recent studies suggested that Direct Interspecies Electron Transfer (DIET) between exoelectrogenic bacteria and methanogenic archaea have potential to increase the production rate of methane. In this process, some bacteria can directly transfer electron without using hydrogen or formate as mediator [1].

There are three mechanisms in DIET: 1) conductive pili, 2) e- transport protein and 3) conductive materials. Among these, most studies found that DIET via conductive materials can reduce lag times and enhance methane production rate. In this mechanism, microorganisms are tightly attached on the surface of conductive materials. For this study, the third mechanism, DIET via conductive materials was chosen to investigate the potential of this mechanism in promoting methane production [2].

2. Materials and Methods

2.1. Conductive Materials

In this study, Green Tuff (GT), a green carbon-based mineral rock made up of volcanic ash and animal fossil was used as conductive material. It contains abundant amount of mineral and conductive materials as well as have soft structure that make it easy to process. Fine and coarse aggregates GT with diameter of 400 nm and 1~5 mm respectively were used to investigate the effect of surface area of conductive materials on methane production rate [3].

2.2. Polyvinyl Alcohol Beads

Polyvinyl alcohol (PVA) has porous structure which was used as media for microbial attachment and growth. For PVA beads preparation, PVA, sodium alginate and conductive materials (fine aggregate GT) were mixed together which was then crosslink with boric acid to produce 4 to 5 mm diameter elastic beads that have high durability and strength. After that, the beads were transferred to sodium sulfate for further strengthening [4].

2.3. Experimental Conditions and Set-up

In this experiment, Schott Duran bottles with capacity of 250 mL were used as reactors (Fig.1). Five type of samples with two reactors for each sample were used. The samples differ based on the presence and absence of PVA beads and conductive materials (GT). Anaerobic sludge with concentration of 6000 mg-SS/L were used as inoculum. For substrate, propionate with concentration of 2000 mg COD/L was used. The temperature was set under mesophilic condition at 37℃. The conditions of the experiment are shown as Table 1.

Table 1: Experimental Conditions

	Sludge	PVA	PVA-GT	GT-Fine	GT-Coarse
Inoculum	Anaerobic sludge				
Working volume (mL)	200				
Sludge (mL)	80~85				
Media (mL)	115~120				
Substrate (mL)	10				
PVA beads/ CM (g)	–	10			
Temperature (℃)	37				
Mixing speed (rpm)	1000				
PVA beads	X	O	O	X	X
Conductive materials	X	X	O	O	O

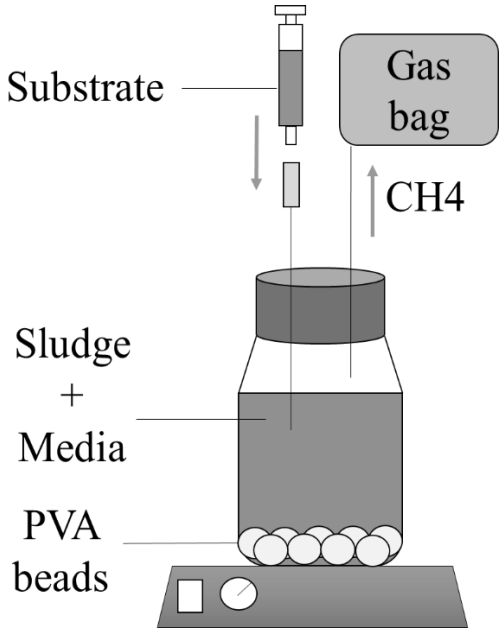

Fig. 1: Reactor set-up

2.4. Analytical Methods

The methane gas was analyzed using gas chromatography equipped with thermal conductivity detector (GC-TCD). Argon gas is use as carrier gas for mobile phase. COD analysis was also being carried out by using HACH method.

For VFA analysis, Agilent 7100 capillary electrophoresis was used to get the accurate results. α-AFQ 109 solution was used as buffer. The samples were then filtered using 0.22μL filter to obtain 300μL of sample. The samples were then used for further analysis.

3. Results and Discussion

The batch of GT-Coarse produced highest amount of methane gas with average of 65% while 39% for PVA-GT. Usually, biogas obtained from anaerobic digestion supposedly has methane concentration around 50% to 70%, but the result shows otherwise for PVA-GT and GT-Fine which produce methane gas lower than 50% which were 39% and 41% respectively [1]. Sludge sample have relatively high methane production rate at average of 60% compared to other samples that used PVA beads and conductive materials.

All sample recorded high COD concentrations. PVA sample recorded the highest concentration of COD at average of 4300 mg/L while the lowest one was recorded by GT-Coarse at average of 2140 mg/L.

Acetic acid and propionic acid were analyze during VFA analysis. GT-Fine recorded the highest amount of propionate at average of 243 mg-C/L and lowest amount of acetate at average of 17 mg-C/L. PVA recorded lowest propionate concentration at average of 35 mg-C/L while PVA-GT recorded the highest amount of acetate at average of 49 mg-C/L.

4. Conclusion

Based on other researches, DIET via conductive materials is more effective in forming methane due to its high conductivity [2]. Thus, in this study, PVA-GT supposedly can produce the highest amount of methane gas and has the lowest concentration of COD compared to other samples. Based on VFA analysis, it can be said that the reactors does not undergoes complete methanogenesis as high concentration of VFA were recorded. Considering these factors, it might be the cause for irregular results. The newly set-up reactors might take some time to achieve stability and optimum conditions to ensure the efficiency of methanogens process. Further study is needed to obtain better results in future.

References

1) Baek G., Kim J., Kim J., Lee C. Role and potential of direct interspecies electron transfer in anaerobic digestion. Energies. 2018;11(1);107
2) Park h. J., Kang J. H., Park H. K., Park D. H. Direct interspecies electron transfer via conductive materials: A perspective for anaerobic digestion application. Bioresource Technology. 2018; 254;300-311
3) 黒田恭平, 延優, 幡本将史, 成廣隆, 山口隆司, 山内正仁, 山田真義 (2018). 天然鉱物を用いたメタン発酵促進技術の開発, 第 52 回日本水環境学会年会講演集, p. 577
4) Pham V. D., Leu T. B. Immobilized bacteria by using PVA (Polyvinyl alcohol) crosslinked with Sodium sulfate. International Journal of Science and Engineering (IJSE). 2014;41-47