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Comparison Biomethane Potential (BMP) Test of Sewage Sludge Recovered from Different Treatment Processes

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Abstract

Anaerobic digestion of sewage concentrates represents a very suitable means of generating bioenergy while reducing a huge amount of waste to disposal. Effective biogas production from sewage sludge can be achieved by optimizing operational conditions. In this study, the research was designed to compare the biogas production efficiency from sewage sludge recovered from coagulation and absorption process with sludge recovered from bioflocculation, centrifuged and chemical coagulation ($Al_2(SO_4)_3$+CMC) processes through biomethane potential experiment (BMP). From the results obtained, the maximum methane production rate of 56.85 $mLCH_4$/gCOD was achieved from concentrates collected during coagulation and absorption treatment process without solid retention time (SRT), concentrates collected during 0.5 d SRT had maximum methane production rate of 110.88 $mLCH_4$/gCOD, methane production rate of 154.28 $mLCH_4$/gCOD was achieved from 2 d SRT concentrate. The $Al_2(SO_4)_3$+CMC treated concentrate had methane yield of 143 $mLCH_4$/gCOD while bioflocculation concentrate had methane yield of 139 mL/gCOD and centrifuged concentrate had the yield of 124 mL/gCOD within the period of 22 to 29 days. The overall result showed that concentrates recovered from coagulation, adsorption and $Al_2(SO_4)_3$+CMC processes produced the highest methane with better efficiency and recorded the most stable performance throughout the period of the experiment and this encouraged the future use in anaerobic digestion for large scale methane production.

Keywords: Biomethane potential; Sewage concentrate; Methane; Coagulation and adsorption; Bioflocculation; Centrifuged concentrate; Chemical coagulation

Introduction

It is important to ascertain methane potential of sewage concentrate before long term anaerobic digestion process for methane recovery. Biomethane potential (BMP) test is the best method to achieve this purpose. BMP is a lab-scale test, usually lasting 30 days. It was developed to determine the anaerobic biodegradability of a substrate or feedstock [1]. This substrate is usually tested in a laboratory environment under optimal conditions. The results obtained from the test can ascertain the concentration of organics in a substrate that can be anaerobically converted to biogas or methane [2]. This is then used to evaluate the potential efficiency of the anaerobic process for a specific waste. Although, the configuration of anaerobic digestion reactors and some parameters such as longer SRT may enhance high methane production than BMP but BMP test remains the best method to initially test biogas production from sewage concentrate and other wastes [3]. Several authors have indicated BMP yield for different results depending on the type of method used [4].

Browne et al. [5] stated that sewage sludge produced unsuitably substrate for commercial-scale anaerobic digestion for bioenergy recovery because of their low solid content and low methane yield as compared to food waste, kitchen waste and vegetable waste [5]. However, in a recent study by Jin et al. [6] Sewage concentrate has been identified as bioenergy potential substrate that will contribute to future green energy considering the huge amount of sludge recovered from wastewater treatment process [6]. As such, effective biogas recovery from sewage concentrate depends on the treatment process used. Sewage concentrates recovered from coagulation and adsorption process have proven to produce a suitable concentrate with COD value suitable for bioenergy recovery [7]. Jin et al. [6] used highbred coagulation-microfiltration reactor for sewage treatment and achieved concentrate with COD value of 15,000 mg/L suitable for bioenergy recovery [6]. Other methods of sewage treatment for concentration efficiency include bioflocculation method, chemical coagulation ($Al_2(SO_4)_3$+CMC), and mechanically enhanced concentration process.

During bioflocculation, microorganisms act on suspended organic matters which make them clump together as floc. Then the floc may float on the surface of the water, bottom or sometimes filtered out of the liquid [8]. Bioflocculants generally have received attention recently due to their biodegradability strength and lack of secondary pollutants from their degradative intermediates. High loaded membrane bioreactor (MBR) can concentrate sewage organic matter by aerobic bioflocculation for anaerobic conversion to methane in a very short solid retention time (SRT) [9]. Bioflocculation process is crucial for membrane bioreactor and conventional activated sludge process to enhance floc formation and sludge settleability during treatment [10]. The procedure to bioflocculants production is generally found to be at the late period of the process or the stable period of bacterial growth. Energy recovery from sewage concentrates may play a vital role in reducing the amount of waste generating daily and reduce the issue of global warming due to direct emission of methane from untreated sewage sludge.

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However, apart from separate studies on bioenergy recovery from concentrated sewage, there are limited publications that properly assessed and compared the optimum methane potential of sewage concentrates recovered from several treatment processes. As the spectrum of potential substrates for biogas production expands to include sewage concentrates recovered from different processes and organic waste, a suitable approach to determine the methane potential of substrate is the BMP test. In this study, the experiment was designed to compare BMP of sewage concentrates collected from pilot-scale membrane coagulation and absorption process with BMP of substrates collected from bioflocculation, centrifuged and chemical coagulation ($Al_2(SO_4)_3$+CMC) processes based on their methane proportion.

Materials and Methods

Experimental setup

The instrument reactor set up used for the experiment comprises of three units, a, b, c as indicated in Figure 1. It consists of a water bath that controls temperature with the reactors of 200 mL volume placed in the bath with a mixer that continuously stirred, A CO_2 fixing unit with NaOH that often absorb the CO_2 and hydrogen sulfide produced in the course of AD process, also consisting a gas measuring unit that comprises of 15 cells in which the gas is measured from water displacement. Vial glasses of 200 mL were provided, 50 mL of substrates was added to the bottles. One of the bottles served as a blank sample. In each of the bottles, 150 mL of BMP activator (microorganism) was added and 150 mL of pure water was added to the blank bottle, 0.5 g of $NaHCO_3$ was added to each of the three bottles, 2 mL of reagent A, 0.4 ml of reagent B, and 0.2 ml of reagent C,D, and E were added to the three bottles accordingly, the pH value of the three set up were checked. In a situation where the pH was above the required value of 6.8 and 7.0, several drops of hydrochloric acid (HCl) was added to drop or balance the value and when the pH value was too low, NaOH was added to step up the pH value, extra bottles were provided with sludge and 10 g/l of NaOH was added to each vial bottle, The three bottles were fixed into nitrogen gas tube to remove oxygen present in the reactor for about 5 minutes, the bottles were then connected to the BMP machine and the data software was restarted for the experiment to proceed.

Sewage concentrate used

The sewage concentrates used was taken from Xiao Jiahe municipal wastewater treatment plant in Beijing P.R China. The plant treats 20,000-ton sewage each day which is usually collected from nearby communities and had no mixture of industrial wastewater. The plant treats sewage with different processes including bioflocculation, chemical coagulation ($Al_2(SO_4)_3$+CMC), coagulation and absorption process. BMP study was tested on all substrates simultaneously.

Analytical method

Anaerobic biodegradability test of the substrates was carried out using automatic methane potential test system of bioprocess Sweden. The system has the same measuring principles as conventional methane potential tests which made the result comparable with standard methods; however, it provides efficient information which provides a better understanding of the degradation dynamics behavior of a specific biomass substrate and improved process operations. Three criteria were used to evaluate BMP anaerobic feedstock in the lab and this includes feedstock characterization: This involves the test for chemical oxygen demand (COD), volatile suspended solids (VSS), pH, and total suspended solids (TSS). Results obtained prior to the experiment are used to know the quantity of feedstock needed to maintain the BMP or keep the BMP experiment stable for a long period, total biogas production: this was measured continuously throughout the BMP experiment by software designed for observing gas production, biogas analysis: Gas chromatography was often used to determine biogas composition during the BMP experiment. This instrument provides accurate and real measurements of the produced biogas during the BMP test. The set-up of gas chromatography enables it to determine the concentration of hydrogen gas, nitrogen, methane and carbon dioxide. Matrix laboratory (MATLAB) computing environment was used to simulate the overall results, plotting of functions and data analysis for efficient results interpretation. Previous studies documented the importance and efficiency of MATLAB in data analysis [11-16].

Results and Discussion

Bioflocculation, centrifuged and chemical coagulation ($Al_2(SO_4)_3$+CMC) substrate

Results from the three BMP test showed that bioflocculation substrate enhanced degradability in BMP process and produced methane rapidly. The gas production increased gradually from the beginning of the experiment to a stable state within 7th day of the experiment as shown in Figure 2. Gas production was stable throughout the remaining period of the experiment. The result showed that there is a large variation in actual methane production from the stream of biofllloculation enhanced substrate. The average methane yield during the stable condition was 20 mL. Even though bioflocculated sewage sludge can be affected by numerous chemical, physical and biological parameters, the BMP results demonstrated that it is possible to initiate and maintain methane production from bioflocculated sludge by controlling the most important process performance factors as process performance was suggested to have influenced the stability in methane

Figure 1: The bio process reactor used for the BMP test (a) Flow cells that transmit data (b) NaOH trap CO_2 (c) AMPTS II.

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production at the later stage of the experiment. Methane production from bioflocculated concentrate was characterized by rapid microbial biodegradation. This perhaps indicates that sewage sludge recovered from bioflocculation process is easily biodegradable and undergoes biodegradation quickly within few days of anaerobic digestion. Extracellular polymeric substances excreted from bacteria during bioflocculation is an important components that serve as carbon and energy during the digestion process and this was suggested to have influence methane production.

Chemical coagulation sewage sludge used was recovered from Ultrafiltration membrane that treats sewage with the addition of $Al_2(SO_4)_3$+CMC when brought into contact with water, they formed positively charge aluminum hydroxide floc which agglomerates the negatively charged bacteria, clays, silt and organic matters causing them to settle at the bottom of the membrane. The sludge was then used as a substrate for BMP test. Results from the BMP test revealed that chemical coagulation process produced a suitable concentrate for anaerobic digestion process for biogas recovery. Biogas production was stable on the 8th day of the experiment with average volume of 19.4 mL.

Centrifuged concentrates refer to the sewage sludge that was mechanically sieved, the particles, and soluble organic matters were settled at the bottom as concentrates. The concentrate was used as feed substrate in the second vial BMP bottle. Gas production increased from the beginning to the 8th day. The degradability and gas production fluctuated within 17 mL and 16 mL throughout the stable period of the experiment. The biochemical methane potential result from centrifuged sludge showed a significant difference when compared to bioflocculation and chemical coagulation sludge. Centrifuged sludge can undergo anaerobic biodegradation but the rate of production of methane from the sludge is very low. This was suggested to be as a result of the presence of easily degradable and none easily degradable organic particles that was forced to settle at the bottom during centrifugation. Easily degradable substances only were methanized during the 27 days BMP test. Biogas productions from bioflocculation enhance substrates was much higher than the mechanically enhanced substrate and $Al_2(SO_4)$+CMC substrates.

Methane yield

Figure 3 depicts methane yield per gram COD of the three substrates. Biodegradability from the three processes revealed differences in methane yield. The $Al_2(SO_4)_3$+CMC enhanced substrate had the highest methane yield of 143 mL/gCOD while the concentrate from bioflocculation had the second highest methane yield of 139 mL/gCOD. The centrifuged substrate produced the lowest methane with the methane yield of 124 mL/gCOD. The BMP result conducted on the three different substrates collected revealed that biogas potential in sewage concentrates depends highly on the pretreatment process. The bioflocculation enhanced substrate and $Al_2(SO_4)_3$+CMC enhanced substrate produced more biogas than the mechanically sieved or centrifuged substrate. However, the result here was compared to the BMP result from substrates collected from pilot-scale enhanced membrane coagulation reactor (E-MCR) which was treated with coagulation and adsorption process. The biodegradation kinetics was studied and the result showed that the biodegradability of the sewage concentrates used was different. The metabolic activity was different from the three samples. This was explained that the behavior of the sewage sludge was dependent on its ability to break down organic matter according to classes of biodegradation

BMP test result of concentrates recovered from coagulation and absorption process

Concentrates were collected from enhanced membrane coagulation reactor (E-MCR) during different operational conditions (startup period, 0.5d and 2d SRT). The startup period had COD value within12081 mg/L. This was high because of the continuous concentration without discharge, and the concentrate value collected during 0.5 days SRT was within 6508 mg/L while the concentrates collected during 2 days SRT was within 8815 mg/L. Table 1 shows COD variation of the collected concentrates from E-MCR. The total solid per gram per liter during the startup period without discharge was within 12.5 g/L, 6.3 g/L during 0.5 d SRT and 8.9 during 2 days SRT. The result obtained during the BMP test is shown in Figure 4. The curve indicated that there was no delay in methane production which showed that these

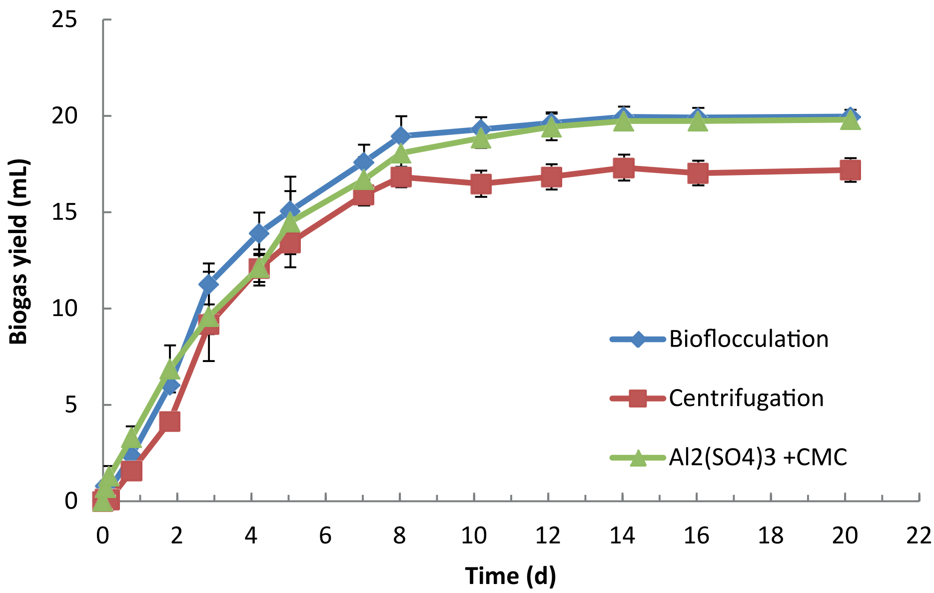

Figure 2: BMP of sewage conctrates collected from bioflocculation, centrifugation and chemical coagulation process.

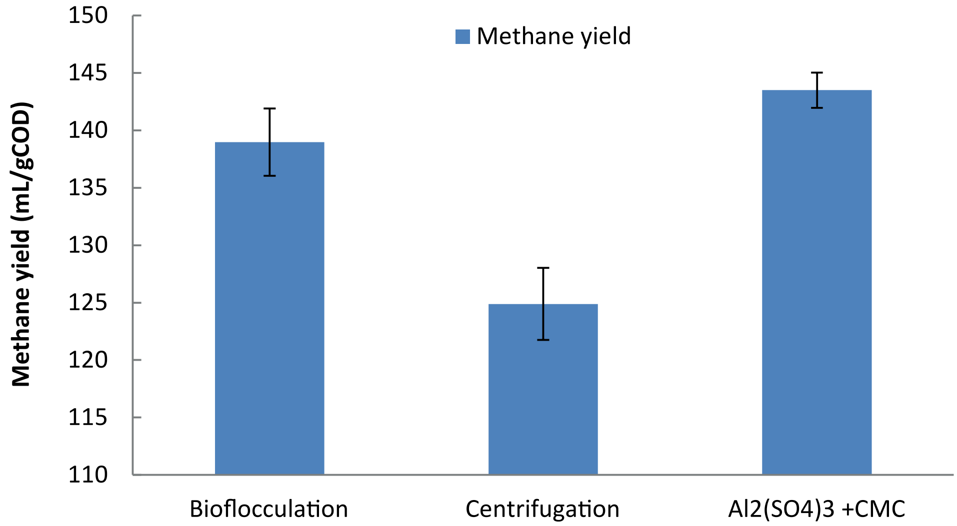

Figure 3: Methane yield from the three BMP process of bioflocculation, centrifuged and chemical coagulation substrate.

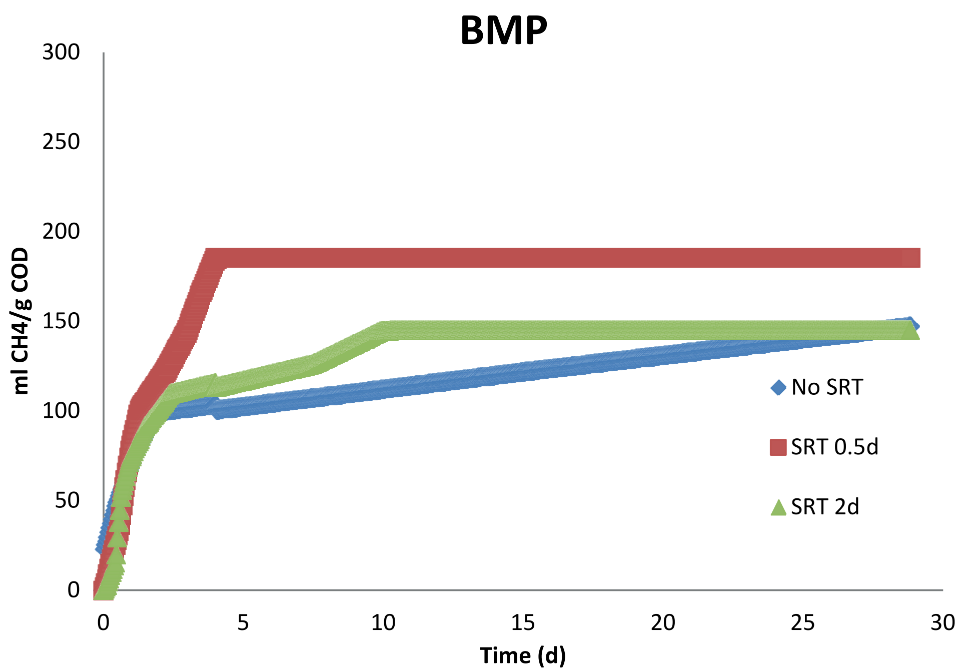

Figure 4: BMP of concentrates from E-MCR coagulation and absorption process.

	COD(mg/L)	TS(g/L)	VS(g/L)	pH
No Discharge	12081 ± 345	12.5 ± 0.6	6.5 ± 0.2	7.78
SRT0.5d	6508 ± 117	6.3 ± 0.2	3.5 ± 0.1	7.82
SRT2d	8815 ± 136	8.9 ± 0.3	4.5 ± 0.2	7.79

Table 1: COD variation of collected concentrate with different SRT conditions.

Condition	Anaerobic Biodegradability	Maximum methane production ($mlCH_4/gCOD$-d)
No discharge	0.42	56.85
0.5d SRT	0.53	110.88
2d SRT	0.41	154.28

Table 2: Anaerobic biodegradability of the sewage concentrate.

sewage concentrates are highly biodegradable under suitable anaerobic digestion conditions. However, concentrates from 0.5 day SRT had the highest methane production rate even with the low COD concentration. The gas production increased gradually from the startup day to a stable state on the 4th day; the methane production per gram COD during the stable period was 180 ml CH_4/g COD while the production from concentrates collected during 2 d SRT was stable on day 10 but the methane production was less than that of 0.5 d concentrate, with the production at the steady state within 140 $mlCH_4$/gCOD. The period without discharge had the lowest biogas production. This is because it was difficult for the highly concentrated sewage to degrade and produce biogas. However, the suitable concentrate for the BMP test was the one from 0.5d SRT and 2 d SRT.

From the result, concentrates collected during the startup period without discharge indicated a delay in methane production with the anaerobic biodegradability of 0.42 and with the maximum methane production rate of 56.85 mlCH_4/gCOD·d. Concentrates collected during 0.5d SRT had the highest anaerobic biodegradability rate with the value of 0.53 and maximum methane production rate of 110.88 mlCH_4/gCOD·d. However, the methane production rate of the period with 2d SRT was the highest with the maximum methane production rate of 154.28 mlCH_4/gCOD·d. Table 2 shows anaerobic biodegradability rate from the concentrates collected during the three different operational conditions of pilot scale enhanced membrane coagulation reactor.

Conclusion

The BMP test was used to verify the variability of methane gas between different potential substrates for biogas production. It was also used to determine the potential toxic substrate and biomethane kinetics in biogas production. From the results presented in this research, it was concluded that substrates collected from coagulation and absorption process had the highest methane potential. A continuously fed anaerobic digestion process is needed to determine the actual organic loading rate and a suitable HRT for maximum and long term methane production and to monitor inhibitory compounds like ammonia which is required to check long term suitability of feed substrates during digestion process. Thus, a small scale continuous stirred tank reactor (CSTR) anaerobic digester is required to accurately access the long term digestion stability of the sewage concentrates recovered from coagulation and absorption process.

Overall, the various methane potential test shows that coagulation and absorption process for sewage treatment for organic matter recovery has a greater advantage in concentration efficiency suitable for anaerobic digestion process for biogas recovery

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References

1. Nizami AS, Murphy JD (2010) What type of digester configurations should be employed to produce biomethane from grass silage?. Renewable and Sustainable Energy Reviews 14: 1558-1568.
2. Kaparaju P, Ellegaard L, Angelidaki I (2009) Optimisation of biogas production from manure through serial digestion: Lab-scale and pilot-scale studies. Bioresour Technol 100: 701-709.
3. Thamsiriroj T, Murphy JD (2011) A critical review of the applicability of biodiesel and grass biomethane as biofuels to satisfy both biofuel targets and sustainability criteria. Applied Energy 88: 1008-1019.
4. Angelidaki I, Alves M, Bolzonella D, Borzacconi L, Campos JL, et al. (2009) Defining the biomethane potential (BMP) of solid organic wastes and energy crops: a proposed protocol for batch assays. Water Sci Technol 59: 927-934.
5. Browne JD, Allen E, Murphy JD (2014) Assessing the variability in biomethane production from the organic fraction of municipal solid waste in batch and continuous operation. Applied Energy 128: 307-314.
6. Jin Z, Gong H, Wang K (2015) Application of hybrid coagulation microfiltration with air backflushing to direct sewage concentration for organic matter recovery. J Hazard Mater 283: 824-831.
7. Gong H, Jin Z, Wang X, Wang K (2015) Membrane fouling controlled by coagulation/adsorption during direct sewage membrane filtration (DSMF) for organic matter concentration. Journal of Environmental Sciences 27: 1-7.
8. Vogelaar JCT, De Keizer A, Spijker S, Lettinga G (2005) Bioflocculation of mesophilic and thermophilic activated sludge. Water Res 39: 37-46.
9. Faust L, Temmink H, Zwijnenburg A, Kemperman AJB, Rijnaarts HHM (2014) High loaded MBRs for organic matter recovery from sewage: Effect of solids retention time on bioflocculation and on the role of extracellular polymers. Water Research 56C: 258-266.
10. Van Dierdonck J, Van den Broeck R, Vervoort E, D'haeninck P, Springael D, et al. (2012) Does a change in reactor loading rate affect activated sludge bioflocculation?. Process Biochemistry 47: 2227-2233.
11. Khoshravesh M, Sefidkouhi MAG, Valipour M (2015) Estimation of reference evapotranspiration using multivariate fractional polynomial, Bayesian regression, and robust regression models in three arid environments. Applied Water Science.
12. Valipour M (2014) Handbook of Drainage Engineering Problems. OMICS Group eBooks.
13. Valipour M (2015a) Calibration of mass transfer-based models to predict reference crop evapotranspiration. Applied Water Science.
14. Valipour M (2015b) Handbook of Environmental Engineering Problems. OMICS Group eBooks.
15. Valipour M (2016) Optimization of neural networks for precipitation analysis in a humid region to detect drought and wet year alarms. Meteorological Applications 23: 91-100.
16. Yannopoulos S, Lyberatos G, Theodossiou N, Li W, Valipour M, et al. (2015) Evolution of Water Lifting Devices (Pumps) over the Centuries Worldwide. Water 7: 5031-5060.

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