International Journal of Engineering & Technology, 7 (3.11) (2018) 254-257

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Influence of temperature and water to poultry waste ratio on methane production from anaerobic digestion

Hazwani Hasmi[1]*, Faieza Buyong[1]

[1]Environmental Technology Programme, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Shah Alam, 40450 Selangor Darul Ehsan
**Corresponding author E-mail: eicha@salam.uitm.edu.my*

Abstract

The operating temperature and water to poultry waste ratio in anaerobic digestion process are among the factors that affect methane production. Therefore, this paper aimed to investigate the influence of temperature and water to poultry waste ratio on anaerobic digestion of poultry waste. In this study, three different temperatures were used; psychrophilic (25 °C), mesophilic (35 °C) and thermophilic (55 °C), while two different water to poultry waste ratio were examined; 1: 1 and 2: 1 (water: poultry waste). The methane production was the highest at mesophilic temperature followed by psychrophilic and thermophilic temperature with cumulative amount of methane at 14.99 x 10^{-3} L, 0.62 x 10^{-3} L and 0.22 x 10^{-3} L respectively. The highest methane production was observed at the water to poultry waste ratio of 2: 1 followed by ratio 1: 1 with cumulative amount of methane production at 0.11 x 10^{-3} L and 0.05 x 10^{-3} L.

Keywords: *Anaerobic digestion, poultry waste, methane, temperature, water to poultry waste ratio,*

1. Introduction

High demand of poultry products had led to the growth of poultry industry. The intensification growth of poultry industry had resulted in accumulation of organic residues such as blood, feathers and offal [15]. These organic residues could become an issue related to environment if they were not managed properly [4].

In this regard, anaerobic digestion is one of the suitable technologies that can be adopted to treat high organic waste while producing clean renewable energy such as methane gas [1]. In addition, anaerobic digestion has several advantages such as low initial operation cost, low energy requirement during the process and low sludge production [13]. Anaerobic digestion is a complex bioprocess that involves microorganisms in the absence of oxygen. There are four stages in anaerobic digestion; hydrolysis, acidogenesis, acetogenesis and methanogenesis. At the beginning of anaerobic digestion process, complex organic compound such as lipids, polysaccharide, proteins and nitrates are degraded by hydrolysis process into simpler compounds such as fatty acids, monosaccharide and amino acids. During acidogenesis, the hydrolysis products are converted into hydrogen, acetic acid and some into volatile fatty acids and alcohols by facultative anaerobic bacteria. This is followed by acetogenesis process, where acid former bacteria converts long chain fatty acids and volatile fatty acids into acetate, hydrogen and carbon dioxide. Finally, methanogenic bacteria decompose acetic acid, hydrogen and carbon dioxide into methane and carbon dioxide at methanogenesis stage [14].

The stability of anaerobic digestion can be affected by several factors including pH, temperature, and carbon and nitrogen ratio, addition of sludge and ratio of water added to poultry waste [7]. One of the key variable in anaerobic digestion is temperature; psychrophilic (25 °C), mesophilic (35 °C), and thermophilic (55 °C), temperature. Although there are three different temperature, Sibiya et al., (2014) reported that mesophilic and thermophilic temperature were more favorable for anaerobic digestion process compared to psychrophilic temperature. In contrast, Zinder et al. (1984) stated that higher temperature could be detrimental for anaerobic digestion process as it could kill the microbes population present in anaerobic digester and reduce the methane production [17, 19].

Water to poultry waste ratio is equally as important as temperature. Water is important throughout the anaerobic digestion process as it helps in dissolving the nutrient contain in substrate before it is used by the microorganisms and also helps in pH buffering reaction [8]. The aim of the present study is to investigate the influence of temperature and water to poultry waste ratio on methane production from the anaerobic digestion of poultry wastes.

2. Methodology

2.1. Materials

Poultry wastes used in this study consisted of chicken fats and chicken intestine collected from a slaughtering house in Meru, Klang, Selangor. Inoculum used in this study is Palm Oil Mill Effluent (POME) that was collected from Tuan Mee Palm Oil Mill in Sungai Buloh, Kuala Selangor, Selangor. The experiment was carried out by using 120 ml of serum bottle with 70 ml of effective working volume as bioreactors.

2.2. Influence of water and poultry waste ratio

To ascertain the ratio of water to poultry waste for the optimization of methane production, two different ratios were tested; 1: 1 and 2: 1 (water: poultry waste). The mixture of water and poultry waste at two different ratios were blended by using Waring Commercial blender until it became slurry. Then, POME was added to the slurry as a source of inoculum. After that, 70 ml of the slurries at the ratio of 1: 1 and 2: 1 were poured in serum bottles separately. The serum bottles were then maintained at 35°C in a water bath.

2.3. Influence of temperature

The mixture of water and poultry waste at the ratio of 2: 1 (water: poultry waste) was blended until it became slurry. Then the slurry was added with POME at the ratio of 2: 1 (POME: slurry) and poured into serum bottles. To study the influence of temperature on the methane production, the serum bottles were maintained at three different temperature; psychrophilic temperature (25 °C), mesophilic temperature (35 °C), and thermophilic temperature (55 °C) in duplicates. Temperature was controlled by using water bath.

2.4. Measurement of methane production

Methane production was measured daily within hydraulic retention time of 15 days by using gas chromatography with flame ionization detector (GC- FID).

3. Results of research

3.1. Influence of water to poultry waste ratio

The results show that the water to poultry waste ratio had influenced the methane production. Figure 1 and Figure 2 depict the cumulative and daily volume of methane production of poultry waste at the ratio of 1: 1 and 2: 1 (water: poultry waste). From Figure 1, the highest methane production was observed at the ratio of 2: 1 followed by ratio 1: 1 with cumulative amount of methane at 0.11 x 10^{-3} l and 0.05 x 10^{-3} l.

As can be seen in Figure 2, the daily methane production for both of the ratios had similar trends. Although the trends were identical, methane production was higher when the poultry waste was added with water at the ratio of 2: 1 compared to ratio of 1: 1 with the range of methane production at 0.002 x 10^{-3} l- 0.01 x 10^{-3} l and 0.001 x 10^{-3} l- 0.005 x 10^{-3} l respectively. Methane production was immediately started at day 0 for both of the ratios with the volume of 0.001 x 10^{-3} l and 0.002 x 10^{-3} l. Previous study by Jha et al. (2013) explained that the degradation process of substrates improved with the addition of water. On day 1 until day 5, slight fluctuated trends were shown for both of the ratios. These trends occurred due to rapid digestion of sugars and amino acids as they were not inhibited by pH reduction hence increased the methane production [12]. On the other hand, methane production reduction may be resulted from the slow degradation of long chain fatty acids and hydrogen due to low tolerance of pertinent bacteria upon low pH [11]. On day 6 until day 8, the methane production continued to increase. This is because, the natural composition that is contained in the substrate and inoculum act as a buffer. Lehtomaki et al. (2007) reported that methane production rose when microorganisms are adapted to their environment. On day 9 until day 15, the methane production of poultry waste added with water at the ratio of 1: 1 started to decline from 0.004 x 10^{-3} l until 0.003 x 10^{-3} l while methane production of poultry waste added with water at the ratio of 2: 1 showed a slightly different trend. On day 9 until day 10, methane production of poultry waste added with water at the ratio of 2: 1 dropped from 0.009 x 10^{-3} l until 0.006 x 10^{-3} l. After that, on day 11 until day 12, the methane production increased again. This trend most likely happened due to the accumulation of volatile fatty acids and rose again because of the acclimation of the microorganisms with their surroundings [14]. Finally, the methane production for both of the ratios decreased. The decrement of methane production most probably happened due to no feeding process which led to deterioration of food source which is needed by the microorganisms in order to have the energy to do their work effectively [16].

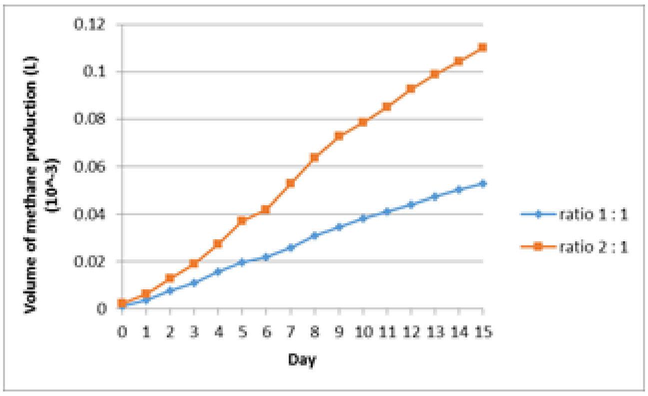

Fig.1. Cumulative volume of methane production at different water to poultry waste ratio

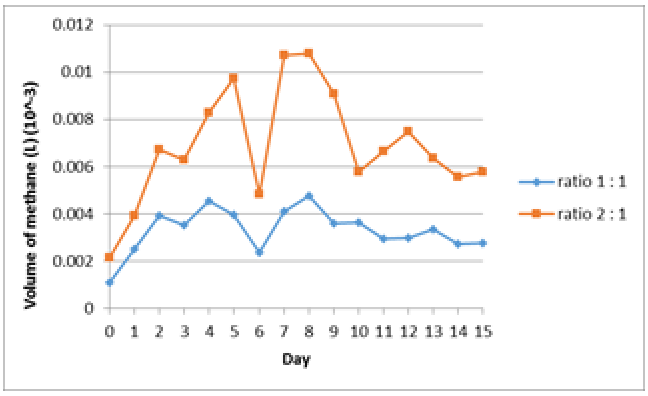

Fig.2. Daily methane production at different water to poultry waste ratio

3.2. Influence of temperature

The influence of temperature on methane production through anaerobic digestion of poultry waste was investigated by using three different temperature; psychrophilic (25 °C), mesophilic (35 °C) and thermophilic (55 °C). Methane production of each temperature were measured daily within 15 days of hydraulic retention time. Figure 3 and Figure 4 illustrate the cumulative and daily volume of methane production at different temperature.

Figure 3 shows the daily trend of methane production at three different temperatures. The methane production range at psychrophilic, mesophilic and thermophilic temperature were 0.01 x 10^{-3} l- 2.5 x 10^{-3} l, 0.006 x 10^{-3} l- 0.18 x 10^{-3} l and 0.005- 0.02 x 10^{-3} l. From Figure 4, it can be clearly observed that the highest methane production was achieved at mesophilic temperature with cumulative amount of methane production at 14.99 x 10^{-3} l followed by psychrophilic and thermophilic temperature with cumulative amount of methane at 0.62 x 10^{-3} l and 0.22 x 10^{-3} l.

As can be seen in Figure 4, methane production on day 0 until day 9 for the anaerobic digestion operated at psychrophilic temperature was slightly increased from 0.006 x 10^{-3} l to 0.05 x 10^{-3} l. Slight increment could be a result of slow hydrolysis at low temperature [18]. On day 10 until day 12, the methane production was gradually decreased from 0.03 x 10^{-3} l to 0.01 x 10^{-3} l. The biochemical process were disrupted by the shrinkage of microbes population inside the digester due to their low tolerance upon low temperature hence, reduced methane production. Surprisingly, the methane production rose to 0.18 x 10^{-3} l on day 13 until day 15. This observation is in a good agreement with earlier studies by Dhaked et al. (2010) which discovered that the degradation process was slow at low temperature. Therefore, longer retention time is needed to produce more methane gas.

After 15 days of anaerobic digestion, it was found that anaerobic digestion operated at mesophilic temperature yielded the most methane gas. On day 0 until day 9, the methane production at mesophilic temperature showed an upward trend with the volume of methane between 0.01 x 10^{-3} l to 1.77 x 10^{-3} l. Eze and Uzodinma, (2009) reported that mesophilic temperature is the most suitable temperature range for most of the methane performing microorganisms. So, the microorganisms worked effectively and increase the methane production. Apart from that, Leven et al. (2007) also stated that anaerobic digestion operated at mesophilic temperature was less affected by the inhibition of ammonia. On day 10 until day 12, the methane production dropped from 1.76 x 10^{-3} l until 0.69 x 10^{-3} l. The inhibition of long chain fatty acids may be one of the reason why the methane production decreased. Accumulation of long chain fatty acids could reduce the pH inside the digester and disrupt the methane production. On day 13, methane production increased to 2.5 x 10^{-3} l due to acclimation of methanogenic bacteria [12]. On day 14 until day 15, methane production shrunk from 2.47 x 10^{-3} l to 0.99 x 10^{-3} l as there was no feeding process [16].

At thermophilic temperature, the methane production showed fluctuated trend with low volume of methane. From the plotted graph in Figure 4, the highest methane production occurred on day 11 with a volume of 0.02 x 10^{-3} l. Previous study by Sibiya et al. (2014) pointed out that operating anaerobic digestion at thermophilic temperature led to unstable digestion process and resulted in low methane production due to the inhibition of ammonia that increased the pH values. The interaction between ammonia and pH caused the anaerobic digestion process to be inhibited at a steady state where the digestion process progressed slowly with a very low volume of methane. According to Hashimoto (1983), microorganisms do not acclimatise towards ammonia during thermophilic anaerobic digestion.

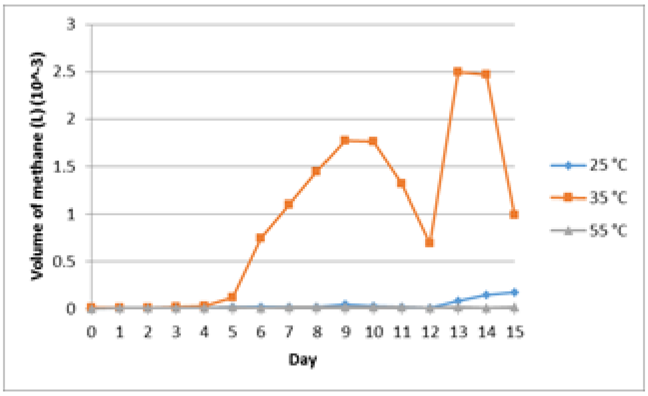

Fig.3. Daily methane production at different temperature; psychrophilic (15 °C), mesophilic (35 °C), thermophilic (55 °C)

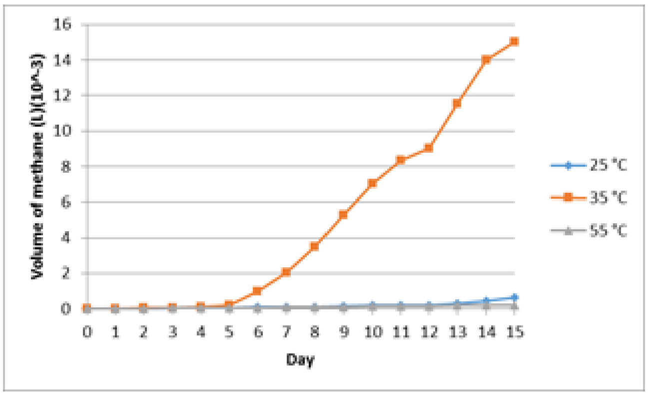

Fig.4. Cumulative methane production at different temperature; psychrophilic (15 °C), mesophilic (35 °C), thermophilic (55 °C)

4. Conclusion

It can be concluded that temperature and ratio of water to poultry waste affects the performance of methane production. The most preferable temperature was at mesophilic temperature followed by psychrophilic and thermophilic temperature while the ratio of 2: 1 (water: poultry waste) turned out to yield more methane gas compared to the ratio of 1: 1.

Acknowledgement

The authors would like to thank Universiti Teknologi MARA and Faculty of Applied Sciences, UITM Shah Alam for their assistance during the project.

References

[1] Budiastuti H, Widyabudiningsih D, & Kurnia D R D (2017). *IOP Conference Series: Materials Science and Engineering*, Temperature effect towards methane gas production and performances of anaerobic fixed bed reactors 162(1).

[2] Chen T H, & Hashimoto A G. *Bioresource Technology* (1996), Effects of pH and substrate:inoculum ratio on batch methane fermentation. 56, 179–186.

[3] Dhaked R K, Singh P, & Singh L (2010). *Waste Management*. Biomethanation under psychrophilic conditions 30(12), 2490–2496.

[4] Edwards D R, & Daniel T C (1992). *Bioresource Technology*. Environmental impacts of on-farm poultry waste disposal- A review 41, 9–33.

[5] Eze J I, & Uzodinma E O (2009). *The Pacific Journal of Science and technology*. Generation of Methane Gas from Poultry Brooding House 10(2), 942–948.

[6] Hashimoto A G. (1983). *Agricultural Wastes* Thermophilic and mesophilic anaerobic fermentation of swine manure 6, 175–191.

[7] Jha A K, Li J, Zhang L, Ban Q, & Jin Y (2013). *Advances in Water Resource and Protection (AWRP).* Comparison between Wet and Dry Anaerobic Digestions of Cow Dung under Mesophilic and Thermophilic Conditions 1(2), 28–38.

[8] Lay J.J, Li Y Y, & Noike T (1997). *Water Research*. Influences of pH and moisture content on the methane production in high-solids sludge digestion 31(6), 1518–1524.

[9] Lehtomäki A, Huttunen S, & Rintala J A (2007). *Bioresources, Conservation and Recycling* Laboratory investigations on co-digestion of energy crops and crop residues with cow manure for methane production: Effect of crop to manure ratio 51, 591–609.

[10] Levén L, Eriksson A R B, & Schnürer A (2007). *Federation of European Microbiological Societies (FEMS).* Effect of process temperature on bacterial and archaeal communities in two methanogenic bioreactors treating organic household waste 59(3), 683–693.

[11] Kabouris JC, Tezel U, Pavlostathis SG, Engelmann M, Dulaney J, Gillette RA, & Todd AC (2009). *Bioresource Technology*. Methane recovery from the anaerobic codigestion of municipal sludge and FOG *100*(15), 3701–3705

[12] Kangle KM, Kore SV, Kore VS, & Kulkarni GS (2012). *A Review*

Article (Open Access). Recent Trends in Anaerobic Codigestion *2*(4), 210–219.
[13] Kim J K, Oh B R, Chun Y N, & Kim S W (2006). *Journal of Bioscience and Bioengineering*. Effects of temperature and hydraulic retention time on anaerobic digestion of food waste 102(4), 328–332.
[14] Li, Jha A K, He J, Ban Q, Chang S, & Wang P (2011). *International Journal of the Physical Science*. Assessment of the effects of dry anaerobic co- digestion of cow dung with waste water sludge on biogas yield and biodegradability 6(15), 3723–3732.
[15] Marculescu C, & Stan C (2011). *Energy Procedia*. Poultry processing industry waste to energy conversion 6, 550–557.
[16] Saidu M, Yuzir A, Salim M R, Salmiati, Azman S, & Abdullah N (2013). *Bioresource Technology* Influence of palm oil mill effluent as inoculum on anaerobic digestion of cattle manure for biogas production 141, 174–176.
[17] Sibiya N T, Muzenda E, & Tesfagiorgis H B(2014). International Conference on Green Technology, Renewable Energy and Environmental Engineering, Effect of Temperature and pH on The Anaerobic Digestion of Grass Silage 27- 28.
[18] Zhu G, & Jha A K (2014). ScienceAsia. Psychrophilic dry anaerobic digestion of cow dung for methane production: Effect of inoculum 39, 500–510.
[19] Zinder S H, Anguish T, & Cardwell S C (1984). *Applied and Environmental Microbiology*. Effects of temperature on methanogenesis in a thermophilic (58 °C) anaerobic digestor *47*(4), 808–813.