IOP Conf. Series: Materials Science and Engineering **401** (2018) 012018 doi:10.1088/1757-899X/401/1/012018

Batch biodegradability study of fresh and aged food waste: performance and kinetic

Roslinda Seswoya*, Muhammad Fahmi Abd Rahman and Nur Aiza Darnak

Micro Pollutant Research Centre (MPRC)
Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

*roslinda@uthm.edu.my

Abstract. Peninsular Malaysia generates 17000 tonnes of municipal solid waste (MSW) per day in 2002 and it is estimated to increase to 31,000 tonnes per day on 2020, unfortunately food waste (FW) is the largest component of MSW. The high amount of FW generated related to landfill's main issues such as foul odour, toxic leachate, emission of greenhouse gases and vermin infestation. FW is highly potential in producing methane because it is rich in volatile solid. Therefore, the research trend on anaerobic digestion of FW has shifted for methane production because methane can be transformed to electrical energy production. The objective of this research is to evaluate the methane potential and kinetics of methane production from the anaerobic digestion of fresh and aged food waste taken from fast food restaurant. The methane production under mesophilic condition was monitored by using Automatic Methane Potential Test System II (AMPTS II). Triplicate sample reactors were prepared for each substrate (fresh and aged FW) at IS ratio of 2.0 on VS basis. Besides that, duplicate blank reactors were prepared concurrently, contained only inoculum. The fresh FW resulted in higher ultimate methane yield (M_o) and methane production rate (R_m). Comparing to results from fresh FW, the M_o and R_m observed from digestion of aged FW were decreased by 17% and 27% respectively. Kinetic analysis using Modified Gompertz modelling showed that M_o for fresh and aged FW were increased, as well as for lag phase (λ). Meanwhile the decreased R_m was observed for fresh and aged FW.

1. Introduction

Anaerobic digestion (AD) has been proven to be an efficient and green technology in disposing of sewage sludge, crop residues, food waste and animal manure [1], [2]. Anaerobic digestion is the condition in which several consortia of microorganisms simultaneously break down the biodegradable material - (organic wastes) without the presence of oxygen. Anaerobic digestion can be used to treat various organic wastes (substrate) and recover bio-energy in the form of biogas, which consists mainly of CH_4 and CO_2 [2]. The design and the performance of anaerobic digestion processes are affected by many factors such feedstock characteristics, reactor design and operation conditions. The physical and chemical characteristics of the organic waste are important information for designing and operating anaerobic digesters because they affect biogas production and process stability during anaerobic digestion [3].

A biochemical methane potential (BMP) test provides a preliminary indication of the biodegradability of a substrate (targeted organic waste) and its potential to produce methane via anaerobic digestion. The manually BMP setup requires periodically checking for the methane production by manual sampling and analysing the gas composition using gas chromatography (GC). Unfortunately, this approach is time- consuming and the regular checking should be at the earlier days of the BMP assay. Beside, the use of gas chromatography for the biogas composition identification stage is challenging due the method development. In practice, BMP test employed the large number of reactors and long incubation periods (e.g. over one month). Lately, the BMP test was conducted using the automatic methane potential test system (AMPTS) for on-line measurements of biodegradability tests. AMPTS II was used in anaerobic biodegradability study of FW [4], [5]. The inoculum to substrate (I/S) ratio of 2.0 was recommended for the BMP test for the digestion of FW in order to limit inhibition effects associated with accumulation of intermediate compounds, such as VFAs [6].

The Modified Gompertz modelling was typically applied model for the determination of methane production kinetics for the degradation of food waste [6]. The ultimate methane yield (M_o) of digestion FW observed from laboratory and Gompertz modelling differed slightly [6].

Based on literature search, it was found that no study has yet been conducted on the comparison of kinetic of methane production from the digestion of fresh FW and aged FW taken from fast food restaurant (generated in Malaysia). Commonly, the anaerobic digestibility study was conducted either for FW from university, canteen or household. Therefore, the main objective of this study is to evaluate the methane potential and kinetics of the digestion of FW collected from fast food restaurant. A series of batch BMP tests were conducted to investigate the effect of the storage time.

2. Material and methods

2.1. Substrate and inoculum

The FW was taken from the restaurant serving fast food. The FW was crushed by using kitchen blender for homogenizing the substrate [7]. The tap water is used for dilution [4]. In this study the fresh FW and aged FW were used as substrate, each at FW to tap water (FW:TP) ratios of 1:1 and 1:1.5 respectively. The inoculum, which was anaerobic bacteria were taken from existing full-scale anaerobic digester treating POME. It is a common practice to use anaerobic bacteria from existing anaerobic digester for the anaerobic digestibility study as described by Rajagopal [7]. The substrate and inoculum were stored in 4^{o}C in refrigerator until use [7].

2.2. Experimental Setup

The batch biodegradability test or BMP tests were conducted using 500 mL of Duran bottle. The BMP assays were conducted using Automatic Methane Potential Test System (AMPTS 11) (Figure 1), in which only methane pass through to the gas volume measuring device and recorded in unit C [8]. Two series of BMP test were conducted; 1) fresh FW (substrate and inoculum were fresh) and 2) aged FW (substrate and inoculum were stored for 7 days in refrigerator at 4^{o}C). The mass of substrate (FW) and the inoculum was calculated on the VS basis at inoculum to substrate ratio of 2.0. The reactors were purged with pure nitrogen in headspace to maintain anaerobic digestion condition were sealed [7]. The tests were done at mesophilic condition (37^{o}C) [4] and agitated at 150 rpm [6]. The triplicate sample reactors (substrate with inoculum) and duplicate blank reactors (only inoculum) were prepared for each BMP experiment [4]. In the termination day of BMP assay, the pH of each reactor were measured to confirm the pH remained in the acceptable range for stable anaerobic process.

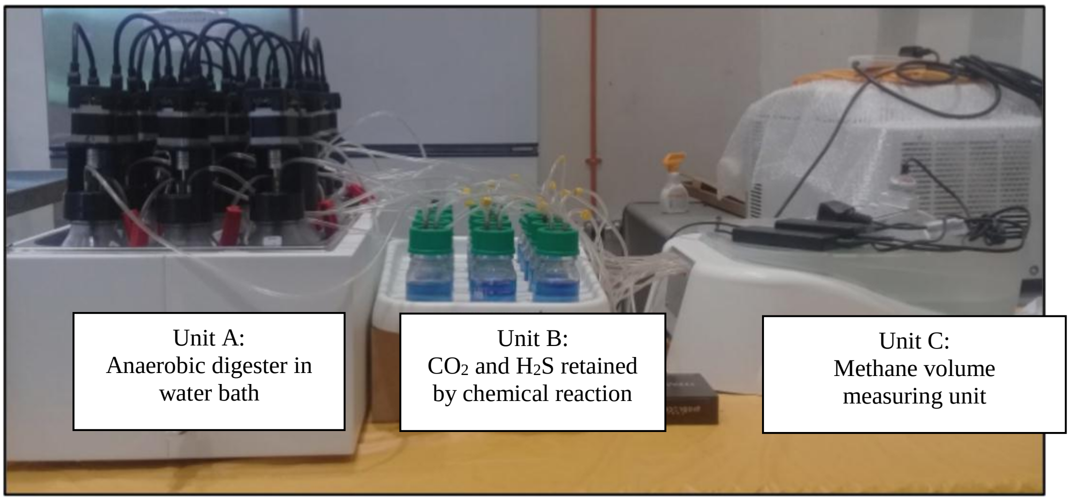

Figure 1. AMPTS II

2.3. Analytical Methods

The samples were measured for solids in g/L (TS and VS) and all tests were based on Standard Methods: procedure 2540G [9]. Meanwhile, VS in % was calculated following the calculation as shown by Bioprocess AB [8].

2.4. Batch kinetics modeling

In this study, the Modified Gompertz model was fitted to the experimentally observed cumulative methane production curves. The Modified Gompertz model has been widely applied in modelling batch methane production from FW digestion (Equation 1) [6], [10]. The parameter to be determined are ultimate methane yield (M_o) and maximum methane production rate (R_m) and lag phase (λ). Excel Solver was used to estimate M_o, R_m, and λ from the nonlinear graphs analysis which fit the experimental data set as recommended by Eskicioglu [11].

$$M = M_0 . \exp\left\{- \exp\left[\frac{R_m . e}{M_0}(\lambda - t) + 1\right]\right\} \quad (1)$$

Where,

M = Cumulative methane yield (mL /g VS added)
Mo = Ultimate methane yield (mL /g VS added)
Rm = Maximum methane production rate (mL /g VS added/day)
t = digestion time (t)
e = 2.718 [12]
λ = The lag phase time (day)

3. Results and Discussion

3.1. Substrate characteristics

The characteristics of substrates for this study are tabulated in Table 1. There was a difference of TS and VS between both samples, which fresh FW have higher TS and VS value compared to aged FW. These may occur because of the different dilution ratio used in the study. VS to TS ratios (VS/TS) typically range from 0.80 to 0.97 [13]. Meanwhile, VS/TS ratio for FW taken from fast food restaurant located at France was 0.93 [14]. This study suggested that the storage time (less than 10 day) is insignificant in changing the VS/TS ratio.

Table 1. Characteristics of FW analysed in this study (N =3)

Parameter	Types of substrates	
	Fresh FW	Aged FW
Total solids, TS (g/L)	155.33 ± 20.28	94.22 ± 3.67
Volatile solid, VS (g/L)	150.56 ± 17.19	90.89 ± 2.69
Volatile solid, VS (%)	4.19 ± 0.42	2.59 ± 0.05
VS/TS Ratio	0.97	0.96

3.2. Ultimate methane yield

Figure 2 showed the comparison of methane yield curve of two samples. The ultimate methane yield from fresh FW is slightly higher than that what been observed from aged FW sample, each at 2349.3 ml CH_4/ g VS and 1933.0 ml CH_4/ g VS respectively. The ultimate methane yield observed from this study was higher; about 4.5 and 3.7 times more than what was observed from fast food restaurant as observed by Capson-Tojo [14]. The effect of storage time of the substrate also being studied in this study. This study suggested that the longer storage time resulted in the lower ultimate methane yield. Lü [15] observed the vice-versa condition, in which the longer storage time improved acidification efficiency, and provide better substrate for methanization. This subsequently leads to significantly increased methane production. The methane production from the aged FW (collected for canteen and being stored for 7 days) was about 1.8 to 2.4 times higher than the fresh FW.

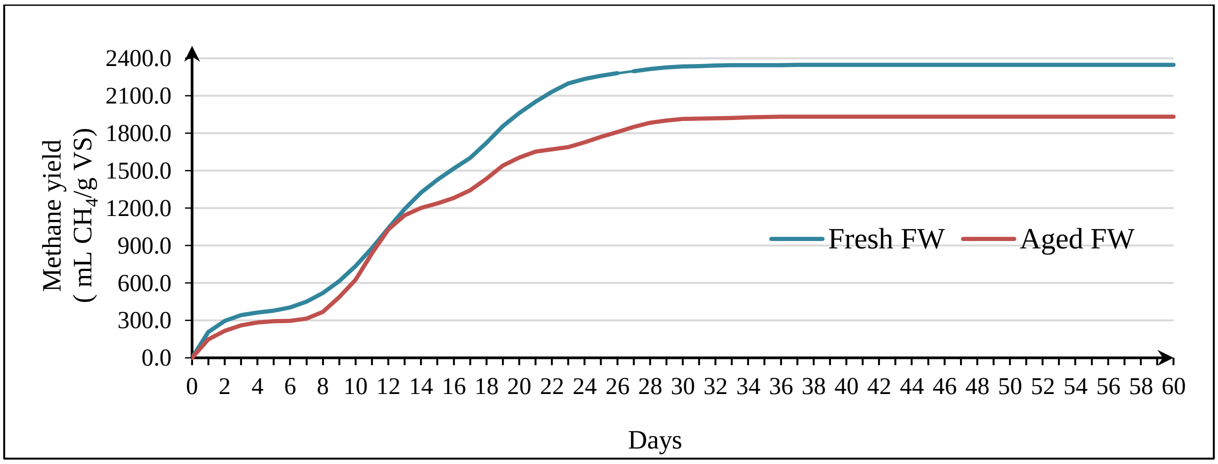

Figure 2. Methane yield curves from fresh and aged FW

3.3. Kinetics of methane production

The methane yield curve plotted using the laboratory data and Modified Gompertz modelling showed that more than 90% of the ultimate methane yield from fresh FW and aged FW were achieved at day 30. Therefore, as for the designing the anaerobic digester, the retention time could be assumed as 30 days. Table 2 showed the kinetic parameters observed from laboratory data and modelling. The ultimate methane yield (M_o) observed from modelling analysis for each digestion were higher than what was observed from the laboratory data, increased up to 7%. Meanwhile, the significant increase of lag phase (λ) and decrease of methane production rate (R_m) were observed from the modelling analysis. However, the lag phase (λ) is still less than two days.

Table 2. Kinetic equation parameters of methane production

Kinetic equation parameter	Fresh FW (Lab)	Fresh FW (Gompertz)	Aged FW (Lab)	Aged FW (Gompertz)
Mo (mL CH_4/gVS)	2349.35	2514.8	1933.02	2059.39
R_m (mL CH_4/gV/day)	148.8	93.24	108.08	79.63
λ (day)	0.04	0.98	0.04	1.58

4. Conclusion

The methane potential from the batch digestion of fresh and aged FW collected from fast food restaurant at inoculum to substrate (I/S) ratio of 2 under mesophilic condition showed a significant difference between them. However, the highest ultimate methane yield (M_o) and methane production rate (R_m) were observed from fresh FW. This showed that the digestion of this type of waste should be done freshly.

Acknowledgements

The authors wished to thank Universiti Tun Hussein Onn Malaysia for the funding of this research (TIER 1-Vot U844). We also wish to thank Cenergi SEA Sdn. Bhd for their cooperation

References

[1] X. Dai, N. Duan, B. Dong, and L. Dai, "High-solids anaerobic co-digestion of sewage sludge and food waste in comparison with mono digestions : Stability and performance," *Waste Manag.*, vol. 33, no. 2, pp. 308–316, 2013.

[2] M. S. Prabhu and S. Mutnuri, "Anaerobic co-digestion of sewage sludge and food waste," *Waste Manag. Res.*, vol. 34, no. 4, pp. 307–315, 2016.

[3] R. Zhang *et al.*, "Characterization of food waste as feedstock for anaerobic digestion," *Bioresour. Technol.*, vol. 98, pp. 929–935, 2007.

[4] V. Cabbai, M. Ballico, E. Aneggi, and D. Goi, "BMP tests of source selected OFMSW to evaluate anaerobic codigestion with sewage sludge," *Waste Manag.*, vol. 33, no. 7, pp. 1626–1632, 2013.

[5] Y. Li, Y. Jin, H. Li, A. Borrion, Z. Yu, and J. Li, "Kinetic studies on organic degradation and its impacts on improving methane production during anaerobic digestion of food waste," *Appl. Energy*, vol. 213, no. September 2017, pp. 136–147, 2018.

[6] G. De Gioannis, A. Muntoni, A. Polettini, R. Pomi, and D. Spiga, "Energy recovery from one- and two-stage anaerobic digestion of food waste," *Waste Manag.*, vol. 68, pp. 595–602, 2017.

[7] R. Rajagopal, J. W. Lim, Y. Mao, C.-L. Chen, and J. Y. Wang, "Anaerobic co-digestion of source

segregated brown water (feces-without-urine) and food waste: For Singapore context," *Sci. Total Environ.*, vol. 443, pp. 877–886, 2013.

[8] Bioprocess Control, *AMPTS II Operation and Maintenance Manual*. Sweden, 2014.

[9] APHA, *Standard Methods for the Examination of Water and Wastewater*, 20th ed. New York: Water Environmental Federation, 2005.

[10] B. Deepanraj, V. Sivasubramanian, and S. Jayaraj, "Effect of substrate pretreatment on biogas production through anaerobic digestion of food waste," *Int. J. Hydrogen Energy*, vol. 42, no. 42, pp. 26522–26528, 2017.

[11] C. Eskicioglu, K. J. Kennedy, and R. L. Droste, "Characterization of soluble organic matter of waste activated sludge before and after thermal pretreatment.," *Water Res.*, vol. 40, no. 20, pp. 3725–36, Dec. 2006.

[12] J. Li, S. M. Zicari, Z. Cui, and R. Zhang, "Processing anaerobic sludge for extended storage as anaerobic digester inoculum.," *Bioresour. Technol.*, vol. 166, pp. 201–10, Aug. 2014.

[13] Y. Li, Y. Jin, A. Borrion, H. Li, and J. Li, "Effects of organic composition on mesophilic anaerobic digestion of food waste," *Bioresour. Technol.*, vol. 244, pp. 213–224, 2017.

[14] G. Capson-Tojo *et al.*, "Accumulation of propionic acid during consecutive batch anaerobic digestion of commercial food waste," *Bioresour. Technol.*, vol. 245, pp. 724–733, 2017.

[15] F. Lü, X. Xu, L. Shao, and P. He, "Importance of storage time in mesophilic anaerobic digestion of food waste," *J. Environ. Sci.*, vol. 45, pp. 76–83, 2016.