Anaerobic Digestion of Fruit Wastes For Biogas Production

Syaliza Abd Hammid[1,3], Nadzirah Aini[1], Rafidah Selaman[2,3],

[1]University Teknologi MARA Cawangan Sarawak, 94300 Kota Samarahan, Malaysia.
[2] University Teknologi MARA Cawangan Sabah, 88997 Kota Kinabalu, Malaysia
[3]Faculty of Applied Science, University Teknologi MARA Shah Alam, 40450 Selangor, Malaysia

ABSTRACT

Biogas production can be generated by sludge digestion process in the form of methane and carbon dioxide through anaerobic digestion process (AD). AD is a biochemical process which involves breaking down biological substances without the presence of oxygen. The ability to reduce organic matter into biogas through the production of biogas (methane gas), not only able to save space on landfills but also introduce new alternatives for natural gas. In this study, fruit wastes; banana and pineapple peels were used to produce biogas by using AD and to determine their physical characterization. The experiment was conducted at mesophilic condition (37^{o}C) for 5 days, and the optimum pH value was between 6.8-7.2. The results had shown 17 -19% of total solid, 85-95% of volatile solids and pH at range of 3.3-6.7%. While total biogas results showed, pineapple peel had a higher value (571.4 ml) compared to banana (386.6 ml). This study also determine the presence of heavy metal (lead and ferum) in fruit wastes (samples) by using AAS, and results showed that the concentration of ferum (2.5256 mg/Kg) was higher in pineapple than banana peel (0.6700 mg/Kg). However, the concentration of lead in pineapple (0.1705 mg/Kg) was slightly lower than banana (0.2121 mg/Kg).

Keywords: *Anaerobic digestion (AD); Fruit waste (FW); Physical characterization; Mesophilic condition; Biogas; Heavy metal; Atomic absorption spectroscopy* (AAS).

---

1. INTRODUCTION

Biogas is one of a renewable energy sources and as an alternative energy sources which has shown compatibility with combustion engine technology. Biogas technology can overcome the needs of energy as the substitute of petroleum in low income country and also, able to reduce the reliability on petroleum.

Biogas is generally composed of mixture of gases mainly methane and carbon dioxide. The biogas production is cheap and can be utilized for many household and farming applications, heating and vehicle fuel. Besides, the biogas slurry is a good source of nutrients for plant growth, since maurial of dung is enhanced due to digestion,

In the past, researches on biogas have focused majorly on animal dung, kitchen waster and animal excreta as feedstock. One of the methods to produce natural biogas is anaerobic digestion (AD). AD is a process where solid organic matter is recycled to produce biogas, which involves series of reactions mediated by many micro-organisms. The reactions involve hydrolysis, acidogenesisi and methanogenesis. The organic matter for AD could come from agriculture waste to municipal solid waste such as fruit peels. The digestion treatment has been one of the effective treatment options for biodegradable organic waste including food waste/food waste leachate, animal manure, and sewage sludge as it effectively reduces the amount of organic waste and produces biogas as a renewable energy. Previous study on co-digestion of watermelons peels with food waste produced 68% methane with 20% carbon dioxide while co-digestion pineapple peels with food waste produced 71% methane and 18% carbon dioxide [1]. According to [2] and [3], mixed fruit and vegetable, and mango-peel waste has shown a great potential in gas production.

Food waste has high organic matter with appropriate moisture content which making food waste as a good source for AD. Therefore in this study, fruit wastes; banana and pineapple peels were used as the initiator to startup the AD process and to determine their potential as the biogas producer for bio-energy sources. Besides, the physical characterization and presence of heavy metal; lead and ferum were also determined.

2. MATERIALS AND METHODS

2.1 Sample collection and preparations

Pineapple skin and banana peel were used as main samples while sludge was taken at the river bed of Sungai Atas, Bau, Sarawak. Fruit samples were grinded to a smaller size and kept in a freezer at $4^{o}C$ prior to use [4]. While, sludge (inoculum) was kept for one week in a water bath at temperature 37°C, to release gases that will interfere the biogas collection from the actual substrate [5].

2.2 Physical characterization of samples

The Total solid (TS), volatile solid (VS) and pH values of both samples were determined according to the method described by [6].

Determination of Total Solid Percentage (%TS)

The crucibles were weighted before and after the addition of samples. Then, both samples with the crucible were placed in an oven and heated at 105°C for 24 hours. After the samples were cooled, the mass was recorded and Total Solid (TS) was calculated using the following formula:

$$\% TS = \frac{(A-B)}{(C-B)} \times 100\%$$

A = crucible weight + Dry sample weight (g)
B = crucible weight
C = crucible weight + Wet sample weight (g)

Determination of Volatile Solid percentage (%VS)

The samples from TS were placed in the muffle furnace at 550°C for 4 hours. After the samples were cooled, the mass was recorded and the percentage of the volatile solid was calculated using the following formula:

$$\% VS = \frac{(A-C)}{(A-B)} \times 100\%$$

A = crucible weight + Dry sample weight (g)
B = crucible weight
C = crucible weight + Ash sample weight (g)

Determination of pH value

Each sample, with a ratio of the sample with distilled water, is 1: 10 (w/v), was put in the conical flask and shake by the orbital shaker at speed 130 rpm for 24 hours. The sample was filtered using the vacuum filter, the liquid part used to determine the pH value by portable pH meter.

2.3 Determination of biogas production

The experimental was set-up with each sample and inoculums ratio 1.5:1.0. The experiment was carried out at mesophilic of 37°C±1°C for 5 days. The pH value was checked regularly to ensure that the pH lies at range of 6.8-7.2. Any reduction or increasing of pH was controlled by using 1M NaOH and 1M HCl. The biogas production was calculated by using water-displacement method.

2.4 Determination of heavy metal of fruit wastes (FW)

The FW samples were dried properly in an oven at $50^{o}C$ for 48 hours. After drying the samples, they were powdered to a fine texture using a grinder. 1g ground sample from each FW was weighted and transferred in 50 mL conical flask and 15mL of the concentrated di-acid mixtures (1:1 nitric acid: perchloric acid). The samples were then heated on a hot plate for 5 hours at $90^{o}C$. After the solution cooled down, the samples were filtered by using filter papers. Lastly, the filtered samples were calibrated by using a 50 mL volumetric flask, and stored in chiller prior to use. The determination of heavy metal (Fe and Pb) in fruit wastes was done using Flame Atomic Absorption Spectroscopy (FAAS).

3. RESULTS AND DISCUSSIONS

The physical characterization of FW involves the determination of total solids (TS), volatile solids (VS) and pH value. TS are the solid substances present in the sample which contains both organic and inorganic matter whereas VS are substances that can easily transform from its solid phase to its vapor phase without going through a liquid phase. Table 1 shows result of average physical characterization for a raw sample of banana and pineapple waste samples.

Table-1: The mean percentage of TS, VS and pH value of fruit waste samples.

Type of fruit peel waste samples	Total solid (% TS)	Volatile solids (% VS)	pH value
Banana	17.1815	85.5699	5.61
Pineapple	18.0355	94.5223	3.38

Based on Table 1, pineapple peel has higher content of solid material (TS) and volatile solid (VS) compared to banana. While, the banana has higher pH value compared to pineapple peel. The result could be linked to the nature and proximate composition of the fruit peels which each of these samples is derived from. The higher percentage of volatile solids, the higher the potential of the sample to undergo AD process.

The overall yield of biogas collected for five days shown in Table 2. The result show that the pineapple peel produced more biogas (571.4 mL) compared to banana peel (386.6 mL), with no significant different in pH (7.09-7.11). Eventhough, the amount of both samples needed in the AD process were almost the same.

Table-2: The total biogas production of fruit peel waste samples

Type of fruit peel waste samples	Amount of food waste needed in AD process (g)	Total biogas for five days (mL)	pH value
Banana	10.8837	386.6	7.09
Pineapple	9.3891	571.4	7.11

The pH for biogas production must be maintained within an ideal pH range for AD, which was very narrow: pH 6.8–7.2. The growth rate of methanogens is greatly reduced below pH 6.6 [7], whereas an excessively alkaline pH can lead to the disintegration of microbial granules and subsequent failure of the process [8]. The optimal pH of methanogenesis is around pH 7.0. The optimum pH of hydrolysis and acidogenesis has been reported as being between pH 5.5 and 6.5 respectively [9]. The cumulative of biogas production for fruit waste samples in five days shown in Figure 1.

Based on the result (Figure 1), both pineapple and banana peels showed an increasing trend from the first day to the second day. On the second day, the biogas from pineapples decreased (2.32%), however on the third day, the biogas yield increased. And start to decline on the fifth day. On the other hand, biogas production from banana peels decreased from the third day.

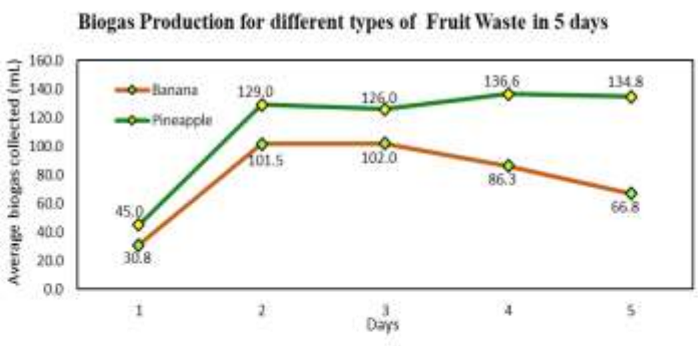

Figure-1: The cumulative of biogas yield for banana peel and pineapple wastes in five days.

The biogas production and efficiency of the anaerobic digestion process is controlled by several factors such as; the type of substrates being digested, total solids (TS) and volatile solid concentration (VS), temperature (T), the presence of toxic materials, pH, hydraulic retention time (HRT), solids retention time (SRT), and other parameter [10][11].

Methanogenesis is normally the rate-limiting step of the whole AD process and is quite sensitive and easily inhibited by certain heavy metals. In this study, average of the heavy metal in pineapple peels has a higher concentration of iron (2.5356 mg/Kg) than banana (0.6700 mg/Kg). However, banana has 0.2121 mg/Kg of lead concentration which was slightly higher than the pineapple (0.1705 mg/Kg).

According to [12], the presence of Copper, Arsenic and Lead may induce an inhibitory effect of anaerobic bacteria due to their toxic effect. Previous study showed that Copper, Lead, Chromium (IV) and Zinc consequently inhibiting the anaerobic digester by inactivated the enzyme in the digester [13]. On the other hand, trace quantities of Nickel, Cobalt, Manganese and Iron were able to stimulate bacterial activities [14]. Therefore, the presence of higher iron and lower lead in pineapple peel (as compared to banana peels), might contribute to the better biogas production compared to banana peel.

Based on the previous study by [15], banana has a higher concentration of iron (0.26 ppm) and leads (0.08 mg/Kg) compared to pineapple which has lower concentration of iron (0.07 mg/Kg) and leads (0.05 mg/Kg). The results were comparable with this study. Factors such as geographical, weather, soil, human activity and fertilizer could contribute to the differences. Besides, the disposal of sewage water and industrial wastes were considered not only a rich source of organic matter and other nutrients but also they elevate the level of heavy metals like Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cd, and Co in receiving soils [16] as it was drained to the agricultural lands where it used for growing crops including vegetables.

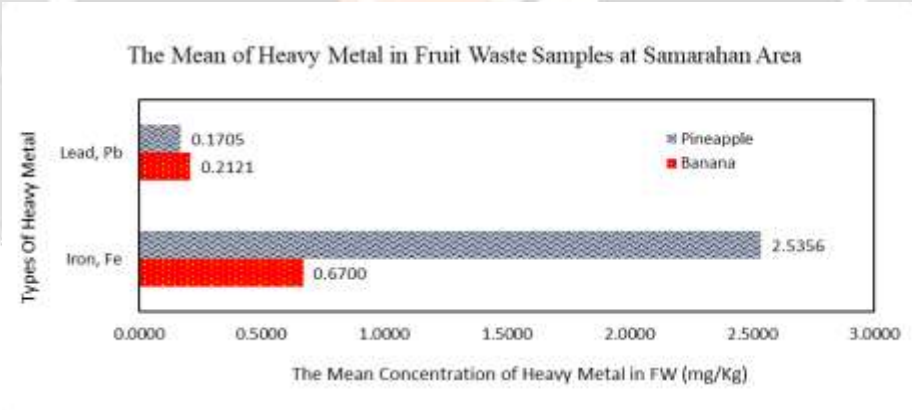

Figure-2: The mean of heavy metal of Fe and Pb in Fruit waste samples at Samarahan area.

4. CONCLUSION

In conclusion, pineapple peels has higher %TS and %VS, with lower content of lead compared to banana peel. Hence, pineapple peels (571.4 mL) has higher biogas potential recovery compared to banana peels (386.6 mL). The energy generated from these fruit wastes, when utilized efficiently, can improves the economy of these fruit processing industries and provides on-site solutions to waste management problems.

5. ACKNOWLEDGMENTS

This work was supported by Faculty of Applied Sciences, University Teknologi MARA Cawangan Sarawak.

6. REFERENCES

[1] Dahunsi Ola. Int.. Con. On African Development Issues
[2] Somayaji, D., Padshetty, N.S. & Nand, K. Asian J. Microbiol.Biotechnol. Environ. Sci. 3: 339-341(2001).
[3] Prema V., Sumitra . and Krishna N.,. Bioresource Technology. Vol. 40(1): 43-48 (1992).
[4] Li, H. L., Guo, X. L., Cao, F. F. & Wang Y. Chem & Biochem Eng. 28(1): 161-166 (2014).
[5] Zeynali, R., Khojastehpour, M., and Ebrahimi-Nik, M. Sustainable Environment Research. 27(6): 259- 264 (2017)
[6] APHA. American Public Health Association (2005).
[7] Mosey, F.E., Fernandes, X.A., Water Science and Technology, 21: 187 196. (1989).
[8] Sandberg, M., Ahring, B.K.,. Applied Microbiology and Biotechnology, 36:800-804 (1992).
[9] Kim, J., Park, C., Kim, T.H., Lee, M., Kim, S., Kim, S.W., Lee, J., Journal of Bioscience nand Bioengineering, 95:271-275 (2003).
[10] Ebunilo, P. O., Aliu, S. A. and Orhorhoro, E. K. Journal of Advanced &Applied Science 4(5): 169-177(2015).
[11] Alli, A., Rundong, L., Shah, F., Mahar, R. B., M. WajidIjaz, S. and Muhammad. International Journal of Waste Resources, 6(3): 2-4 (2016).
[12] Zandvoort, M.H.; van Hullebusch, E.D.; Fermoso, F.G. & Lens, P.N.L. Engineering in Life Sciences, 6:293-301 (2016).
[13] H. Cadillo-Quiroz, S.L. Bräuer, E. Yashiro, C. Sun, J.B. Yavitt, S.H. Zinder Environ. Microbiol., 8: 1428-1440 (2006).
[14] N. Basiliko, J.B. Yavitt. Biogeochemistry, 52:133-153 (2001).
[15] Asquer, C., Pistis, A., & Scano, E. A. Environmental Engineering and Management Journal, 12(11): 89-92 (2013).
[16] Singh, K.P., Mohon, D., Sinha, S. and Dalwani, R. Chemosphere 55: 227-255 (2004).