ISBN 978-1-84626-xxx-x
Proceedings of 2016 International Conference on XXXXXXXXXXXXXXX (xxxxxx2016)
San Francisco, 26-28 October, 2016, pp. xxx-xxx

Biogas Production from Anaerobic Digestion of Fruit and Vegetable Waste from Johannesburg Market

Ireen Maile[1], Edison Muzenda [1, 2], Charles Mbohwa [3]

[1] Department of Chemical Engineering, University of Johannesburg

[2] Department of Chemical, Materials and Metallurgical Engineering, Botswana International University of Science and Technology. Visiting Professor, University of Johannesburg

[3] Department of Quality and Operations Management, University of Johannesburg

Abstract. Biogas production from anaerobic digestion is a promising technology for sustainable energy development. Biochemical methane potential (BMP) tests are normally run to determine the possible methane that can be obtained from each biomass. The aim of this study is to determine the biochemical potential of fruits and vegetable wastes from the Johannesburg market. The biochemical methane potential tests were carried out using the bioprocess control Automatic Methane Potential Test System (AMPTS) II machine. The initial pH of the feedstock was low during the preparation of the feed since fruits and vegetable waste (FVW) are acidic and thus buffer solutions were used to increase the pH to 6.5-7.5. The BMP for the FVW was determined to be on average 300 ml CH_4 /g VS added with methane content between 50-60 % volume.

Keywords: Biogas, Fruits and vegetables, Microbes, Methane yield, pH

1. Introduction

Biogas can be used in place of fossil fuel derived energy and it is clean and renewable [1], [2]. Different biomass are used for anaerobic digestion that includes; waste water, sewage sludge, food waste, fruits and vegetables waste, municipal solid waste [3]-[8]. Biogas production has multiple benefits; energy production, waste minimization, from landfilling reduction and reduction of pollution levels, bio-fertilizer from digestate, pure chemicals, and creation of green jobs [9].

Biochemical methane potential (BMP) tests are normally run to determine the possible methane that can be obtained from each biomass. This tests help in process optimization and also establishing the profitability of the anaerobic digestion plant in terms of yield and quality of the gas produced in respect to the substrate [1]. A laboratory scale batch system is normally used which determines the ability of substrate to produce biogas. However, fruits and vegetables are normally acidic and therefore a pH control needs to be applied to monitor and keep it at the optimum condition.

The BMP of waste water, sewage sludge, food waste, fruits and vegetables waste, municipal solid waste was studied and determined to be 190-320 ml CH_4/g VS, 101-349 ml CH_4/g VS, 245-510 ml CH_4/g VS, 470 ml CH_4/g VS, and 60-580 ml CH_4/g VS respectively [10]-[14]. Biodegradation of organic waste, especially fruits and vegetable waste has been widely studied, however for fruit and vegetable markets an intensive study is needed for optimization of the process parameters for maximum gas yield. Thus study focused on the biochemical potential of fruits and vegetables from the Johannesburg market.

2. Materials and Methods

The biochemical methane potential tests were carried out to determine the potential of the (fruit and vegetable waste) FVW from the Johannesburg Market.

2.1. Materials

The materials used were FVW from the Johannesburg Market (City Deep), cow dung to provide the necessary bacteria for the digestion process. The following chemicals were used to adjust the pH since they were mostly acidic to a range of 6.5-7.5, Sodium Hydroxide (NaOH), $Ca(OH)_2$, and $CaCO_3$. Deionized water (H_2O) was used to prepare the solutions and also for the equipment (water bath and flow cell). Nitrogen (N_2) gas is used to purge the entire system, allowing for an anaerobic environment.

2.2. Experimental methods

The biochemical methane potential tests were carried out using bioprocess control AMPTS II. The machine is made up of 3 components (i) digester, (ii) CO_2 fixing unit, and (iii) gas collecting unit. It's a batch system which is set up and led to run until digestion is complete. FVW samples collected from the landfill were used as substrate. A 500 ml digester, with effective volume of 400 ml, was used for biogas production which had head space of 150 ml. The temperature of the process was kept constant at mesophilic temperature of 37 °C.

Sodium hydroxide, obtained from Sigma-Aldrich (South Africa), was used for CO_2 removal. A 3M NaOH solution was prepared to be used as the scrubbing solution to absorb the impurities. A pH indicator solution was added to determine the saturation point for the cleaning solution for replacement. The substrate as obtained from the site was made up of different type of wastes in different sizes. A household blender was used to homogenize the feedstock which was then prepared and fed into the digester. A pH test was done after the substrate was inoculated using cow dung to adjust it to the optimum of 6.5-7.5.Nitrogen gas was used to purge the system by removing the oxygen and creating an anaerobic condition. The digester was connected to a 100ml bottle (used as scrubber) filled with 80 ml of the 3M NaOH solution. The gas exiting the CO_2 fixing unit was sent to the flow cell (gas collection) where the volume of biomethane is determined as shown in Fig. 1. A sample of the gas produced was analyzed using the gas chromatograph machine to determine the gas composition.

Fig. 1: Bioprocess AMPTS II experimental setup for BMP analysis

3. Results and Discussion

Biochemical methane potential of FVW from the Johannesburg Market was studied and the results that were obtained are discussed in this section. The initial pH of the feedstock was low during the preparation of the feed since FVW are acidic and thus buffer solutions were used to increase the pH to 6.5-7.5.

3.1. The effect of buffering solution on methane yield

The digester with pH adjusted with $CaCO_3$ resulted in high biomethane yields of 3354 Nml/g VS on average as shown in Fig. 2. This can be attributed to the source of nutrients role played by $CaCO_3$ on the microbes. The main contributor is the Ca^+ ions which favour the performance of the micro-organisms [15], [16]. This can be seen also in the yields obtained with $Ca(OH)_2$ which are 2 to 3 times more as compared to the NaOH buffered digester as depicted in Fig. 3.

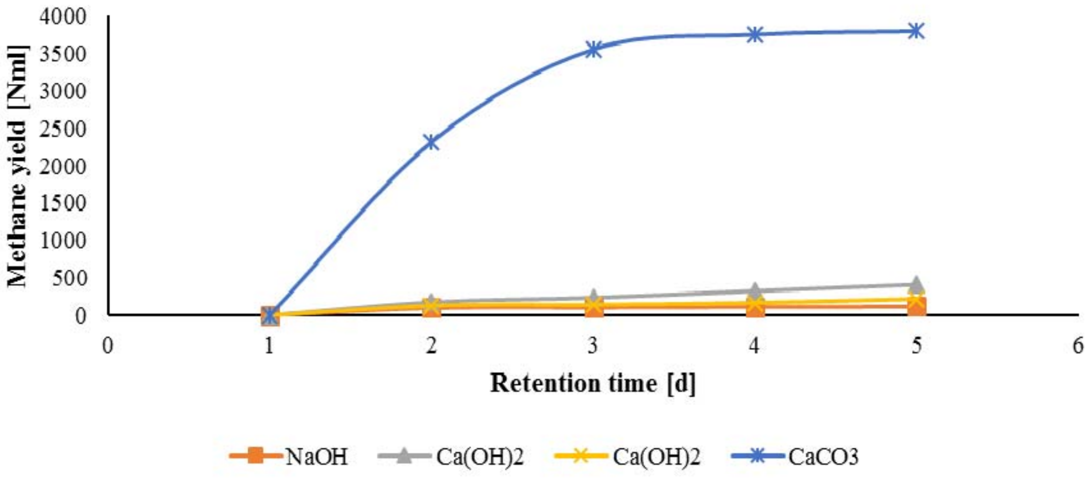

Fig. 2: Cumulative methane yield from the different digesters

3.2. The effect of process parameters

The hydraulic retention time for the FVW biomethane test was short as observed in Fig. 2 and Fig. 3 as the digestion process would normally run. This may be due to the pH drop during digestion of fruits and vegetables. Hence, pH monitoring is recommended as the methanogenic bacteria are sensitive to pH change. The drop of pH also leads to accumulation of volatile fatty acids which hinders anaerobic digestion process and further leads to digester failure [15], [17]. The ratio of substrate to inoculum also affects the yield and retention time as a balance should exists such that there is available substrate for the microbes in the digester. The digestion in this study was up to 5 days and generally that is when the process starts to stabilize.

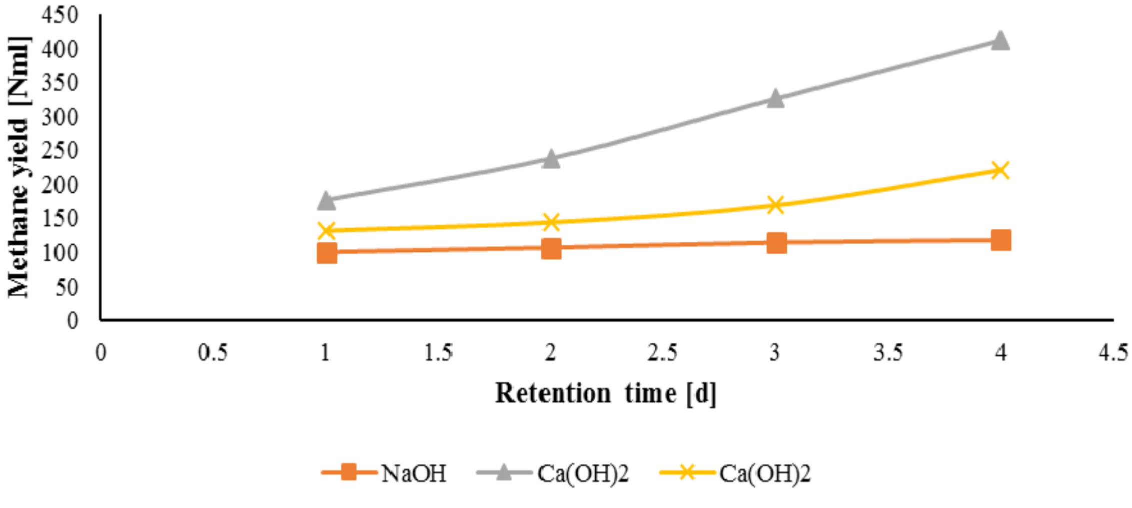

Fig. 3: Effect of inoculation on biogas production

The dynamics of anaerobic digestion are complex and thus optimization studies need to be carried out in order to investigate the operating conditions favourable for a set of substrates. The inoculum to substrate ratio affects the gas yield, the type of substrate and its characteristics also affect the anaerobic digestion process.

3.3. The rate of production of biogas

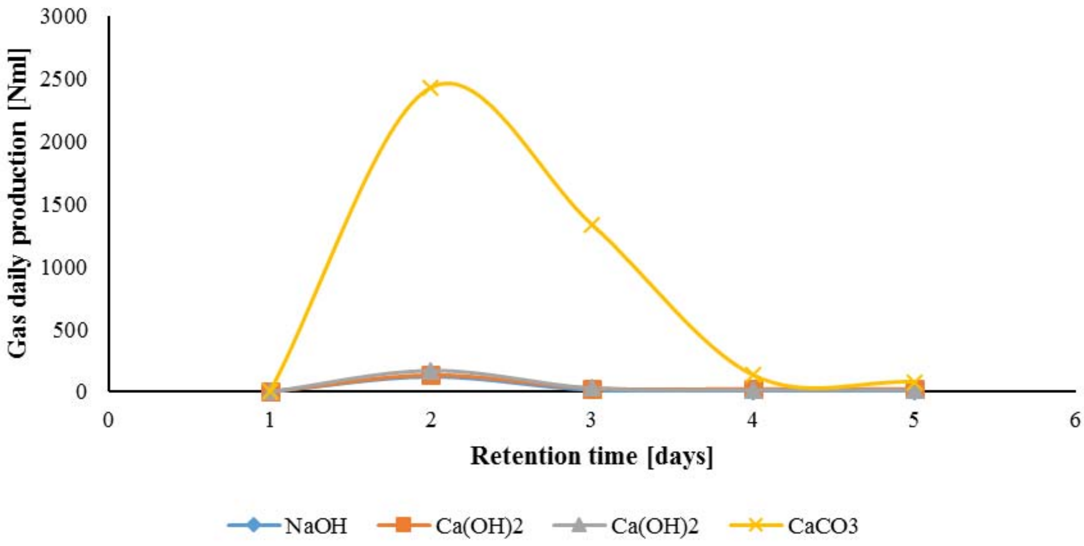

Fig. 4: Gas production rate

Daily methane production rate for the digesters was recorded and shown in Fig. 4. The digesters (1-3) had an optimum production of 3 days and digester 4 had 4 days respectively. The day with the highest rate as observed is day 2 for all digesters where hike is realised especially for digester 4 and a very sharp deterioration as the digestion process comes to an end. The anaerobic digestion of fruit and vegetable waste is a complex and sensitive process because of their acidic nature and hence co-digestion with a more basic substrate can address this challenge, pre-treatment of the substrate by buffers like NaOH, a two-step continuous AD process which separates the hydrolysis step from the methanogenesis step [1], [18, [19].

3.4. The composition of the biogas

The other important aspect in anaerobic digestion is the determination of the composition of the biogas. The methane content was in the range of 50-60 % volume. The BMP for the FVW was determined to be on average 300 ml CH_4 /g VS added and this results are in agreement to the results obtained by Sitorusa, et al. [20].

4. Conclusions

Biogas production from fruit and vegetable waste was studied to determine the biochemical methane potential using Bioprocess AMPTS II. The study showed that pH plays an important role in anaerobic digestion and thus the optimum pH should be maintained throughout the process. $CaCO_3$ is a good buffer but poses threat to the environment hence its use was discontinued. The BMP for FVW is 300 ml CH_4 /g VS added with methane content of 50-60 % in volume.

5. Acknowledgements

The authors acknowledge the South African National Energy Development Institute (SANEDI), University of Johannesburg's Global Excellence Scholarship (GES), City of Johannesburg (CoJ), University of Johannesburg's Process Energy and Environmental Technology Station (PEETS). Botswana International University of Science and Technology and the UJ Bioenergy research team for supporting this research.

6. References

[1] F. Raposo, V. Fern´andez-Cegr, M. A. De la Rubia, R. Borja, F. B´ eline, C. Cavinato, et al., "Biochemicalmethane potential (BMP) of solid organic substrates: evaluation of anaerobic biodegradability

using data from an international interlaboratory study," *J Chem Technol Biotechnol* vol. 86, pp. 1088-1098, 2011.

[2] Yadvika, Santosh, T. R. Sreekrishman, S. Kohli, and V. Rana, "Enhancement of biogas production from solid substrates using different techniques-a review," *Bioresource Technology,* vol. 95, pp. 1-10, 2004.

[3] M. S. Rao and S. P. Singh, "Bio energy conversion studies of organic fraction of MSW: kinetic studies and gas yield organic loading relationships for process optimization," *Biores. Technol.,* vol. 95, pp. 173-185, 2004.

[4] L. Krzystek, S. Ledakowicz, H. J. Kahle, and K. Kaczorek, "Degradation of household biowaste in reactors," *J. Biotechnol.,* vol. 92, pp. 103-112, 2001.

[5] C. Gallert, A. Henning, and J. Winter, "Scale-up of anaerobic of the biowaste fraction from domestic wastes," *Water Res.,* vol. 37, pp. 433-1441, 2003.

[6] T. Forster-Carneiro, M. Pérez, L. I. Romero, and D. Sales, "Dry-thermophilic anaerobic digestion of organic fraction of the municipal solid waste: focusing on the inoculum sources," *Bioresource Technology* vol. 98, pp. 3195-3203, 2007.

[7] H. Bouallagui, Y. Touhami, R. BenCheikh, and M. Hamdi, "Bioreactor performance in anaerobic digestion of fruit and vegetable wastes," *Proc. Biochem,* vol. 40, pp. 989-995, 2005.

[8] D. Bonzonella, P. Pavan, S. Mace, and F. Cecchi, "Dry Anaerobic digestion of differently sorted organic municipal solid waste: a full scale experience," presented at the Fourth International Symposium of Anaerobic digestion of Solid Waste, Copenhagen, Denmark, 2005.

[9] L. Deressa, S. Libsu, R. B. Chavan, D. Manaye, and A. Dabassa, "Production of Biogas from Fruit and Vegetable Wastes Mixed with Different Wastes," *Environment and Ecology Research* vol. 3, pp. 65-71, 2015.

[10] D. Scaglione, S. Caffaz, E. Ficara, F. Malpei, and C. Lubello, " A simple method to evaluate the short-term biogas yield in anaerobic codigestion of WAS and organic wastes," *Water Science and Technology,* vol. 58, pp. 1615-1622, 2008.

[11] G. Liu, R. Zhang, H. M. El-Mashad, and R. Dong, "Effect of feed to inoculum ratios on biogas yields of food and green wastes," *Bioresource Technology,* vol. 100, pp. 5103-5108, 2009.

[12] A. Hejnfelt and I. Angelidaki, "Anaerobic digestion of slaughterhouse by-products," *Biomass and Bioenergy,* vol. 33, pp. 1046-1054, 2009.

[13] Y. B. Fernández, A. Soares, R. Villa, P. Vale, and E. Cartmell, "Carbon capture and biogas enhancement by carbon dioxide enrichment of anaerobic digesters treating sewage sludge or food waste," *Bioresource Technology* vol. 159, pp. 1-7, 2014.

[14] D. P. Chynoweth, C. E. Turick, J. M. Owens, D. E. Jerger, and M. W. Peck, "Biochemical methane potential of biomass and waste feedstocks," *Biomass and Bioenergy,* vol. 5, pp. 95-111, 1993.

[15] W. Parawira, "Anaerobic treatment of agricultural residues and wastewater," Department of Biotechnology, Lund University, 2004.

[16] M. Hamed, E. Mashad, and Z. Ruihong, "Biogas production from co-digestion of dairy manure and food waste," *Bioresource Technology,* vol. 101, pp. 4021-4028, 2010.

[17] W. Yuanyuan, Z. Yanlin, W. Jianbo, and M. Liang, "Effects of volatile fatty acid concentrations on methane yield and methanogenic bacteria," *Biomass and bioenergy,* vol. 33, pp. 848-853, 2009.

[18] F. Raposo, R. Borja, B. Rincón, and A. M. Jiménez, "Assessment of process control parameters in the biochemical methane potential of sunflower oil cake," *Biomass and Bioenergy,* vol. 32, pp. 1235-1244, 2008.

[19] A. K. Kivaisi and S. Eliapenda, "Application of rumen microorganisms for enhanced anaerobic degradation of bagasse and maize bran," *Biomass & Bioenergy,* vol. 8, pp. 45-50, 1995.

[20] B. Sitorusa, Sukandar, and S. D. Panjaitan, "Biogas recovery from anaerobic digestion process of mixed fruit -vegetable wastes," *Energy Procedia* vol. 32, pp. 176-182, 2013.