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Impacts of Mixing on Anaerobic Composting and Enhancing Biogas Recovery

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ABSTRACT

The effectiveness of cow dung for biogas production was investigated, using a laboratory scale 10L bioreactor working in batch and semi-continuous mode at 53ºC. Anaerobic digestion seemed feasible with an organic loading of up to 1.7 kg volatile solids (VS)/L d and an HRT of 10 days during the semi-continuous operation. The averaged cumulative biogas yield and methane content observed was 0.15 L/kg VS_{added} and 47%, respectively. The TS, VS and COD removals amounted to 49%, 47% and 48.5%, respectively. The results of the VS/TS ratio showed very small variation, which denote adequate mixing performance. However, there was some evidence of ammonia inhibition probably due to the uncontrolled pH employed. The data obtained establish that cow dung is an effective feedstock for biogas production achieving high cumulative biogas yield with stable performance. The future work will be carried out to study the effect of varying organic loading rate on anaerobic digestion of cow dung in a semi-continuous mode.

Keywords- cow dung; anaerobic digestion; biogas production.

I. INTRODUCTION

There is a great deal of environmental pressure in many parts of the world to ascertain how livestock waste can best be handled. Livestock manure, like cow dung in the absence of appropriate disposal methods can cause adverse environmental and health problems such as: pathogen contamination, odour, air borne ammonia, green house gases, etc [1]. Anaerobic digestion has been considered as waste-to -energy technology, and is widely used in the treatment of different organic wastes, for example: organic fraction of municipal solid waste, sewage sludge, food waste, animal manure, etc [2]. Anaerobic treatment comprises of decomposition of organic material in the absence of free oxygen and production of methane, carbon dioxide, ammonia and traces of other gases and organic acids of low molecular weight [3].

Recently, large volume of cow dung generated from feedlot farming increases annually, most of which are disposed into landfills or are applied to the land without treatment. Anaerobic digestion provides an alternative option for energy recovery and waste treatment. In this paper, cow dung was assessed for the use of anaerobic digestion with the objectives of treating the dung waste to decrease disposal costs and to generate biogas. The biogas produced contains mainly methane and carbon dioxide, and can be used as a source of renewable energy. The aim of this paper was to investigate the effectiveness and the performance characteristics of anaerobic digestion of cow dung for biogas production in batch and semi-continuous operation.

II. MATERIALS AND METHODS

2.1 Substrate Preparation

Fresh cow dung was collected from the Feedlot slaughterhouse in Malaysia. The cow dung was diluted with tap water at the ratio 1:1, and then fibers were screened through a sieve (0.5cm x 0.5cm) mesh size. The prepared substrate was stored at 4ºC prior to use. Then Palm oil mill effluent (POME) was used as inoculums. The composition of the raw cow dung is shown in Table-1.

Table 1: Characteristics of cow dung used in the study.

Parameters	Composition

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TS (mg/L)	156
VS (mg/L)	32.5
COD (mg/L)	2,200
NH_3-N (mg/L)	680
Ph	7.1-7.4
Moisture content (%)	41.2

2.2 Start-up and Operation

A 10L-jacketed fermenter (Biostat B) equipped with pH probe, stirrer, sampling ports and temperature controller was used in this study. The working volume of the bioreactor was maintained at 7 Litre and ran under uncontrolled pH, which is without acid or base addition. Experiments was carried out at thermophillic temperature of 53ºC by circulating water from a thermostat through a water jacket surrounding the bioreactor, and mixing was aided by a mechanical stirrer set at a speed of 150rpm. The system was started up as batch to achieve an active acidifying culture by loading the substrate seeded with POME, then sealed and purged with Nitrogen gas for 15 minutes. Semi-continuous feeding started from day 10, where a known volume of slurry was withdrawn daily from the reactor and replaced with fresh feedstock via the slurry sampling ports equivalent to an HRT of 10 days. In addition, approximately 50 ml of the sample was taken daily from the bioreactor through the sampling port, which then underwent series of analysis. Biogas production was measured by water displacement method.

2.3 Analytical Methods

The samples taken were analyzed for total solids (TS), volatile solids (VS), and chemical oxygen demand (COD) using the Standard Method [4]. Ammonia nitrogen (NH_3-N) content was examined using the spectrophotometer (HACH, DR/2500). The composition of methane in the biogas produced was analyzed using a gas chromatography equipped with a thermal conductivity detector (TCD). The column used was a HP Molesieve 30m × 0.53mm × 0.05mm capillary column. The injector, oven and detector temperatures were set at 150ºC, 60ºC and 200°C, respectively. Argon served as the carrier gas while nitrogen was used as the makeup gas.

III. RESULTS AND DISCUSSIONS

The digestion performance of cow dung was investigated based on the results obtained from the process monitoring for: VS reduction, TS reduction, VS/TS ratio, COD reduction, NH_3-N concentration, pH and biogas production with its methane content. Although, variations in reactor performance were observed in the early period of digestion, the observed pH of 6.65-7.81 were primarily within the acceptable range for anaerobic digestion for the entire operations. This implies average buffering capacity of the mixed substrate. Generally, degradation of substrates starts between day one to day three before it commences the production of biogas in the batch operation.

3.1 Biogas Production

The cumulative biogas production during the study period is shown in Figure-1. It was observed that biogas production was actually slow at starting and the end of observation. This is predicted because biogas production rate in batch condition is directly equal to specific growth of methanogenic bacteria [5]. During the first 3 days of observation, there was less biogas production and mainly due to the lag phase of microbial growth. Whereas, in the range of 4 to 6 days of observation; biogas production increases substantially due to exponential growth of methanogens. Highest biogas production rate of 3.4 L was measured on day 6. On the commencement of semi -continuous digestion, biogas production was observed to decrease considerably and, this is probably due to unregulated pH region employed, which concurrently leads to increase in concentration of ammonia nitrogen that might be assumed to inhibit the process. It was reported by Chen Ye, et al [6] that high concentration of ammonia nitrogen is toxic to anaerobes, which will decrease the efficiency of the digestion and upset the process. Besides, the fluctuations in the daily biogas production found during the semi - continuous, it could also be attributed to the varying input of VS load. At the end of the observation, cumulative biogas yield of 0.15 L $kg^{-1}VS_{added}$ was achieved. This yield seems particularly similar to that reported by [7] during the anaerobic digestion of beef manure in mixed and unmixed reactors. It is clear that cow dung is an effective feedstock for anaerobic digestion and could significantly enhance the cumulative biogas production. It therefore shows that considerable amount of anaerobic bacteria in the cow dung functions effectively to degrade the organic fraction from cattle manure even though pH was unregulated. The methane content of the biogas generated during the entire operation was on average 47%. This result implies that all the processes are most likely in balanced and stable operation.

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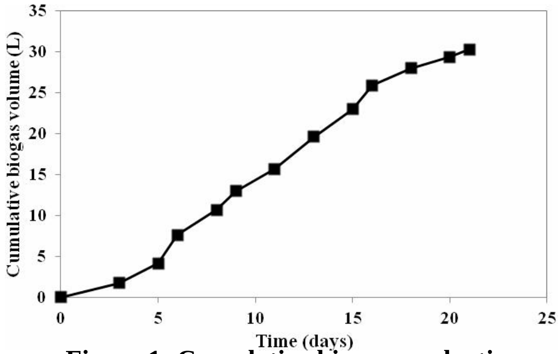

Figure 1: Cumulative biogas production.

3.2 Effect on pH and Ammonia-nitrogen Concentration

The pattern of pH and ammonia nitrogen demonstrated by all experimental mixing ratios was typical of a digester operating under stable condition (Figure-2).

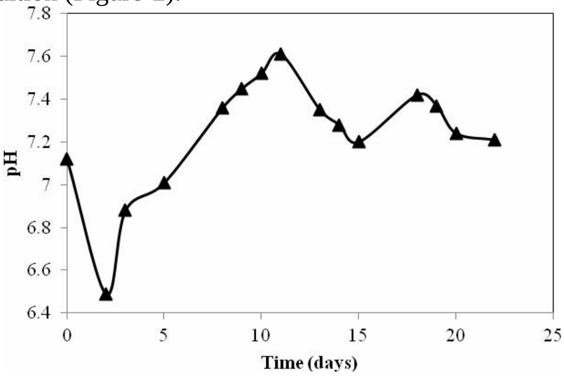

Figure 2: pH profile during anaerobic digestion of cow dung.

A decrease in the process pH was observed in the first few days of the digestion and this is due to high volatile fatty acid (VFA) formation [8]. In consequence, a large fluctuation was observed in ammonia nitrogen concentrations, achieving a maximum value of 1.66 g/l, 1.77g/l and 1.76 g/l at mixing ratios 0.5:5, 1:5 and 1.5:5, respectively during the batch operation. However, the Ph increased to its normal operating value after VFAs metabolism. Ammonia nitrogen concentration and pH was observed to increase substantially with little variation on the commencement of the semi-continuous operation, leading to lower biogas yield. Bujoczek *et al*., [9] have reported that, the efficiency of converting the organic matter in cattle manure to methane decreased as the organic loading increased. It was earlier seen from the mixing ratio of 0.5:5 tested data not shown, that the variation of NH_3-N concentration had no obvious variation and maintained below 500 mg/l. At the end of the experiment, NH_3- N was reduced to 87% which is 20% higher than that at mixing ratio 1:5 and 1.5:5. This showed that higher reduction in efficiency of NH_3-N was achieved and this is likely caused by the availability of microbial population in the POME, which aids the anaerobic bioconversion. It was reported by Angelidaki and Ahring [10] that process stability due to NH_3 resulted in VFA accumulation and lowering of pH, thus decreasing the concentration of free NH_3 in the reactor. This explains the observed ability of the operation to stabilize even with high ammonia concentration and with lower, but stable biogas production.

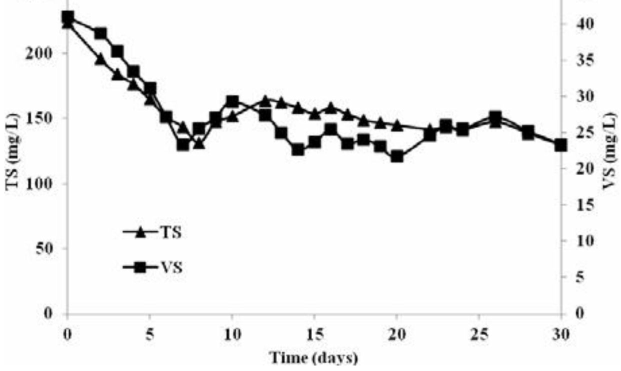

Figure 3: TS and VS profile for cow dung digestion.

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3.3 Total Solids and Volatile Solids in Bioreactor

Figure-3 shows the TS and VS profiles of the bioreactor content during the experiment. TS and VS destruction is a vital aspect in evaluating anaerobic digestion performance. The most effective performance in terms of VS degradation was observed during batch digestion, probably through efficient hydrolysis in the acid phase. However, on day 10 when the system was operating under semi-continuous mode, a slight removal of VS was observed with large fluctuations probably due to sampling difficulties. Although there is still tendency for further TS and VS reduction with low or non biogas production, it presumably because of the inherent hardly biodegradable constituents, consequently higher ammonia concentration contribute to process inhibition. According Nielsen and Angelidaki [11], animal manure such as cattle manure used in this study contain lignocellulosic rich materials; hence makes anaerobic digestion quite un-optimum. The TS and VS reduction of 49% and 47%, respectively was stably achieved during the operation.

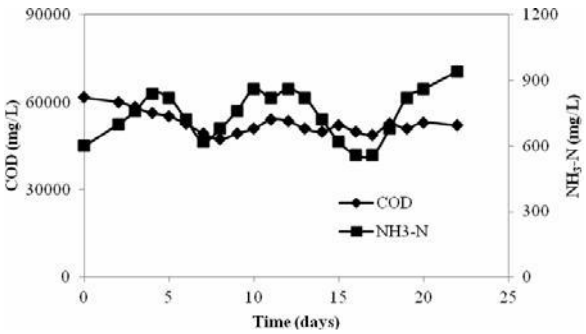

Figure 4: COD removal and NH_3-N concentration for anaerobic digestion of cow dung.

Furthermore, physical hindrance caused by accumulation of inorganic matter inside the bioreactor is determined by the VS/TS ration. VS/TS ration during the entire operation was averagely 0.2 with little variation. This implies that no accumulation of grit was occurred and the bacteria populations are in favourable condition even while pH was unregulated. It was reported by Chae *et al*., [12] that the VS/TS ratio of digester is an excellent indicator to ascertain the accumulation of unwanted materials and the adequacy of mixing system employed. Thus, these results denote that the bioreactor is under adequate mixing.

3.4 COD Reduction in Bioreactor

From Figure-4 it can be seen that the averaged COD removal efficiency was 48.5%, which is comparatively lower than the commonly obtained COD removal from cattle manure (51-79%) [13]. This result was believed to be due to the high COD exhibited by the inoculum which leads to increase in influent COD concentration. In effect, it dominates the microbial activity thereby resulting in lower COD removal efficiency. It was also observed that the majority of the COD treatment prevailed in the batch as compared to semi-continuous operation, but a more stable treatment was found during the semi-continuous operation. This stability indicates clearly the benefit of the semi-continuous system.

IV. CONCLUSIONS

This study investigated the effectiveness of cow dung for biogas production and presented the performance characteristics of the anaerobic digestion in batch and semi -continuous operations. Under these conditions, the cow dung digestion reaches 47% VS reduction and approximately 48.5% COD reduction with biogas yield of 0.15 L biogas/kg VS_{added}. Despite large variations in pollutants concentrations, an improved performance of anaerobic digestion of the biodegradable fraction of cow dung was achieved. The results showed that cow dung might be one of feedstock for efficient biogas production and waste treatment.

REFERENCES

[1] Harikishan S. Sung S. 2003. Cattle waste treatment and class-A biosolid production using temperature-phased anaerobic digester. Advances in Environmental Research. 7: 701-706.
[2] Li R., Chen S. and Li X. 2009. Anaerobic co-digestion of kitchen waste and cattle manure for methane production. Energy Sources. 31: 1848-1856.
[3] Lopes W. S., Leite V. D. and Prasad S. 2004. Influence of inoculum on performance of anaerobic reactors for treating municipal solid waste. Bioresource Technology. 94: 261-266.
[4] American Public Health Association. 1998. Standard Method for the Examination of Water and Wastewater 15th Ed. Washington, APHA, USA.
[5] Nopharatana A., Pullammanappallil P.C. and Clarke W.P. 2007. Kinetic and dynamic modelling of batch anaerobic

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digestion of municipal solid waste in a stirred reactor. Waste management. 27: 595-603.
[6] Chen Y., Cheng J.J., and Creamer K.S. 2008. Inhibition of anaerobic digestion process: A review. Bioresource Technology. 99(10): 4044-4064
[7] Sadaka S. and Engler C. 2000. Effects of mixing on anaerobic composting of beef manure. In: Proceeding of ASAE Annual International Meeting, Technical papers: Engineering Solutions for a New Century, 9-12 July, pp. 4993-5001.
[8] Rao M.S., Singh S.P., Singh A.K. and Sodha M.S. 2000. Bioenergy conversion studies of the organic fraction of MSW: assessment of ultimate bioenergy production potential of municipal garbage. Applied Energy. 66: 75-78.
[9] Bujoczek G., Oleszkiewicz J., Sparling R. and Cenkowski S. 2000. High solid anaerobic digestion of chicken manure. J. agric. Engng. Res. 76: 51-60.
[10] Angelidaki I. and Ahring B.K. 1993. Thermophilic anaerobic digestion of livestock waste: The effect of ammonia. Appl. Microbiol. Biotechnol. 38: 560-564.
[11] Nielsen H.B. and Angelidaki I. 2008. Strategies for optimizing recovery of the biogas process following ammonia inhibition. Bioresource Technology. 99: 7995-8001.
[12] Chae K.J., Yim S.K., Choi K.H., Park W.K. and Lim K. 2011. Anaerobic digestion of swine manure: Sung-Hwan farm-scale biogas plant in Korea. http://www.kriegfischer.de/texte/farm scale%20biogas%20plants.pdf
[13] Castrillon L., Vazguez. I., Maranon E. and Satre H. 2002. Anaerobic thermophilic treatment of cattle manure in UASB reactors. Waste Management and Research. 20: 350-356.

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