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BIOMETHANE POTENTIAL OF SELECTED FAECAL MANURE FOR DIGESTION AND CO-DIGESTION IN BIOGAS PRODUCTION

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ABSTRACT

Biomethane Potential (BMP) test of selected complex organic manure namely; Cow manure, Piggery manure, Poultry Manure and Human faecal manure was conducted in accordance with recommendations of the Anaerobic Biodegradation, Activity and Inhibition (ABAI). Faecal manures from cow, pig, poultry and human were collected from the Faculty of Agriculture Farm Project, University of Benin. The result of the test showed that Cow manure has a BMP of 0.2 L CH_4/g VS, Pig manure 0.16 L CH_4/g VS, Poultry manure 0.27 L CH_4/g VS and human faecal manure 0.28 L CH_4/g VS. In terms of methane yield and comparison with other substrates tested, human faecal manure has the highest BMP, followed by poultry manure. Essentially, human faecal manure and poultry manure have very high potential as feedstock for anaerobic digestion for biogas production when compared to cow and pig manure. BMP test has high reliability and validity as it is based on conditions that approximate practical anaerobic digestion processes. In other words, this test is of significant importance in predicting the biogas and methane potential of feedstock before embarking on the actual building and/or fabrication of bio-digestion process.

1. INTRODUCTION

In Nigeria, there exist considerable research efforts in biogas production from a range of feedstock, however testing for methane potential of biogas feedstock is not a common practice. It is absolutely of importance to ascertain methane potential of complex organic manure from faecal waste before embarking on a long term anaerobic digestion process for methane recovery (Browne *et al.,* 2013. This study investigated the BMP of selected complex organic manure namely; Cow manure, Piggery manure, Poultry Manure and Human faecal manure. The BMP is defined as the maximum volume of methane produced per g of VS substrate (Rodrigo *et al.,* 2011). It is important in providing an indication of the biodegradability of a substrate and its potential to produce methane through anaerobic digestion (AD). The BMP test is a method of establishing a baseline for performance and provides data which are useful for designing and optimization of methane production. The results obtained from the test can ascertain the concentration of organics in a substrate that can be anaerobically converted to biogas or methane (Browne *et al.,* 2013). This is then used to evaluate the potential efficiency of the anaerobic process for a specific feedstock. However, BMP test remains the best method to initially test biogas production from complex organic concentrate and other feedstocks (Alepu *et al.,* 2016). Temperature, pH, stirring intensity, physico-chemical characteristics of substrates, and substrate/inoculum (S/I) ratio are key parameters effecting BMP (Shi*,* 2012).

Esposito et al. (2012) determined the BMP of organic substrate mixed with an anaerobic inoculum in defined operational conditions and the gas evolved is quantified using specific measurement method. Alternatively, Specific Methananogenic Activity (SMA) test can be used to estimate biochemical activities of organisms present as well as the CH_4 producing potential for particular substrate concentration level where the presence of substrate is not a limiting factor (Hussein and Dubey, 2017). SMA is determined by mixing known quantities of biomass and supplementary substrate in a serum bottle in concentrations enough to allow maximum biogas activity in accordance with Jijai *et al*., (2014). This test is carried out at controlled temperature of 35^{o}C and the resultant CH_4 is estimated by liquid displacement. In the recent times, new instruments have been designed to analyse the AD process as well as biogas yield and composition. Shi (2012) mentioned the Automatic Methane Potential Test System (AMPTS) which removes CO_2 and other acid gas in the biogas before estimating the CH_4 yield, the instrument utilises the basic principle of the conventional BMP test. Methane production is directly measured on-line by means of liquid displacement and buoyancy method. The AMPTS was developed by the Bioprocess Control Sweden Company. Angelidaki *et al.* (1998) developed a computerised automatic biogas activity monitoring (BAM) system for assessing the production of gas in closed vials. The system was applied to monitor the specific biogas activity of granular sludge from an up-flow anaerobic sludge blanket reactor. While most of these previous researches were on faecal sludge, industrial waste or lignocellulosic biomass and on large AD systems, it becomes economical to utilized the conventional BMP test especially for pilot researches on specific raw faecal materials for ease of feedstock selection or segregation.

2. MATERIALS AND METHODS

In this study, Cow manure, Piggery manure, Poultry Manure and Human faecal manure were collected and prepared in batch, fixed in sealed serum bottles containing an inoculum, sample and de-ionised water. The bottles were flushed with atmospheric Nitrogen followed by incubation for more than 30 days at 37^{o}C until no biogas was produced in line with Schievano *et al.* (2008). The biogas was measured at intervals either qualitatively or quantitatively. Qualitative measurement was carried out using Gas Chromatography while extra pressure was withdrawn by a syringe to quantitatively estimate biogas production. The BMP was estimated in accordance with Equation 1 (Jijai *et al*., 2014):

$$BMP = \frac{Maximum\ Cumulative\ Methane\ (L)}{gCOD_{removed}} \quad (1)$$

The standard protocol adopted for this test is in accordance with recommendations of the Anaerobic Biodegradation, Activity and Inhibition (ABAI) Task Group of the International Water Association (IWA) in 2009. Fresh cow, pig, poultry and human faecal was collected from the Faculty of Agriculture Farm Project, University of Benin. The BMP was conducted at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife. An airtight bottle was filled with inoculum, substrate and the medium. The Total Solid (TS) and Volatile Solid (VS) contents were measured according to Standard Methods (Esposito *et al.,* 2012; Jingura and Kamosoko, 2017).

The gas phase volume was allowed to reach a total conversion of the added COD in the 500ml serum bottle. The bottle was filled with 100ml of inoculum and 100ml of substrate with an added medium. The pH was monitored to ensure that it was within the range of 6.5 – 7.5 (Esposito *et al.,* 2012). the gas volume in the bottle was kept at 389 ml to prevent the gas pressure from exceeding 2 atm and consequent overpressure. The headspace was flushed with N_2 gas before the bottle was closed to enhance O_2 removal which otherwise, leads to aerobic respiration which hinders activity of methanogens and causes loss of methane potential. The bottles were kept at desirable temperature while mixing through shaking and the gas pressure development was monitored in time to prevent overpressure. Furthermore, the gas production and composition were measured using a Gas Chromatography and this was done over time until the gas production rate is 0. The CO_2 contained was dissolved in NaOH to prevent it from affecting the volumetric methane. Temperature and pH in each BMP bottle were also monitored for at least once a day with a thermometer and a pH meter respectively.

Figure 1: BMP test bottles on laboratory shaker

Biogas production was determined indirectly, by measuring the cumulative pressure inside the bottles through pressure transducers. Pressure was continuously measured using a data acquisition system interfaced with a computer. In addition, a pressure-control bottle containing the equivalent volume of sample replaced by tap water was included to account for abiotic internal pressure variations due to temperature and atmospheric pressure changes. Similarly, temperature was monitored through thermocouples measuring gas-phase temperature changes in tap water containing bottles. Finally, pressure data were converted to volume of biogas at standard temperature and pressure (STP), according to the ideal law of gases.

3. RESULTS AND DISCUSSION

The BMP results of faecal samples are as presented in Table 1. Cow manure had a BMP of 0.2 L CH_4/g VS, Pig manure 0.16 L CH_4/g VS, Poultry manure 0.27 L CH_4/g VS and human faecal manure 0.28 L CH_4/g VS.

Table 1: Comparison of methane potential of cow and poultry manure

No.	Sample	BMP (L CH_4/g VS)	Percentage composition (%)	Hydraulic retention time (day)	Temperature (^oC)
A.	Cow Manure	0.2	42.55	61	25 - 33
B.	Poultry Manure	0.27	57.45	61	25 - 33

Table 2: Comparison of methane potential of cow and pig manure

No.	Sample	BMP (L CH_4/g VS)	Percentage composition (%)	Hydraulic retention time (day)	Temperature (^oC)
A.	Cow Manure	0.2	55.56	61	25 - 33
B.	Pig Manure	0.16	44.44	61	25 - 33

Table 3: Comparison of methane potential of cow and human faecal manure

No.	Sample	BMP (L CH_4/g VS)	Percentage composition (%)	Hydraulic retention time (day)	Temperature (^oC)
A.	Cow Manure	0.2	41.67	61	25 - 33
B.	Human Faeces	0.28	58.33	61	25 - 33

Results presented in Table 1 are in tandem with those of Fantozzi *et al.* (2008) on the analysis of biogas yield and quality produced by anaerobic digestion of different combination of biomass and inoculum. The result show that Chicken manure have 66.6% biogas yield while Cow manure have 46.5% biogas yield, in other words, Chicken manure has a higher BMP than Cow dung. While several researchers quantified the percentile of biogas production, it is important to note the emphasis on the feedstock types. Olowoyeye (2003) conducted a comparative study on biogas production using different animal dungs and found Cow manure yield to be 0.174 ml, Pig manure 0.647ml and Chicken manure to be 1.03ml. The result obtained for Chicken manure suggests some similarities with that of Fantozzi *et al.,* (2008) and that shown in Table 1. Browne et al. (2013) and Pham *et al.* (2013) evaluated the BMP of multiple streams of waste including pig slurry and noted that Cow manure have a higher BMP than Pig manure in line with the results in Table 2. Conversely, while there is sufficient research corroborating the results obtained for Chicken manure, Cow manure and Pig manure, there are scarce literatures on the BMP of Human faecal manure which may be due to its socio-cultural acceptability for use as biogas feedstock. Atilade *et al.* (2014) also carried out a comparative study on biogas generation from Chicken waste, Cow dung and Pig waste using constructed plastic bio – digesters and found Chicken waste to be 71.39% biogas yield, Cow dung to be 62.68% of biogas yield and Pig manure to be 61.07% biogas yield. The result of Atilade *et al.* (2014) is in consonance with the result as shown in Table 1 and 2. Human faecal have the highest BMP as shown in Table 3 when compared with Chicken manure, Cow manure and Pig manure. This result is in concordance with the publication of Dahunsi and Oranusi (2013) on the co-digestion of food waste and human excreta for biogas production.

4. CONCLUSION

This research evaluated the influence of the inoculum in the anaerobic digestion process in terms of methane yield. the experiments were carried out in mesophilic condition in accordance with ABAI. The differences in the quantities of biogas and methane produced for the different inoculum and substrates were analysed using BMP toolkit. It has high reliability and validity as it is based on conditions that approximate practical anaerobic digestion processes. The result show that Cow manure has a BMP of 0.2 L CH_4/g VS, Pig manure 0.16 L CH_4/g VS, Poultry manure 0.27 L CH_4/g VS and human faecal manure 0.28 L CH_4/g VS. In terms of methane yield and comparison with other substrates tested, human faecal manure has the highest BMP, followed by poultry manure. Cow manure has a higher BMP than that of Pig manure. In other words, human faecal manure and poultry manure have very high yield potential as feedstock for anaerobic digestion for biogas production when compared to cow and pig manure.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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