M. Alamgir, S.M.T. Islam and J. A. Saju (Eds.)
ISBN: 978-984-35-4034-8

Proceedings of the Waste Safe 2023 – 8th International Conference on Integrated Solid Waste and Faecal Sludge Management
25-26 February 2023, Khulna, Bangladesh

Anaerobic Digestion of Placenta Waste: Hazardous Waste Management at Healthcare Institutions Through Resource Recovery

Nischal Khadka*, Suman Dhun Shrestha, Bikash Adhikari*** and Nawatch Surinkul******

*Department of Civil and Environmental Engineering, Mahidol University, Thailand
**Global Sanitation Graduate School - Nepal, School of Engineering - Kathmandu University, Nepal
***Department of Environmental Science and Engineering, Kathmandu University
****Department of Civil and Environmental Engineering, Mahidol University, Thailand

ABSTRACT

The management of healthcare waste has become a confronting challenge for hospitals and local authorities in developing countries, imperiling the health of those associated with generating, handling and managing hazardous waste. Natural degradation through the anaerobic digestion process has been used successfully to decompose biodegradable healthcare waste such as pathological waste. This study was carried out primarily with an aim to assess the biogas production from (i) anaerobic digestion with placenta as the substrate and cow dung as inoculum, and (ii) from co-digestion of placenta with kitchen waste. Biochemical Methane Potential (BMP) test was adopted for gas measurement from anaerobic digestion of 3 samples; (sample A): cow dung as main substrate, (sample B) placenta waste as main substrate with cow dung for inoculum, and (sample C): co-digestion of placenta and food waste as substrate with cow dung as inoculum. The feeds were maintained in 500 ml reagent bottles with 10% total solids (TS) content and 0.5 substrate to inoculum ratio, at two different temperatures: (1) mesophilic temperature (35±2℃) and (2) room temperature (23±1℃). The results showed the digestion of placenta and cow dung at mesophilic temperature (sample B at 35±2℃) had the highest cumulative methane yield at about 60.73 ml/gm VS in the 30 days period of the experiment. The similar results were seen among the samples kept at room temperature as the feed with placenta and cow dung (sample B at 23±1℃) had the highest methane yield at about 32.93 ml/gm VS. The lower methane production from the co-digestion of placenta and food waste in this experiment, under both temperatures, indicates that the composition of food waste used in this experiment had high composition of vegetable peels that decreased the carbon to nitrogen ratio.

Keywords: healthcare waste management, hazardous waste, placenta waste, anaerobic digestion, biogas

INTRODUCTION

Pathological waste are the by-products from the diagnosis, treatment or immunization of human beings or animals with potential health risks to the healthcare providers, patients, waste handlers and individual members of the community (Prüss et al., 1999). These waste include sharps, human or animal tissues and even body parts such as fetus and placenta, along with body fluids and other infectious materials that have been contaminated during the procedure of treatment. Generally in developing countries, there is no separate handling or treatment of the hazardous and infectious waste and the policies also lack the mechanisms and regulations, thus treating both the medical waste and the household waste as homogeneous municipal waste (ENPHO, 2000).
The WHO suggests that 75-90% of healthcare waste may not be hazardous to living beings, these include mostly paper, plastics, and other organic and inorganic waste from healthcare facilities. All the same, the remaining 10-25% could be hazardous as well as infectious due to its exposure in our

ISBN: 978-984-35-4034-8

environment, potentially causing life-threatening diseases such as acquired immunodeficiency syndrome (AIDS), hepatitis A, and cancer (Prüss et al., 1999). Such types of wastes are characterized by the Environmental Protection Agency (EPA) as corrosive, inflammable, reactive, or toxic.

In healthcare institutions, the total waste generated is surfeited with placental delivery that occurs after a childbirth. A placenta weighs an average of 590±82 gm, which means the generation of pathological waste at this rate can constitute an acute waste management problem for the HCIs (Panti et al., 2012). The risk from the exposure to these wastes becomes higher when it is dumped along with other general waste which ultimately ends up in our surroundings and potentially damaging aquatic life, spreading water-borne diseases like cholera, jaundice, typhoid and hepatitis, and even causing air pollution through the emission of greenhouse gasses and other toxic substances in your surroundings.

In low-income countries, the treatment of healthcare waste is done by conventional approaches such as low-heat thermal sterilization known as autoclaving or by high-heat burning such as incineration. The process like incineration can release highly toxic particulate matter such as dioxins, furnaces and heavy metals like mercury, zinc, lead, etc. EPA has found that these particulate matters can not only cause cancer, but even with its small injection into our body is likely to cause birth defects, developmental and immune system disorder problems and some acute health issues (Dhakal et al., 2015).

Therefore, in addition to handling the pathological waste by simply landfilling or incinerating, natural degradation through anaerobic digestion, composting and vermiculture have also been used successfully to decompose the biodegradable healthcare waste. Hence, the anaerobic digestion (AD) process can be a significant solution to all the aforesaid problems in managing healthcare waste as the byproducts from this process can be recovered into another resources such as biogas for alternative source of fuel and the digestate as compost or soil amendments.

OBJECTIVES & LIMITATIONS

The main objective of this study is to assess the yield of methane gas from anaerobic digestion of placenta and through co-digestion with kitchen waste.

Other specific objectives are:

1. To assess the methane yield gas from placenta, and from co-digestion of placenta with food waste.
2. To compare the methane yield from the anaerobic digestion of placenta, and from co-digestion of placenta and food waste.

Few researches, as for example one by Dhakal et al., 2015, have been conducted on biogas production from anaerobic digestion of human organs and particularly using only placenta as a substrate. Most of the research work for the feed of biogas is focused on the kitchen waste, municipal waste, and cattle dung, mixture of human waste and cattle dung, agricultural waste, etc. (Moller, et al., 2004). The purpose of co-digestion with kitchen waste is to improve the microbial activity, thus greater yield of biogas.

The limitations faced in this study are as follow

i. Due to limited laboratory instrumentation, only two replicates of the samples were experimented.
ii. Analysis of other components of healthcare waste (pathological waste) was not done.
iii. Analysis of the digestate could not be performed due to time and resource constraints.

METHODS AND METHODOLOGY

After the overview of the study and sample collection, physical analysis and laboratory analysis of the samples of substrate and inoculum were carried out. For the measurement of methane gas production from anaerobic digestion of the placenta and food waste, a laboratory setup of the Biomethane Potential (BMP) test was adopted.

ISBN: 978-984-35-4034-8

Sampling for batch reaction

Anaerobic digester of 500 ml reagent bottles were used for anaerobic digestion of the samples to be analyzed. Each sample was replicated into four batches, two of them were kept at 23±1℃ (room temperature) and the other two at 35±2℃ (mesophilic temperature for optimum cumulation of methane gas) (Cioabla et al., 2012). All the batches were maintained at 10% total solid (TS) content of the samples used since, optimum cumulative biogas is obtained at 10.16% total solids (Orhorhoro et al., 2017).

The total number of batch reactors prepared for this experiment were:

- Samples taken x Temperature x Replicates = 3 x 2 x 2 = 12

Table 1: Sampling of the batch reactors

Sample Name	Substrate	Inoculum	Temperature (℃)
A1	Cow dung	-	35±2
A2	Cow dung	-	23±1
B1	Placenta	Cow dung	35±2
B2	Placenta	Cow dung	23±1
C1	Placenta + Food Waste	Cow dung	35±2
C2	Placenta + Food Waste	Cow dung	23±1

Materials used

Laboratory equipment used in this study to carry out the experiments are listed below:

- Sample bottles (1000 ml)
- IV set (rubber pipe with a switch)
- Reagent bottles (500 ml)
- Rubber corks
- Glass pipe
- Graduated cylinder
- Water Bath
- Bond set (glue)
- Volumetric flask
- Beehive shelf

Chemical required

- Sodium hydroxide solution (1 M concentration)

The NaOH solution was used to pass down the gas produced from the digesters to absorb the content of carbon dioxide (CO_2) (Lasocki et al., 2015).

Physical analysis

Total Solids (TS) and Volatile Solids (VS) of the substrates were calculated for the physical analysis under the standard procedure of American Public Health Association (APHA) 2013. After knowing the

APHA formula for the calculation of TS and VS are given below:

$$TS = \frac{Weight\ after\ 105\ °C - Crucible\ weight}{Sample\ weight} * 100\%$$

$$VS = \frac{Weight\ after\ 105\ °C - Weight\ after\ 505\ °C}{Sample\ weight} * 100\%$$

Preparation for laboratory analysis

The reagent bottles were sealed with a cork in which an IV set was connected for the outlet of the gas to pass through the NaOH solution and followed by the downward gas displacement setup for the measurement of the methane gas produced daily. The reagent bottles were then covered completely by aluminum foil and the whole BMP setup was maintained in a shaded area of the laboratory.

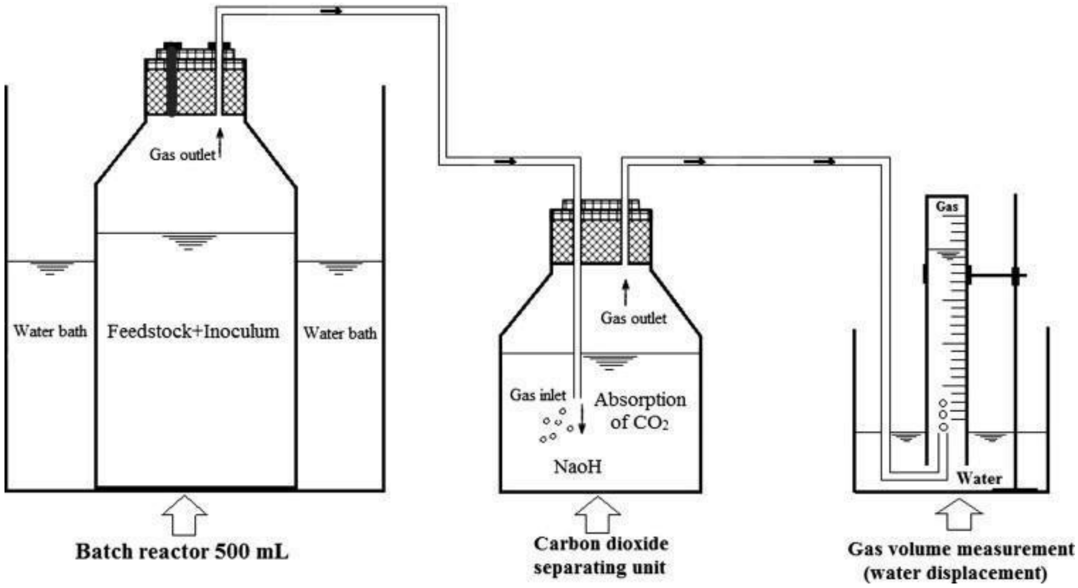

Figure 1: Laboratory BMP setup for the volume measurement of methane gas

FINDINGS

Results from physical analysis and experimental analysis were obtained from the study.

Physical analysis result

The table below shows the value for the TS and VS of different substrates and inoculum used.

Table 2: Physical analysis of the substrates

Sample	Weight of sample (g)	Weight of crucible (g)	Total Weight (Crucible + sample) (g)	Weight after 24 hours in 105℃ (g)	Weight after 1 hour in 600℃ (g)	Total Solids (TS) (%)	Volatile Solids (VS) (%)
Placenta	18.51	37.42	55.93	41.61	38.52	22.65	73.79
Food waste	14.39	37.79	52.18	39.51	37.94	11.97	91.53
Cow dung	15.04	41.25	56.29	43.59	41.62	15.56	84.09

Experimental analysis result

The experimental setup of anaerobic digestion for the production of biogas was started from 29th July, 2019 for a period of 30 days. The average pH in the digesters was measured to be 6.8.

Every digester had a head-space of about 1/2 to 2/3 of the bottle which was good for the storage of the gas produced. The table below shows the composition and weight of different substrates taken for each batch.

ISBN: 978-984-35-4034-8

Table 3: Weight of substrates taken to make batches at 10% TS

Sample Name	Substrates used for each batch	Temp. (°C)	Weight of Cow Dung (g)	Weight of Placenta (g)	Weight of Food Waste (g)	Water Added (ml)	Total Weight (g)
A1	Cow dung	35	152.9	-	-	84.95	237.85
A2	Cow dung	Lab temp	152.9	-	-	84.95	237.85
B1	Placenta+Cow dung	35	76.4	29.9	-	64.37	107.7
B2	Placenta+Cow dung	Lab temp	76.4	29.9	-	64.37	107.7
C1	Placenta+Food waste+Cow dung	35	152.9	37.75	37.75	140.23	368.6
C2	Placenta+Food waste+Cow dung	Lab temp	152.9	37.75	37.75	140.23	368.6

DATA ANALYSIS

The graphical representation of the average cumulative methane yield v/s daily methane yield in 30 days for all the samples are demonstrated below:

Sample A1 **Sample A2**

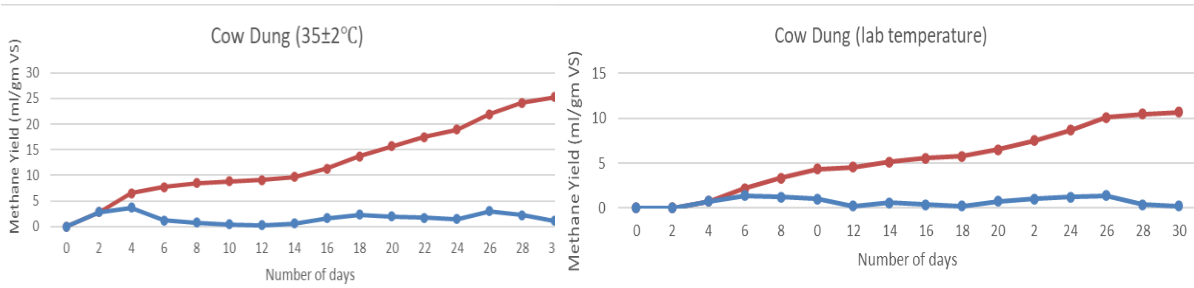

Figure 2: Average cumulative methane production from digestion of cow dung as the main substrate

Sample B1 **Sample B2**

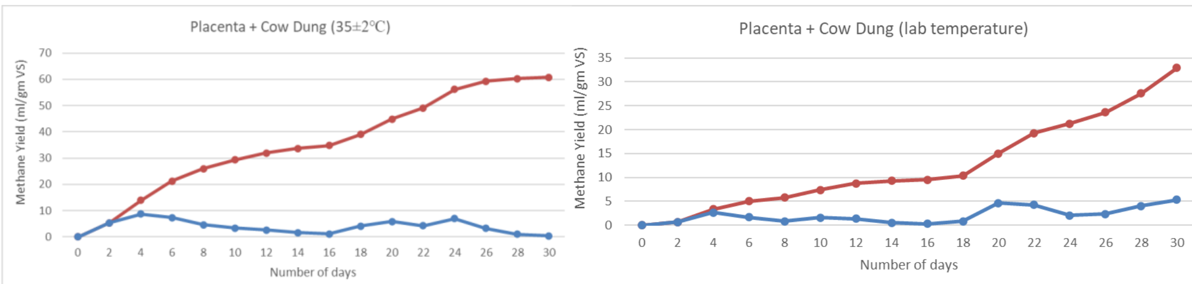

Figure 3: Average cumulative methane production from digestion of placenta waste and cow dung

Sample C1 **Sample C2**

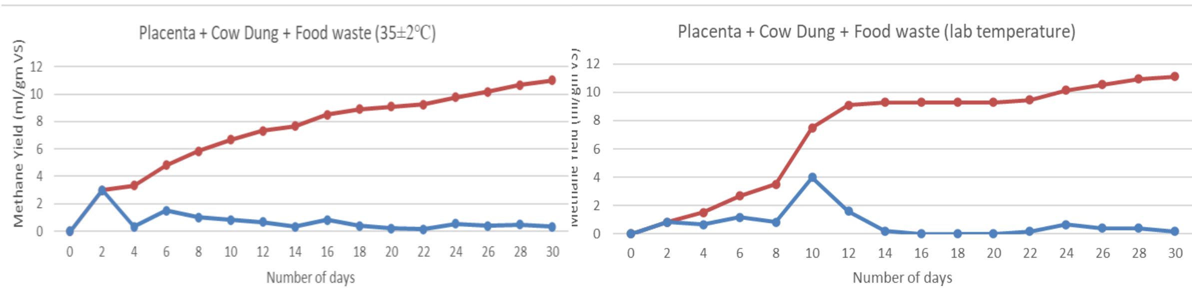

Figure 4: Average cumulative methane production from co-digestion of placenta and food waste

ISBN: 978-984-35-4034-8

Comparing all six graphs, digestion of placenta with cow dung has the highest rate of average cumulative methane yield at mesophilic temperature with 60.73 ml/gm VS of the feed. Similarly, among the samples kept at room temperature, the feed with placenta and cow dung had the highest methane yield at about 32.93 ml/gm VS. While co-digestion of placenta waste with food waste produced significantly lower yield of cumulative methane gas.

DISCUSSION

Carbon to Nitrogen (C/N) ratio is an important parameter in waste composition for determining the degradation rate of an organic matter. The lower methane production from the co-digestion of placenta and food waste, under both temperatures, indicates that the composition of food waste used in this experiment had high composition of vegetable peels that decreased the carbon to nitrogen ratio (Wescott et al.) (Herbert et al.). The lesser amount of carbon in the feed means the energy required for the anaerobes to grow is not sufficient.

CONCLUSION

From the results, it can be concluded that placenta waste is a good organic substrate for anaerobic digester and thus can be used for high yield of biogas from anaerobic digestion in healthcare institutions. Installing an anaerobic digester could be a better solution for safe disposal of hazardous medical waste such as 'placenta'. The slurry produced after the digestion can be used as both soil amendment and fertilizer.

Normally food waste as substrate in co-digestion has great potential to provide high yield of biogas (Kunwar, 2017). But from the results, it is found that food waste with more vegetable peels can decrease the biogas yield as it has a C:N (carbon to nitrogen) ratio of 11:1 to 13:1 (Wescott et al.) (Herbert et al.).

As in general, about 50% of the waste in a healthcare institution is organic matter such as food waste, paper, biodegradable pathological waste, etc. which is possible for treatment along with placenta waste towards safe management through anaerobic digestion.

RECOMMENDATION

Few recommendations from the study are listed below;

- Further research on the energy equivalence of biogas is required to estimate the potential energy production.
- Biogas composition from anaerobic digestion of pathological waste (such as placenta) to compare resource recovery.
- Pathogens analysis from the digestate to analyze the effectiveness of treatment.

ACKNOWLEDGEMENT

For this study, we are thankful for the support from Mr. Pramesh Koju and Ms. Bedana Maharjan from the Infection Prevention and Control Department - Dhulikhel Hospital, and the Department of Environmental Sciences and Engineering, School of Science - Kathmandu University, Dhulikhel.

REFERENCES

Adrian Eugen Cioabla, Ioana Ionel, Gabriela-Alina Dumitrel and Francisc Popescu. 2012. Comparative study on factors affecting anaerobic digestion of agricultural vegetal residues. Biotechnol Biofuels.

Ejiroghene Kelly Orhorhoro, Patrick Okechukwu Ebunilo, Godwin Ejuvwedia Sadjere. Experimental Determination of Effect of Total Solid (TS) and Volatile Solid (VS) on Biogas Yield. American Journal of Modern Energy. 2017.

Holly Wescott, Andy Bary, Craig Cogger, Chery Sullivan, Andrew Mack. U.S. Environmental Protection Agency–Region 10 and Washington State Department of Ecology. Washington State Compost Educator's Guide.

Karki, A., Shrestha, J. N., & Bajgain, S. (2005). Biogas as a renewable source of energy in Nepal: Theory and development. Kathmandu, Nepal: Biogas Support Programme Nepal.

Mathava Kumar, Yan-Liang Ou, Jih-Gaw Lin, 2010. Co-composting of green waste and food waste at low C/N ratio, Waste Management, Volume 30, Issue 4, 2010, Pages 602-609, ISSN 0956-053X, https://doi.org/10.1016/j.wasman.2009.11.023.

Nimesh Dhakal, Amrit Bahadur Karki and Mahesh Nakarmi. Waste to Energy: Management of Biodegradable Healthcare Waste through Anaerobic Digestion. Nepal Journal of Science and Technology Vol. 16, No.1 (2015) 41-48.

Orhorhoro, Ejiroghene & Ebunilo, Patrick & Godwin, Ejuvwedia & Sadjere, & Ejuvwedia, Godwin. (2017). Experimental Determination of Effect of Total Solid (TS) and Volatile Solid (VS) on Biogas Yield. American Journal of Modern Energy. 3. 131-135. 10.11648/j.ajme.20170306.13.

Panti, A. A., Ekele, B. A., Nwobodo, E. I., & Yakubu, A. (2012). The relationship between the weight of the placenta and birth weight of the neonate in a Nigerian Hospital. Nigerian medical journal : journal of the Nigeria Medical Association, 53(2), 80–84. doi:10.4103/0300-1652.103547

Pino, Amabelia & Casanova, Omar & Barbazan, Monica & Mancassola, V. & Rodríguez, Jimena & Arló, Laura & Borzacconi, Liliana & Passeggi, Mauricio. (2012). Characterization and evaluation of biosolids produced by anaerobic digestion of agroindustrial residues. Ciencia del Suelo. 30. 129-136.

Prüss, A., Giroult, E., & Rushbrook, P. (1999). Safe management of wastes from health-care activities. WHO, Geneva. 380 pp. Retrieved from http://www.searo.who.int/srilanka/documents/safe_management_of_wastes_from_healthcare_activities.pdf