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Biogas Potentials for Anaerobic Co-Digested Rumen Contents and Sewage Sludge

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Abstract
Sewage sludge (SS) and rumen contents (RC) are produced daily in waste stabilization ponds and abattoirs respectively as organic wastes. However, these wastes could pose a threat to the environment if not properly managed hence, this research investigated the potentials of these wastes in generating biogas. This was achieved by digesting different SS/RC ratios anaerobically for 30days and recording the biogas produced under mesophilic condition. The SS and RC were obtained from Ahmadu Bello University (ABU) waste stabilization pond and cattle (Bos indicus) respectively, while the SS/RC ratios considered were 1:0, 0:1, 1:1, 1:2 and 2:1. Results showed that the co-digested organic wastes produced more biogas compared to mono-digestions of equivalent volumes of SS (1:0) and RC (0:1). This is because the recorded daily biogas potentials for SS/RC ratios 1:0, 0:1, 1:1, 1:2 and 2:1 were 12.77, 19.59, 21.79, 23.85 and 20.45ml per gram of TS added respectively. Hence, it was concluded that biogas potential for SS improved by 70.63%, 86.77% and 60.14% when co-digested with RC at SS/RC ratios 1:1, 1:2 and 2:1 respectively, while that of RC improved by 11.23%, 21.75% and 4.39% at SS/RC ratios 1:1, 1:2 and 2:1 respectively.

Keywords: Abattoir, Feedstock, Mesophilic, Ratios, WSP

INTRODUCTION
The discharge of untreated sewage into the environment could cause a lot of adverse effects on human health since sewage usually contains numerous life-threatening pathogens including *Vibrio cholerae* and *Salmonella typhi*. It could also lead to eutrophication of streams and rivers with its associated effects. Hence, in 1979, the management of Ahmadu Bello University (ABU), Zaria-Nigeria decided to design and construct a Waste Stabilization Pond (WSP) that could treat the wastewater generated within the university community before discharging to the nearby Kubani stream. However, during the operation of a WSP, sludges are frequently formed as byproduct and needs to be removed periodically in order not to reduce the volume and treatment efficiency of the pond thus, increasing the operating cost of WSP. Zaria, being the host community of Ahmadu Bello University is known to have numerous abattoirs especially for the ruminants. Usually, the ingesta (rumen contents) in these abattoirs are disposed by merely dumping on the ground surface until they accumulate to form heaps, allowed to dry and then burnt openly. This is not environmentally friendly because rumen contents contain so much bacteria (Chloe *et al.,* 2019; Kristi *et al.,* 2018 and Nematollah *et al.,* 2013) hence, if disposed in this manner, the watery component could leach into the ground to contaminate groundwater. In addition, the open burning of these dried heaps of rumen contents pollutes the atmosphere.

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Global warming is one of the main environmental problems disturbing the world however, several researchers including Azilah *et al.* (2019) and Dolf *et al.* (2019) have shown that the use of renewable energy at homes, institutions and industries could reduce its effects considerably. Biogas has been identified for long as one the sources of renewable energy (Richard *et al.,* 2011; Balat and Balat, 2009). It is generated when bacteria decompose organic materials in the absence of oxygen to produce mostly methane and carbon dioxide in a process known as anaerobic digestion. The gas produced usually consist of 55 – 75% methane and 25 – 45% carbon dioxide with trace amount of other gases especially nitrogen (Ayhan *et al.,* 2016). The sludge in WSP and rumen contents in abattoirs are all biodegradables hence, could be used as feedstock for anaerobic digestion. However, the mono-digestion of abattoir wastes have been reported of creating technical challenges due to the inhibitory effects of ammonia and fatty acids on methanogens (Sebastian and Przemyslaw, 2015). Mono-digestion of sewage sludge also have the limitation of low quantity of biogas production compared to the volume of feedstock added in a digester, as some of the organic matters in the sludge are already stabilized by the bacteria present (Garg, 2009). In other words, the bacteria in sewage sludge are activated and would readily digest organic wastes more than those present in fresh rumen contents. However, most related research on the subject matter worked on either co-digestion of cow dung/poultry droppings with agricultural wastes or co-digestion of sewage sludge with agricultural wastes or co-digestion of different agricultural wastes (Tian *et al.,* 2023; Mrosso *et al., 2023*; Rani *et al.,* 2022; Ona *et al.,* 2019; Chua *et al.,* 2013). In other words, literatures on the use of rumen contents and sewage sludge as co-digested substrate are rare at the moment. Hence, co-digestion being the simultaneous anaerobic treatment of two or more biodegradables of different characteristics with the aim of enhancing biogas production, could be applied on these wastes (sewage sludge and rumen contents). Apart from improving the overall biogas production, the co-digestion of these wastes will reduce the cost of biogas production as both the sewage sludge and rumen contents can jointly be treated in a single installation or digester. Hence, it is important to investigate the biogas potentials of the said wastes when co-digested at different ratios in order to make necessary recommendations based on their performances.

Materials and Method

Sewage sludge from the anaerobic tank of Ahmadu Bello University WSP (11°8'17.05"N, 7°39'27.47"E) and fresh rumen contents of a cattle (*Bos indicus*) from Zango Shanu abattoir, Zaria (11°8'11.82"N, 7°39'59.88"E) were separately collected in a 5-liter container. The sludge and rumen contents were properly decanted in order to ensure that only the solid proportions are retained for the experiment. Sewage sludge to rumen contents (SS/RC) ratios of 1:0, 0:1, 1:1, 1:2 and 2:1 were prepared based on the total solids (TS) contents of the sludge and rumen contents, and were identified as A, B, C, D and E respectively. Since both organic materials (sewage sludge and rumen contents) already contain anaerobic bacteria, additional bacteria were not introduced as inoculum into the various SS/RC ratios. The SS/RC ratios 1:0 and 0:1 (i.e. A and B) were prepared for the sake of serving as controls in order to compare the results of the co-digestions with the mono-digestions of sewage sludge and rumen contents respectively. However, the exact quantities of sewage sludge and rumen contents used in the various SS/RC ratios are given in Table 1.

Table 1: Proportions of feedstock components in digester

Assay ID	SS/RC ratio	Sewage sludge (ml)	Rumen contents (ml)	volume of feedstock (ml)
A	1:0	1000	0.0	1000
B	0:1	0.0	1000	1000
C	1:1	500	500	1000
D	1:2	333.4	666.6	1000
E	2:1	666.6	333.4	1000

The various SS/RC ratios showed in Table 1 were measured into 2000ml conical flasks (digesters) using a graduated cylinder and were thoroughly mixed. Thereafter, samples were immediately obtained and analyzed for concentrations of total solids (TS) added in the digesters using standard method (APHA, 2012). The pH values of the mixtures were adjusted by adding few drops of 10M NaOH solution to each mixture until the pH readings were between 6.5 and 7.8. Thereafter, the conical flasks were corked in order to maintain anaerobic (oxygen free) conditions and kept in a mesophilic environment (30^{o}C to 37^{o}C) during retention period.

The quantity of biogas generated in the digesters were measured using the downward water displacement method. This was achieved by filling 1200ml beaker up to 90% capacity (1080ml) thereafter, 1200ml graduated cylinder fully filled with water was inverted and submerged below the water surface in the beaker, and clamped vertically by means of retort stand. A delivery tube was connected from the digester to the inverted graduated cylinder as shown in Figure 1. Thus, the biogas formed in the digester moved to the inverted graduated cylinder through the delivery tube. This consequently displaced corresponding volume of water from the inverted graduated cylinder to the beaker. Hence, the observed drop in water level in the graduated cylinder was recorded as the amount of biogas produced at the ambient temperature and pressure.

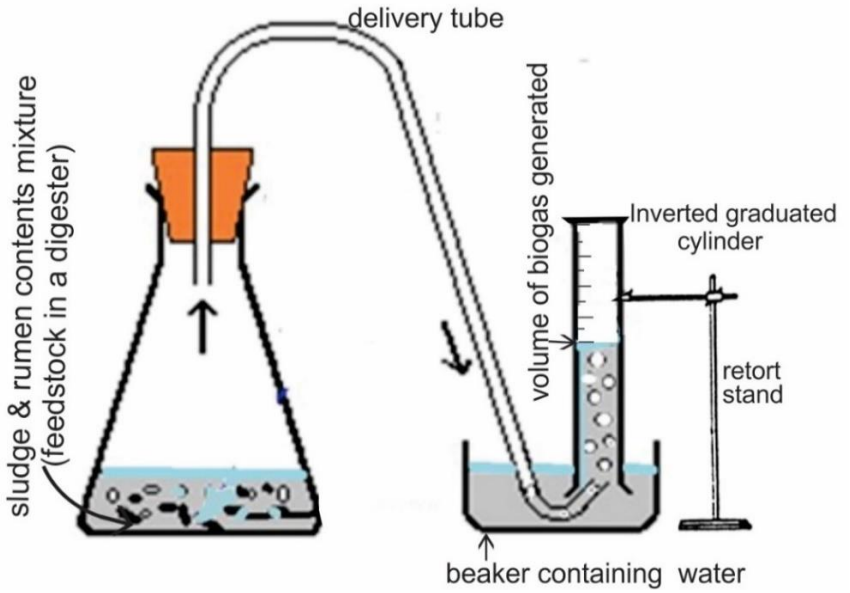

Figure 1: Determination of volume of biogas produced by water displacement method

The biogas production for each experimental assay was recorded in two days intervals while the cumulative biogas in each case was record for a period of 30days from the commencement of the experiment. This is in line with the reports of Tian *et al.* (2023), Adjama *et al.* (2022) as well as Almomani and Bhosale (2020). Hence, the average daily biogas production was determined by dividing the cumulative biogas produced at the 30th day by 30. The result

obtained was divided by the quantity (grams) of TS added in the digester thus, obtaining the daily biogas potential or yield in ml per gram of TS added. However, the quantity (grams) of TS added in each digester was known by multiplying the volume of feedstock in the digester (1000ml) by the concentration of TS.

RESULTS AND DISCUSSION

The concentrations of TS added in the digesters with SS/RC ratios 1:0, 0:1, 1:1, 1:2 and 2:1 are 1.67, 1.39, 1.51, 1.46 and 1.55g/l respectively while the results of the cumulative biogas production for the various experimental conditions (assays) are presented in Figure 2. The figure revealed that the cumulative biogas produced in the mono-digestion of sewage sludge (SS/RC ratio 1:0) during the first 8days (173ml) was higher than the mono-digestion of rumen contents (SS/RC ratio 0:1) which was 166ml. Nevertheless, the reverse occurred for the remaining days, as the final cumulative volumes of biogas produced for SS/RC ratios 1:0 and 0:1 are 640 and 817ml respectively. This might be due to the fact that bacteria in the sewage sludge were already active in degrading organic matters in the WSP prior to the experiment while those in the rumen contents were still acclimatizing during the said period. However, the quantity of degradable organic matters present in fresh rumen contents is usually higher than that of sewage sludge since the former often contain undigested ingesta (mostly grasses). This explain the reason why more biogas were produced in the mono-digestion of the rumen contents from the 10th till 30th day compared to the mono-digestion of sewage sludge.

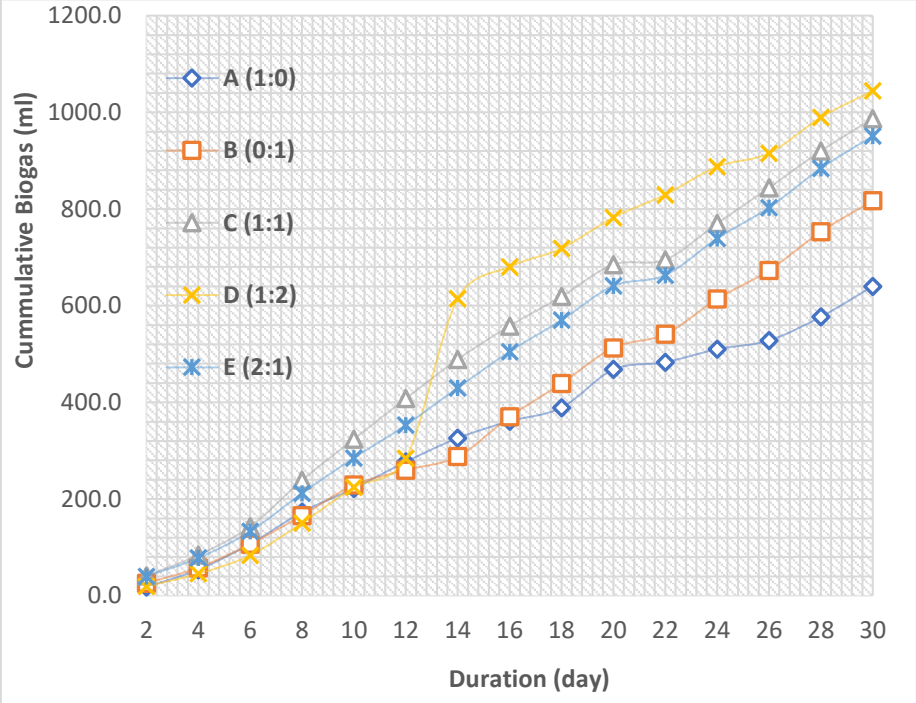

Figure 2: Cumulative biogas production

Figure 2 also revealed that more quantities of biogas were produced in all the cases involving co-digestion (SS/RC ratios 1:1, 1:2 and 2:1) compared to the mono-digestions (1:0 and 0:1) which is in agreement with past related literatures including Fares and Rahul (2020); Nkodi *et al.* (2020); Spyridon and Gerrit (2019). However, the cumulative biogas produced in co-digestion with SS/RC ratios 1:1, 1:2 and 2:1 were 987, 1045 and 951ml respectively. In other words, the biogas production improved with an increase in rumen contents in the feedstock (SS/RC ratio). This might be due to the spike in activities of bacteria present in the rumen contents, caused by the already activated bacteria in the sewage sludge, which in turns degrade the numerous undigested organic matters usually present in rumen contents.

Based on the values obtained as concentrations of TS added in the digesters as well as the final

cumulative volumes of biogas shown in Figure 2, the daily biogas potentials (yields) were calculated as shown in Table 2.

Table 2: Biogas potential of various experimental assays

Assay ID (a)	SS/RC ratio (b)	Conc. of TS added in g/l (c)	Volume of feedstock in ml (d)	Quantity of TS added in grams $= \frac{(c)\times(d)}{1000}$ (e)	Final cum. biogas in ml (f)	Average daily biogas in ml $= \frac{(f)}{30}$ (g)	Average daily biogas potential in ml per gram of TS added $= \frac{(g)}{(e)}$
A	1:0	1.67	1000	1.67	640	21.33	12.77
B	0:1	1.39	1000	1.39	817	27.23	19.59
C	1:1	1.51	1000	1.51	987	32.90	21.79
D	1:2	1.46	1000	1.46	1045	34.83	23.85
E	2:1	1.55	1000	1.55	951	31.70	20.45

Conc. = concentration, cum. = cumulative, SS = sewage sludge, RC = rumen contents, TS = total solids
(a), (b), (c), ……., (g) = column 1, 2, 3,……., 7 respectively.

It is clearly revealed in Table 2 that daily biogas potentials for mono-digestions of the sewage sludge (SS/RC 1:0) and rumen contents (SS/RC ratio 0:1) are 12.77 and 19.59ml per gram of TS added respectively. On the other hand, the values for co-digestions with SS/RC ratios 1:1, 1:2 and 2:1 are correspondingly 21.79, 23.85 and 20.45ml per gram of TS added. In other words, the highest daily biogas potential occurred when the SS/RC ratio is 1:2. Hence, biogas potential of the sewage sludge (SS) improved by 70.63%, 86.77% and 60.14% when co-digested with rumen contents (RC) at SS/RC ratios 1:1, 1:2 and 2:1 respectively, while that of rumen contents improved by 11.23%, 21.75% and 4.39% at SS/RC ratios 1:1, 1:2 and 2:1 respectively.

CONCLUSION

Based on the analyzed results acquired from this research, the following deductions are drawn:

i. Sewage sludge from ABU Waste Stabilization Pond and rumen contents from cattle (*Bos indicus*) have daily biogas potentials of 12.77 and 19.59ml per gram of TS added respectively, when mono-digested anaerobically without inoculum. However, more biogas are produced at the initial stage (first 6 to 8days of retention) for mono-digestion of the sewage sludge compared to rumen contents.

ii. Anaerobic co-digestion of the sewage sludge (SS) and rumen contents (RC) at SS/RC ratios 1:1, 1:2 and 2:1 produced more biogas compared to mono-digestions of equivalent volumes of SS and RC. Nevertheless, average daily biogas potential for SS/RC ratio 1:2 (23.85ml per gram of TS added) is higher than SS/RC ratio 1:1 (21.79ml per gram of TS added) and SS/RC ratio 2:1 (20.45ml per gram of TS added).

iii. Biogas potential of the sewage sludge (SS) improved by 70.63%, 86.77% and 60.14% when co-digested with rumen contents (RC) at SS/RC ratios 1:1, 1:2 and 2:1 respectively, while that of rumen contents improved by 11.23%, 21.75% and 4.39% respectively.

REFERENCES

Adjama, I., Derkyi, N.S., Uba, F., Akolgo, G.A. and Opuko, R. (2022). Anaerobic Co-Digestion of Human Feces with Rice Straw for Biogas Production: A Case Study in Sunyani. *Modeling and Simulation Engineering,* 2022(2608045), 1 – 7 https://doi.org/10.1155/2022/2608045

Almomani, F. and Bhosale, R.R. (2020). Enhancing the Production of Biogas through Co-digestion of Agricultural Waste and Chemical Pre-Treatment. *Chemosphere (Elsevier)*, 255: 1 – 13. https://doi.org/10.1016/j.chemosphere.2020.126805

APHA (2012). Standard Methods for Examination of Water and Wastewater (22nd Edition). American Public Health Association (APHA), American Water Works Association (AWWA), Water Pollution Control Federation (WPCF), Washington DC.

Ayhan, D., Osman, T and Durmus, K. (2016). Biogas Production from Municipal Sewage Sludge (MSS). *Energy Source, Part A: Recovery, Utilization and Environmental Effects,* 38(20), 3027-3033.

Azilah, H., Azlina, A.A and Che, M.I. (2019). The Impact of Renewable Energy Consumption on Carbon Dioxide Emissions: Empirical Evidence from Developing Countries in Asia. *International Journal of Energy Economics and Policy,* 9(3), 135-143.

Balat, M and Balat, H. (2009). Biogas as a Renewable Energy Source – A Review. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects,* 31(14), 1280-1293.

Chloe, M., Fiona, C., Eva, L., Michael, R., Paul, W.O and Paul, D.C. (2019). The Rumen Microbiome: A Crucial Consideration when Optimising Milk and Meat Production and Nitrogen Utilisation Efficiency. *Gut Microbes,* 10(2), 115-132.

Chua, K.H., Cheah, W.L., Tan, C.F. and Leong, Y.P. (2013). Harvesting biogas from wastewater sludge and food waste. IOP Conf. Series: Earth and Environmental Science 16 (2013) 012118, https://doi:10.1088/1755-1315/16/1/012118

Dolf, G., Francisco, B., Deger, S., Morgan, D.B., Nicholas, W and Richardo, G. (2019). The Role of Renewable Energy in the Global Energy Transformation. *Energy and Strategy Reviews,* 24, 38-50.

Fares, A and Rahul, R.B. (2020). Enhancing the Production of Biogas through Anaerobic Co-Digestion of Agricultural Waste and Chemical Pre-Treatments. *Chemosphere,* 225,128605, 1-13.

Garg, S.K. (2009). Sewage Disposal and Air Pollution Engineering (Environmental Engineering Vol. II) 22nd Edition. Khanna Publishers, New Delhi, India.

Kristi, M.C., Kathleen, J.A., William, R.L., Gavin, C.C and Hannah, C.C. (2018). Ruminant Nutrition Symposium: Tiny but Mighty: The Role of the Rumen Microbes in Livestock Production. *Journal of Animal Science*, 96(2), 752-770.

Mrosso, R., Kiplagat, J. and Mecha, A.C. (2023). Anaerobic Codigestion of Tuber Waste and Fruit Waste: Synergy and Enhanced Biogas Production. *International Journal of Chemical Engineering,* ID 6637249, 1 – 10 https://doi.org/10.1155/2023/6637249

Nematollah, D., Keyvan, K and Abbas, Z. (2013). Special Rumen Microbiology. *International Journal of Advanced Biological and Biomedical Research,* 1(11), 1397-1402.

Nkodi, M.T., Mulaji, K.C., Mabela, M.R., Kayembi, S.J., Bie, M.E., Ekoko, G and Taba, K.M. (2020). Investigation of Factors Affecting Biogas Production from Cassava Peels by Fractional Factorial Design Experimental Methodology. *Journal of Applied Life Sciences International,* 23(2): 49-56.

Ona, I.J., Loyal, S.M., Agogo, H.O., Iorungwa, M.S. and Ogah, R. (2019). Biogas Production from the Co-Digestion of Cornstalks with Cow Dung and Poultry Droppings. *Journal of Agricultural Chemistry and Environment,* 8, 145 – 154. 8, 145-154. https://doi.org/10.4236/jacen.2019.83012

Rania, P., Bansal, M., Pathak, V.V. and Ahmad, S. (2022). *Journal of Taibah University for Science,* 16 (1), 147 – 154. https://doi.org/10.1080/16583655.2022.2035928

Richard, A., Martina, F.B and Edward, A. (2011). Biogas as a Potential Renewable Energy Source: A Ghanaian Case Study. *Renewable Energy,* 36, 1510-1516.

Sebastian, B and Przemyslaw, K. (2015). Co-Digestion of Pig Slaughterhouse Waste with Sewage Sludge. *Waste Management,* 40, 119-126.

Spyridon, A and Gerrit, J.W. (2019). Elevated Biogas Production from the Anaerobic Co-Digestion of Farmhouse Waste: Insight into the Process Performance and Kinetics. *Waste Management & Research,* 37(12), 1240-1249.

Tian, P., Gong, B., Bi, K., Liu, Y., Ma, J,. Wang, X., Ouyang, Z. and Cui, X. (2023). Anaerobic Co-Digestion of Pig manure and Rice Straw: Optimization of Process Parameters for Enhancing Biogas Production and System Stability. *International Journal of Environmental Research and Public Health,* 20 (804), 1 – 14. *https://doi.org/10.3390/ijerph20010804*