IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 5, May 2016.
www.ijiset.com
ISSN 2348 – 7968

Analysis of the Effect of Carbon/Nitrogen (C/N) Ratio on the Performance of Biogas Yields For Non-Uniform Multiple Feed Stock Availability and Composition in Nigeria

Oghenero W. Orhorhoro[1], Ejiroghene K. Orhorhoro[2]*, Patrick O. Ebunilo[2]

[1] Department of Electrical/Electronic Engineering, Delta State Polytechnic, Otefe-Oghara.
[2] Department of Mechanical Engineering, University of Benin, Benin City, Edo State, Nigeria

Corresponding author: Ejiroghene K. Orhorhroro
Email: kelecom@yahoo.com

Abstracts: This research work is aim at the analysis of the effect of carbon/nitrogen (C/N) ratio on the performance of biogas yields for non-uniform multiple feed stock availability and composition in Nigeria. Eight different samples of substrates with different C/N ratio were charged differently and together in this order: low C/N ratio, high C/N ratio and combination of both low and high C/N ratio. Analysis was carried out on hydraulic retention time, biogas yields, and rate of frequency of evacuation. The results showed that C/N ratio of substrates affect hydraulic retention time, biogas yields and the rate of frequency of evacuation. Therefore, for a better biogas yields combination of low and high C/N ratio substrates is necessary.

Keywords: C/N ratio, Substrates, Biogas yields, Rate of frequency of evacuation, Nigeria

INTRODUCTION

Anaerobic digestion (AD) has become an increasingly important industrial process. The production of biogas from AD process is of growing interest to many developed and developing countries, as fossil-fuel resources decline (Igoni et al., 2008; Bruni et al. 2010 and Ebunilo et al., 2015). The available energy sources in Nigeria are wood, fossil fuel, coal, petroleum, natural gas, hydro etc and the cost of energy for domestic, commercial and industrial uses in Nigeria has risen astronomically in the past few years (ECN, 1997; Ebunilo et al., 2016).

ISSN 2348 – 7968

Biogas technology which has to do with AD processes have for many years been used to treat and sanitize sewage sludge waste from aerobic waste water, agricultural wastes, food wastes and animal manure, reduce its odour and volume, and produce useful biogas. Several researchers (Schomaker et al., 2000; Adelekan and Bamgboye, 2009; Ofoefule and Uzodinma, 2009; Adeyosoye et al., 2010; Ebunilo et al., 2015; Ebunilo et al., 2016) have reported production of biogas from different substrates such as cassava peels, rice wastes, yam wastes, plantain wastes, sweet potato peel, wild cocoyam peel, plantain peel, talinum triangulare (water leaves), rice husks, rice wastes and various bulk organic wastes in Nigeria. Biogas in turn is a first generation, renewable biofuel that offers the prospect of replacing fossil fuels in the transportation sector and limiting the net greenhouse gas emissions implicated in climate change (Ebunilo et al., 2016).

Carbon/Nitrogen ratio (C/N) ratio means the ratio of carbon element amount in organic matter to its content of nitrogen element amount (FAO/CMS, 1996). The best C/N ratio is 20-30 atoms of carbon for each atom of nitrogen (20-30 carbon atoms: 1 nitrogen atom) (Mattocks, 1984; FAO/CMS, 1996; EREC, 2002). High or low C/N ratio will effect negatively on the digestion of the substrate. Organic wastes differ in their C/N ratio, for example; C/N ratio for cow dung is 24, vegetable wastes (11-19), cassava peel (55), yam peel (36), sweet potato peel (40-46), Beans wastes (24-30), rice wastes (90-130), fish wastes (2.5-5.5), plantain wastes (30-37), fruit wastes (20-50) and for sheep dung is 19 (Karki and Dixit, 1984, FAO/CMS, 1996, Dioha et al., 2013). For good biogas production the adjusting of C/N ratio is desirable and this can be achieved by mixing wastes of high ratio with those of low ratio (FAO/CMS, 1996).

The ideal C/N ratio for anaerobic bio-digestion is between 20:1 and 30:1 (Marchaim, 1992). If C/N ratio is higher than that range, biogas production will be low. This is because the nitrogen will be consumed rapidly by methanogenic bacteria for meeting their protein requirements and will no longer react on the left over carbon remaining in the material. In such case of high C/N ratio, the gas production can be improved by adding nitrogen in farm cattle urine or by fitting latrine to the plant (Fulford, 1988). Materials with high C/N

ISSN 2348 – 7968

ratio typically are residues of agricultural plants. Conversely if C/N ratio is very low, that is outside the ideal range stated above, nitrogen will be liberated and it will accumulate in the form of ammonia. Ammonia will raise the pH value of the slurry in the digester. A pH value which is higher than 8.5, will be toxic to the methanogenic bacteria in the slurry. The cumulative effect of this is also reduced biogas production.

The important of biogas operating parameters cannot be neglected if optimum biogas yields must be achieved. Factors such as carbon/ nitrogen ratio, temperature, seeding, pH, hydraulic retention time etc. must be considered. This research work is aim at the effect of carbon/nitrogen (C/N) ratio on the performance of biogas yields for non-uniform multiple feed stock availability and composition in Nigeria.

MATERIALS AND METHODS

The materials used in this research work are as follows: vegetable wastes, cow dung, cassava peel, yam peel, sweet potatoes peel, beans wastes, rice wastes, plantain wastes, biogas anaerobic digester (AD), thermometer for temperature reading, pressure gauge for pressure readings, weighing scale for measurement of substrates, manual compressor for evacuating the gas from the AD digester, gas bottle for biogas storage and rubber hose.

Different samples of substrates comprising of vegetable wastes, cow dung, cassava peel, yam peel, sweet potatoes peel, beans wastes, rice wastes and plantain peel were collected and measured with weighing balance. Each of the substrates composition weighed 10kg and this was mixed with water in ratio of 1:2 and finally charged into the AD digester separately, composition with C/N ratio less than 20, those with C/N ratio above 30 and the combination of both low and high C/N ratio. The digester content was stirred several times per day with the aim of mixing the substrates inside the digester for efficient biogas generation. The continuous stirring prevents the formation of swimming layers and it can as well bring the micro-organisms (MOs) in contact with the feedstock particles. The pressure and temperature readings were monitored with pressure gauge and thermo meter respectively. The test was subjected to a period of 37 days. The initial and final masses of the gas bottle were taken note of. The quantity of biogas

ISSN 2348 – 7968

generated is calculated by subtracting the initial mass of the gas bottle from the final mass of the gas bottle.

RESULTS

The result obtained with different compositions of substrates is shown in table 1 and table 2 respectively. Biogas yielding rates and biogas evacuation rate is calculated from equation 1 and equation 2 respectively.

$$R = \frac{BY}{HRT} \quad 1$$

$$EVA_R = \frac{N_E}{HRT} \quad 2$$

Where;

HRT= Hydraulic retention time

BY = Biogas yield

R = Rate of Biogas yields

S= Sample

S_1= Cow dung

S_2 = Vegetable wastes

S_3 = Beans wastes

S_4 = Plantain peel

S_5 = Potato peel

S_6 = Yam peel

S_7 = Cassava peel

S_8 = Rice wastes

S_A= Composition with low C/N ratio

S_B = Composition with high C/N ratio

S_C = Composition with low and high C/N ratio

EVA_R= Evacuation rate

N_E= Numbers of evacuation

R = Rate of biogas yields

Table 1: Comparison analysis of evacuation frequency

S	N_E											HRT	EVA_R
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th		
S_1	5	3	3	2	4	-	-	-	-	-	-	17	0.294
S_2	5	3	2	3	3	3	-	-	-	-	-	19	0.316
S_3	9	5	3	3	3	-	-	-	-	-	-	23	0.217
S_4	11	6	3	3	3	-	-	-	-	-	-	26	0.192
S_5	11	5	4	3	4	-	-	-	-	-	-	27	0.185
S_6	12	5	3	3	4	-	-	-	-	-	-	27	0.185
S_7	11	5	4	4	4	-	-	-	-	-	-	28	0.179
S_8	14	5	4	3	3	4	-	-	-	-	-	31	0.194

ISSN 2348 – 7968

S_A	5	3	2	2	2	3	3	-	-	-	-	20	0.350
S_B	15	5	4	3	5	5	-	-	-	-	-	37	0.162
S_C	12	3	2	2	3	3	3	4	-	-	-	32	0.250

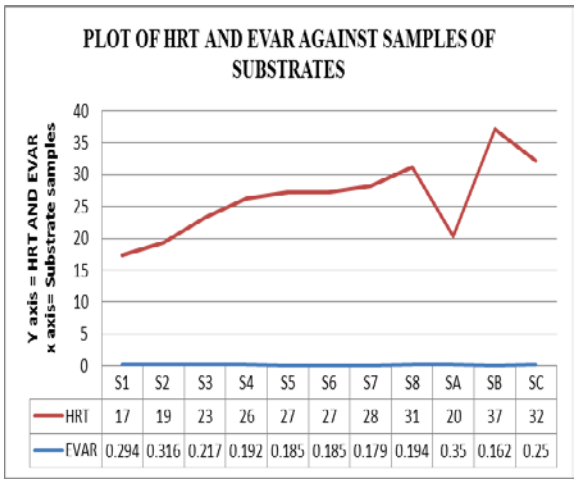
Table 2: Comparative analysis of rate of Biogas yield

S	HRT (DAYS)	BY (Kg)	R (Kg/day)
S_1	17	0.77	0.045
S_2	19	0.93	0.049
S_3	23	2.16	0.094
S_4	26	1.76	0.067
S_5	27	1.73	0.064
S_6	27	1.81	0.067
S_7	28	1.87	0.067
S_8	31	2.13	0.069
S_A	20	1.15	0.058
S_B	37	2.98	0.081
S_C	32	3.45	0.108

DISCUSSION

The hydraulic retention time show that sample 1(S_1) which is cow dung has the lowest hydraulic retention time when compared to the rest substrate samples (Figure 1). The low hydraulic retention time of sample 1 (S_1) confirmed that digestion was faster unlike sample B (S_B) that took longer time. Since sample B (S_B) comprises of substrates with high carbon/nitrogen (C/N) ratio unlike the other samples. This indicated that C/N ratio affect substrates digestion rate. However, when both low and high C/N ratio substrates (S_C) where used together, the digestion rate improved. This implies that the higher the C/N ratio of substrates composition, the longer the digestion of the substrates. On the other hand the lower the C/N ratio the faster the digestion of substrates and the shorter the hydraulic retention time.

V



ISSN 2348 – 7968

Figure 1: Graph of HRT and EVA_R against Substrates samples

Also, the rate of biogas evacuation shows that the samples with low C/N ratio had faster rate of evacuation frequency when comparison to samples with high C/N ratio. Figure 2 show that biogas yields were in this order: $S_C > S_B > S_3 > S_8 > S_7 > S_6 > S_5 > S_4 > S_A > S_2 > S_1$. This confirms that mixture of low and high C/N ratio will bring about high biogas yields.

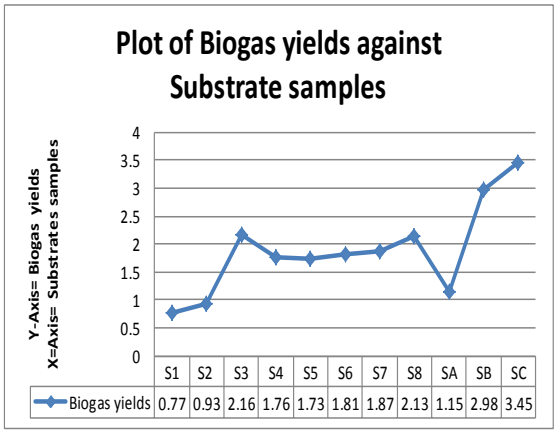


Figure 2: Graph of Biogas yields against Substrate samples

CONCLUSION

Several operating parameters such as substrates composition, design of digester, nature of substrate, pH, temperature, loading rate, hydraulic retention time (HRT), C: N ratio, volatile fatty acids (VFA), etc. influence biogas yields. This research work on the effect of C/N ratio on biogas yields shows that biogas production is influence with C/N ratio. The result show that the higher the C/N ratio, the higher the hydraulic retention time and the lower the frequency of evacuation. Therefore, for a better biogas yields combination of both low and high C/N ratio substrates is necessary.

REFERENCES

1. Adelekan, B.A. and Bamgboye, A.I. (2009): Comparison of Biogas Productivity of Cassava Peels Mixed in Selected Ratios with Major Livestock Waste Types. African Journal of Agricultural Research Vol. 4 (7), pp. 571 – 577.

2. Adeyosoye, O. I., Adesokan, I. A., Afolabi, K. D. and Ekeocha, A. H. (2010). Estimation of Proximate Composition and

ISSN 2348 – 7968

Biogas Production from in Vitro Gas Fermentation of Sweet Potato (Ipomea batatas) and Wild Cocoyam (Colocasia esculenta) Peels. African Journal of Environmental Science and Technology Vol. 4(6), pp. 388 – 391

3. Bruni, E., Jensen, A.P., Pedersen, E.S. and Angelidaki, I. Anaerobic digestion of maize focusing on variety, harvest time and pretreatment. Appl. Energy 2010, 87, 2212–2217.

4. Ebunilo P.O., Aliu S.A. and Orhorhoro E.K. (2015). Performance Study of a Biogas Pilot Plant using Domestic Wastes from Benin Metropolis. International Journal of Thermal & Environmental Engineering volume 10, No 2 (2015), 135-141

5. Ebunilo P.O., Aliu S.A. and Orhorhoro E.K. (2015).Comparative Analysis of Biogas Yield from Different Composition of Domestic Wastes from Benin City, Nigeria. Journal of Advanced &Applied Science (JAAS) Volume 04, Issue 05, Page 169-177, 2015.

6. Ebunilo P.O., Orhorhoro E. K., Oboh V., Onochie P. U.(2016). Effect of Temperature on Biogas Yields Using South-South Nigeria as a Case Study. International Journal of Technology Enhancements and Emerging Engineering Research, Volume 4, Issue 3, pp.50-54, March, 2016 Edition-ISSN 2347-4489

7. Energy Commission of Nigeria (1997). Potential for Renewable Energy Application in Nigeria

8. (EREC): Methane (Biogas) from Anaerobic Digesters. U.S Department of Energy. Merrifield. Virginia. USA. 2002

9. FAO/CMS. A system Approach to Biogas Technology. Biogas Technology: a training manual for extension.1996. Available at website:-http://www.fao.org

10. Fulford, D. (1988). Running of Biogas Program Handbook, Intermediate Technology Publications, London.

11. Igoni, A.H.; Ayotamuno, M.J.; Eze, C.L.; Ogaji, S.O.T. and Probert, S.D. Designs of anaerobic digesters for producing biogas from municipal solid-waste. Appl. Energy 2008, 85, 430–438.

ISSN 2348 – 7968

12. I.J. Dioha, C.H. Ikeme, T.Nafi'u, N.I. Soba and Yusuf M.B.S. Effect of Carbon to Nitrogen ratio on Biogas Production. International Research Journal of Natural Sciences, Vol. 1 No.3, pp.1-10, September, 2013. Published by European Centre for Research Training and Development UK.

13. Karki A.B., and Dixit K. (1984), Biogas fieldbook. Sahayogi press, Kathamandu, Nepal.

14. Marchaim, U. (1992). Biogas Processes for Sustainable Development. FAO Agricultural Services Bulletin 95. Food and Agricultural Organization of the United Nations.

15. Ofoefule A.U and Uzodinma E.O. (2009) Biogas production for blends of cassava (manihot utilissima) peels with some animal wastes. International Journal of Physical Sciences. Vol.4 (7), pp. 398- 402.

16. P.O. Ebunilo, E.K. Orhorhoro, O.A. Adegbayi (2016). Investigation of the Purification of Biogas from domestic wastes using local materials in Nigeria. International Journal of Scientific & Engineering Research, Volume 7, Issue 2, February-2016, 505 ISSN 2229-5518

17. Schomaker, A. H. H. M., Boerboom, A. A. M., Visser, A., Pfeifer, A. E. (2000). Anaerobic Digestion of Agro-Industrial Wastes: Information Networks.Technical Summary of Gas Treatment, DG12- SSMI Ed., AD-NETT report, Netherlands