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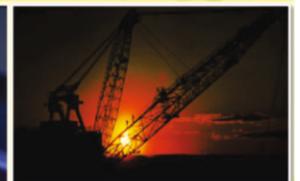
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Synergistic Effect of Co-digesting Different Mix Ratios of Water Hyacinth and Cow-dung for Biogas Production.

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A B S T R A C T

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synergistic effect,
water hyacinth,
cow-dung,
co-digestion,
biogas production

The synergistic effect of co-digesting water hyacinth (WH) with cow-dung (CD) for optimum biogas production was evaluated. Different mix ratios of WH to CD were digested in a laboratory scale anaerobic digester over a retention time of 40 days. The volume of biogas produced was determined using water displacement method. The ultimate biogas yield and synergy factors for all the mixes were calculated. The third order polynomial curve for the different mixes had a R^2 value of 0.9834 which is quite significant. The curve also showed that the highest ultimate biogas yield of 141.72 L was produced by 2 WH: 8 CD and impressively makes it the best CD-aided WH digestion mix. The highest synergy factor of 1.31 was observed for 2 WH: 8 CD which collaborates the fact that the best mix of CD-aided WH digestion in terms of biogas yield is 2 WH: 8 CD.

Introduction

Water hyacinth (WH) covers water bodies, thereby reducing the gaseous exchanges that takes place at the air to water interface and hence reducing the photosynthetic activity of submerged plants by hindering the penetration of the sun's rays (Perna and Burrows, 2005). Also WH is known to cause severe ecological and economic problems by creating a lingering shortage of dissolved oxygen harmful to water fauna and flora, impeding navigation and fishing activities and blocking irrigation systems (Malik, 2007). Authorities in the study of WH believe that it is difficult to eradicate it, since the conditions that allow it to thrive are not easily controlled (Howard and Matindi, 2003).

Cow-dung (CD), a readily available animal manure in Nigeria, contains several pathogenic organisms which can cause diseases in humans if not properly handled. There are no proper disposing units for CD especially in developing countries like Nigeria.

Interestingly, CD is a very good starter for poor producing biogas feed stocks (Ofoefule *et al.*, 2010 and Yadvika *et al.*, 2004).

Biogas is a colourless and odourless gas which burns with a blue flame (Veeken and Hamelers, 2000). Biogas is produced through the process of anaerobic digestion (AD). AD is considered as a waste-to-energy technology, widely used in the treatment of different organic wastes such as organic fraction of municipal solid waste, sewage sludge and animal manure (Li *et al.*, 2009). Co-digestion of different materials may enhance the AD process due to better carbon and nutrient balance (Mshandete *et al.*, 2004; Parawira *et al.*, 2004). According to Mata-Alvarez *et al.* (2000), digestion of more than one substrate in the same digester can establish positive synergism and the added nutrients can support microbial growth. Li *et al.* (2011) found that the added co-substrate not only helped to balance the C: N ratio, but also solved the problems of ammonia inhibition generally encountered during anaerobic digestion of animal manure. But co-digestion does not always give a higher methane yield than digestion of each substrate

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separately. For example, Liu *et al.* (2009) found that under thermophilic conditions, the methane yield from co-digestion of food and green wastes was in the middle between the methane yields obtained from digestions of each substrate separately. They also found that under mesophilic conditions of 35 °C, the yield from the co-digestion was lower than the yields obtained from each of the single digestions. Al-Imam *et al.* (2013) analysed and compared biogas from cow dung, poultry waste and water hyacinth but did not carry out a co-digestion of the different feed stocks. In this study, the synergistic effect of producing biogas from the co-digestion of different mix ratios of WH and CD was investigated.

Methodology

WH were harvested from a private pond in Akure. The pond is shown in Plate 1. CD were gotten from the Federal University of Technology, Akure animal farm. Eleven mix ratios of WH to CD were investigated (10:0, 9:1, 8:2, 7:3, 6:4, 5:5, 4:6, 3:7, 2:8, 1:9 and 0:10). The feed stocks were digested for 40 days in a 25 L capacity plastic prototype digester, with a thickness of 2 mm, height of 400 mm and width of 320 mm. A schematic representation of the digester is shown in Figure 1 while Plate 2 shows the experimental set-up.

The Total Volume of Digester (TVD) was calculated as shown in equation 1:

$$TVD = 25 \text{ L} \dots\dots\dots(1)$$

But the Volume of the Digestion Chamber (VDC) should be $\frac{3}{4}$ the TVD to allow for gas collection.

Therefore, VDC was calculated using equations 2 and 3

$$VDC = \frac{3}{4} \times TVD \dots\dots\dots(2)$$

$$VDC = \frac{3}{4} \times 25 = 18.75 \text{ L} \dots\dots\dots(3)$$

One-fourth of the TVD should be allowed for gas collection, hence, the Volume of the Gas Chamber (VG) was calculated using equations 4 and 5.

$$VG = \frac{1}{4} \times TVD \dots\dots\dots(4)$$

$$VG = \frac{1}{4} \times 25 = 6.25 \text{ L} \dots\dots\dots(5)$$

The volume of biogas produced was determined using water displacement method as described in Otun et al. (2014) and Ojo et al. (2016). In the water displacement method of gas collection, a measuring cylinder was inverted inside a bowl filled with water in order to prevent the escape of air. The digester gas outlet was connected to the measuring cylinder and the displacement of water was measured. From Archimedes' principle, the volume of gas produced was assumed to be equal to the volume of water displaced.

The Ultimate biogas yield for each mix was obtained by calculating the average of the cumulative biogas volume from day 35 to 40. The temperature within the digester and the pH of the digestion substrates were monitored daily throughout the duration

of the experiments. The temperature within the digester was measured using a mercury thermometer calibrated in degree centigrade while the pH was determined using a pH meter. The synergy factor was calculated from the ultimate values of biogas yield using equation 6

$$\text{Synergy factor} = \frac{y_{BG, exp}^{mix}}{y_{BG, theo}^{mix}} \dots\dots\dots(6)$$

where $y_{BG, exp}^{mix}$ is the experimental biogas yield and $y_{BG, theo}^{mix}$ is the theoretical biogas yield

The experimental biogas yield is the ultimate biogas yield of the particular mix without considering the mix ratio. The theoretical biogas yield is the ultimate biogas yield of the particular mix taking into consideration the mix ratio.



Plate 1: WH in a private pond in Akure.

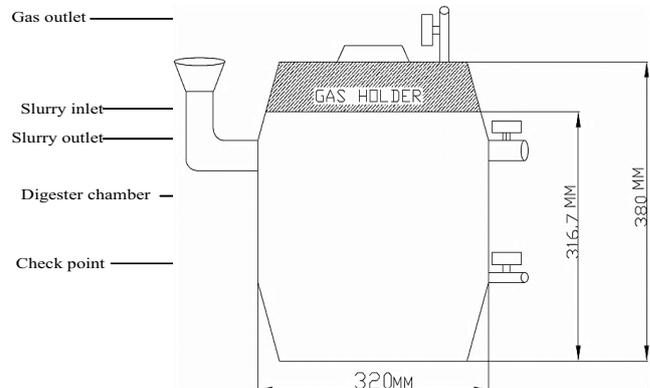


Figure 1: Schematic representation of digester



Plate 2: Experimental set-up

Result and Discussion

The ultimate values of biogas yields produced for the different mixes as well as their synergy factors are presented in Table 1. Ultimate values of biogas yields of the mixes represent the biogas yield as retention time approaches infinity (Mondal and Biswas, 2012).

Table 1: Ultimate biogas yield and synergy factor for the different mixes

S/N	Mix ratios		Ultimate Biogas Produced (Litres)	Synergy factor
	WH	CD		
1	10	0	32.17	1
2	9	1	53.17	1.27665194
3	8	2	67.04	1.311270195
4	7	3	81.04	1.337205465
5	6	4	89.3	1.274221626
6	5	5	99.29	1.247988939
7	4	6	116.38	1.307082369
8	3	7	128.11	1.300397905
9	2	8	141.72	1.312295128
10	1	9	132.77	1.130226777
11	0	10	126.95	1

The ultimate biogas production curve for CD-aided WH digestion is shown in Figure 2. The third order polynomial curve has a R^2 value of 0.9834 which is quite significant. The graph shows that the highest ultimate biogas yield of 141.72 L was produced by 2 WH: 8 CD and impressively makes it the best CD-aided WH digestion mix.

A temperature range of 28.1 °C to 32.9 °C was observed during the digestion process. This shows that the digestion process occurred within the mesophilic temperature range, which is ideal for AD as this temperature range adequately supports microbial activities within the digester (Wang *et al.*, 2009). The pH of the substrates ranged from 6.1 to 8.4 with the values low at the start of the digestion process and gradually increasing to its maximum at the end of the digestion process. The values observed for the pH evidently describes the three main stages (hydrolysis, acetogenesis/acidogenesis and methanogenesis) that clearly defines any AD process (Li *et al.*, 2011).

Table 1 also revealed that the synergism between the feed stocks in the different mixes was commendable as all the mixes had synergy factors greater than 1. Synergy factor is a statistic used to measure the interaction between the components of a complex system. The highest synergy factor of 1.31 was observed for 2 WH:8 CD which collaborates the fact that the best mix of WH to CD to be co-digested in terms of biogas yield is 2 WH:8 CD.

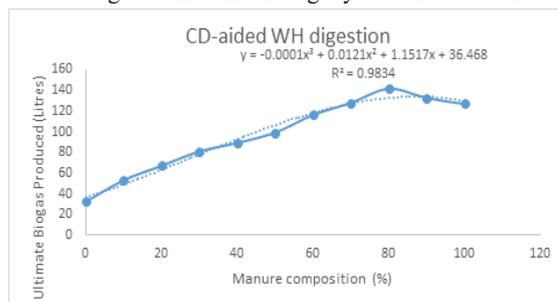


Figure 2: Ultimate biogas production for CD-aided WH digestion

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Conclusion

11 mix ratios of WH to CD were evaluated. Each experimental run was assessed in triplicate over a period of 40 days. The ultimate biogas yield as well as synergy factor for the different mixes was determined. The digestion process took place within mesophilic temperature range and the pH of the digestion substrates were ideal for digestion to take place. From the results obtained the best mix of the CD-aided WH digestion is 2 WH: 8 CD. The study has reaffirmed that WH and CD have great potentials for generation of biogas due to the high volume of biogas yield. The co-digestion of these wastes should be encouraged in order to optimize biogas yield.

References

- Al Imam, M. F.I, Khan, M. Z. H., Sarkar, M. A. R., Ali, S. M. (2013). Development of biogas processing from cow dung, poultry waste, and water hyacinth. *International Journal of Natural and Applied Science*, 2(1): 13-17
- Howard, G. W. and Matindi, S. W. (2003). Les espèces étrangères envahissantes dans les zones humides de l'Afrique, UICN, GISP, RAMSAR, 15 pp.
- Li, Y, Yan, X. L, Fan, J. P, Zhu, J. H, Zhou, W. B. (2011). Feasibility of biogas production from anaerobicco-digestion of herbal-extraction residues with swine manure. *Bioresource Technology*, 102:6458–63.
- 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.
- Liu, G., Zhang R, El-Mashad H.M, Dong R. (2009). Effect of feed to inoculums ratios on biogas yields of food and green wastes. *Bioresource Technology*, 100: 5103–8.
- Malik, A. (2007). Environmental challenge vis a vis opportunity: The case of water hyacinth. *Environmental International*, 33: 122-138.
- Mata-Alvarez, J., Mace, S., and Llabres, P. (2000). Anaerobic digestion of organic solid wastes: An overview of research achievements and perspectives. *Bioresource Technology*. 74: 3-16.
- Mondal, C. and Biswas, G. K. (2012). A comparative study on production of biogas using green and dried vegetable wastes by anaerobic batch digestion process. *International Journal of Engineering and Science*. 1 (6):01-06
- Mshandete, A., Kivaisi, A., Rubindamayugi, M. and Mattiasson, B. (2004). Anaerobic batch co- digestion of sisal pulp and fish wastes. *Bioresource Technology*, 95 (1), 19–24.
- Ofoefule, A. U, Uzodinma, E. O. and Anyanwu, C. N. (2010). Studies on the effect of anaerobic digestion on the microbial flora of animal wastes: digestion and modelling of process parameters. *Trends in Applied Sciences Research*. 5 (1): 39-47.
- Ojo O. M., Babatola J. O., Akinmusere K. O. and Adesina A. A. (2016). Quantitative and qualitative evaluation of biogas production from pig dung and poultry dung. Proceedings of the 2016 Annual Conference of the School of Engineering and Engineering Technology (SEET), the Federal University of Technology, Akure, Nigeria, 16-18 August, 2016. pp 105 – 113
- Otun, T.F, Ojo, O.M, Ajibade, F.O. and Babatola, J.O. (2015). Evaluation of biogas production from the digestion and codigestion of animal waste, food waste and fruit waste. *International Journal of Energy and Environmental Research*, 3(3): 12-24.
- Parawira, W., Read, J. S., Mattiasson, B. and Björnsson, L. (2008). Energy production from agricultural residues: high methane yields in pilot-scale two-stage anaerobic digestion. *Biomass and Bioenergy*. 32: 44-50.
- Perna, C. and Burrows, D. (2005). Improved dissolved oxygen status following removal of exotic weed in important fish habitat lagoons of the tropical Burdekin Riva floodplain, Australia, *Mar. Pollution Bulletin.*, 51, 138–148.
- Veeken, A. H. M., Hamelers, B.V.M. (2000). Effect of substrate –seed mixing and leachate recirculation on solid state digestion of biowaste. *Water Science Technology*, 41,255-62.

- Wang, H., A. Lehtomaki, K. Tovanen, J. Puhakka. (2009). Impact of crop species on bacteria community structure during anaerobic co-digestion of crops and cow manure. *Bioresource Technology*, 100: 2311-2315
- Yadvika, S., Sreekrishnan, T.R., Kohli, S and Rana, V. (2004). Enhancement of biogas production from solid substrates using different techniques – a review. *Bioresource Technology*, 95: 1-10