Relative effectiveness of biogas production using poultry wastes and cow dung

Kamoru Akanni Adeniran[1*], Isiguzo Edwin Ahaneku[2], Isaac Nataniel Itodo[3], Habeeb Ajibola Rohjy[2]

(1. *Department of Agricultural and Biosystems Engineering,University of Ilorin, P.M.B. 1515, Ilorin, Kwara State, Nigeria*;
2. *Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria*;
3. *Department of Agricultural Engineering, University of Agriculture, Makurdi, Nigeria*)

Abstract: A comparative study of biogas production of different proportions of poultry wastes and cow dung was conducted under the same operating conditions. The study was based on Completely Randomsied Design replicated three times. Three different mix ratios of poultry wastes and cow dung were tested (namely 3:1, 1:1 and 1:3) and all of them were diluted with the same amount of water. Each treatment was replicated three times. Biogas production was measured for a period of seven days and volume of gas produced was determined by water displacement method at room temperature of 25 – 30°C. Biogas production started on the second day, and reached apex on the sixth day for Digester A (cow dung:poultry wastes r = 1:3). Production reached its peak on the seventh day for Digester B (cow dung:poultry wastes r = 2:2). For Digester C (cow dung:poultry wastes r = 3:1), biogas production started on the second day and attained maximum on fifth day. The average gas production for Digesters A, B and C were 3.84, 3.55, and 3.19 mL respectively. The study shows that the largest volume of biogas production was obtained using the 3:1 mix ratio of poultry wastes to cow dung. Poultry wastes therefore are effective for production of biogas than cow dung. Statistical analysis reveals that wastes fed into the digester and days of experiment were significant at 99% confidence level. The volumes of wastes generated by the digesters were statistically different from each other. Digester A produced the highest mean biogas of 4.48 mL/day and this value was significantly higher than ones produced by Digesters B and C (4.26 and 3.72 mL/day respectively). Finaly, for a developing country like Nigeria, where wastes are not productively used, wastes generated from animal wastes can be effectively managed through conversion into biogas. Wastes are therefore turned to wealth, which increases the income of the society.

Keywords: biogas production, bio-digester, poultry wastes, cow dung, biogas volume and yield

Citation: Adeniran, K. A., I. E. Ahaneku, I. N. Itodo, and H. A. Rohjy. 2014. Relative effectiveness of biogas production using poultry wastes and cow dung. Agric Eng Int: CIGR Journal, 16(1): 126−132.

1 Introduction

The rapid increase in world population and the great developments in industrial, commercial, agricultural sectors require large quantities of energy, and create large quantities of wastes that should be disposed of with minimum negative environmental impacts and costs. Also, the limited sources and quantities of non-renewable energy (oil, natural gas, and fossil coal) with their negative impacts on human health and environment, necessitates the search for new and renewable sources for energy with less negative impacts (Rai, 1989). The dependence on fossil fuels as primary energy source has lead to global climate change, environmental degredation and human health problems. Freeman and Ryle (1997) reported that the initial interests in use of animal wastes as biofuels came from India where the obvious raw material has been cow dung. It is a common practice for cow dung to be dried and then used directly as a solid fuel

Received date: 2012-03-30 **Accepted date:** 2013-12-20
* **Corresponding author: Kamoru Akanni Adeniran,** Department of Agricultural and Biosystems Engineering,University of Ilorin, P.M.B. 1515, Ilorin, Kwara State, Nigeria. Email: kadeniran_2003@yahoo.com.

for cooking. Sathianathan (1999) reported that the first plant for obtaining methane from human waste was built in 1990 at the Homeless Lapers Asylum, Matunga now known as Acworth Zeprocy Hospital (Wadala, India). Hajamis and Ranade (1992) reported that after the World War I, a form of septic tank involving the anaerobic digestion of municipal sewage began in Germany. Methane produced in such system was either used for fueling the town truck yard to fed into the public gas supply network. In Egypt, the first biogas digester was in Elgabel el-Asfer farm in 1939 to treat sewage sludge (Abbasi et al., 1990). Metcalf and Eddy (2005) reported that the use of anaerobic digestion process for treating waste waters has grown tremendously in Europe during the past decade. Worldwide, more than 1,000 biogas production units are now operating or are under construction. It is estimated that European plants comprise 44% of the installed base with only 14% located in North America. Sayigh (1992) reported that biogas is highly relevant in energetic environment of Brazil as a tropical country with more than 30 million inhabitants who depend on wood burning as fuel. As far as 1950, the fact that biogas was obtained from forest sources presented a relative reduction in its total production. The emergence of biogas from sugarcane by-products, however, made significant contribution to its availability in rural Brazil. In Philippinnes, the Department of Environment and Natural Resources has been promoting biogas production as a means of waste management and pollution control in large pig farms especially those already equipped with waste lagoon. Unlike India, cattle farms are few in the Philippinnes where there are many pig and poultry farms (FAO, 1996). Exploitation of animal dung for production of biogas in Nigeria is in its infancy. The pioneer biogas plants are a 10 m^3 biogas plant constructed in 1995 by the Sokoto Energy Research Centre (SERC) in Zaria and an 18 m^3 biogas plant constructed in 1996 at Ojokoro Ifelodun Piggery Farm, Lagos by the Federal Institute of Industrial Research Oshodi (FIIRO) Lagos (Zuru et al., 1998). Approximately 70% of Nigeria's 120 million people lives in areas where no formal waste management systems are in place. Eze et al., (2007) reported the Nigeria's biogas potentials (minimum value) from solid waste and livestock excrements. It revealed that in 1999, Nigeria's biogas potential represents a total of 1.382×10^9 m^3 of biogas/year or an annual equivalent of 4.81 million barrels of crude oil. The abundant availabilty of animal manure in Nigeria (particularly from poultry enterprises), which could cause health hazards during decay could be turned to biogas for utilization by the rural communities and later in future be commercialised for sale to urban dwellers. Waste can be turned to wealth. There is yet another wave of renewed interest in biogas usage due to increasing concerns of climate change, indoor air pollution and increasing oil prices. The main objective of this study was to determine the effectiveness of biogas production from poultry wastes and cow dung.

2 Materials and methods

2.1 Experimental design

The study was based on Completely Randomsied Design (CRD) replicated three times. The treatments (Table 1) include loading three different mix ratios of 3:1:2, 2:2:2 and 1:3:2 of poutry wastes and cow dung respectively diluted with the same amount of water. 225 g of poultry waste and 75 g of cow dung were mixed with 150 mL of water and loaded into Digester A. 150 g of poultry wastes and 150 g of cow dung were mixed with 150 mL of water and loaded into Digester B. Finally, 75 g of poultry wastes and 225 g of cow dung were mixed with 150 mL of water and loaded into Digester C. Each treatment was replicated three times. Nine different digersters of the same design and size were used in the study.

Table 1 Treatments imposed on three digesters

Digester Type	Digester A	Digester B	Digester C
Mix Ratios*	3:1:2	2:2:2	1:3:2
Mass Ratio of the Mix, g	225:75:150	150:150:150	75:225:150

Note: *Mix ratio of poultry wastes:cow dung:water.

2.2 Slurry mixing tank

A slurry mixing tank (Figure 1) was developed. It is a pre-mixing chamber where different components of the raw materials for the gas production (water and manure) were mixed to form a uniform mixture of the slurry, which is fed into the digester (Figure 2). A 500 mL cylinder was used for the construction of this component. It is made of glass, the height is 12.5 cm and diameter of 9.7 cm.

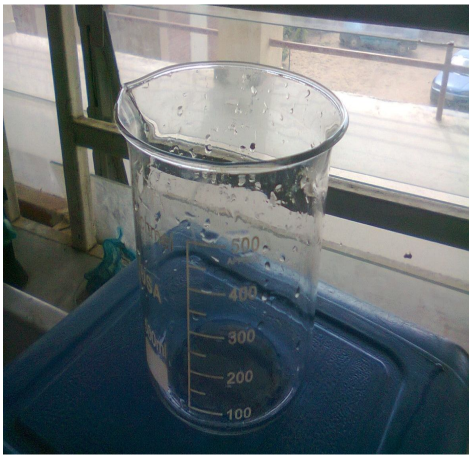

Figure 1 Slurry mixing tank

Figure 2 Bio-digester

2.3 Materials for biogas production

Parameters used in selecting the feedstocks used in this study include those reported by Nagamani and Ramasamy (2007). These parameters include economic considerations, methane yield of the feedstock, bacterial physiology, and quality of the end-product required. The economic considerations include labour involved, cost, availability and nearness to the point-of-use of the feedstock. Eze et al. (2007) reported that if all the livestock wastes in Nigeria are recovered and utilized to produce methane, approximately 7% – 10% of the total energy consumption could be replaced. It was reasoned that the availability of animal-based feedstock, particularly in rural areas, could provide successful operations for biogas digesters. Animal dungs are available throughout the year, moreover, both dry and wet dung could be used as feed stocks. Eze et al. (2007) further reported that the annual amount of fresh livestock residue in Nigeria was about 83,037,500 Mt. Arthur (2004) reported that the gas yield of a feedstock can be determined by:

$$Gy = \frac{Vd}{Fs} \tag{1}$$

where, Gy = biogas yield of feedstock, m³/kg; Vd = digester volume, mL; Fs = mass of feedstock in the digester, kg.

2.4 Yield of biogas

The yield of biogas was determined using the expression stated below:

Yield (mL/kg) = volume of gas collected/ mass of input waste (2)

2.5 Research methodology

Digester volume = 500 mL, Volume of slurry = 450 mL and Headspace = 50 mL.

Slurry = weight of manure + water in ratio of 1:0.5 for (cattle and poultry dung) and water respectively. That is 300 g of poultry and cattle dung + 150 mL of water.

Digester A: Cow dung 25% of 300 g = 75 g, Poultry 75% of 300 g = 225 g.

Digester B: Cow dung 50% of 300 g = 150 g, Poultry wastes 50% of 300 g = 150 g.

Digester C: Cow dung 75% of 300 g = 225 g, Poultry wastes 25% of 300 g = 75 g.

3 Results and discussion

3.1 Effects of waste treatment on biogas production

The quantity of biogas produced daily from cow dung and poultry wastes in different proportions 25%, 75%; 50% and 50%, 75% and 25% over a period of seven days were tabulated in Table 2. Figure 3 shows the mean biogas production from the three different digesters. The results show that Digester A recorded the highest biogas production of about 7.49 mL compared to the other two digesters on the sixth day of the experiment. The biogas production from this Digester A was also seen to increase progressively from the first day through to the sixth day and decline sharply on the seventh day. It can be said to have reached its optimum production on the sixth day. Digester B increased progressively from the first day through to the fifth day and droped relatively on the sixth day but then increased sharply on the seventh day to about 7.21 mL. Optimum biogas production was not attained in this case as there was evidence from the Figure 3 to suggest further production. Digester C rose progressively from 0 mL from the start of the experiment to about 6.72 mL on the fifth day and then decreased the two remaining days of the study. Optimum gas production could be said to be attained on the fifth day since it recorded the highest mean biogas within the time frame for Digester C. Generally the study shows that biogas production increased from the begining of the study and as the days increased, reached an optimum value in a given time and decreased after optimum gas production. From the gas production analysis, average volume of biogas was maximum in Digester A (P = 75%, C = 25%) producing 3.84 mL, followed by Digester B (P = 50%, C = 50%) which produced total biogas of 3.54 mL and Digester C (P = 25%, C = 75%) producing the least biogas of 3.19 mL. The higher volume gas produced by Digester A may be due to higher nitrogen content in poultry droppings as compared to other feedstocks (Ojolo et al., 2007b). Also, the higher biogas production from poultry droppings could also be attributed to large amount of available nutrients presented in the droppings. According to Hill and Brath (1997) substrates should contain adequate amount of carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorous, potassium, calcium, magnesium and a number of trace elements. Average biogas production from digesters A, B and C were 3.84, 3.55 and 3.19 mL/day. Analysis of variance and test of significance were carried out to test for significant differences in biogas production in digester. Thus, any of the three designs may have been appropriate for the experiment. The cumulative biogas yield from 450 g (1:0.5 waste to water ratio) slurry of poultry and cattle dung digested over a period of seven days at room temperature was found to be 26.86, 24.86 and 22.30 mL at thermophillic temperature (37^{0}C). Mixing or shaking the digester is very important as it prevents scum formation within the digester. The main disadvantage of poultry manure is that it produces a proportion of hydrogen sulphide, which even when present in only small proportions, corrodes metal fittings. Ojolo et al. (2007a) obtained similar results, the average biogas production from poultry droppings, cow dung and kitchen waste was 0.0318, 0.0230 and 0.0143 dm^3/day, respectively. Also Ojolo et al., (2007b) reported that in a comparative study of biogas production from poultry droppings, cattle dung, kitchen waste, fruit waste and vegetable waste carried out under the same operating conditions, poultry droppings produced 0.0332 dm^3/day, cow dung produced 0.0238 dm^3/day, kitchen waste produced 0.0080 dm^3/day, vegetable waste produced 0.0066 dm^3/day and fruit waste with 0.0022 dm^3/day. Ojolo et al., (2007b) concluded that poultry droppings produced more biogas because it contains more nutrients and nitrogen compared with plant and other animal wastes. Ofoefule and Uzodinma (2009) also obtained similar results. Cassava peels obtained from cassava tubers were anaerobically digested using 50 L capacity fermentor and in blends with some animal wastes. The peels were blended with cow dung (CD), poultry droppings (PD) and swine dung (SD), in the ratio of 1:1. The mean flammable biogas yield of the cassava peels

Table 2 Volume of gas produced by the three digesters

Days	Mean Volume/mL		
	Digester A	Digester B	Digester C
1	0	0	0
2	1.48	1.20	0.78
3	2.36	2.00	1.61
4	4.68	4.25	4.00
5	5.52	5.20	6.72
6	7.49	5.00	4.69
7	5.33	7.21	4.50

Note: where digesters A, B and C were loaded with 225 g of poultry waste and 75 g of cow dung (ratio 3:1) mixed with 150 mL of water, Digester B loaded with 150 g of poultry wastes and 150 g of cow dung, mixed with 150 mL of water and Digester C was loaded with 75 g of poultry wastes and 225 g of cow dung mixed with 150 mL of water.

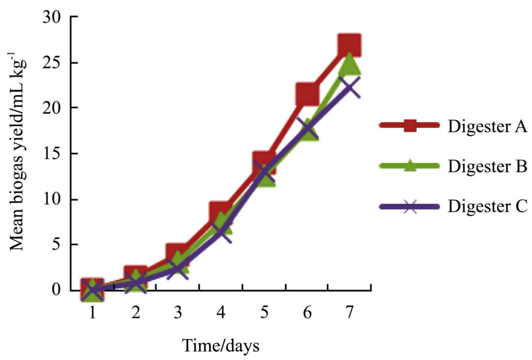

Figure 3 Cummulative biogas yield during the period of study

alone was 2.29 ± 0.97 L/total mass of slurry. When blended with CD, PD and SD, mean flammable biogas yield was increased to 4.88 ± 1.73, 5.55 ± 2.17 and 5.65 ± 2.62 L/total mass of slurry respectively.

The main disadvantage of poultry manure is that it produces a proportion of hydrogen sulphide, which even when present in only small proportions, corrodes metal fittings (Ojolo et al., 2007a). It is also poisonous, but not in the quantities produced (less than 0.075 mL), so it's not enough to be a hazard. When it burns in air it oxidises to sulphur-dioxide.

Cow dung produces almost no hydrogen-sulphide but needs larger quantities than poultry to produce the same amount of gas. Finally, the study shows that abundant animal wastes generated in Nigeria can be converted to useful products (methane and digestate) using anaerobic digestion.

3.2 Two factor experimental design

Table 3 shows the results obtained on the effect of types of wastes and days of the experiment using two ways analysis of variance. The analysis reveals that wastes fed into the digester and days of experiment were significant at 99% confidence level. The hypothesis of equal mean treatment effect of wastes and days of experiment is therefore rejected. This study shows that the days of the experiment did not record the same mean values of biogas production. This assertion was confirmed using Duncan multiple range test as seen in Table 4. Table 4 indicates that on the fifth day the highest mean value of biogas was recorded which is significantly higher than the values recorded from the sixth day and the seventh day ($\alpha = 0.05$). The sixth day and the seventh day produced relatively the same quantity of biogas but were statistically higher compare to the yield from the fourth, third and second day respectively. The volumes of produced digestate proved to be statistically different from each digester as shown in Table 5. Table 5 shows that using Duncan multiple range Digester A produced the highest mean biogas of 4.50 mL and this value in Table 6 is shown to be significantly different than that produced by the Digester B and Digester C. The results of the estimated marginal means test presented in Table 7 show that Digester A produced the highest mean biogas values in all the days of the experiment except the seventh day. Digester B was also seen to perform more than Digester C in terms of biogas production.

Table 3 Two way analysis of variance

Source	Sum of squares	Df	Mean square	F	Sig.
Day	191.367	5	38.273	1.246E4	0.001*
Digester	5.226	2	2.613	850.595	0.001*
Day * Digester	26.672	10	2.667	868.165	0.001*
Error	0.111	36	0.003		
Total	223.376	53			

Table 4 Duncan multiple range test for days

Day	N	Subset				
		1	2	3	4	5
Day Two	9	1.1522				
Day Three	9		1.9900			
Day Four	9			4.3111		
Day Seven	9				5.6789	
Day Six	9				5.7289	
Day Five	9					5.8122
Sig.		1.000	1.000	1.000	.064	1.000

Table 5 Duncan multiple range test for digesters

Digester	N	Subset		
		1	2	3
Digester C	18	3.7161		
Digester B	18		4.1444	
Digester A	18			4.4761
Sig.		1.000	1.000	1.000

Note: where digesters A, B, and C are as defined in Table 1.

Table 6 Average yield of biogas per day

Digester A	Total Volume/mL	Average yield per day/mL day^{-1}
A_1	26.86	4.48
A_2	26.94	4.49
A_3	26.83	4.47
Digester B	Total Volume/mL	Average yield per day/mL day^{-1}
B_1	25.00	4.17
B_2	24.98	4.16
B_3	26.62	4.44
Digester C	Total Volume/mL	Average yield per day/mL day^{-1}
C_1	22.30	3.72
C_2	22.29	3.71
C_3	22.30	3.72

Note: where digesters A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2 and C_3 are replicates of digesters A, B and C respectively.

Table 7 Estimated marginal means for Days and Digesters

Day	Digester	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Day Two	Digester A	1.480	0.032	1.415	1.545
	Digester B	1.200	0.032	1.135	1.265
	Digester C	0.777	0.032	0.712	0.842
Day Three	Digester A	2.357	0.032	2.292	2.422
	Digester B	2.007	0.032	1.942	2.072
	Digester C	1.607	0.032	1.542	1.672
Day Four	Digester A	4.683	0.032	4.618	4.748
	Digester B	4.250	0.032	4.185	4.315
	Digester C	4.000	0.032	3.935	4.065
Day Five	Digester A	5.517	0.032	5.452	5.582
	Digester B	5.200	0.032	5.135	5.265
	Digester C	6.720	0.032	6.655	6.785
Day Six	Digester A	7.493	0.032	7.428	7.558
	Digester B	5.000	0.032	4.935	5.065
	Digester C	4.693	0.032	4.628	4.758
Day Seven	Digester A	5.327	0.032	5.262	5.392
	Digester B	7.210	0.032	7.145	7.275
	Digester C	4.500	0.032	4.435	4.565

Note: where digesters A, B, and C are as defined in Table 1.

4 Conclusions

The study shows that biogas production started on the second day, and reached apex on the sixth day for Digester A. Production reached its peak on the seventh day in Digester B. For Digester C, it started on the second day and attained maximum on the fifth day. The average gas production from 75%, 25%; 50%, 50% and 25%, 75% of poultry and cattle dung respectively was 3.84, 3.55, and 3.19 mL. A ratio of 75% : 25% and 225 g : 75 g of poultry and cow waste respectively which described the composition of Digester A in this experiment was found to yield the best result out of the three digesters. Digester B which has the ratio 50% : 150 g and 50% : 150 g of poultry and cow waste respectively was also seen to fare very well and can serve an alternative tool for production of biogas where Digester A is unattainable. Most importantly, more time could mean more biogas yield for Digester B. It’s concluded that the waste can be managed through conversion into biogas, turning waste into wealth which is a source of income for the society.

References

Abbasi, S. S, G. S. Geetha, K. S. Jagadeesh, and J. K. R. Reddy. 1990. *Biological Wastes*. http://www.wikipedia.com (accessed September 18, 2011).

Arthur, M. 2004. Biogas production from stillage (Scientific, Technical and Economic Aspects). University of Luneburg, Germany. http://www.hach- lange.com (accessed September 18, 2011).

Eze, I. S., C. N. Anyanwu, O. U. Oparaku, and C. O. B. Okoye. 2007. *Animal Manure: A Resource or a Waste?* 37th Annual Conference of Nigerian Society of Chemical Engineers. http://www.nschef.org (accessed July, 2011).

Food and Agricultural Organization (FAO).

1996. *A System Approach to Biogas Technology,* Food and Agricultural Organization, Rome. (FAO/CMS, 1996; pp 64).

Freeman, G., and L. Ryle. 1997. *Methane Generation by Anaerobic Fermentation.* London: Intermediate Technology Publishers Ltd. http://www.new-agri.co.uk (accessed September 18, 2011).

Hajamis, S. R., and D. R. Ranade. 1992. Biological nitrogen fixation and biogas technology, Tamil Nadu University, India. http://www.ias.ac.in/currsci (accessed September 18, 2011).

Hill, J., and A. Brath. 1997. A dynamic model for simulation of animal waste digestion, Water Pollution Control, Canton, Ohio. http://www.hach-lange.com (accessed September 18, 2011).

Metcalf, L. E., and H. P. Eddy. 2005. *Wastewater engineering: Treatment and reuse.* 4th Edition, Tchbanoglous, G., F. L. Burton, and H. D. Stensel (eds). New Delhi: Tata McGraw-Hill Publishing Company Ltd. pp 1505-1533.

Nagamani, B., and K. Ramasamy. 2007. Biogas production technology: An Indian perspective, Tamil Nadu Agricultural University,India. http://www.ias.ac.in/currsci/jul10/articles 13.htm (accessed ??)

Ojolo, S. J., S. A. Oke, K. Animasahun, and B. K. Adesuyi. 2007a. Utilization of poultry, cow and kitchen wastes for biogas production: A comparative analysis. *Iranian Journal of Environmental Health Science and Engineering,* 4(4): 223-228.

Ojolo, S. J., R. R. Dinrifo, and K. B. Adesuyi. 2007b. Comparative study of biogas production from five substrates. *Advanced Materials Research,* 18-19: 519-525.

Ofoefule, A. U., and E. O. Uzodinma. 2009. Biogas production from blends of cassava (*Manihot utilissima*) peels with some animal wastes. *International Journal of Physical Sciences,* 4(7): 398-402. http://www.academicjournals.org/IJPS (accessed September 18, 2011).

Rai, G. D. 1989. *Non-Conventional Energy Sources.* Delhi: Khana Publishers. (7: 247-299).

Sathianathan, M.A (1999). Biogas – Achievements and Challenges: Association of Voluntary Agencies for Rural Development, New Delhi. www.indiatogether.org. Accessed 24th June, 2011.

Sayigh, M. A. 1992. *Renewable Energy,* Technology and Environment, Volume 3: Pergamon Press, Oxford. http://www.ieiglobal.org/ESDv5n1/biogasdiss emination (accessed September 18, 2011).

Zuru, A. A., H. Saidu, E. Odum, and O. A. Onuorah. 1998. A comparative study of biogas production from horse, goat, and sheep dung. Nigerian Journal Renewable Energy, 6(1-2): 43-47.