Relative Effectiveness of Biogas Production using Poultry Wastes and Cow Dung

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Abstract

A comparative study of biogas production of different proportions of poultry wastes and cattle dung was conducted under the same operating conditions. The study was based on Completely Randomsied Design replicated three times. The treatments include loading three different mix ratios of 3:1, 1:1 and 1:3 of poutry wastes and cow dung respectively diluted with the same amount of water. 225g of poultry waste and 75g of cow dung was mixed with 150ml of water and loaded into biodigester A. 150g of poultry wastes and 150g of cow dung was mixed with 150ml of water and loaded into biodigester B. Finally, 75g of poultry wastes and 225 of cow dung was mixed with 150ml of water and loaded into biodigester C. Each treatment was replicated three times. Biogas production was measured for a period of 7days and volume of gas produced was determined by water displacement method at room temperature of 25^{o}C – 30^{o}C. Biogas production started on the 2nd day, and reached apex on the 6th day for digester A. Production reached its peak on the 6th day for digester B. For digester C, biogas production started on the 3rd day and attained maximum on 6th day. The average gas production for digesters A, B and C were 3.84ml, 3.55ml, and 3.19ml 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. Poutry wastes therefore is effective for production of biogas than cow dung. The 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 4.50ml and this value was significantly higher than the volumes of the two other digesters (B and C). Finally, 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 generation of the society.

Keywords: Biogas production, Bio-digester, Poultry wastes, Cow dung, Biogas volume and yield

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 off 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 least 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. The initial interests in use of animal wastes as biofuels came from India where the obvious raw material has been cow dung (Freeman & Ryle, 1997). It is a common practice for cow dung to be dried and then used directly as a solid fuel for cooking. 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 (Sanathianathan, 1999). After the World War I, a form of septic tank involving the anaerobic digestion of municipal sewage began in Germany (Hajamis & Ranade, 1992). 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). The use of anaerobic digestion process for treating waste waters has grown tremendously in Europe during the past decade. Worldwide, more than 1,000 vendors supplied systems are now operating are under construction. It is estimated that european plants comprise 44% of the installed base with only 14% located in North America (Metcalf & Eddy, 2005). 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 (Sayigh, 1992). 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 $10m^3$ biogas plant constructed in 1995 by the Sokoto Energy Research Centre (SERC) in Zaria and an $18m^3$ biogas plant constructed in 1996 at Ojokoro Ifelodun Piggery Farm, Lagos by the Federal Institute of Industrial Research Oshodi (FIIRO) Lagos (Zuru *et.al.,* 1989). Approximately, 70% of Nigeria's 120 million people live in areas where, no formal waste management systems are in place. A recent study assessed 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 $1.382\times10^9 m^3$ 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 production. This can be commercialised for sale to people in rural and urban areas. Thus, animal wastes can be turned to a source of wealth generation. 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 (Zuru *et.al.,* 1989). The main objective of this study was to determine the effectiveness of biogas production from poultry wastes and cow dung.

2. Materials and Method

2.1 Experimental Design

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

2.2 Slurry Mixing Tank

A slurry mixing tank 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 is fed into the digester. A 500ml cylinder was used for the construction of this component. It is made of glass, the height is 12.5cm and diameter of 9.7cm.

2.3 Materials for Biogas Production

Parameters used in selecting the feedstocks (Nagamani & Ramasamy, 2007) 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. If all the livestock waste in Nigeria are recovered and utilized to produce methane, approximately 7 – 10% of the total energy consumption could be replaced (Eze *et.al.,* 2007). 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, moreso, 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 83.04×10^{12} tonnes. The gas yield of a feedstock (Arthur, 2004) can be determined from:

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

where: Gy = Biogas yeild (m^3/kg), Vd = Digester volume (m^3), Fs = Mass of feedstock in the digester (kg).

2.4 Yield of Biogas

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

$$\text{Yield} = \text{volume of gas collected (l)/mass of input waste(g)} \tag{2}$$

2.5 Research Methodology

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

Slurry means weight of manure + water in ratio of 1:1/2 for (cattle and poultry dung) and water respectively. That is 300g of poultry and cattle dung + 150ml of water.

Digester A: Cattle dung 50% of 300g = 150g, Poultry 50% of 300g = 150g

Digester B: Cattle dung 75% of 300g = 225g, Poultry waste 25% of 300g = 75g.

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

3. Results and Discussion

3.1 Effects Waste Treatment on Biogas Production

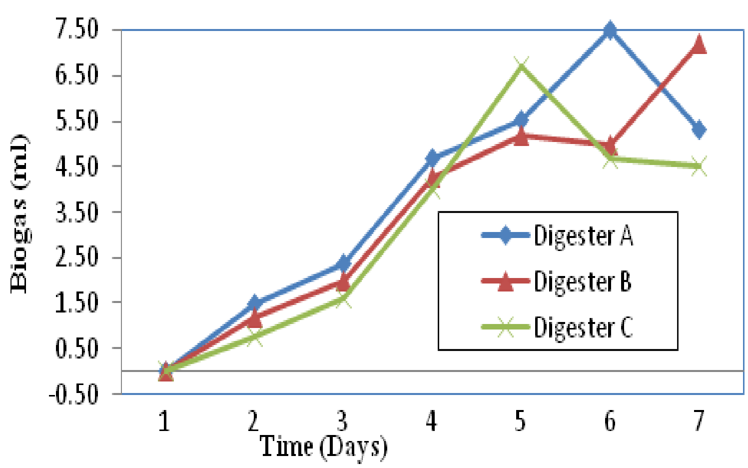
The quantity of biogas produced daily from cattle dung and poultry waste in different proportions 75%, 25%, 50%, 50% and 25%, 75% of wastes over a period of 8 days were tabulated in Table 1. Fig 1 shows the mean biogas production from the three different digesters. The results show that digester A recorded the highest biogas production of about 7.49ml 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 day one through to day six and decline sharply on the seventh day. It can be said to have reached its optimum production on sixth day.

Table 1. *Volume of gas produced by the three digesters*

Days	Mean Volume (ml)		
	Digester A	Digester B	Digester C
1	0.00	0.00	0.00
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

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

Fig.1. *Biogas production during the period of study*



Digester B increased progressively from day one through to day five and drops relatively on the six day but then increased sharply on the seventh day to about 7.21ml. Optimum biogas production was not attained in this case as there was evidence from the Fig 1 to suggest further production. Digester C rose progressively from 0.00ml from the start of the experiment to abut 6.72ml in day 5 and then decreases the two remaining days of the study. Optimum gas production could be said to be attained in 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 increases and reaches an optimum value in a given time and decreases after optimum gas production. From the gas production analysis, the total volume of biogas was maximum in digester A (P= 75%, C= 25%) produced 26.86ml, followed by digester B (P= 50%, C= 50%) which produced total biogas of 24.86ml and digester C(P= 25%,C=75%) producing least biogas of 22.30ml. The higher volume gas produced by digester A may be due to higher nitrogen content in poultry droppings as compared to other feedstocks. Also, the higher biogas production from poultry droppings could also be attributed to large amount of available nutrients present in the droppings. According to Hill & 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 3.84ml/day, 3.55ml/day and 3.19ml/day respectively.

An analysis of variance and test of significance was carried out to test whether there are differences in the biogas production or in the digester. Thus, any of the three designs may have been appropriate for the experiment. The cumulative biogas yield from 450g (1:0.5 waste to water ratio) slurry of poultry and cattle dung digested over a period of 7days at room temperature was found to be 26.86ml, 24.86ml and 22.30ml. 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. The average biogas production from poultry droppings, cow dung and kitchen waste was 0.0318dm^3/day, 0.0230dm^3/day and 0.0143dm^3/day, respectively (Ojolo et.al., 2007). Also in a comparative study of biogas production from poultry droppings (Ojolo et.al., 2007), cattle dung, kitchen waste, fruit waste and vegetable waste carried out under the same operating conditions, poultry droppings produced 0.0332dm^3/day, cow dung produced 0.0238dm^3/day, Kitchen waste produced 0.0080dm^3/day, vegetable waste produced 0.0066dm^3/day and fruit waste with 0.0022dm^3/day. Poultry droppings produced more biogas because it contains more nutrients and nitrogen compared with plant and other animal waste (Ojolo et.al., 2007). Cassava peels obtained from cassava tubers were anaerobically digested using 50L capacity fermentor and in blends with some animal wastes (Ofoefule & Uzodinma, 2009). 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 alone was 2.29 ± 0.97L/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. It is also poisonous, but not in the quantities produced, 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 manure) using anaerobic digestion.

3.2 Two Factor Experimental Design

Table 2 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 3. Table 3 indicates that day five recorded the highest mean value of biogas, which is significantly higher than the values recorded from days six and seven. Days six and seven produced relatively the same quantity of biogas but were statistically higher compare to the yield from day four, three and two respectively. The volumes of wastes generated by digesters proved to be statistically different from each other as shown in Table 4. Table 4 shows that using Duncan multiple range digester A produced the highest mean biogas of 4.50ml and this value shown in Table 5 was significantly higher than that produced from the two other digesters (B and C). The results of marginal means test (Table 6) shows that digester A produced the highest mean biogas values in all the days of the experiment except day seven. Digester B was also seen to perform more than digester C in terms of biogas production.

Table 2. *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 3. *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 4. *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

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

Table 5. *Average yield of biogas per day*

Digester A	Total Volume (ml)	Average yield per day (ml/day)
A_1	26.80	3.83
A_2	26.94	3.85
A_3	26.83	3.83
Digester B	**Total Volume (ml)**	**Average yield per day (ml/day)**
B_1	25.00	3.57
B_2	24.98	3.57
B_3	26.62	3.52
Digester C	**Total Volume (ml)**	**Average yield per day (ml/day)**
C_1	22.30	3.18
C_2	22.29	3.18
C_3	22.30	3.18

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 6. *Marginal means tests for the 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

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

4. Conclusion

The study shows that biogas production started on the 2nd day and reached apex on the 6th day for digester 1.Production reached its peak on the 6th day in digester 2. For digester 3, it's started on the 3rd day and attained maximum on 6th day. The average gas production from 75%:25%, 50%:50% and 25%:75% of poultry wastes to cattle dung respectively was 3.84ml, 3.55ml, and 3.19ml. A ratio of 75%:25% and 225g:75g 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%:150g and 50%:150g 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. It's concluded that the waste can be managed through conversion into biogas, turning waste into wealth which is a source of income generation for the society.

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