EFFECTS OF STIRRING ON THE PROPERTIES OF POULTRY DROPPING BIOGAS

SALEH, A.[1]*, AKANDE, F.A.[2] AND TIMOTHY, A.[3]

[1]Department of Agricultural Bio-Resources Engineering, Ahmadu Bello University, Zaria, Nigeria
[2]Department of Agricultural, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[3]Department of Agricultural and Biosystems Engineering, Landmark University, Nigeria

ABSTRACT

This study evaluated the effects of stirring on the properties of biogas produced from poultry dropping with respect to the quality and quantity of the biogas produced. A plastic batch-flow floating-drum biogas plant was designed and constructed. Poultry dropping from deep litter mixed with water ratio 1:2 (45 kg: 90 litres dropping-to-water slurry ratio) was used as slurry for the gas production. Proximate analyses of the poultry dropping were carried out to determine its potentials for biogas production. Levels of stirring were zero, once per day and twice daily. Each stirring was five slow rotations of the agitator. Properties of the produced biogas that were determined in the laboratory were methane value, carbon (IV) oxide, H_2S, pH value, ash and moisture content while the calculated properties were potential calorific value, average gas yield and carbon/nitrogen ratio. The results of the proximate analyses showed that the poultry dropping has high contents of Carbon (C), Nitrogen (N), volatile solids and pH value indicating its suitability for biogas production. The result also showed that the biogases up to 65% methane, 33.12% CO_2 and 2.93% H_2S contents. The treatment with once stirring/day produces the highest weight of biogas of 1.55 kg while treatment with twice stirring/day produced the least with 1.06 kg. Similarly, the twice stirring/day gave the least value of methane while once stirring/day gave the highest value of methane. The calculated calorific values ranged between 6.07 and 6.46 kWh/m³. The mean values of C/N ratio before and after gas production were 7.5 and 8.81, respectively. It could, thus, be concluded that stirring had significant effects on the quantity and qualities of biogas from poultry dropping.

Keywords: poultry dropping, biogas, slurry, slurry ratio, stirring
***Correspondence:** salehaminu@gmail.com

INTRODUCTION

Modern civilization and its economy have become dependent upon a remarkable consumption of energy derived from burning of fossil fuels. The problems of availability and depletion of non-renewable sources, among others, promote use of renewable sources of energy as guaranteed sources especially in rural communities where materials for generation are abundant [1]. Moreover, the dependence on fossil fuels as primary energy source has led to global climate change, environmental degradation and human health problem. More than ever, on-going researchers have developed more efficient technologies, minimize waste and optimize recycling of existing resources [2]. Rising energy prices and concerns about long term sustainability have once again brought renewable energy sources to the forefront. Nigeria is abundantly blessed with different types of energy resources. There are equally abundant agricultural by-products that remain untapped. This energy needs to be tapped especially as the energy supply of the country is grossly inadequate.

With continuous increase in world population and rise in living standards, the demand for energy is steadily increasing. Global environmental issues, such as global warming, early exhaustion of fossil fuel and accompanying potential social uprising in fossil fuel producing areas due to agitation by activists for resource control and degradation of the environment poses serious problems for continuous energy generation, consumption and sustenance. In addition, environmental hazards from careless dumping of animal and human residues would be controlled if these residues can be converted into biogas. Deforestation would also be reduced if people no longer rely solely on firewood for cooking in addition to creation of employment for most of the rural communities. In view of this, environmentally-friendly technology and a shift to non-fossil energy resources that are renewable such as natural energy and biomass are inevitable [3]. Biogas is said to be ideal in deciding alternative energy for rural people in the sense that it is cheap, available and local in origin and production. It is also an energy source that is useful for multiple purposes – heating, lighting, small-scale power generation, and so on [4]. Consequently, this study was set to investigate how stirring of slurry would affect the quantity and quality of biogas produced from poultry dropping.

MATERIALS AND METHODS

A plastic batch-flow floating-drum biogas plant was designed and constructed (Plate 1). Poultry manure from a deep litter mixed with water was used as slurry for gas production. Proximate analyses of the poultry droppings were carried out to determine its potentials for biogas production. Biogas was produced at different levels of stirring (zero, once per day and twice per day). Each stirring was five slow revolutions of the stirrer. Slurry ratio of 1:2 was obtained using 45 kg and 90 litres of manure and water respectively. Properties determined in the laboratory were methane value, carbon (IV) oxide, H_2S, pH value, ash and moisture contents while the calculated properties were potential calorific value, average gas yield and carbon/nitrogen ratio.

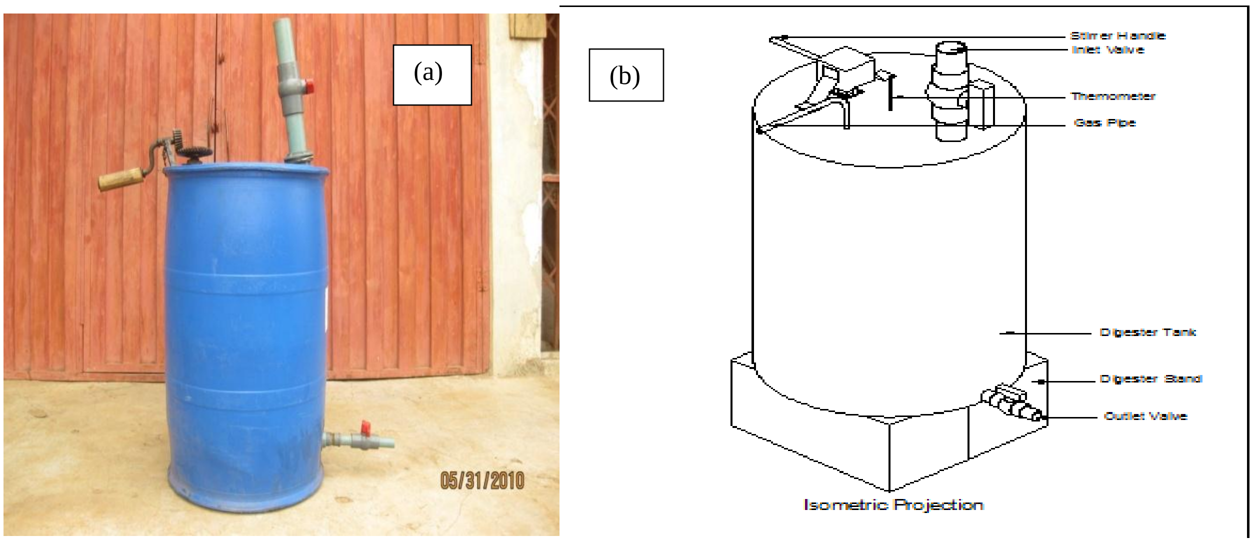

Plate 1: (a) Pictorial and (b) Isometric views of the digester

Experimental set-up

The operational parameter (stirring) was varied to determine its effects with respect to gas production and quality. Slurry ratio (poultry dropping to water) of 1:2 was used. Each ratio sample was again given varied treatments with regards to stirring. First, a slurry ratio of 1:2 by mass of dry poultry manure and water was used to produce gas without stirring the content throughout the gas production process while noting the quantity of gas produced daily. Then the same slurry ratio was used as the next treatment but this time stirring the mixture once daily to the end of gas production process, again noting the quantities of daily gas production. The third treatment with the same slurry ratio was stirred twice daily at 12 hr. interval noting daily gas production until it seize. Stirring was timed at 7:00 am for once/day treatment and 7: 00 am and 7:00 pm for twice daily treatment. The gas produced daily was weighed using a digital weigh balance (2000 kg capacity with 0.01 mm sensitivity)to determine the amount of gas produced. The orthographic projection of the digester is show in Figure 1.

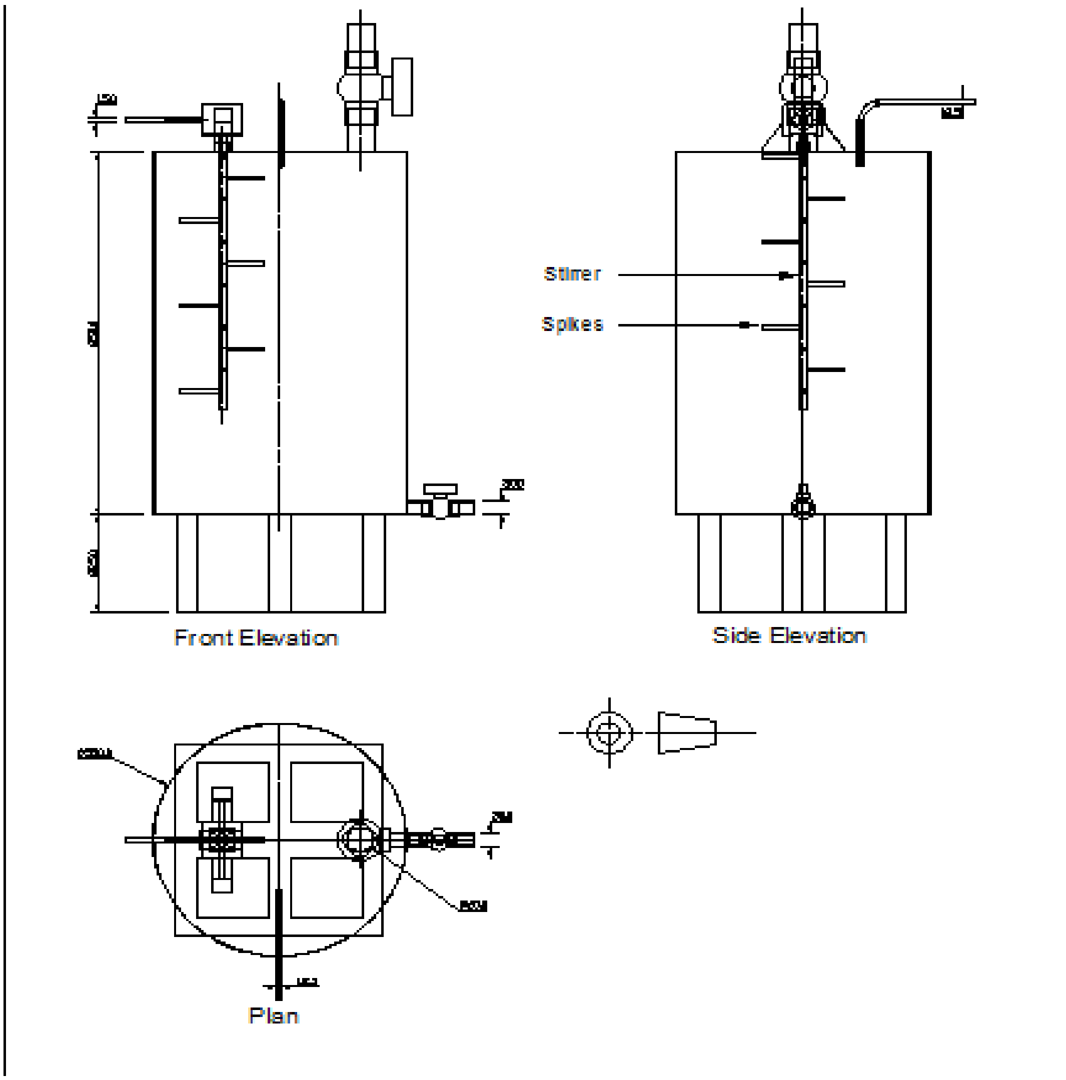

Figure 1: Orthographic projection of the biogas digester

Sample collection and slurry preparation

About 500 kg of fresh poultry dropping was collected from a laying stock deep litter system managed by White-House Farm, Ilorin using spades and buckets and dried under the shade to achieve a constant weight. The dried litter was stored in a double polythene bag and sealed to prevent moisture entering the system. They were then oven dried at 60°C for 24 hrs. The product was then ground to small particles of 6 mm size to determine its proximate and ultimate analyses. It was ensured that foreign materials such as sand, cotton materials, feathers, plastics, metals, maize cobs, wood and other feed materials that might have spilled from the feeders were removed from the sample such that they were not allowed into the digester.

The substrate was prepared in a pre-mixing tank (Plate 2) with the aid of a stick of about 1m long until a homogeneous mixture was achieved. The slurry thus formed was charged into the digester through the slurry inlet valve. This mixture adequately filled ⅔ of the digester volume, as recommended [5]. The slurry inlet valve was then closed.

Plate 2: Slurry preparation in a pre-mix chamber

Stirring commenced for the second and the third treatments 24 hours after charging the digester for treatments where agitation was considered. The agitation was performed as much as necessary but as little and as gentle as possible since too fast mixing with faster rotation may disturb the microbial process and thus slow down the release of gas. An all-through mixing may also lead to half-digested substrate living the digester pre-mutually. Stirring was repeated every 24 and 12 hours throughout the experiments for the once/day and twice/day treatments respectively. The amount of gas produced was recorded and weighed every 24 hours after the first release until gas production ceased. The gas being released was also weighed, record. A simplified overall chemical reaction of the process can be summarized as:

$$C_6H_{12}O_6 = 3CH_4 + 3CO_2 \qquad (1)$$

Determination of moisture content and calorific value

The dried sample of the poultry manure were grounded to smaller particles of 6 mm size and taken to the laboratory for analysis. The moisture content and calorific values were determined from the equations (2) and (3) respectively [6];

$$MCdb = \frac{Wi - Wd}{Wi} \qquad (2)$$

Where: $MCdb = Moisturecontent(drybasis), \%$

$Wi = Initialweightofthesample, g$

$Wd = Weightofthedriedsample, g$

$$CVg = CVm * Mc \qquad (3)$$

Where: CVg = Calorific Value of the Produced gases, kWhr/m³

CVm= Calorific Value of Methane given as 9.94 kWhr/m³,

Mc = Methane Value of the produced Biogases, %

Biogas collection and recording

An empty car tyre inner tube (175/185 - 13/14) was weighed with the aid of a digital precision weighing balance (2000 g capacity and 0.01 g sensitivity) to determine its initial weight. It was then connected to the gas outlet valve of the digester (Plate 3). When the valve was opened, biogas produced in the digester flowed into the tube as a result of pressure difference between the digester and the tube. Swelling of the tube was observed for about 10 minutes to ensure that the tube size remain constant. The tube is then disconnected and weighed to determine the new weight. The difference in weight was the weight of the gas produced. This process was repeated every 24 hours until no change in weight is observed, i.e. when the gas ceases to flow. The contents of the tubes were periodically discharged into the gas collection tank after weighing. For the three experimental set-ups, gas production was observed to begin between the 3rd and 4th day after feeding the digester.

Plate 3: Biogas sample being collected in a tube

Analyses of biogas produced

To determine the quality of the produced gas, samples of the gas were subjected to various laboratory tests in order to determine some of their important properties. These include methane (CH_4) content of the gases, carbon (IV) oxide, hydrogen sulphide (H_2S) and other trace elements. The principle of measurement is the measurement of reduction in volume which occurs when individual constituent of the gas were removed separately by absorption in liquid reagents using Orsat Apparatus. The Orsat apparatus was used to measure volumes of carbon (IV) dioxide, hydrogen sulphide, oxygen and carbon (II) oxide within a fixed volume of a sample gas (100 cc).

RESULTS AND DISCUSSION

Table 1: Mean proximate analysis of poultry dropping before and after digestion

S/N	Property	Before Digestion(%)	After Digestion (%)
1	**Moisture Content**	15.96	13.17
2	**Carbon (C)**	32.90	23.81
3	**Nitrogen (N)**	4.42	2.73
4	**Carbon/Nitrogen (C/N) Ratio**	7.50	8.10
5	**Ash**	25.97	58.84
6	**Volatile Solids (VS)**	74	40
7	**Total Solids (TS)**	13	10
8	**pH**	5.6	8.13

Table 2: Mean values of the tested properties of the produced biogas

S/N	Parameter	Samples (%)		
		1:2 (with zero agitation)	1:2 (with one agitation/day)	1:2 (with twice agitation/day)
1.	**Methane (CH_4)**	64.20	65.00	61.06
2.	**Carbon (IV) Oxide (CO_2)**	29.94	30.66	33.12
3.	**Hydrogen Sulphide (H_2S)**	2.84	2.11	2.93

Table 3: Multiple test for methane (CH_4)

	parameters`	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	CH_4 (1:2, with no agitation)	2	61.0600	
	CH_4 (1:2, zero one agitation/day)	2		64.2000
	CH_4 (1:2, with twice agitation/day)	2		65.0000
	Sig.		1.000	.068

Table 4: ANOVA: Two-factor without replication

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	250.6	62.65	5.503333
Row 2	4	128.58	32.145	4.7427
Row 3	4	10.58	2.645	0.141367
Column 1	3	97.37	32.45667	816.252
Column 2	3	97.64	32.54667	863.0886
Column 3	3	96.98	32.32667	945.5345
Column 4	3	97.77	32.59	991.5817

Table 5: ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Gas Properties	7201.873	2	3600.937	696.0484	7.9E-08	5.143253
Treatment	0.1218	3	0.0406	0.007848	0.998936	4.757063
Error	31.0404	6	5.1734			
Total	7233.036	11				

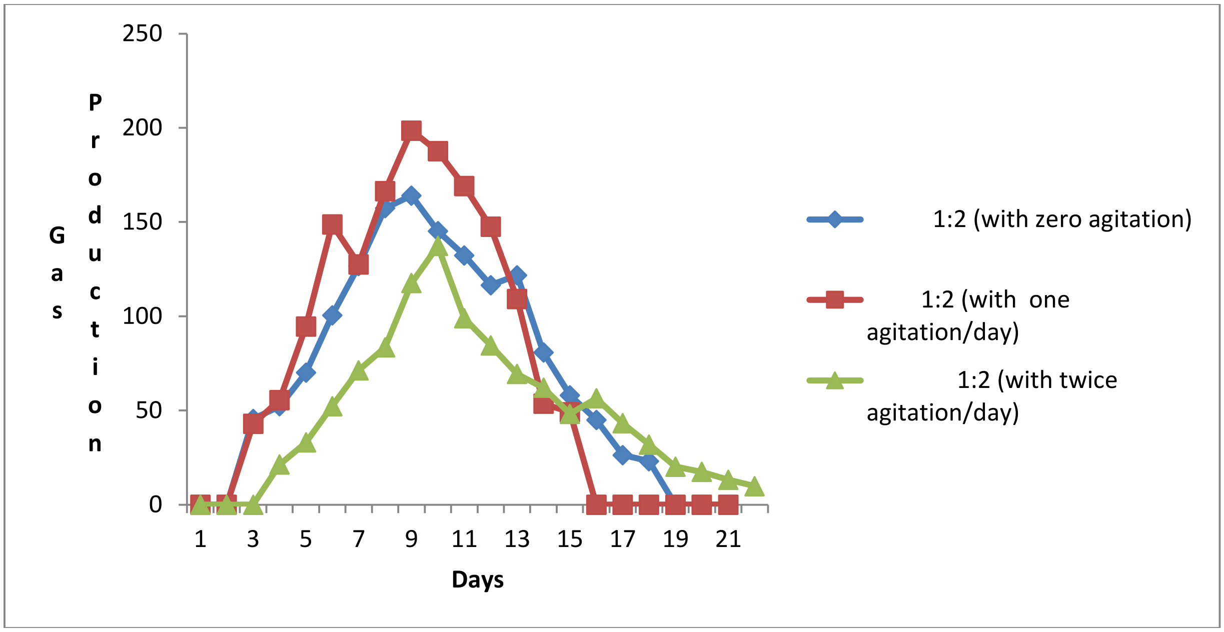

Figure 2: Graphical representation of biogas produced from the treatments

Analyses of the poultry dropping and sludge

Results of the proximate and ultimate analyses of the samples of the poultry dropping both before and after the digestion process shows a marked differences in the concentrations of various parameters tested as indicated in Table 1. It revealed that the average moisture content of the poultry dropping before and after the gas production was 15.69% and 13.17% respectively. This results are in agreement with [6, 7] who found the moisture of poultry litter for biogas production to be between 12 and 25%. This could be attributed to the fact that water dissociated into hydrogen and oxygen ions during the fermentation of the slurry. The hydrogen ions combine with the carbon ions to form methane while oxygen ions combine with carbon to form carbon (IV) oxide.

The high moisture content in the poultry dropping is what caused it to produce various toxic gases as well as noxious odour, especially when kept in a poorly ventilated area. The amount of water has reduced after digestion thus leaving a thick slurry.

The dropping was also analyzed with respect to nitrogen, carbon, and hydrogen. The nitrogen content obtained both before and after digestion were 4.42 and 2.73% respectively which is in agreement with Medeirus and Gaby [6] who determined that poultry dropping contains about 3-5% Nitrogen. The carbon contents before and after digestion were 32.90 and 23.81% respectively. There was an increase in ash contents of the stabilized dropping sample and the digested sample of the effluent from 25.97 to a whopping 58.84%. The result is in agreement with Ruffin and Mccaskey [7] who found the range of acceptable ash contents before digestion to be between 15-28% for poultry dropping. They also found that the high ash content of the dropping may also result from the use of wood shavings as bedding material. This higher ash content after digestion was an indication of the removal of the vital energy contents inform of biogas from the poultry dropping sample leaving incombustible matter that forms bulk of the ash contents in the sludge. The increase in the ash content also causes a reduction in C and N contents of the digested samples. The high ash content of the dropping may also result from the use of wood shavings as bedding material. The initial higher carbon content of 32.90% is an indication that the substrate will produce a reasonable amount of biogas. The drop in carbon content after the production of the biogas to about 23.81% means that most of the organic carbon was burnt into ashes while the remaining quantity were converted into methane.

The value of the C/N ratio before the biogas formation commence in this study was determined to be 7.5: 1 which is in agreement with [8, 9, 10, 11]. However, the value of C/N ratio (8.7:1) was higher at the end of the process indicating that the rate of carbon has been burnt inform of ash content which is in line with the recommendations of [8, 10, 11].

Analysis of pH value

The pH values of the dropping before and after the digestion process were 5.6 and 8.13 respectively. These results were good in that anaerobic digestion would take place when the pH value of the slurry was neutral, that is, 7.0; indicating that methane-producing bacteria lived well under neutral to slightly alkaline conditions. After the digestion process, the medium turned alkaline, given a pH of 8.16. This is in agreement with other studies [12, 13, 14] that the slurry was gradually transforming from alkalinity to basicity while the digestion process was taking place. Equally, it is in agreement with Steffen *et al.* [11] who suggested the optimum pH requirement of biogas production as between 6.8 and 7.4.

Quantitative analysis of the produced biogas

The daily values of the biogas produced from the various treatments were observed and recorded as indicated in Figure 2. Comparison of these results revealed that gas production in treatments 1:2 (with no agitation), 1:2 (with once agitation/day) starts on the third day after charging the digester while treatment 1:2 (with twice agitation/day) starts on the fourth day. While all the treatments could be said to have same water contents, early gas formation in treatment 1:2 (with once agitation/day) may be attributed to the effects of less agitation. It was also observed that the biogas produced on the first day in treatment 1:2 (without agitation) was slightly higher than that of treatment 1:2 (with one agitation/day) even as they have the same water ratio. This may be concluded that although all the treatments has adequate water to kick-start fermentation process, microbial activities seems to have been disrupted by the initial agitation in treatment 1:2 (with once agitation/day), supporting the findings of [15, 16, 17]. Gas production is seen to be further delayed in treatment 1:2 (with twice agitation/day), perhaps because the agitation is so excessive causing more disruption of the microbial activities.

The treatment with ratio 1:2 (with once agitation/day) produces the highest weight of biogas of 1.55 kg with the shortest retention period of 15 days; however, biogas formation was actually for 13 days only. Its peak production day was the 9th with 198.50 g and steadily dropped to the 15th day when biogas production ceased. It was followed closely by the treatment 1:2 (without agitation) which has the same ratio but with no agitation whose total produced gas weight were 1.47 kg and a retention period of 18 days. However, gas produced further dropped in treatment 1:2 (with twice agitation/day) to 1.06 kg with a retention period of 22 days. This shows that although the constituents of the three treatments are the same, their retention time and total gas production differs due to the process of agitation that was given to the treatments. Similar observations were made on treatment 1:2 (with once agitation/day) that stirred digesters offers less retention time as well as providing increased biogas production, which is in agreement with [8, 13, 18, 19]. These stress the importance of agitation as a vital factor in biogas production for stabilizing the process and prevent stagnation, [12, 15, 17, 20, 21, 22] rightly observed. It is also interesting to notice that although treatment 1:2 (both with agitation) were all stirred during the experimental process, treatment 1:2 (with once agitation/day) produces higher biogas than treatment 1:2 (with twice agitation/day). This emphasizes the importance of adequate agitation as little and as gentle as possible since too frequent mixing with faster rotation may disturb the microbial process and thus slow down the release of gas, supporting the findings of others [5. 12, 13, 23]. It also explain why treatment 1: 2 ratio (with zero agitation) has the lower biogas production and longest retention period of 19 days as compared with treatment 1:2 (with once agitation/day) there is no adequate homogeneous mixture to facilitate suitable microbial activities thus delaying biogas formation, further indicating that relatively un-moist slurries inhibits biogas formation due to unfavorable conditions for proper digestion as argued by others such as [11, 13, 24]. Similarly treatment 1:2 (with twice agitation/day) has the least gas production with the highest retention period of 22 days due to delay caused by excessive agitation that prolonged the bacterial activities on the substrate.

Analyses for the properties of the produced biogases

The contents of methane (CH_4), CO_2, and H_2S were determined in all the three treatments investigated. The average values of these properties are indicated in Table 2. The biogas from ratio 1:2 treatment with once agitation/day has the highest methane content of 65 % while the lowest amount of 61.06% was found in the treatment of ratio 1:2 with twice agitation/day. However, their CO_2 and H_2S contents when compared shows that the former treatment has lower content, perhaps due to the earlier conclusion that most of the carbon content in the sample were burnt and turned to ash while the gas production process was on. This also indicates that H_2S is soluble in water forming a weak acid

The single factor ANOVA and Duncan Multiple Range Test (DMRT) tests revealed that all the chemical parameters tested were significant across the four treatments at 95% level of significance. Methane content in treatment 1:2 (with twice agitation/day) was seen to have differed in other treatments, Table 3.

Treatments 1:2 (with no agitation and with once agitation/day) are relatively the same but are significantly higher than treatment 1:2 (with twice agitation/day).

Analyses of the properties of the produced biogases with respects to treatments

The ANOVA analysis in Tables4and 5revealed the analytical comparison of the tested gas properties and the various treatments involved in the gas production. Column represents different treatments with F-cal = 0.007848 which is less than F-critical = 4.757063 and having a probability value (P-value) of 0.998936 implying that there is no significant effect in the rate of slurry formation and the results of the total amount of gas produced.

Row represents the tested properties of the produced gases and showed that F-cal = 696.0484 which is greater than F-critical = 5.143253 having a P-value of 7.9 x 10^-8. This implies that there is a significant difference in the values of the tested properties of the biogases produced in all the treatments. It should be noted that all the gasses produced are significant and should not be neglected.

Determination of calorific (or heating) values

From equation 2, the calorific values for the respective treatments were determined and were found to be in the range of 6.07 – 6.46 kWh/m³.

CONCLUSION

Non-renewable gases are environmentally unfriendly, relatively costly and subject to rapid depletion. On the other hand, the renewable gases create less pollution, are capable of being renewed at a relatively short period of time and may even be relatively cheaper than non-renewable gases. It has been observed that the importance of biogas for economic and waste management is increasing, with environment aims as the main driving force in some instances. The abundant availability of animal residues in Nigeria, particularly from poultry enterprises could cause health hazards (if not properly handled for effective biodegradation). Stirring was proved to be very important factor in biogas production when using poultry manure as substrate. Biogas production increases with adequate quantity of water in the mix. This was because increasing water quantity changes the pH and temperature in addition to decreasing total solid ratio thereby speeding up the microbial activities in the digester. Maximum gas production was obtained when the slurry ratio of dropping to water was 1:2 with one agitation/day.

REFERENCES

1. RAI, G.D. (1989). Non-Conventional Energy Sources: Khana Publishers, Delhi. (**7**:247-299).
2. EARTH TRENDS, (2005). 'Energy Consumption by Source': Earth Trends Data Tables, World Resources Institute.
3. WORLD ENERGY COUNCIL, (1993). 'Energy for Tomorrow's World: The Realities, the Options and the Agenda for Achievements': Vol. 25, *World Energy Council Publication*, USA, pp: 6.
4. TAMBUWAL, A.D. (2002). 'A Comparative Study of Biogas Production from Camel, Cattle, and Horse Dungs': *Paper Presented at NASEF 02*, Kaduna Nigeria.
5. KUMAR, M. (1989). 'Handbook for Rural Technology for Processing Animal by-Products': *Food and Agricultural Organization (FAO Bulletin No. 79), Rome, Italy*.
6. MEDEIRUS, G. & GABY, F. (2007). 'Biomethanization Technology in Sustainable Energy': *GGG –Energy, Environment, Engineering and Consulting;* Montreal, Canada. pp 32.
7. RUFFIN, B.G, & MCCASKEY, T.A., (1991). 'Feeding broiler litter to beef cattle': *Alabama Cooperative Extension Service Circular. ANR-557*.
8. KOSSMANN, W., HABERMEHL, S., HOERZ, T., KELLNER, C. & EULER, H. (2006). 'Biogas Digest, Volume II – Biogas Application and Product Development': *Information and Advisory Service on Appropriate Technology*, Eschborn, Germany.
9. FAO, (1996): A System Approach to Biogas Technology, Food and Agricultural Organization, Rome. (FAO/CMS, 1996; pp 64)
10. CROW, J. (2006). 'Biogas Energy, Arizona Public Service Co., Arizona, USA
11. STEFFEN, R., SZOLAR, O. & BRAUN, R. (1998). Feedstocks for Anaerobic Digestion: Institute for Agrobiotechnology, University of Agricultural Sciences, Vienna, pp 2-10
12. MATTOCKS, R. (1994). 'Understanding Biogas Generation'*: Volunteer in Technical Assistance, (VITA),* Arlington, Virginia, USA.
13. WERNER, U., STOHR, U. & NICOLAI, H. (1989). 'Biogas Plant in Animal Husbandry':

German Appropriate Technology Exchange (GATE), Eschborn, Germany.
14. HABMIGEGERN, J. (2003). 'Methane Digester for Biogas': *Information and Advisory Service on Appropriate Technology*, Eschborn, Germany.
15. ONG, H.K., GREENFIELD, P.F., & PULLAMMANAPPALLIL, P.C. (2002). Effect of mixing on biomethanation of cattle-manure slurry: *Environmental Technology*, **23**:1081-1090.
16. AL-SADI, M. (2010). Design and Building of Biogas Digester for Organic Materials Gained from Solid Wastes': Ph.D. Thesis, An-Najah National University, Nablus; Palestine
17. YONGFU Y, YIBO Q, YUNXUAN G, HUI Z, YUANSHENG X, CHENYONG X, GUOYUAN F, JIENQUAN X, TAIMING Z & GANL (2001): The biogas technology in China. Agricultural Pub House, Beijing, pp 20-54
18. HILL, D.T. (1984). "Methane productivity of the major animal waste types". *Journal of American Society of Agricultural Engineering*, **27**:50.
19. BROUGHTON, A.D. (2009). 'Hydrolysis and Acidogenesis of Farm Dairy Effluent for Biogas Production at Ambient Temperature': MSc. Thesis; Massey University, Palmerston North, New Zealand.
20. LEE, S.R., CHO, N.K. & MAENG, W.J. (1995). 'Using the Pressure of Biogas Created During Anaerobic Digester as a Source of Mixing Power': *J. Fermet, Bioenergy*, **80**(4): 415 – 417.
21. SMITH, L.C., ELLIOT, D.J., & JAMES, A. (1996). 'Mixing in UpflowAnaerobic Filters and its Influence on Performance and Scale-up': *Water Resources*, **30**(2): 3061.
22. ADRIAN, A. (2007). 'Padae Biodigester Installation Report': Border Green Energy Team (BGET) Volunteer, Tak Province, Thailand. pp 16-18.
23. JANTRANIA, A.R. (1985). 'High Solids Anaerobic Fermentation of Poultry Manure': D.Sc. Thesis; The Ohio State University
24. THY, S. (2003). 'Management and Utilization of Biodigester in Integrated Farm Systems' .University of Tropical Agricultural Foundation, Phom Penh, Cambodia.