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ANAEROBIC CO-DIGESTION OF CATTLE PAUNCH MANURE AND COW DUNG FOR BIOGAS PRODUCTION

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ABSTRACT

The study was designed to determine the optimal mixing ratio of cattle paunch manure (PM) and cow dung (CD) in biogas production under tropical condition. The mixing ratio used were 100: 0, 75: 25, 50: 50, 25:75 and 0:100 for paunch manure and cow dung, respectively. The fermentation was carried out in five 30 litres digesters locally fabricated for 30 days. The biogas yields obtained were in the order of 50% PM + 50% CD > 75% PM + 25% CD > 100% PM + 0% CD > 25% PM + 75% CD > 0% PM + 100% CD. Thus, the optimum mixture ratio for paunch manure and cow dung obtained from this study is 50% PM + 50% CD mixture ratio with cumulative yield biogas of 76.42L/Total Mass of Slurry (TMS) within the period of study. The experimental data of all the treatments were fitted to Gompertz relation, which showed adequate fit.

Keywords: cattle paunch manure, cow dung, co-digestion, mixture effect, Nigeria.

INTRODUCTION

Melford (2003) observed that management of Nigeria's environment is costing the nation roughly $5billion annually as a result of poor agricultural practices, oil exploration, oil spills, grazing and habitat destruction etc. In Nigeria, environmental pollution and access to energy resources present challenges to human health, environmental health and economic development. The need for alternative renewable energy sources from locally available resources cannot be over emphasized. Appropriate and economically feasible technologies that combine waste treatment and energy production can simultaneously protect the surrounding water resources and enhance energy availability (Mshandete and Parawira, 2009). Wastes generated during the slaughtering of farm animals are blood, horns, bones, reject meat, spent-water, and paunch manure etc. Paunch manure has been reported to be a major abattoir waste volume-wise in some municipal abattoirs in Nigeria (Ezeoha and Idike, 2007). Paunch manure (the contents of the rumen in ruminants) was therefore found to be one of the major abattoir wastes that require proper management and treatment in most abattoirs in the country. The availability and need to explore and established the utility of cattle paunch manure has being reported by Ezeoha and Idike, (2007) and Chukwuma *et al*., (2012). Slaughter house wastes contains mostly biodegradable matter and are malodorous, this makes it suitable for anaerobic digestion. The availability of paunch manure and cow dung in municipal abattoirs at zero or minimal cost across the country makes co-digestion of these two major abattoir wastes economical feasible. Biogas technology in which biogas is derived through anaerobic digestion of biomass, such as agricultural wastes, municipal and industrial waste is one of such appropriate technology which could be adopted to ease environmental problems and enhance energy production in municipal abattoirs in Nigeria. Mshandete and Parawira (2009) noted that lack of basic and advanced technology by African scientists could be one of the factors contributing to poor biogas technology application in Africa; the authors recommended that relevant and appropriate research be carried out to adopt the biogas technology to the local conditions in African countries. Hence, there is need to research under the tropical environmental conditions with simplified technology for waste treatment and management, affordable by local communities in Africa.

Currently there is no organized system of treatment of slaughter wastes in most of the municipal abattoirs in the country (Nwanta *et al.*, 2010; Chukwu 2008; Chukwuma *et al*., 2012). Ezeoha and. Idike (2007) investigated on the biogas production potential of cattle paunch manure, they reported that biogas production from the wastes were rather low when compared to values found in literature for other animal manure. The low values were attributable to the composition of the substrate, - fibrous vegetable materials usually with low biodegradability. They recommended more research so that the optimum specific gas productivity value for cattle paunch manure could be realized. To improve the biogas production of paunch manure and cow dung there is need to further combine these major animal wastes, to determine and possibly obtain the benefit of co-digestion which has been reported by various researchers (Braun and Wellinger, 2002; li *et al*., 2011). The objective of this study is to determine the synergistic effect of co-digestion of cattle paunch manure with cow dung at various ratio on the basis of increase in biogas production (without any form of pH adjustment, temperature regulation, pretreatment of wastes).

MATERIALS AND METHODS

Substrates sources and characteristics

Fresh substrates utilized in this research were randomly collected from Awka municipal abattoir. The substrates were taken immediately to Spring Board Laboratories, Udoka Housing Estate, Awka for compositional analysis. The parameters determined include moisture content, total solid (TS), volatile solid (VS), total Kjeldahl nitrogen (TKN), carbon content and pH. The result of the analysis is shown in Table-1 below:

Table-1. The composition of the substrates.

Composition	Paunch manure	Cow dung
Moisture content (%)	86	79
Total solid (%)	40	19
Volatile solid (%)	26	15
TKN (mg/g)	3.45	2.98
Carbon content (%)	12.6	9.8
pH	7.0	7.2

The pH measurements were taken with a pH meter (Fisher Scientific Accumet Basic, Model AB 15 pH meter). Total Solids (TS) of the samples, Volatile Solids (VS), and Total Kjeldahl Nitrogen was measured using Standard Methods (APHA; 2005) while Carbon content was carried out using Walkley and Black (1934) method.

Many research work on anaerobic digestion of waste has shown that pH of substrates has strong influence on the rate of biogas production and on the yield of biogas by the substrates. The methanogenic bacteria are known to be very sensitive to pH. The pH of the substrates was therefore measured on the seventh day to determine system stability of the anaerobic process. The pH of the mixtures is shown in Table-2 below:

Table-2. The pH values of digestion and co-digestion of paunch manure with cow dung on the 7th day of digestion period.

Digester	100:0	75:25	50:50	25:75	0: 100
pH	6.6	6.4	6.5	6.4	6.5

The values of the pH of the substrates determined in this research fall within the range of 6.4 - 6.6. The anaerobic digestion of these wastes was carried out progressively without any noticeable inhibition.

Experimental design and setup

The anaerobic inoculum used, was 60 days mesophilic anaerobically digested cow dung, this is to ensure complete removal of any remaining biodegradable fraction from the seed sludge. 5 kg of paunch manure and cow dung were weighed and mixed in the ratio of 100% PM + 0% CD, 75% PM + 25% CD, 50% PM + 50% CD, 25% PM + 75% CD and 0% PM + 100% CD, 15 litres of water was added to the waste, mixed properly and fed in batch type digesters for a period of thirty days to determine. The experiment was done in replicate. The 100% PM + 0% CD and 0% PM + 100% CD are single substrate digestions and are used as data baseline as recommended by Buendia *et al*. (2009). Details of the experimental setup are given elsewhere (Chukwuma *et al*., 2013). The prevailing temperature range was 24^{O}C - 30^{O}C during the period of study.

Kinetic data analysis

Kinetics of batch biomethanation process of cattle paunch with cow dung as co-substrates was studied using Gompertz model. A Gompertz curve or Gompertz Model, named after Benjamin Gompertz, is a sigmoid function. It is a type of mathematical model for a time series, where growth is slowest at the start and end of a time period. The righthand or future value asymptote of the function is approached much more gradually by the curve than the left-hand or lower valued asymptote, in contrast to the simple logistic function in which both asymptotes are approached by the curve symmetrically. It is a special case of the generalized logistic function (Krishania *et al*., 2013; Gupta *et al*., 2009).

The experimental data obtained from mono-digestion and co-digestion of both substrates were checked for the fitness using Gompertz equation by assuming that biogas production rate in batch condition is corresponds to specific growth rate of methanogenic bacteria in the bio-digesters, biogas production rate was predicted using Gompertz equation as reported by Gupta *et al*., 2009 and Budiyono *et al*., 2010. Gompertz relation is given as:

$$Y = a * \exp(-\exp(b - c * x) \quad (1)$$

Where, Y is the cumulative of specific biogas production, l/total mass of surry; is the biogas production potential, l, b is the lag phase period (minimum time to produce biogas), day; c is the maximum biogas production rate (l/day); and X is the time, day. Three parameters a, b and c are constants and were estimated for best fit using MATLAB software program.

RESULTS AND DISCUSSIONS

Biogas production of the various mixtures

All the digesters started gas production on the second day; this could be attributed to optimum composition of the substrate mixture and the effect of inoculum. Cow dung used as seed sludge has been acclaimed to contain bacteria that kick starts anaerobic digestion (Momoh and Nwaogazie, 2008). This optimum condition might be responsible for the short lag phase of all the treatments. A plot of daily quantity of biogas produced versus retention time is plotted on Figure-1 below. The daily biogas production varies from a minimum of 0 L/TMS for 75% PM + 25% CD to a

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maximum of 3.75 L/TMS for 50% PM + 50 % CD mixture. In a similar research work, Li *et al.* (2011), assessed cow dung and waste water sludge for biogas generation. He observed that the trends of daily biogas generation kept increasing until reaching the peak, and then began to decline.

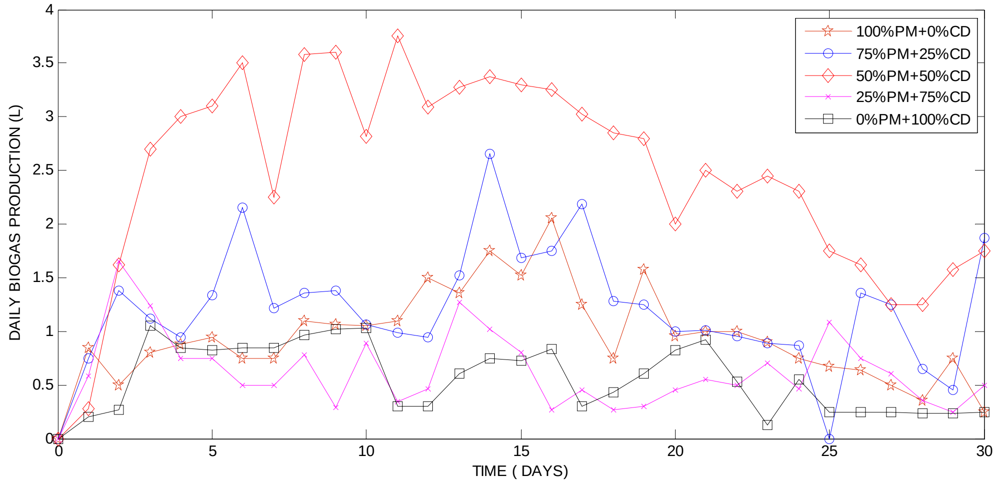

Figure-1. Daily biogas yield from mono-digestion of cattle paunch and cow dung with their mixtures.

From Figure-1 above, several peaks were observed for both single digestions and co-digestions, this is similar to research work by Li *et al.* (2009). The daily biogas trend of several peaks in this research work could be attributed to the effect of temperature which is a major factor in biogas yield. Biogas production in tropics is largely affected by fluctuations in sunlight, which invariably determines digester's performance. The daily biogas yield reached the peak value for 0% PM + 100% CD, 75% PM + 25% CD, 50% PM + 50% CD and 100% PM + 0% CD digestion mixtures in the second week. The 100% PM + 0% CD single digestion reached its peak value on the third week, this could be attribute to the composition of paunch manure which is mainly fibrous material, rich in lignocelluloses. The decomposition of these fibrous matters takes longer time by micro-organisms since the content and distribution of lignin is responsible for the restricted enzymatic degradation of lignocelluloses, by limiting the accessibility of enzymes (Taherzadeh *et al.*, 2011). Biogas production yield generally seems to be lower at the beginning and at the end of digestions. This general trend is attributed to biogas production rate in batch condition which directly corresponds to specific growth rate of methanogenic bacteria in the bio-digester (Gupta *et al.*, 2009; Budiyono *et al.*, 2010).

The plot of the biogas cumulative yield is shown in Figure-2 below. Within the first two days of observation, biogas productions started and continued until the end of the 30 days detention period for all the bio-digesters.

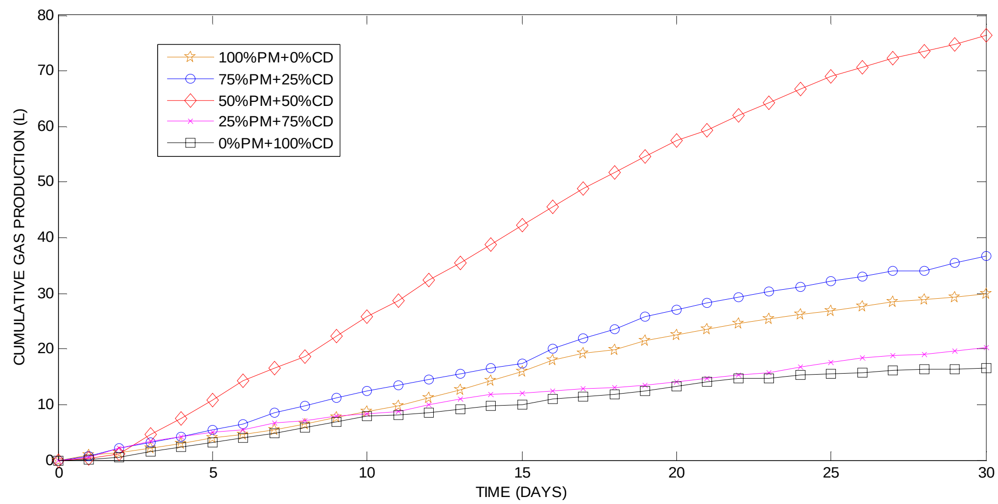

Figure-2. Cumulative effect of mixture ratio of paunch manure and cow dung on biogas yield

From Figure-2 above, it could be seen that from the startup of biogas production for the different mixture ratio, the 50% PM + 50% CD digester took the lead till the end of gas production for all the digesters. The 0% PM + 100% CD digester mixture had the least gas production. Wilkie (2005) reported that cow dung is established to have low available volatile solids because ruminants extract much of the nutrients from the fodder and the leftover is rich in lignin complexes which were extensively exposed to enzyme action of the four chamber stomach of ruminants. The low nutrient residue of cow dung as a result of enzymatic action of microorganism in the rumen of ruminant could be responsible for the least biogas production of cow dung. Hence, the 100% PM + 0% CD single digestion (paunch manure alone) is established from this study to have higher biogas yield than the 0% PM + 100% CD single digestion (cow dung alone).

Co-digestion performance: Antagonistic and synergistic effects

In co-digestions of cattle paunch manure and cow dung, there was improved waste treatment efficiencies and higher cumulative biogas production due to synergistic effect. The synergistic effect is mainly attributed to more balanced nutrients, increased buffering capacity, decreased effect of toxic compounds and the structural changes of the fibers in co-digestion. More balanced nutrients in co-digestion would support microbial growth for efficient digestion, while increased buffering capacity would help maintain the stability of the anaerobic digestion system. Table-3 illustrates the synergistic and antagonistic effect of the digestion mixtures.

Table-3. Antagonistic and synergistic effect of co-digestion of cattle paunch and cow dung.

Digesters	**Co-digestion**	**Biogas performance**			
		Paunch manure (L)	**Cow dung** (L)	**Increase** (L)	**Increase** (%)
100:00		29.99	-		
75:25	36.64	22.49	4.08	10.37	28.30
50:50	76.42	14.99	8.15	53.28	69.72
25:75	19.57	7.50	12.23	-0.16	-0.82
00:100	-	-	16.30		

As a result of synergistic effect, there was 28.30% increase in gas production in the 75% PM + 25% CD mixtures. The synergistic mixture effects of the substrates is seems to be more pronounced in the 50% PM +50% CD digestion mixture, which had 69.72% improvement in biogas production compared to the baseline digesters. The antagonistic effect was observed in the 25% PM + 75% CD mixture, the biogas production in this mixture was slightly less than cow dung baseline datum, this emphasizes that much of cow dung is detrimental to the co-digestion of both substrates. The 50% PM + 50% CD digestion mixture represent the optimum digestion mixture. This result is consistent with other research (Li *et al*., 2011; Chukwuma *et al*., 2012), who had 1:1 ratio between two different substrates as optimum digestion mixture ratio.

Kinetic data analysis

Table-4 presents the parameters obtained in the optimization process and also demonstrates adequate fit using Gompertz model. The biogas yield potential (a) was maximum in 50% PM + 50% CD digester and least in mono-digestion of cow dung; this indicates that co-digestion has biogas enhancing effect. The R-square value was above 0.9914, which means that Gompertz model might be able to explain 9914% (and over) of total variation in the experimental data. The SSE that measures the total deviation of the response values from the fit was lowest for 100% PM + 0% CD digester.

Table-4. Kinetic parameters and goodness of fit obtained with the gompertz model.

	a	**b**	**c**	**SSE**	**R^2**	**Adj. R^2**	**RMSE**
100% PM + 0% CD	34.98	1.51	0.1098	3.503	0.9988	0.9987	0.3602
75% PM + 25% CD	44.28	1.31	0.0947	15.51	0.996	0.9957	0.7579
50% PM + 50% CD	87.42	1.2	0.109	19.1	0.9989	0.9988	0.8411
25% PM + 75% CD	26.45	0.79	0.0702	7.26	0.9914	0.9908	0.5186
0% PM + 100% CD	18.29	1.01	0.1155	5.091	0.9932	0.9927	0.4342

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The plots of Gompertz model fitted to the experimental data are shown in Figures 3 to 7, the plots validates that the Gompertz equation best describe the cumulative biogas production as a function of time.

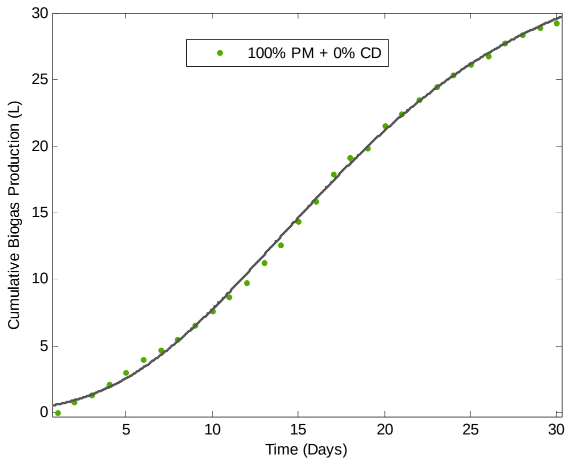

Figure-3. Fitting of parameters of Gompertz equation for biogas production of 100%PM + 0% CD.

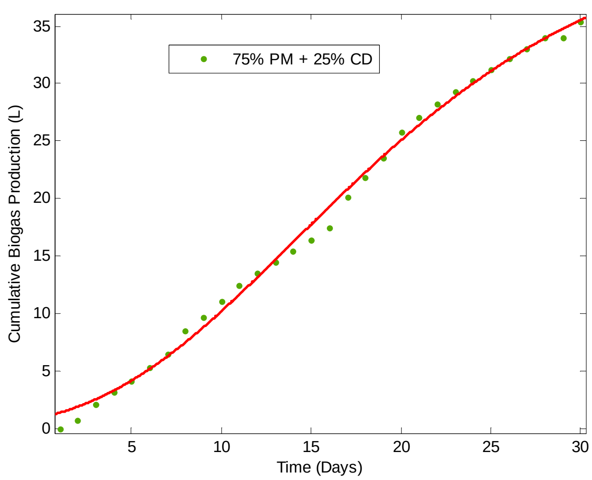

Figure-4. Fitting of parameters of Gompertz equation for biogas production of 75%PM + 25% CD.

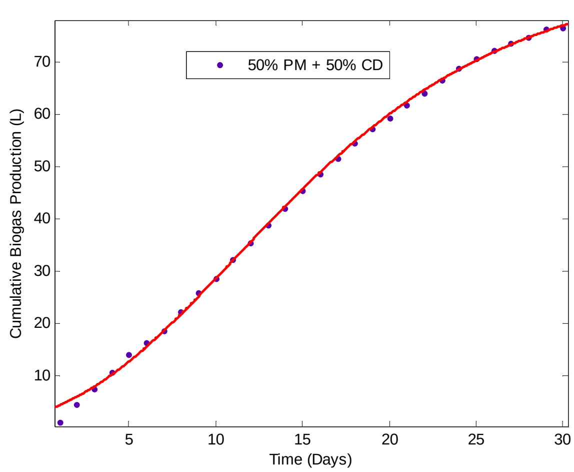

Figure-5. Fitting of parameters of Gompertz equation for biogas production of 50%PM + 50% CD.

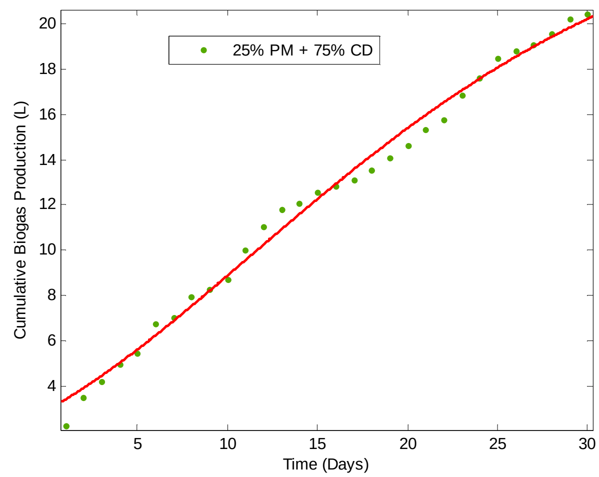

Figure-6. Fitting of parameters of Gompertz equation for biogas production of 25%PM + 75% CD.

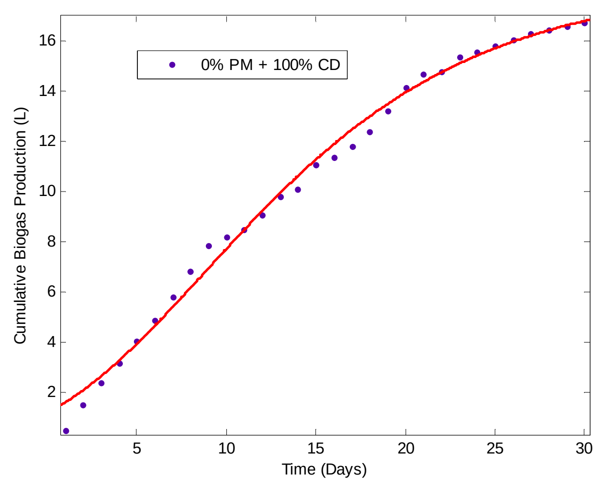

Figure-7. Fitting of parameters of Gompertz equation for biogas production of 0%PM + 100% CD.

CONCLUSIONS

The biogas production potential for paunch manure and cow dung dropping mixture is in the order of 50% PM + 50% CD > 75% PM + 25% CD > 100% PM + 0% CD > 25% PM + 75% CD > 0% PM + 100% CD. The optimum mixture ratio for paunch manure and cow dung obtained from this study is 50% PM + 50% CD mixture ratio. Co-digestion performance indicates that a maximum of 69.72% improvement was noted in the co-digestion of the optimum mixture ratio of both substrates. The experimental data was adequately fitted by Gompertz model. Successful co-digestion of these two major abattoir wastes available in municipal abattoirs (which will not incur transportation costs for on-site treatment) will enhance clean energy production in municipal abattoirs for meat processing and will also eliminate environmental hazards as a result of poor management and treatment these wastes.

REFERENCES

American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF). 2005. Standard Methods for the examination of water and wastewater. 21th Edition, Centennial Edition. Washington, DC., USA.

Braun R. and Wellinger A. 2002. Potential of co-digestion. Institute of Agro biotechnology. Department of Environmental Biotechnology, Lorenz Strasse.

Budiyono I N., Widiasa S. Johari and Sunarso. 2010. The kinetic of biogas production rate from cattle manure in batch mode. International Journal of Chemical and Biological Engineering. 3: 39-44.

Chukwu O. 2008. Analysis of Groundwater pollution from abattoir waste in Minna, Nigeria. Research Journal of Dairy Sciences. 2(4): 74-77.

Chukwuma E. C., Nzediegwu C., Umeghalu E. C., Ogbu K. and Chukwuma G. O. 2012. Co-digestion of paunch manure with cow dung: an effective strategy for waste management in Awka municipal abattoir. Proceedings of the 2012 National Conference on Infrastructural Development and Maintenance in the Nigerian Environment, Faculty of Engineering Nnamdi Azikiwe University, Awka, Nigeria.

Chukwuma E. C., Umeghalu, I. C. E., Orakwe, L. C., Bassey, E. E. and Chukwuma, J. N. 2013. Determination of optimum mixing ratio of cow dung and poultry droppings in biogas production under tropical condition. 8(18): 1940-1948.

Ezeoha SL and Idike FI. 2007. Biogas production potential of cattle paunch manure. Journal of Agricultural Engineering and Technology (JAET). Vol. 15.

Gupta A., Chandra R., Subbarao P. M. V. and Vijay V. K. 2009. Kinetics of batch biomethanation process of jatropha and pongamia oil cakes and their co-digested subtrates. Journal of Scientific and Industrial Research. 68: 624-629.

Krishania M, Vijay V.K. and Chandra. R. 2013. Methane fermentation and kinetics of wheat straw pretreated substrates co-digested with cattle manure in batch assay, Energy. http://dx.doi.org/10.1016/j.energy.2013.05.028.

Li X., Li L., Zheng M., Fu G. and Lar J. S. 2009. Anaerobic co-digestion of cattle manure with with corn stover pretreated by sodium hydroxide for efficient biogas production. Energy. 23: 4635-4639.

Li J., Ajay K. J., Junguo H., Qiaoying B., Sheng C., and Peng W. 2011. Assessment of the effects of dry anaerobic co-digestion of cow dung with waste water sludge on biogas yield and biodegradability. International Journal of the Physical Sciences. 6(15): 3723-3732.

Marchaim U. 1992. Biogas Processes for Sustainable Development. Publications Division, Food and Agriculture Organization of the United Nations, Vialedelle Terme di Caracalla, Rome, Italy. http://www.fao.org/docrep/t0541e/t0541e06.htm.Retrieved on 25/3/2011.

Melford I. 2003. Waste - is the developing world ready? Science in Africa. http://234next.com/csp/cms/sites/Next/Home Expert says Nigeria must reduce waste generation.

Momoh O. L. Y. and Nwaogazie I. L. 2008. Effect of waste paper on biogas production from co-digestion of cow dung and water hyacinth in batch reactors. Journal Applied Science and Environmental Management. 124: 95-98.

Mshandete A. M. and Parawira W. 2009. Biogas technology research in selected sub-Saharan African countries-review. African Journal of Biotechnology. 8(2): 116-125.

Nwanta J. A., Onunkwo J. and Ezenduka E. 2010. Analysis of Nsukka metropolitan abattoir solid waste and its bacterial contents in South Eastern Nigeria: Public Health implications. Archives of Environmental and Occupational Health. 65(1): 21-26.

Taherzadeh M. J., Aslanzadeh S. and Horvath I. S. 2011. Pretreatment of straw fraction of manure for improved biogas production. Bioresource. 6(4): 5193-5205.

Walkley A. and. Blackley I. A. 1934. An Examination of Degtjareff Method for Determining Soil Organic Matter and a Proposed Modifi cation of the Chromic Acid Titration Method. Soil Sci. 37: 29-37.

Wilkie A. C. 2005. Anaerobic digestion of diary manure, design and process consideration. National Resource, Agricultural and Engineering Service. 176: 301-312.