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Evaluation of a Prototype Biodigester for the Production of Organic Fertilizer from Cow Dung

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Abstract – *The main objective of this research work was to evaluate the technological characteristics of a prototype biodigester for the production of organic fertilizer using cow dung. The result of the analysis conducted shows that the rate of production of both the gas and organic fertilizer depends on technological characteristics of the equipment. At an environmental temperature of between 35°C and 37°C, the optimum operating condition observed were: P^H between 7.0-7.3, feed moisture content of 13.5% and 22.7%, and extent of biodegradation was 32.7% for cow dung. The digested slurry was deodorized and disinfected for safe handling and can be applied to agricultural plants as organic fertilizer.* ***Copyright © 2016 Praise Worthy Prize S.r.l. - All rights reserved.***

Keywords*: Biogas Production, Anaerobic and Aerobic Digestion, Organic Fertilizer*

I. Introduction

Processing of organic waste presents an alternative solution to present environmental pollution, fuel energy problems and could serve as an alternative to related problems associated with farming and Animal husbandry [1]-[3]. Development in biogas technology lead to different types of bioreactors design in many countries, these include: the Chinese, Indian, Cameroonian and Upper Volta design, of all these designs; non can effectively performed outside the environment in which they were designed due to heavy reliance of digestive bacteria on the technological characteristics of the plants which vary from place to place [4], [5].

However in our design, effort was geared towards designing a digester to effect a given desired product specification in any given environment using the most economical and efficient way and the easy to be adapted in any part of the world.

The system is powered by electric motor which eases mixing and breaking of scurms formed, allow room for external heating and can easily be moved from one location to another because it has rollers.

The acceptability of final product depends on its aesthetic conditions, most especially the odour arising from the final product.

According to literatures [6], deodorization /disinfecting of the digested slurry could be achieved via chemical treatment with H_2O_2 or 1zAL (a commercial disinfectant) and other disinfectant or controlled biodegradation process.

In the later, a guided control of the biodegradation technological parameters such as temperature, moisture content, and concentration /composition of the composites does significantly reduced the odor arising from the product.

II. Methodology

Samples of Cow dung were procured from Federal University of Technology Minna Agric farm in Nigeria. The chemical analyses of the samples were carried out according to standard test methods (ASTM D1103-80 and ASTM D1104-56).

The standard test methods adopted for proximate analysis included moisture content determination (ASTM E871) ash (ASTM D1102), volatile matter (ASTM E 872) [7]. A prototype bio digester was used during the aerobic and anaerobic digestion of cow dung. The digester is a combination of both fixed dome shape and bag digester (see Fig. 1). The digester was design to treat $1m^3$ of cowdung with density rages between $950kg/m^3$ and $960kg/m^3$. The digester was loaded until 2/3 of it was filled with cow dung having a moisture content of between 12% and 13.5%. The digestion was allowed to proceed to completion with minimum retention time of 22 days, digester temperature was maintained between 35^0C and 37^0C, Nitrogen/carbon ratio of between 15:1 and 30:1, intent mixing, P^H of between 7 and 7.3, pressure of between $1.05kN/m^2$ and $1.10kN/m^2$.

The gas was collected in a plastic bag gas collector and their volume measured. The slurry left after digestion was collected weighed. Biochemical and microbial analysis of the slurry collected after digestion was carried out to identify the strains of bacterial present according to standard test method. The tests include; bacterial Identification and coliform count, bacterial morphological test and biochemical reactions (characteristics test) which are covered by ASTM D5465-93(2012) [7] and the results are presented in Table II and Table III.

After the identification of the strains of bacterial present in the digested slurry, about 25mls of the digested slurry was measured into a volumetric flask H_2O_2 was titrated against the digested slurry until no odour was smell from the slurry and the volume of H_2O_2 used was measured and recorded.

III. Results and Discussion

A detail investigation of organic waste degradation in a prototype plant had been performed under natural environmental condition. The results obtained are as discussed below. All results are presented on percentage wet basis.

Fig. 1. Prototype digester

TABLE I
PERCENTAGE COMPOSITION OF VARIOUS PARAMETERS IN COW-DUNG DIGESTIONS

Residence time day	Moisture content (%)	Volatile- solid (%)	Ash (%)	Total solid (%)	Volatile solid removed (%)	volume of gas generated (m^3) $\times10^{-3}$
0	13.50	38.53	61.47	86.50	0.00	0.000
5	17.13	34.05	65.45	82.87	4.48	0.011
10	18.20	31.00	69.00	81.80	3.05	0.006
15	21.68	28.24	73.76	78.32	2.76	0.101
20	22.70	25.93	74.07	77.30	2.31	0.101

From Table I it can be deduced that about 12.6% volatile solid from cow-dung had been converted to gas within 20th days of retention time, with highest mass being converted within the 5th day which is in agreement with what was reported in [8], [9]. The increase in moisture content from 13.5% to 22.7% was as a result of water formation during digestion of the biomass material.

Moisture and ash content increased with increase in residence time. The increase in ash content could be attributed to the accumulation of inorganic matters or grits in the digester. Joseph, [10], [9], reported a similar observation. It can also be observed from Table I that the overall gas production between the first day and the 24th day was 0.028. Since the digestion was carried out under environmental condition (winter), the temperature range in the digester was maintained between 35°C and 37°C.

This may account for the low gas generated as compared to that reported in [11], where the temperature range was between 40°C and 47°C.

The physical and biochemical test result conducted on the digested slurry to acertain the safe discharge of the slurry to the envinronment after digestion shows from Table II that among the species of bacteria identified from the digested slurry were *staphylococcus, Aureous*, *Bacillus spp* and *Excheriche colli*).

However pathogenic gram positive cocci of the general staphylococcus and streptococcus identified are commonly pyogenic and are resistance to dryness and certain antibiotic which favor their transformation from organic fertilizer (if not properly treated) to plants and animals while gram negative rod like *E colli* causes traveler's diarrhea, meningitis, urine and other infectious diseases and are also resistance to dryness and other penicillin treatment [12]-[15].

TABLE II
PHYSIOLOGICAL & BIOCHEMICAL TEST RESULTS

Sample	Gram stain	Shape	Catalase test	Coagulase test	Methyl red test	Lactose test	Glucose/ Succrose Test	fructose test	Organism confirm
A	-	Short rod	-	-	+	+	+	-	E-coli
B	+	Long rod	+	-	-	-	+	+	*Bacillus spp*
C	+	Cocci	+	+	-	+	+	+	*Staph aureus*
D	+	Long rod	+	-	-	-	+	+	*Bacillus spp*
E.	-	Short rod	-	-	-	+	+	-	*E- coli*

Table III
% BACTERIA CHANGE FOR ANAEROBIC AND AEROBIC DIGESTION OF COW-DUNG

Residence time (days)	No. of bacteria in 1g of sample ($\times10^6$)		Bacteria population change wt%	
	Aerobic	Anaerobic	Aerobic	Anaerobic
1	1.19	1.19	0	0
2	5.36	2.17	417	98
3	8.10	1.274	274	1057
4	4.76	5.69	-334	-705
5	6.51	4.02	-175	-167
6	5.03	7.75	-143	373
12	3.55	3.75	10	11
18	3.65	3.86	10	11

From Table III, it can be observed that bacteria had their maximum multiplication on the 3rd day (1.274×10^7 and 8.10×10^6) and a subsequent decrease on the 4th day (5.69×10^6 and 4.7×10^6) per gramme of the sample for anaerobic and aerobic digestion of cow dung respectively. However between 12th and 18th day there was sluggish increase in bacteria population (3.75×10^6 to 3.86×10^6 for anaerobic and 3.55×10^6 to 3.65×10^6 for aerobic. The low bacterial population observed between the 4th and 18th days in the case of aerobic digested slurry could be attributed to the presence of molecular oxygen in the digester which inhibits the growth of methanogenes [16]-[18].

Comparison between Table I and Table III shows that the rate of production of gas and slurry depends on the bacterial population. For example, when the bacterial population was 4.02×10^{6}, the gas produced was $0.011\times10^{-3}m^{3}$ and when bacterial population dropped to 3.75×10^{6}, the gas produced was $0.006\times10^{-3}m^{3}$ respectively.

The digested slurry was subjected to deodourisation and disinfection test and the result shows that for every $20cm^3$ of digested slurry an average volume of $6.28cm^3$ of H_2O_2 and $0.02cm^3$ of IZAL is needed to deodorize and completely disinfect it, which means that the slurry from the digester is safe to handle after the treatment.

IV. Conclusion

Analysis conducted on the digested slurry from the prototype plant shows that the mount of gas generated is almost as expected, and the organic fertilizer produced in this way is safe to handle and can be applied to plants as organic fertilizer, hence the use of the Prototype plant for the production of organic fertilizer will improve the quality and quantity of food produced, enhance environmental pollution control strategies and reduced reliance on synthetic fertilizers.

References

[1] M. Kuglarz, B. Mrowiec, J. Bohdziewicz, Influence of kitchen biowaste addition on the effectiveness of animal manure digestion in continuous condition. http://www.wis.pk.edu.pl/media/file/konferencje/Kuglarz_Mrowiec.pdf

[2] Pawełczyk A., Auraviev D. Zintegrowana technologia oczyszczania ciekłych odpadów z hodowli trzody chlewnej (The integrated treatment for purification of liquid pig wastes). *Przemysł Chemiczny*, 82 (8-9) (2003) 2-4 (in Polish).

[3] Szymańska E. Wpływ chowu trzody chlewnej na środowisko (The influence of pig farming on the environment). *Zeszyty Naukowe Akademii Rolniczej we Wrocławiu*, 540 (2006) 531-536 (in Polish)

[4] Amrit B. Karki, Biogas as renewable energy from organic waste, *Biotechnology-Vol X* (2014).

[5] Sandhya Nand (2011)/06:17:33:19. Bioreactor classification and Type www.biotecharticle.com/Application- Article/Bioreactors-classification-and-Types-7994.html.

[6] Battmeli A, C, Delgenès JP, Moletta R, Anaerobic digestion of waste activated sludge combined with ozone post-treatment and recycling, *Journal of water Sci Technol. 48(4)* (2003) 61-8. http://www.ncbi.nlm.nih.gov/pubmed/14531423

[7] Alhassan M. and John M A, Effect of bone during fixed bed pyrolysis of Pistachio nut shell. *International Journal of Science and Engineering Investigations, 2*, (2013) 37-48.

[8] W. F. Owen, D.C. Stuckey, J.B. Healy Jr., L.Y. Young, P.L. McCarty, Bioassay for monitoring Biochemical methane potential and Anaerobic Toxicity, water resources. *Water Research*, *Volume 13*, Issue 6, (1979) pp 485–492.

[9] Baba Shehu Umar Ibn Abubakar and Nasir Ismail, Anaerobic digestion of cow dung for biogas production, *ARPN Journal of Engineering and Applied Sciences,vol 7*, No2 (2012) 169-172.

[10] Joseph O Odigure, Biodegration of Poultry waste, 10th *Annual Conference On Biotechnology Society* of Nigeria April 2- 5 (1997), 1-6.

[11] Ward, R. F, Engineering Design of Biogas Units for Developing Countries, *International conference on Biogas tech. transfer and Diffusion, Cairo,* (1984) 35-42.

[12] ODEQ (2001). Research concerning human pathogens and environmental issues related to composting of non-green feedstocks. Oregon Department of Environmental Quality. http://www.compost.org.uk/images_client/news/human%20pathogens.pdf

[13] Horan N. J, *Biological Waste Water Treatment System* (John Aviley and Sons Inc England, Inc England, 1990) 107-117.

[14] E.W. Mester, *Microbiology*, , 3rd Edition (Sounder College Publishing, Japan, 1983)

[15] Charles G. Gunnerson and David B. Sturckey, Anaerobic digestion, Principle and Practice for Biogas System. A world bank Technical Paper Number 49 on *Integrated Resources recovery*, (1986) 5-30

[16] M. Tabatabaei, R. A. Rahim, N. Abdullah, A-D. G. Wright, Y. Shirai, K. Sakai, A. Sulaiman, M. A. Hassan. "Importance of the methanogenic archaea populations in anaerobic wastewater treatments". *Process Biochemistry. 2010. Volume 45*, 1214-1225.

[17] Toprak, Hikmet. "Temperature and organic loading dependency of methane and carbon dioxide emission rates of a full-scale anaerobic waste stabilization pond". *Water Research, Volume 29*, (1995) pp 1111-1119.

[18] J. Wang, J. Zhang, H. Xie, P. Qi, Y. Ren, Z. Hu. "Methane emissions from a full-scale A/A/O wastewater treatment plant". *Bioresource Technology*, *Volume 102*, (2011) 5479-5485

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