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BETWEEN AND BETWIXT SOIL FERTILITY IMPROVEMENT AND DISEASE TRANSMISSION: AN ASSESSMENT OF THE SUITABILITY OF ANAEROBIC DIGESTION EFFLUENT FOR DIRECT APPLICATION AS FERTILIZER

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Abstract

Although anaerobic digestate has been identified as a rich source of essential plant nutrients, its safety measured by the concentration of pathogen present is of great concern to end users. This research explored the efficiency of the mesophilic biodigestion process in the stabilization and sanitization of cow dung and chicken droppings. 6kg each of cow dung and chicken droppings were collected fresh and free from impurities, pre-fermented, mixed with water in the ratio 1:1 by volume to form slurry, fed into the respective reactors and digested for 30 days at an average daily ambient temperature of 37°C. The pH of the medium fluctuated between 6.5 and 8.0. The analysis of the feedstock and effluent of the digesters showed that a total solids reduction of 75.3% and 60.1% were recorded for cow dung and chicken droppings respectively while the reductions in total coliforms were 95% and 70% respectively. E.coli and Shigella spp., were removed while Salmonella spp. and Klebsiella spp. where still present in the digestate. Notwithstanding these results, the digestate still requires further treatment for it to be suitable for application on unrestricted crops either as fertilizer; otherwise a health problem would be created as attempt is made to improve soil fertility.

Keywords: Biodigestion, Digestate, Pathogen reduction, Retention time, Total solids.

1. Introduction

Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and in the presence of anaerobic micro-organisms [1]. The digestion process is carried out using an airtight reactor and other equipment used for waste pre-treatment and gas removal. The process generates a product called "biogas" that is primarily composed of methane, carbon dioxide, and compost products suitable as soil conditioners on farmlands [2]. Anaerobic digestion can be seen as a method to treat organic wastes [3].

In Sub-Saharan Africa, only 36% of the population is served with improved sanitation facilities, and only 58% are served with a safe and clean water supply [4]. This need for adequate sanitation and energy has made biogas technology a welcomed development. Biogas technology contributes to environmental sanitation as animal wastes like cow dung and chicken droppings could be harnessed, treated to remove pathogens to significant degrees and finally utilized as biofertilizers. The development of biogas technology will facilitate the achievement of the Millennium Development Goals of the United Nations. The first goal of the MDGs is to eradicate extreme poverty and hunger. Thus, by utilizing the slurry (the digested waste) that is produced from the biogas systems, a community can fertilize its crops and also improve the composition of its soil [5]. There exist abundant evidence that climate change is a severe threat to socio-economic development and can substantially affect a nation's GDP, as it affects water, forest, sanitation, food security, industrial development, housing, energy, health and the air we breathe [6]. Thus, development of biogas technology is a suitable alternative energy source that would be affordable and environmentally friendly and that would help preserve the green forest thus achieving the seventh Millennium Development Goal of environmental sustainability.

Anaerobic digestion draws up carbon, hydrogen and oxygen from the feedstock. Meanwhile, essential plant nutrients (nitrogen (N), phosphorus (P) and potassium (K)) remain largely in the digestate [7]. The availability of nutrients is higher in digestate than in untreated organic waste. For instance, digestate has 25% more accessible Ammonia nitrogen (NH4-N) and a higher pH value than untreated liquid manure [3].

The quality and composition of the dewatered digestate solid depend on the feedstock and the digestion process [8]. More so, the dewatering separates the digestate into two fractions: the fibre and the liquid effluent. The fibre is bulky and contains a low level of plant nutrients and thus can be used as a soil conditioner and as low grade fertilizer although further processing of the fibre through composting can produce good quality compost. Whereas, the liquid effluent on the other hand contains a large proportion of nutrients and can be used as a fertilizer. The high water content of the liquor facilitates its application through conventional irrigation methods. Thus, the use of fibre and liquor from anaerobic digestion has led to improved fertilizer utilization and therefore less chemical consumption in cropping systems [3].

Notwithstanding this huge benefit of the anaerobic digestate in the improvement of soil fertility and consequently crop production, the safety of the digestate, measured by the concentration of pathogens present, is of great concern to end users [8]. The faeces of livestock has been observedto consist of undigested food, mostly cellulose fibre, undigested protein, excess nitrogen from digested protein, residue from digested fluids,waste mineral matter, worn-out cells from intestinal linings, mucus, bacteria, and foreign matter such as dirt consumed , calcium, magnesium, iron, phosphorus, sodium, etc. Improper disposal of animal faeces can therefore cause oxygen-depletion in the receiving environment. It can also cause nutrient-over enrichment of the receiving system. And the possibility of disease causation is also present [9]. Pathogens like Salmonella spp., Escherichia coli, Shigella spp., Klebsiella spp., etc may contaminate the biogas slurry. Among them, some of the bacteria have longer life and do not get destroyed during the digestion period. Some pathogens survive better in the wet condition and these organisms may still be present in slurry even after discharging from the outlet [10].

The objective of this study therefore is to assess the efficiency of the anaerobic digestion at mesophilic temperature range in the treatment of cow dung and chicken droppings in order to establish if the pathogen removal (biochemical characterization for presence or absence only) is sufficient to use the effluent as fertilizer. The choice of cow dung and chicken droppings was premised on the fact that most animal husbandry in Nigeria revolves predominantly around cattle and poultry among others. Thus these materials are more available in most commercial farms and would thus be more readily used than other animal substratesfor biogas generation in Nigeria.

2. Materials and Methods

The two 25-litre biogas digester tanks each of height 0.5m and diameter 0.25m were fabricated from galvanized steel; which was strong enough to withstand the weight and pressures of the contained slurry. The cylindrical shape was adopted to enhance better mixing. The tank was air tight and is clearly placed above the ground level and outside the shed where it is exposed to the sunlight for partial heating. Other materials used in this study include pH meter model pHS-2S, (Shanghai Jinyke Rex, China) for measuring the pH of slurry every week day throughout the retention period, Gallenhamph weight balance, Mettler P160N used for measuring the weight of evaporating dish and sample for Total solid analysis, Gallenhamph water bath was used to evaporate the sample for total solid analysis to dryness and 2/1 ^{o}C thermometers used to obtain daily temperature of the digester as well as the ambient temperatures for Samaru, Zaria.

Cow dung was collected fresh and free from impurities from the Zango abattoir in Zaria, Kaduna state while the chicken droppings were collected fresh and also free from impurities (such as wood filings) from the poultry Department of the National Animal Production Research Institute (NAPRI), Shika, Zaria, Kaduna State. They were stuffed into bags and transported to the research site located within the grounds of the Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria where they were subjected to further pre-treatment. 6kg each of cow dung and chicken droppings were respectively mixed with water in the ratio 1:1 by volume to form slurry and treated in two purpose-built 25-litre anaerobic digesters (figure 1). Each digester system comprised a pre-fermentation tank, a digester, a gas collection system and a digestate collection tank. The pre-fermented feedstock waste was added to the feed tank together with recycled digestate taken from the collection tank. The design of the digesters was based on Ajoy Karki's Biogas model[11] incorporating the separate floating gas holder system. The slurry was allowed to occupy three quarter of the digester space leaving a clear height of about 0.0625m as space for the gas production. The inflow was directed downward to break scum as the new substrate drops and to cause the solids to accumulate at the bottom of the tank where after digestion they were easily removed.

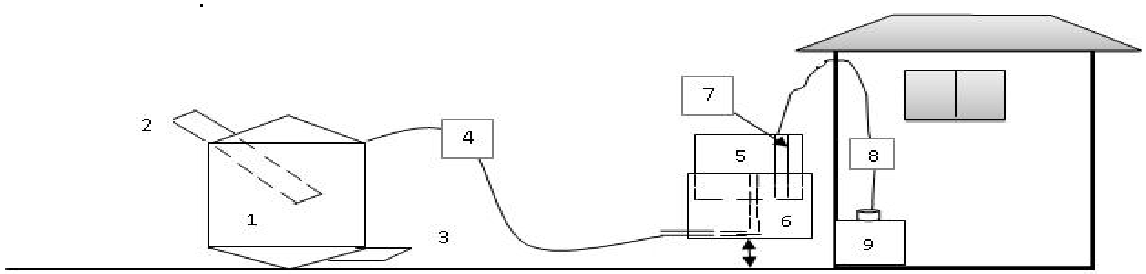

Figure 1: Schematic view of the plant setup

Key:

1. Digester Body	2. Feedstock inlet pipe	3. Effluent outlet pipe	
4. Hose from Digester to gas holder	5. Gas holder	6. Water jacket	7. Rule
8. Hose to cooking stove	9. Cooking stove in the kitchen		

Samples of the feedstock and effluents of both digesters were taken for analysis for a number of process parameters such as total solids content and pH. Total solid was measured in order to estimate all the organic and inorganic solid matter thereby characterizing the feedstock and the effluent and describe the waste reduction.

In addition to the total coliform count, the samples were also analyzed for presence of Salmonella, Escherichia coli, Shigella and Klebsiella. All the analyses were carried out according to previously described standard methods [12, 13, 14]. The biogas yield and the concentration of methane in the gas were also monitored daily.

3. Results and Discussion

The results obtained in this study are presented using statistical tools, tables and histograms. The average daily ambient temperature during the period of study was 37^{o}C while the average digester temperature was 32.6^{o}C. The pH of the two digesters fluctuated optimally between 6.5 and 8.0 (See figure 3 and 4). The daily biogas production of 7.03×10^{-3} m^3 (65.59% methane content) and 6.35×10^{-3} m^3 (61.71% methane content) were recorded for cow dung and chicken droppings respectively. The methane content was estimated by comparing the volume of gas produced before and after removal of carbon dioxide via lime scrubbing.

Figure 2 shows a comparison of the total solids of the feedstock and effluent for both cow dung and chicken droppings. The calculation of the total solids contents of the feedstock and the effluent confirms the conversion performance of the digester (treatment efficiency). There was a reduction in total solid content of 75.3 % and 60.1% for cow dung and chicken droppings respectively. Table 1 gives the total Coliforms counted in the feedstock and the effluent of the cow dung and chicken droppings digested.

Table 1 shows that the reduction in total coliforms for cow dung was 95% while that of chicken droppings was 70%. Notwithstanding these high percentage reductions, the total coliform contents of 2.00×10^{7} CFU/100ml and 6.00×10^{7} CFU/100ml for cow dung and chicken droppings effluents were still above the tolerable limits for irrigation for unrestricted crops (crops that are consumed raw).

In addition, from the biochemical tests carried out, *Salmonella spp*, *E. coli*, *Shigella spp* and *Klebsiella spp*. were implicated in the isolates from the feedstock while only *Salmonella spp* and *Klebsiella spp*. were implicated in the effluent. Although *E. coli* and *Shigella spp.* were identified in the feedstock, they were not found in the effluent. This implied that the anaerobic digestion process in addition to reducing the total coliforms significantly possibly removed *E.coli* and *Shigella spp*. from the effluents of the anaerobic digestion of cow dung and chicken droppings.

The presence of *Salmonella* in the effluent of mesophilic anaerobic digestation means that it is not suitable to be spread on agricultural land without further treatment to eliminate the pathogen. Since pathogens and indicator bacteria were recovered from the mesophilic digester, it appears that these organisms are able to survive at 32^{o}C. Thus, further treatment would be required to be able to use the digestate for unrestricted irrigation.

Furthermore, the resulted biofertilizers are not only suitable for use as soil conditioners and fertilizers, but can also suppress soil-borne and foliar plant pathogens [17, 18, 19]. Thus the utilization of the biofertilization will improve the crop yield of farmers especially in the rural areas which will be of great economic benefit to the nation at large.

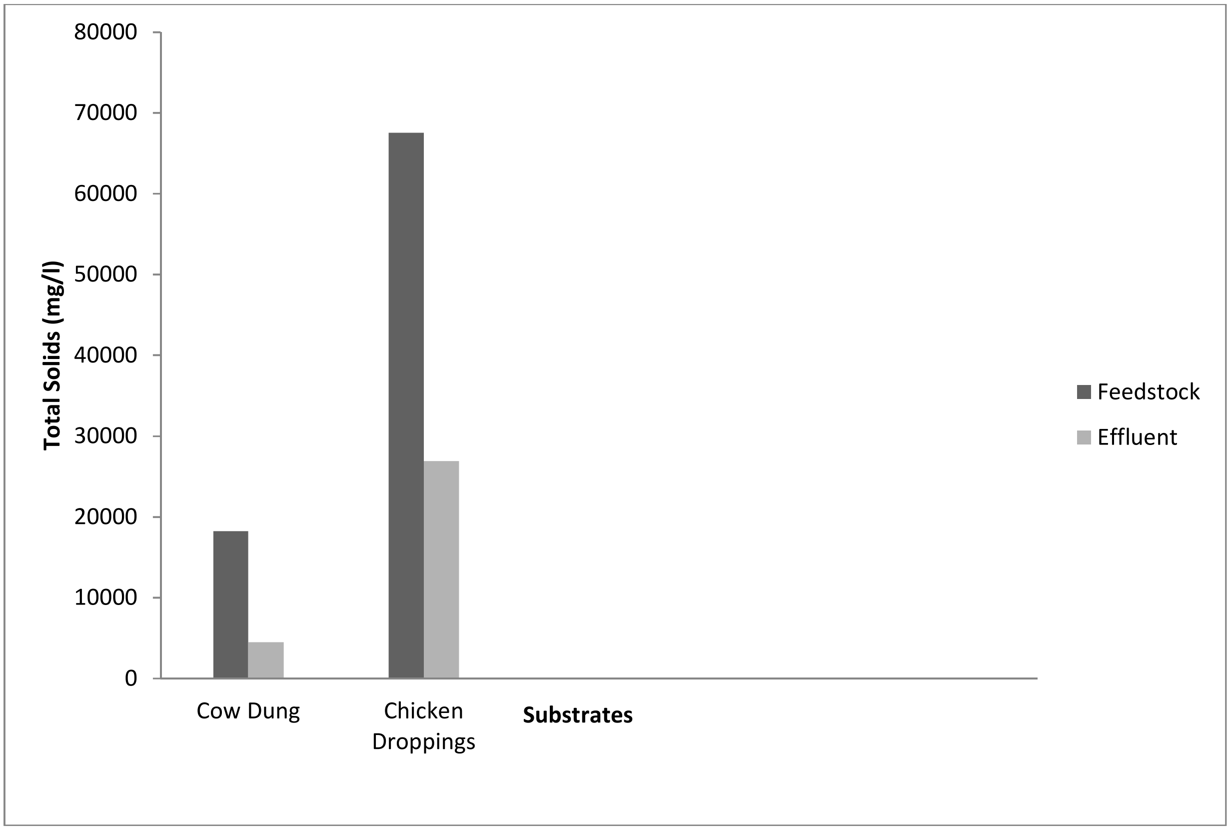

Figure 2: Comparison of Total Solids of Feedstock and Residue of Two Substrates

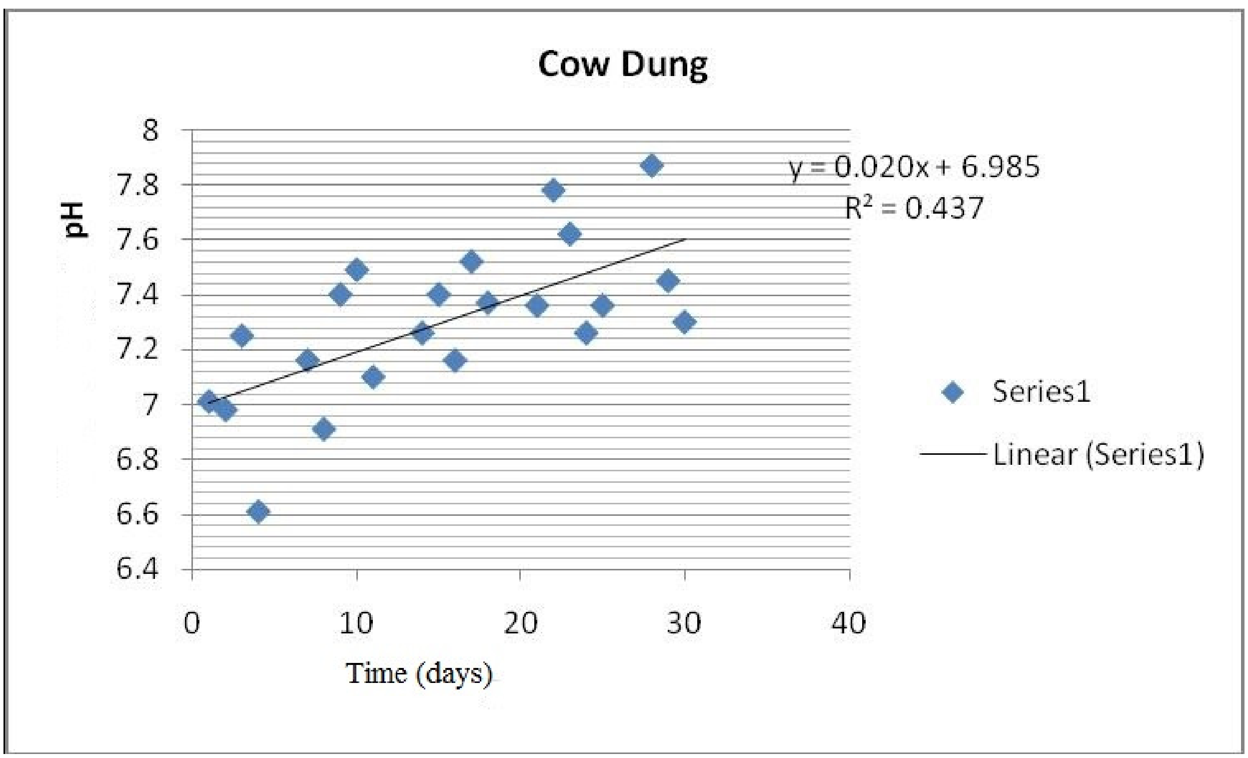

Figure 3: Rate of change in pH of the Cow Dung at various times intervals

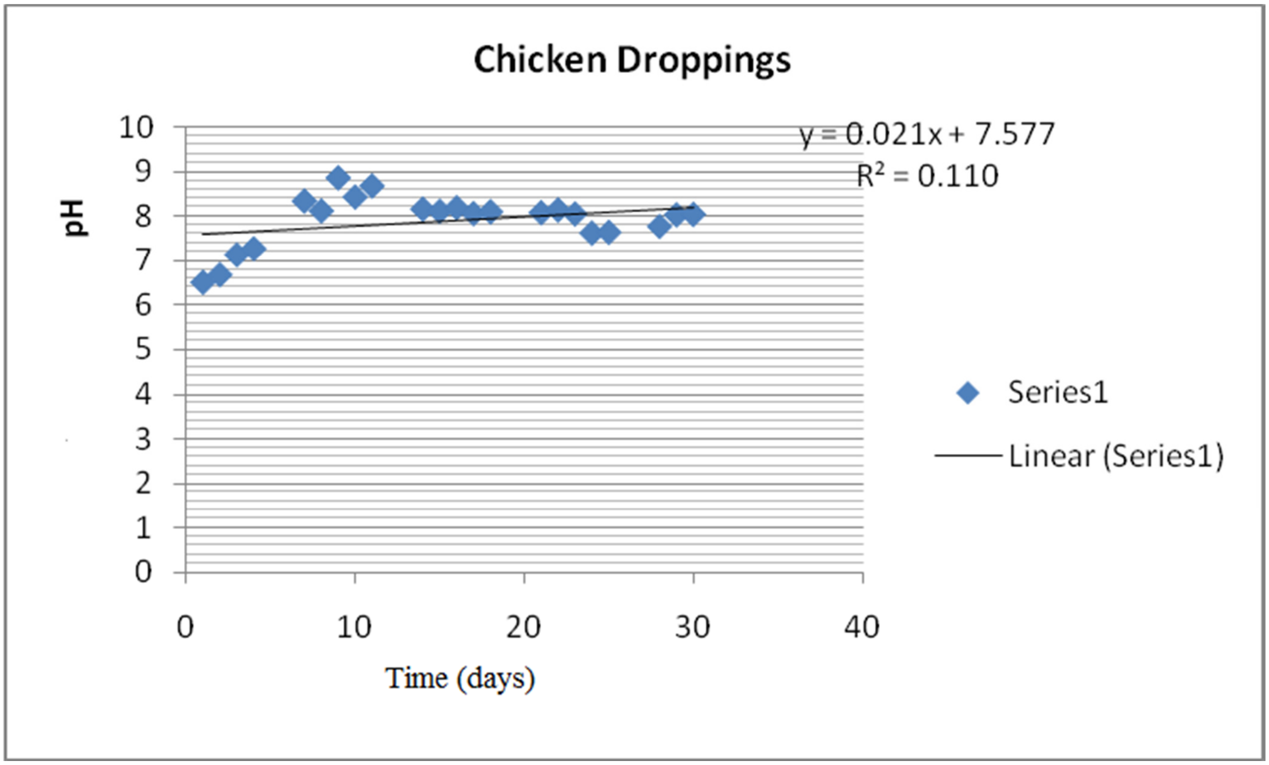

Figure 4: Rate of change in pH of the Chicken Droppings at various times intervals

Table 1: Total Coliforms counted in Feedstock and Effluent

	Total Coliforms (CFU/100ml)		E. coli (CFU/100ml)		Standards Recommended [15,16]
Substrates	Cow Dung	Chicken Droppings	Cow Dung	Chicken Droppings	
Feedstock	4.0 x 10^8	2.00 x 10^8	3.5 x 10^8	1.7 x 10^8	10^5 or 10^6 when the exposure is less
Effluent	2.00 x10^7	6.00 x 10^7	0	0	
% Reduction	95	70	100	100	

4. Conclusion and Recommendations

The study has shown that the anaerobic digestion process could be an effective waste treatment option with respect to the reduction of total solids.

Notwithstanding the high reduction of pathogens from both cow dung and chicken droppings after the anaerobic digestion, the concentration of total coliforms only allows for restricted irrigation according to the WHO-guidelines for "safe use of waste water, excreta and greywater".

This study could not evaluate if an increase in the retention time would further reduce the pathogen content.

The study therefore recommends that anaerobic digestate should be subjected to further treatment to reduce the pathogens to tolerable limits before applying to crops that are eaten directly. Thus, the attempt to solve soil fertility problem does not create an attendant health problem.

In the case where the digestate is used directly as fertilizer without further treatment, great caution has to be taken to ensure that it is only used on crops (like vegetables) that are not eaten raw. It should be applied directly on the roots and should not be spread on top of the vegetables. In addition, contact with mouth or wounds have to be avoided and hands must be washed thoroughly after use.

References

[1] Ojolo, S. J., Dinrifo, R. R and Adesuyi, K. B.,''Comparative Study of Biogas Production from Five Substrates'', *Advanced Materials Research Journal,* Vols. 18-19 (2007) pp. 519-525.

[2] Koberle, E. ''Animal Manure Digestion Systems in Central Europe. In'': Proceedings of the Second Biomass Conference of the Americas, August 21-24, 1995 Portland, Oregon, National Renewable Energy Laboratory (NREL). 23:34

[3] Monnet, F. ''An Introduction to Anaerobic Digestion of Organic Waste'', being a Final Report Submitted to Remade, Scotland available on http://www.remade.org.uk/media/9102/an introduction to anaerobic digestion nov2003.pdf (30/05/2011)

[4] World Health Organization and United Nations Children's Emergency Fund. ''Water for life: making it happen''. *Joint Monitoring Programme for Water Supply and Sanitation.2005,* www.who.int/water_ sanitation_health/waterforlife.pdf Accessed December 2008.ISBN 92 4 156293 5, France.

[5] United Nations. ''*The Millennium Development Goals Report 2006''*. Published by United Nations Department of Economic and Social Affairs. New York, NY. 2005

[6] Machunga-Disu L. L. and Machunga-Disu Z. ''Sustainable management of natural resources and the need for revenue transparency, subsidy reform and full deregulation: The Transformation from Fossil Fuel to Green Energy, Green Deal Nigeria. A publication of Heinrich Boll Stiftung, Nigeria''. Available oninehttp://ng.boell.org/downloads/Chapter - 6 Oil and Gas Technical Background _Paper.pdf accessed 17/05/2012

[7] Igboro, S. B..''Production of Biogas and Compost fromCow Dung in Zaria, Nigeria'', an Unpublished PhD Dissertation in the Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria Nigeria, 2011.

[8] Mata-Alvarez, J., Mace, S., and Llabres, P. ''Anaerobic digestion of organic solid wastes.An overview of research achievements and perspectives''. *Bioresource Technology* 74 (1), 3-16. 2003

[9] Ezeoha S. L and Ugwuishiwu B. O: ''Status of Abattoir WastesResearch inNigeria '' *Nigerian Journal of Technology*, Vol. 30, No. 2, 2011. pp. 143-148

[10] Karki A. B., Shrestha N. J., and Bajgain S. (eds). ''*Biogas as Renewable Energy Source in Nepal: Theory and Development*.'' *Nepal, BSP*. 2005

[11] Karki A.''FromKitchenWaste to Biogas: An EmpiricalExperience. In'': *Biogas and Natural Resources Management*, No. 75. 2002

[12] APHA. ''Standard Method for the Examination of Water and Wastewater'' (19th. ed). Washigton D.C., *American Public Health Association Inc*. 1995

[13] Bopp C. A., Brenner F. W., Wells J. G., Strockbine N. A.: ''Escherichia, Shigella and Salmonella''. In: Manual of ClinicalMicrobiology. (Murray, P. R., E. J. Baron, M. A. Pfaller, F. C. Tenover, R. H. Yolken, Eds.) American Society for Microbiology, Washington, DC. 2005. pp. 459-474.

[14] Gomis S. M., Riddell C, Potter A. A., Allan B. J.: ''Phenotypic and genotypiccharacterization of virulence factors of Escherichia coli isolated from broiler chickens with simultaneous occurrence of cellulitis and othercolibacillosislesions.'' *Can. J. Vet. Res*. 2001. 65, 1-6.

[15]World Health Organization ''Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture'', *Technical Report Series* no 778, World Health Organization, Geneva; 1989.

[16] World Health Organization '*'Health Guidelines for the Use of Wastewater inAgriculture,*'' World Health Organization, Geneva; 2004.

[17] Yang S. S., Recent advance in composting. In: Huang, SF; Pan, SY; Kao, CF, Editors. *Proceedings of the international seminar on issues in the management of Agricultural resources*. September 6-8, 2000. Food and Fertilizer Technology Centre for the Asian andPacific Region (FFTC), Taipei, Taiwan: National Taiwan University; 2000.p 166-85.

[18] Hadar Y., and Mandelbaum R., Suppressive compost for bio control of soil-borne plant pathogens. Phytoparas. 20: 113-6. 1992 .Koberle, E.: ''Animal Manure Digestion Systems in Central Europe. *In'': Proceedings of the Second Biomass Conference of the Americas, August 21-24, 1995 Portland, Oregon, National Renewable Energy Laboratory (NREL).* 23:34

[19] Zang W., Han D. Y., Dick W.A., Davis K. R., and Hoitink H. A. J., Compost and compost water extract-induced systemic acquired resistance in cucumber and Arabidopsis*. Phytopathol*. 88: 450-5. 1998.