Journal of Animal and Veterinary Advances 12 (18): 1439-1444, 2013
ISSN: 1680-5593

Development of a Convenient Method of Rumen Content Composting

[1]B.C. Roy, [1]M.R.I. Khan, [1,2]M.M. Rahman, [2,3]Mohamad Amran Mohd. Salleh,
[2,4]Amimul Ahsan and [1]M.R. Amin
[1]Department of Animal Science, Bangladesh Agricultural University,
2202 Mymensingh, Bangladesh
[2]Institute of Advanced Technology, [3]Department of Chemical and Environmental Engineering,
[4]Department of Civil Engineering, University Putra Malaysia,
43400 UPM, Serdang, Selangor, Malaysia

Abstract: Massive amount of rumen content and blood were produced from the slaughtered animal in a single day of Eid-ul-Azha in Bangladesh that creates an unhygienic and hazardous environment at that time. A convenient composting method can efficiently utilized these rumen contents and blood. For this purpose, three different treatments mentioned as rumen content only (T_1), rumen content with biogas slurry (T_2) and rumen content with cattle blood (T_3) were studied with 3 replications for anaerobic composting. The parameters studied were Organic Matter (OM), Crude Protein (CP), Carbon Nitrogen ratio (C/N ratio), Crude Fiber (CF), Ether Extract (EE), Nitrogen Free Extract (NFE), ash and pH. The result revealed that amount of CP was higher in T_3 (17.43%) followed by T_2 (16.27%) after 90 days of anaerobic composting and the differences were significant ($p<0.01$) among treatment groups. Initial and final C/N ratios were 33.46 and 31.42, 27.66 and 23.88 and 27.93 and 22.83 in case of T_1, T_2 and T_3, respectively. Final C/N ratio showed the significant difference ($p<0.01$) among different treatment groups. The pH of the final compost was significantly increased in T_3 (22%) followed by T_2 (20%).

Key words: Rumen content, anaerobic composting, OM degradation, C/N ratio, CP

INTRODUCTION

Composting is a process of aerobic or anaerobic (Shrestha *et al*., 2011) decomposition of organic matter under controlled conditions by microorganisms, producing a stable organic product with carbon-dioxide, water and heat produced as by products (Rynk *et al*., 1992). Composting is an effective way to treat livestock wastes which provides an environment friendly crop production system by utilizing solid organic wastes (Lee *et al*., 2009). It also called the controlled biological decomposition of organic matter into stable humus like product called compost. It is essentially the same process as natural decomposition except that it is enhanced and accelerated by mixing organic waste with other ingredients to optimize microbial growth. The potential benefits of composting manure and other organic wastes are improved manure handling; reduced odor, fly and other vector problems and reduced weed seeds and pathogens. Application of compost in the soil improves its fertility, tilt and water holding capacity. It is also free of offensive odors and can be stored for extended periods (Graves and Hattemer, 2000).

Compost improves the physical properties of soil by serving as a soil conditioner through the addition of humus and organic matter to the soil. The compost has the advantage of improving soil structure, increasing soil organic matter, suppressing soil-borne plant pathogens and enhancing plant growth (Imbeah, 1998; Hoitink and Fahy, 1986) but raw manure or immature compost may cause phytotoxicity to plants and adversely affect the environment when applied to soil. The addition of humus and organic matter increases the water and nutrient holding capacity of the soil, decreases the soil bulk density and improves the soil aeration and pore structure. These improvements result from the direct effects of the composting materials itself and the promotion of soil microbial activity and earthworms. Most plant nutrients in compost are in an organic form.

Although, compost is not high in nitrogen, phosphorous or potassium, these nutrients are released slowly over a long period of time. This results in a more efficient utilization of nitrogen and a decreased potential for nitrogen leaching. Nutrients become available to plant roots at a slower rate from compost compared to inorganic fertilizers (Lee *et al*., 2009).

Corresponding Author: M.M. Rahman, Department of Animal Science, Bangladesh Agricultural University, 2202 Mymensingh, Bangladesh

Rumen content is a material from the rumen which is the first stomach compartment of the ruminants. It is account for about 80% of the capacity of the adult ruminant stomach. It has a repulsive and (Church, 1993) inherent odor when processed into feedstuff. The bulk digestion of the rumen content is an important source of energy, protein and vitamins especially vitamin B complex. Disposal of rumen contents and other abattoir waste in landfills is costly and an environmental concern while burning or burying this waste outside of landfills may affect air and ground water quality (Saarijarvi *et al*., 2004). Consequently, development of new options for disposal of rumen contents is a current area of research interest. Passive composting has been successfully used for disposal of dead carcasses (McCaskey *et al*., 1996; Elwell *et al*., 1998; Stanford *et al*., 2000) wet waste/slurries (Tritt and Schuchardt, 1992), manure (Lee *et al*., 2009) and rumen contents (Farinet *et al*., 1992) from abattoirs. However, composting of rumen contents from cattle, sheep/goat abattoirs has not previously been evaluated in Bangladesh. Consequently, the overall goal of the current study was to develop a simple, rapid and low-cost method during Eid-ul-Azha and also for year-round composting of rumen contents from slaughtered cattle or sheep/goat. Additional study goals included determination of the value of finished compost as fertilizer and an evaluation of the presence of pathogenic bacteria such as *E. coli* in the finished compost.

A large amount of slaughter house waste as well as rumen content is produce in Bangladesh every year. Bangladesh is densely livestock populated country obtaining 23.051 million cattle from which 2.465 million is slaughtered every year (FAO, 2006). The quantity of the different types of wastes was estimated from total number of slaughtered animal/year. It was found that the total rumen content production was 49300 MT/year from cattle in Bangladesh. Furthermore, a lot of cattle, goat, sheep and buffalo were slaughtered in a single day of Eid-ul-Azha. Massive amount of rumen content and blood from the slaughtered animal have creates an unhygienic and hazardous environment at the time of Eid-ul-Azha. It is necessary to develop a convenient method to recycle and reuse of that unwanted waste materials.

An alternative solid waste treatment strategy is anaerobic biological treatment either in anaerobic digesters or in landfill bioreactors (Reinhart and Townsend, 1998). Anaerobic biological treatment can be an acceptable alternative to current disposal strategies because it reduces the volume of solid wastes, stabilizes the wastes, produces a residue that can be used for soil conditioning and recovers energy from wastes in the form of methane (Stroot *et al*., 2001). It is known that a large amount of nitrogen is emitted as ammonia (NH_3) during aerobic decomposition of organic matter. Kithome *et al*. (1999) observed that 47-62% of the total nitrogen was lost as NH_3 after 25 days of composting poultry manure. NH_3 emission reduces the quality of compost as a fertilizer and also creates severe odor problems. To keep this point in mind, this study was conducted anaerobically to recycle the rumen content for organic fertilizer production. Therefore, the experiment was conducted to develop a convenient, easy and quick composting method for the proper recycling of rumen content.

MATERIALS AND METHODS

Experimental design, location and duration: The experiment was conducted under three different treatments mentioned as rumen content only (T_1), rumen content with bio-gas slurry (T_2) and rumen content with cattle blood (T_3). In each treatment, there were three replications to minimize the experimental errors. Detail experimental design is given in Table 1. Parameters studied were Organic Matter (OM), Crude Protein (CP), Carbon Nitrogen ratio (C/N ratio), Crude Fiber (CF), Nitrogen Free Extract (NFE), ash and pH. The chemical analysis of rumen content, biogas slurry and cattle blood was performed in the Departmental Laboratory. The composting operation was conducted in the sheep, goat and horse farm, Bangladesh Agricultural University, Mymensingh. The compositing period was 90 days, i.e., 28 November, 2010 to 27 February, 2011.

Collection of rumen content, biogas slurry and cattle blood: The rumen content and blood samples of cattle were collected from a private slaughter house at Kewatkhali in Mymensingh District. The samples were put into poly sac and carried to the Lab. Animal Science Deapartment. Biogas slurry was collected from the sheep, goat and horse farm (Field Laboratory of the Department of Animal Science) and stored in air tight condition before chemical analysis. Chemical composition of collected rumen content, cattle blood and biogas slurry was shown in Table 2.

Table 1: Layout of the experiment

	Treatment		
Replication	T_1	T_2	T_3
R_1	T_1R_1	T_2R_1	T_3R_1
R_2	T_1R_2	T_2R_2	T_3R_2
R_3	T_1R_3	T_2R_3	T_3R_3

T_1 = 30 kg rumen content only; T_2 = 30 kg rumen content+3 kg biogas slurry; T_3 = 30 kg rumen content+750 g cattle blood

Table 2: Chemical composition of collected rumen content, cattle blood, biogas slurry and saw dust

	Composition of raw materials (%)					
Raw materials	Moisture	CP	EE	CF	NFE	Ash
Rumen content	83.22	5.12	1.50	5.48	3.88	0.80
Biogas slurry	85.36	3.96	2.14	3.68	3.76	1.10
Cattle blood	82.56	15.64	0.24	-	0.72	0.84
Saw dust	8.41	0.11	0.14	80.56	10.33	0.45

Preparation of composting pit: A place of comparatively high land at sheep, goat and horse farm of Bangladesh Agricultural University was selected to prepare composting pits where rain water was not logged. A total of 9 similar pits were prepared for the mentioned 3 treatments whose diameter was 75 cm and depth was 45 cm. Polyethylene was set at the bottom and side wall of the pits to create an anaerobic condition and to prevent leaching and water contamination with compost.

Preparation of mixture for composting: The 30 kg rumen content and 750 g cattle blood for T_1; 30 kg rumen content and 3 kg biogas slurry for T_2 and 30 kg rumen content only for T_3 were selected for each treatment and replication. Required amount of saw dust was mixed with the composting materials in such a way that the moisture of the final mixture was near about 60%. Properly mixed composting materials were put into the selected different pits and tightly covered with the polyethylene to prevent aeration. An 8 cm thick soil layer was prepared to cover the composts for 90 days. Composting temperature was of 28-40°C (average temperature was 32°C) inside the pit during composting period.

Collection of compost sample for chemical analysis: Samples were collected from T_1, T_2 and T_3 just after proper mixing of said ingredients with rumen content. Then, samples were collected from all composting pits after 90 days of anaerobic composting and analyzed sub-sequently. The parameters studied were moisture, Dry Matter (DM), Crude Protein (CP), Crude Fiber (CF), ash, Ether Extract (EE), Nitrogen Free Extract (NFE) and Carbon Nitrogen (C/N) ratio. After composting of 90 days, all changes were compared to evaluate the compost quality. All the samples were analyzed in triplicate and mean values were recorded. DM was determined by oven drying of the samples at 103°C for 2 days. CP was determined by Kjeldahl Method and EE was determined by Soxhlet apparatus. Fiber was determined by acid and alkali digestion, described by Page *et al*. (1982). Ash was determined by burning the samples at 550°C for 5.5 h in a muffle furnace. OM was determined by deducting the ash value from DM. The pH of different composts were measured using a pH meter by diluting the samples with distilled water at a ratio of 1:5 after 2 h of continuous shaking. Analytical procedures were conducted at the laboratory of Animal Science Department and Bangladesh Institute of Nuclear Agriculture (BINA) according to AOAC (1990).

Statistical analysis: The data were analyzed by Completely Randomized Design (CRD) with the principles of Steel and Torrie. Mean values were determined by using computer Statistical Package MSTAT-C Program with Standard Error of Mean (SEM). Differences among the treatment means were determined by the Duncan's Multiple Range Test (DMRT) value with the principles of Steel and Torrie.

RESULTS AND DISCUSSION

Table 3 showed the detail results of the composting experiment. Initial and final OM was 32.98, 32.66 and 33.16 and 32.09, 29.20 and 28.94% in case of T_1, T_2 and T_3, respectively. The organic matter was slightly reduced after 90 days of anaerobic composting. This is might be due to decomposition of OM by anaerobic microorganisms during anaerobic composting of rumen content. A significant different ($p<0.05$) was found in OM degradation at different treatments. The result revealed that the biogas slurry and cattle blood have a significant influence on OM degradation.

Significant differences were found in CP content of rumen content composting at different treatments. Cattle blood contained compost (T_3) showed the highest CP (17.43%) followed by T_2 (16.27%) after final composting. Blood contains a high amount of nitrogenous substances that helps for vigorous microbial growth and helps to increase CP in T_3. Moreover, nitrification occurs by nitrifying bacteria during anaerobic composting process that also a cause of higher CP in T3. Biogas slurry is also a good source of N that helps to increase CP in T2. On the other hand, a massive amount of N is lost during aerobic composting process. Kithome *et al*. (1999) observed that 47-62% of the total nitrogen was lost as NH_3 after 25 days of composting poultry manure. NH_3 emission reduces the quality of compost as a fertilizer and also creates severe odor problems. Taufik also found N loss in poultry manure composting when they composted it by staking. So, anaerobic composting is better than aerobic process in case of N conservation. Shrestha *et al*. (2011) were performed a comparative study on compost prepared from cattle rumen content composted for 3 and 9 months. The 9 months old compost inoculated with a Nutri-Life 4/20 inoculum and two commercial preparations (Living Soil and Nutri-Life 4/20) and all were incubated for 48 h.

Table 3: Effect of bio-gas slurry and cattle blood on rumen content composting (DM basis)

Parameters	Composting state	Treatment T_1	T_2	T_3	SEM	Level of Sig.
OM	Before	32.98	32.66	33.16	0.186	NS
	After	32.09^a	29.20^b	28.94^b	0.582	*
CP	Before	12.63^c	14.65^b	16.33^a	0.552	**
	After	12.69^c	16.27^b	17.43^a	0.758	**
C/N ratio	Before	33.46^a	27.66^b	27.93^b	0.975	**
	After	31.42^a	23.88^b	22.83^b	1.374	**
CF	Before	28.57	27.76	27.74	0.209	NS
	After	25.37^a	22.10^b	21.53^b	0.624	**
EE	Before	2.25	2.30	2.32	0.037	NS
	After	2.26^b	2.83^a	3.03^a	0.132	*
NFE	Before	41.48	40.92	40.73	0.233	NS
	After	39.90	38.97	38.67	0.241	NS
Ash	Before	11.06	12.41	12.10	0.538	NS
	After	11.12	11.55	10.84	0.612	NS
pH	Before	7.52	7.52	7.66	0.595	NS
	After	7.58^b	7.93^a	8.15^a	0.957	*

T_1 = Rumen content only; T_2 = Rumen content with biogas slurry; T_3 = Rumen content with cattle blood. Mean values with different superscript in the same row differ significantly. NS: Not Significant; **$p<0.01$; *$p<0.05$

Nutri-Life 4/20 showed the highest concentrations of NO_3^--N and K^+-K while rumen compost extract showed higher humic and fulvic acids concentration.

The composting process destroys pathogens, converts unstable ammonium N to stable organic forms, reduces the volume of waste and improves the nature of the waste (Imbeah, 1998; Georgacakis *et al*., 1996; Sequi, 1996). It also makes the wastes easier to handle and transport and often allows for higher application rates because of the more stable, slow release nature of the N in compost (Lee *et al*., 2009; Sequi, 1996). Long curing phase in anaerobic composting makes the lower particle size by breaking large particles. The effectiveness of the composting process is influenced by factors such as temperature, moisture content (Stentiford, 1996), pH, C:N ratio, particle size and degree of compaction (Lau *et al*., 1993).

The C/N ratio is one of the important parameter of compost quality. Initial C/N ratio was ranged between 27.66-35.00. A significant ($p<0.01$) reduction of C/N ration was found after 90 days of composting in T_2 and T_3. The changes in the C/N ratios during composting reflect the organic matter decomposition and stabilization achieved during composting. The C/N ratio decreased from an initial value of 33.46-31.42, 27.66-23.88 and 27.93-22.83 in case of T_1, T_2 and T_3, respectively. Lower initial C/N ratio causes the decreased microbial breakdown that increases the composting period (Huang *et al*., 2004). Nitrogen is used for the synthesis of cellular material, amino acids and proteins and is continuously recycled through the cellular material of the micro-organisms. Any nitrogen that is incorporated into the microbial cells becomes available again when the micro-organism dies. Because a large part of the carbon is continuously released while the majority of the nitrogen is recycled, the C/N ratio decreases over the composting period in this experiment. It is recommended to maintain C/N at 25-30 as it is considered as the optimum ratio for composting (Huang *et al*., 2004). Bhamidimarri and Pandey (1996) also have successfully co-composted piggery wastes with sawdust at C/N of 25-30. They reported that sawdust appeared to be an ideal bulking agent for composting pig manure because of its ability to absorb moisture and its structure provides adequate porosity in the compost heap.

Crude fiber content of the final compost reduced significantly after 90 days of rumen content composting. Reduction of crude fiber occurs due to break down of cellulose, hemicelluloses and lignins by microbes. Variation in the reduction of CF in different treatments also found significant difference ($p<0.01$). The highest reduction was occurred at T_3 (22%) followed by T_2 (20%) and the lowest break down was occurred at T_1 (11%). Ping *et al*. (2010) stated that degradation of CF might be increased by adding enzymes during composting process and they observed 50% higher CF breakdown in enzyme treated compost. Not only this, CF degradation also depends on moisture content, types and numbers of microorganisms, temperature, pH, C/N ratio. Obodai *et al*. (2010) also stated that CF content was gradually reduced on the progression of compost maturation. Average pit temperature was found 32°C during the whole composting period which might be created a comfortable environment to break down the fibers and other organic compounds. It is reported that pure cultures of rumen content contains a number of microorganisms along with compost such as *Azotobacter* sp., *Azospirillum brasilense*, *Bacillus* sp., *Cellulomonas cellosea*, *Chaetomium* sp., *Metarhizium anisopliae*, *Pseudomonas* sp., *Polyanguim cellulosum*, *Streptomyces* sp., *Trichoderma* sp., together with unidentified microbes from the compost (Shrestha *et al*., 2011). These microorganisms are involved in nitrogen fixation such as *Azotobacter* sp. and *Azospirillum* sp., (Khammas and Kaiser, 1992), phosphate solubilization and nutrient release such as *Azotobacter* sp. (Garg *et al*., 2001), pectin decomposition such as *Bacillus* sp. (Halsall and Gibson, 1985), disease suppression/ protection against plant pathogens such as *Trichoderma* sp. (Harman, 2006), soil bioremediation such as *Trametes* sp. (Atagana, 2009) and cellulose degradation such as *Cellulomonas* sp. (An *et al*., 2005).

Ether Extract (EE) content was slightly increased after composting and found significantly higher ($p<0.05$) in T_3 than bio-gas slurry treatment (T_2). It is assumed that anaerobic microorganisms synthesis long chain fatty acids during composting. Results also found that there were no significant differences in case of NFE and ash content of different treatments of rumen content composting.

The pH is another important parameter to measure compost quality. The pH was more or less similar before composting but it was found that final pH was higher than the initial value. The initial pH depends on the composition of the composting materials. The initial pH was 7.52, 7.52 and 7.66 in case of T_1, T_2 and T_3, respectively. Differences were significantly higher in T_3 (8.15) and T_2 (7.93) than T_1 (7.58). Generally, the pH varies between 5.5 and 8.5 during the course of composting (Graves and Hattemer, 2000). In the early stages of composting, organic acids may accumulate as a by-product of the digestion of organic matter by microorganisms. A basic pH (>8.5) promotes the conversion of nitrogenous compounds to ammonia. This ammonia formation serves to further increase the alkalinity and not only slow the rate of composting but also promote the loss of nitrogen through ammonia volatilization. Fang *et al*. (1999) and Huang *et al*. (2004) also stated that NH_4-N contents of composting materials significantly increased the pH due to ammonification as well as the mineralization of organic-N compound.

CONCLUSION

It might be concluded from the overall results that cattle blood and biogas slurry would be utilized as enhancing ingredients for rumen content composting.

REFERENCES

AOAC, 1990. Official Methods of Analysis. 15th Edn., Association of Official Analytical Chemists, Arlington, VA., USA.

An, D.S., W.T. Im, H.C. Yang, M.S. Kang and K.K. Kim *et al*., 2005. Cellulomonas terrae sp. nov., a cellulolytic and xylanolytic bacterium isolated from soil. Int. J. Syst. Evol. Microbiol., 55: 1705-1709.

Atagana, H.I., 2009. Biodegradation of PAHs by fungi in contaminated-soil containing cadmium and nickel ions. Afr. J. Biotechnol., 8: 5780-5789.

Bhamidimarri, S.M.R. and S.P. Pandey, 1996. Aerobic thermophilic composting of piggey solid wastes. Water Sci. Technol., 33: 89-94.

Church, D.C., 1993. Digestive Physiology and Nutrition of Ruminants, Volume 1. O.S.U. Book Stores, Inc., Corvallis, pp: 143-189.

Elwell, D.L., S.J. Moeller and H.M. Keener, 1998. Composting large swine carcasses in three amendment materials. Proceedings of the Animal Production Systems and the Environment: An International Conference on Odor, Water Quality, Nutrient Management and Socioeconomic Issues, July 19-22, 1998, Des Moines, IA., pp: 15-20.

FAO, 2006. Food and Agricultural Organization of the United Nations. FAO, Rome, Italy.

Fang, M., J.W.C. Wong, K.K. Ma and M.H. Wong, 1999. Co-composting of sewage sludge and coal fly ash: Nutrient transformation. Bioresour. Technol., 67: 19-24.

Farinet, J.L., Y. Hurvois and F. Forest, 1992. Wastes management and processing for energy, organic fertilizer and pollution control in a tropical slaughterhouse. Proceedings of 6th EC Conference, Biomass for Energy, Industry and Environment, April 22-26, 1992, Athens, Greece, pp: 944-948.

Garg, S.K., A. Bhatnagar, A. Kalla and N. Narula, 2001. *In vitro* nitrogen fixation, phosphate solubilization, survival and nutrient release by *Azotobacter* strains in an aquatic system. Bioresour. Technol., 80: 101-109.

Georgacakis, D., A. Tsavdaris, J. Bakouli and S. Symeonidis, 1996. Composting solid swine manure and lignite mixtures with selected plant residues. Biores. Technol., 56: 195-200.

Graves, R.E. and G.M. Hattemer, 2000. Composting. In: National Engineering Handbook, United States Department of Agriculture (Ed.). Chapter 2, NRCS, USA.

Halsall, D.M. and A.H. Gibson, 1985. Cellulose decomposition and associated Nitrogen fixation by mixed culture of *Cellulomonas jelida* and *Azospirillum* sp. and *Bacillus macerans*. Applied Environ. Microbiol., 50: 1021-1026.

Harman, G.E., 2006. Overview of mechanisms and uses of *Trichoderma* spp. Phytopathology, 96: 190-194.

Hoitink, H.A.J. and P.C. Fahy, 1986. Basis for the control of soilborne plant pathogens with composts. Annu. Rev. Phytopathol., 24: 93-114.

Huang, G.F., J.W.C. Wong, Q.T. Wu and B.B. Nagar, 2004. Effect of C/N on composting of pig manure with sawdust. Waste Manage., 24: 805-813.

Imbeah, M., 1998. Composting piggery waste: A review. Biores. Technol., 63: 197-203.

Khammas, K.M. and P. Kaiser, 1992. Pectin decomposition and associated nitrogen fixation by mixed cultures of *Azospirillum* and *Bacillus* species. Can. J. Microbiol., 38: 794-797.

Kithome, M., J.W. Paul and A.A. Bomke, 1999. Reducing nitrogen losses during simulated composting of poultry manure using adsorbents or chemical amendments. J. Environ. Qual., 28: 194-201.

Lau, A.K., P.H. Liao and K.V. Lo, 1993. Evaluation of swine waste composting in vertical reactors. J. Environ. Sci. Health Part A: Environ. Sci. Eng. Toxicol., 28: 761-777.

Lee, J.E., M.M. Rahman and C.S. Ra, 2009. Dose Effects of Mg and PO_4 Sources on the Composting of Swine Manure. J. Hazard. Mater., 169: 801-807.

McCaskey, T.A., J.A. Little, R.M. Krotz, S.P. Lino and T.C. Hannah, 1996. Onfarm composting feasible for disposal of swine carcasses. Highlights Agric. Res. Alabama Agric. Exp. Stat., 43: 18-20.

Obodai, M., W. Amoa-Awua and G.T. Odamtten, 2010. Physical, chemical a nd fungal phenology associated with the composting of wawa sawdust (*Triplochiton scleroxylon*) used in the cultivation of oyster mushrooms in Ghana. Int. Food Res. J., 17: 229-237.

Page, A.L., R.H. Miller and D.R. Kenny, 1982. Method of Soil Analysis. Part II. Chemical and Microbiological Properties. 2nd Edn., American Society of Agronomy, Madison, WI, USA.

Ping, R., X.S. Yun, R.X. Wen and Z.W. Juan, 2010. Effects of enzyme on material transformation of cow dung compost. Agric. Sci. Technol., 11: 143-146.

Reinhart, D.R. and T.G. Townsend, 1998. Landfill Bioreactor Design and Operation. 1st Edn., Lewis Publishers, Boca Raton, Florida, ISBN: 1-56670-259-3, pp: 189.

Rynk, R., M. van de Kamp, G.B. Willson, M.E. Singley and T.L. Richard *et al*., 1992. On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service, New York, ISBN: 9780935817195 Pages: 186.

Saarijarvi, K., P. Virkajarvi, H. Heinonen-Tanski and I. Taipalinen, 2004. N and P leaching and microbial contamination from intensively managed pasture and cut sward on sandy soil in Finland. Agric. Ecosyst. Environ., 104: 621-630.

Sequi, P., 1996. The Role of Composting in Sustainable Agriculture. In: The Science of Composting, Part 1, De Bertoldi, M., P. Sequi, B. Lemmes and T. Papi (Eds.). Blackie, Glasgow, UK., pp: 23-29.

Shrestha, K., E.M. Adetut, P. Shrestha, K.B. Walsh, K.M. Harrower, A.S. Ball and D.J. Midmore, 2011. Comparison of microbially enhanced compost extracts produced from composted cattle rumen content material and from commercially available inocula. Bioresour. Technol., 102: 7994-8002.

Stanford, K., F.J. Larney, A.F. Olson, L.J. Yanke and R.H. McKenzie, 2000. Composting as a means of disposal of sheep mortalities. Compost Sci. Utilization, 8: 135-146.

Stentiford, E.T., 1996. Composting Control: Principles and Practice. In: The Science of Composting, Debertoldi, M., P. Sequi, B. Lemmes and T. Papi (Eds.). Chapman and Hall, London, pp: 49-59.

Stroot, P.G., K.D. McMahon, R.I. Mackie and L. Raskin, 2001. Anaerobic codigestion of municipal solid waste and biosolids under various mixing conditions: I. digester performance. Water Res., 35: 1804-1816.

Tritt, W.P. and F. Schuchardt, 1992. Materials flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany. A review. Bioresour. Technol., 41: 235-245.