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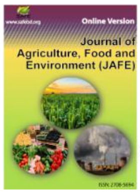

Original Article

Influence of bulking materials on the organic matter degradation during composting of cattle manure

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Cattle manure, bulking materials, composting and organic matter

A B S T R A C T

This study aimed to understand the degradation pattern of cattle manure with different types of bulking materials during composting. For this purpose, a composting experiment was conducted with three bulking materials e.g., T_1 (composting with dry chopped straw), T_2 (composting with dry tree leaves) and T_3 (composting with saw dust) with 3 replications. Parameters studied were dry matter (DM), organic matter (OM), ash, organic carbon (OC), total nitrogen (TN), crude fiber (CF), carbon nitrogen ratio (C/N) and pH at different days of intervals. Results showed that the bulking materials have a significant influence on the quality of the final compost. The highest DM content was observed in T_3 (48.17%) and the lowest DM content was observed in T_2 (38.36%) after 45 days of composting. There were significant ($p<0.01$) higher reduction rate of OM, OC and CF were found in T_3 compared to T_1 and T_2 and the differences were also significant ($p<0.01$) among days intervals over 45 days of experimental period. TN content gradually decreases with the increase of time. But there was no significant difference in TN alteration among the treatments along with time intervals. There were significant differences ($P<0.01$) in C/N among treatments and a gradual increment of C/N was found with the advancement of the composting operation. There was a little change in pH of all the treatments but those treatments were not followed a trend during the total experimental period. Finally, it may be concluded that CF and OM degradation rate is faster in T_3compared to T_1 and T_2. These might be indicated that saw dust might be used as an efficient bulking material that enhances OM degradation during composting of cattle manure.

Introduction

Livestock farming play an important role in the economy of Bangladesh (Baset *et al.*, 2003; Begum *et al.*, 2007; Rahman *et al.*, 1997, 1998 and 1999) that helps to establish livestock industries for the last two decades. Bangladesh is ranked fourth for livestock population in the world which is contributing for milk, meat and eggs for 160 million people in Bangladesh. The growing livestock industry over the last 20 years created serious waste disposal problems. The large quantities of manure produced during animal production are difficult to manage and expensive to dispose. It is also estimated that approximately 156 million tons of cattle manure are produced in Bangladesh every year (Modak *et al.*, 2019). These manures are a potential source of hazard to the environment due to the release of N and P to the streams, ponds and ground water; as well as ammonia, hydrogen sulphide gas in the air (Ashan *et al.*, 2014; Lee *et al.* 2009; Sarker *et al.*, 2018) due to inappropriate disposal of waste (Rahman *et al.*, 2008: Roy *et al.*, 2013; Sarker *et al.*, 2009). Livestock manures are also potential risk of health and environmental issues to those of human wastes and should be treated properly. The utilization of waste as an organic fertilizer can be convenient option of disposing the waste. Cattle manure is a valuable resource as a soil fertilizer, as it provides high contents of macro- and micro-nutrients for crop growth and is a low-cost alternative to mineral fertilizers (Ghos *et al.*, 2004). Composting is one of most convenient way of utilizing cattle manure that increases soil fertility and crop production. Aerobic microorganisms, along with bacteria, protozoa, yeast, mould, actinomycetes, rotifers are involved in composting process and decompose the organic substances into humus like substances that improve soil fertility. It also provides essential nutrients such as nitrogen, phosphorus, potassium, as well as enhances the microbial population necessary to release nutrients from the soil as well as the manure. Composting is a process of biological decomposition and stabilization of organic substrates, under controlled conditions that allow the development of thermophilic temperatures as a result of biologically produced heat, to produce a stable product, free of pathogens and plant seed and which can be beneficial for land application (Won *et al*., 2016; Rahman *et al*., 2013). In recent years, intensive livestock production has resulted in high density of animals in small areas, producing large quantities of solid waste with relatively insufficient nearby land for application (Ahsan *et al*., 2013). In that condition, composting might be an effective way of recycling manures.

During composting process, nitrogen is largely emitted as ammonia (NH_3) when organic matter is actively decomposed (Kuroda *et al*., 2004). The NH_3 emission occurred in quite high concentrations and large amount of nitrogen is lost during the treatment. For a successful composting, key factors such as temperature, aeration, moisture and nutrients should be appropriately controlled. The C/N ratio is one of the important factors affecting composting process and compost quality. It is considered C/N ratio at 25-30 as the initial optimum ratio for composting (Lee *et al.*, 2009). During composting process, organic materials are modified by decomposition through a wide variety of biological and biochemical processes. Commonly used bulking materials for good composting are saw dust, straw, crop residue and tree leaves (Alam *et al*., 2013). Saw dust is a carbon source has a very fine particle size providing a good carbon source (Won *et al*., 2016). However, it is very poor in providing air circulation. It is also quite absorbent, and when moisture fills the spaces, air has a hard time circulating. If using fine materials like saw dust, it will need to be turned frequently or air will need to be forced through the pile which is hard with dense material. Primary goals of composting have included the safe handling of organic wastes and enhancement of soil's fertility. In the present study, we compared composting operations using different bulking materials under similar conditions and elucidated the effects of bulking materials in cattle manure composting. Therefore, the present study was carried out with the following objectives:

i. To see the effect of organic matter degradability of cattle manure with different bulking materials.
ii. To identify better quality compost from cattle manure using different bulking materials.

Materials and methods

Experimental location and duration

The experiment was conducted in two phases: The first phase was the preparation of compost and the second phase was laboratory analysis of compost. Preparation of compost and related activities were carried out at the goat and sheep farm under the Department of Animal Science, Bangladesh Agricultural University, Mymensingh. The composting period was 45 days i.e. 28 January to 12 March 2019. The laboratory analysis of the compost was completed at the laboratory in the Department of Animal Science, Bangladesh Agricultural University, Mymensingh.

Design of experiment

Cattle manure was used as composting material in this experiment. To fulfill the objectives of this experiment, three treatments were conducted with different bulking materials, such as composting with dry chopped straw (T_1), composting with dry tree leaves (T_2), composting with saw dust (T_3). The samples from composted materials were collected at 0, 15, 30 and 45 days for proximate analysis. In each treatment there were three replications to minimize the experimental errors. A total of nine composting pits were prepared for conducting this experiment.

Collection of raw materials

Manure for this experiment was collected from cattle shed of the Department of Animal Science, Bangladesh Agricultural University, Mymensingh. Dry rice straw and dry leaves were collected chopped before mixing with manure for composting are collected from nearby the manure pit of the farm premises. Saw dust was collected from a nearby sawmill.

Preparation of compost pit and composting operation

Animal Science Field Laboratory has its own concrete-made compost pits. Nine pits were used for 3 different treatments of composting. The pits were well built with an altitude of 3 feet, length of 2 feet, and width of 1.5 feet providing with sufficient environment for composting. The composting shed was an open shed for the composting operation which was always locked to prevent entry of unauthorized persons or other unwanted beings. The entire experiment remained undisturbed during the experiments. About 55 kg of mixed cattle manure that contains 60% moisture was used to fill the aforementioned compost pit each. About 200 ml of *Trichoderma spp* suspension (spore density 3.5×10^8 CFU/ml) was mixed well during premixing with the bulking materials in all 9 compost mix, as it is a quick decomposer of waste biomasses. On the beginning of composting pit temperature was 22ºC. Turning or mixing of composting materials was performed after every 15 days to provide oxygen to the microbes.

Collection of sample for laboratory analysis

Samples were prepared from the mixed composting materials just after mixing on the 1^{st} day of experiment. There were three replications in each treatment of the composting. Then the collected samples were stored in refrigerator at 4º C temperature in Animal science laboratory for further analysis. Second collection was done after 15 days of first and the final sample collection was on the 45th day of composting process. After each collection each sample was analyzed to determine dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), Ash and pH of each replication of respective sample.

Determination of proximate components

The samples were weighed and dried in an oven at a temperature of 105 degree Celsius for 2 days until the constant weight is attained. Nitrogen content of all samples was determined by Kjeldhal digestion. A 5gm sample with concentrated H_2SO_4 and 1.5g mixed catalyst distilled into 2 percent boric acid solution and titrated with 0.1N HCl. The CF content of the supplied sample was calculated by subtracting the weight of ignited sample from the weight of acid and alkali treated oven dried sample. For pH determination, 2g of sample from each replication were taken followed by adding 50 ml of distilled water and mixed thoroughly by rigorous stirring. The extracts were filtered through filter paper and pH of the sample was determined using a laboratory pH-mV meter. After determination of DM, the samples were taken for determination of OM by deducting ash. One (1) g of sample was ignited in a muffle furnace at 550 ºC for 5 hours. After ignition the remaining weight of sample was ash. The weight of ash was deducted from the DM for estimation of OM. All analyses were done according to AOAC (1990).

Statistical analysis

The data were analyzed for in a Completely Randomized Design (CRD) in SAS software. Significant mean values were tested with Duncan's Multiple Range Test (DMRT). All data were presented as Means ± SEM.

Results and discussion

Dry matter (DM) changing pattern during composting

DM changing pattern of different composting up to 45 days period were shown in Table 1. It was found that the DM content increased with the increasing of time. Initial higher DM was found in T_1 the final highest DM content (48.17%) was observed in T_3 after 45 days of composting. Composting operations were done at aerobic condition and frequent turning operations were favorable for moisture loss might be cause of higher DM content. There was significant difference in different treatments ($p<0.05$), days intervals ($p<0.01$) and the interaction of treatments and days intervals ($p<0.05$. This same trend of result was observed by Adely and Kits (1983) who reported that DM content increased during composting period. The DM content composting materials is an important parameter of composting. Sherman (2005) stated that initially 65% moisture contents is suitable for aerobic microbial growth, but compost with too little moisture does not have enough available water for the microorganisms to effectively metabolize nutrients, a function essential for material decomposition. Conversely, materials too saturated with moisture could operate under anaerobic conditions due to the lack of oxygen entrance into the heap. In this composting operation, initial moisture was little higher; therefore, frequent turning was executed in the earlier composting to ensure O_2 inside the composting pit.

Table 1. Status of DM (%) during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	$25.65^b±0.65$	$27.88^a±0.26$	$22.15^c±0.45$	*	**	*
15	$32.51^b±0.33$	$31.29^c±0.45$	$33.86^a±0.42$			
30	$36.35^b±0.30$	$33.09^c±0.49$	$45.28^a±0.62$			
45	$38.59^b±0.44$	$38.36^b±0.45$	$48.17^a±0.52$			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, ** means significant at 1% level of probability, *means significant at 5% level of probability, DI=Days of intervals, Treat= Treatment, T*DI=Interaction of treatment and day intervals.

Organic matter (OM) changing pattern during composting

OM changing pattern of different composting up to 45 days period were shown in Table 2. The study found a gradually increase in OM content in all of the treatments of composting over 45 days. In case of cattle manure with rice straw (T_1), the lowest OM content was observed at 0 day of composting and highest at 45 days. Similarly, in case of cattle manure with dry tree leaves (T_2), the lowest OM content was observed at 0 day of composting and highest at 45 days and in case of cattle manure with saw dust (T_3), the lowest OM content was observed at 0 day of composting and highest at 45 days. There was significant difference in OM alteration among treatments ($p<0.05$), day intervals ($p<0.01$) and the interaction of treatments and days intervals ($p<0.05$) over 45 days of period. Compost stability refers to the resistance of compost organic matter to further rapid degradation and can be directly measured by respiration rates (Eggen and Vethe, 2001; Sullivan and Miller, 2001). Different types of volatile organic compounds and their intermediates were recovered from the composted materials. The major phytotoxic compounds include either phenolic compounds or short chain fatty acids (Young and Chou, 2003). The amount of these compounds varies with the composting method and feedstock.

Table 2. Status of OM (%) during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	$21.50^a±0.43$	$20.50^a±0.34$	$21.54^b±0.57$	*	**	*
15	$22.49^b±0.09$	$22.53^b±0.39$	$23.12^a±0.70$			
30	$25.32^b±0.27$	$23.58^c±0.33$	$26.26^a±0.39$			
45	$26.68^b±0.15$	$24.96^c±0.47$	$27.51^a±0.81$			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, ** means significant at 1% level of probability, *means significant at 5% level of probability, DI=Days of intervals, Treat= Treatment, T*DI=Interaction of treatment and day intervals.

Changing pattern of ash during composting

The changing pattern of ash at different treatments up to 45 days period was shown in Table 3. The study found a gradual increase in ash content in all of the treatments of composting over 45 days period of composting. The minimum ash content was observed in T_2 at 0 day, and the maximum ash was observed in T_3 at 45 days. There was significant difference in different treatments, the interaction of treatments and days intervals ($p<0.05$). Roy *et al.* (2013), Alam *et al.* (2013) and Jacob *et al.* (1997) also stated that the ash content increased due to increasing of composting time.

Table 3. Status of ash (%) during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	$2.26^b±0.08$	$2.25^b±0.32$	$3.07^a±0.10$	*	*	*
15	$2.37^b±0.42$	$2.89^b±0.19$	$3.41^a±0.61$			
30	$2.55^b±0.39$	$3.26^a±0.51$	$3.69^a±0.55$			
45	$2.85^c±0.20$	$3.96^b±0.26$	$4.64^a±0.34$			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, *means significant at 5% level of probability, DI=Days of intervals, Treat= Treatment, T*DI= Interaction of treatment and day intervals.

Changing pattern of organic carbon (OC) during composting

The changing pattern of OC at different treatments up to 45 days period was shown in Table 4. A decreasing pattern changing OC was found in all three treatments up to 45 days of composting period. The highest OC contents were found at the starting day in T_3 and the lowest OC was found in T_2 at 45th day of composting. There was significant difference in OC decomposition among treatments and day intervals ($p<0.01$) and the interaction of treatments and days intervals ($p<0.05$) over 45 days of composting period. The data revealed that total organic carbon gradually decreased with the advancement of composting period. Compost is an organic matter resource that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media, and it contains plant nutrients but is typically not characterized as a fertilizer. Composting is considered as a viable and environmentally sound method of waste management that hastens the decomposition of the organic waste under controlled conditions, thereby reducing its volume (Eneji *et al*., 2001). It is a microbial driven process, during which microorganisms utilize the decomposable organic waste both as a source of food and energy (Chefetz *et al*., 1998). Eneji *et al*. (2001) found an increase in humic acid and acid-extractable phosphorus along with a decline in the levels of carbon and nitrogen. Generally, the source of raw material influences the humification process during composting (Chefetz *et al*., 1998). This is not unexpected since composting is essentially a biochemical process in which C and N are mineralized and lost in gaseous forms as carbon dioxide, ammonia, N_2O and N_2. Eneji *et al*. (2003) also reported a decrease in total C by 18% after 195 days of co-composting animal wastes.

Table 4. Status of OC (%) during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	15.41^a±0.08	14.43^b±0.27	15.91^a±0.47	**	**	*
15	14.63^b±0.15	13.62^c±0.19	15.17^a±0.22			
30	13.00^b±0.05	13.02^b±0.22	13.36^a±0.41			
45	12.42^a±0.24	11.82^b±0.20	12.45^a±0.33			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, ** means significant at 1% level of probability, *means significant at 5% level of probability, DI=Days of intervals, Treat= Treatment, T*DI=Interaction of treatment and day intervals.

Changing pattern of total nitrogen (TN) during composting

The changing pattern of TN at different treatments up to 45 days period was shown in Table 5. There was a decreasing pattern of total N was observed at different treatments of composting throughout composting period. The highest N loss was occurred in T_1 during 45 days of composting. But the differences in TN content were statistically not significant among the treatments, day intervals and the interaction of treatments and days intervals over 45 days of composting period. The enhancement of total N in compost was probably due to mineralization of the organic matter containing proteins (Kaushik and Garg, 2003). Gaseous nitrogen losses during composting occur mainly as NH_3 but may also occur as nitrogen gas and NO_x (Lee *et al*., 2009). Hansen *et al*. (1989) reported that the total N loss was 33% of the initial N during the composting of sewage and straw mixtures and that it increased up to 50% of the initial N during the composting of poultry manure.

Table 5. Status of TN (%) during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	1.09±0.01	1.07±0.01	1.08±0.06	NS	NS	NS
15	1.07±0.04	1.06±0.03	1.06±0.02			
30	1.05±0.02	1.04±0.03	1.04±0.02			
45	1.01±0.01	1.02±0.03	1.03±0.03			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, NS means not significant, DI=Days of intervals, Treat= Treatment, T*DI=Interaction of treatment and day intervals.

Changing pattern of crude fiber (CF) during composting

The changing pattern of CF at different treatments up to 45 days period was shown in Table 6. A clear decreasing pattern of CF content in all treatments was found during 45 days of composting. The highest degradation of CF was occurred in T_3, followed by T_1 and T_2. There were significant differences in CF degradation among treatments and day intervals ($p<0.01$) and the interaction of treatments and days intervals ($p<0.05$) over 45 days of composting period. Faster CF degradation rate in T_3 might be indicated that saw dust provides a favorable condition for microbial activity. It might be indicated that microbial enzymes involve in CF digestion that reduced the CF content during aerobic composting process.

Table 6. Status of CF (%) during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	26.82^b±0.29	18.94^c±0.34	28.37^a±0.50	**	**	*
15	22.31^b±0.57	16.59^c±0.42	25.36^a±0.52			
30	21.28^a±0.66	15.07^b±0.47	22.36^a±0.47			
45	20.09^a±0.59	13.29^b±0.12	19.09^a±0.55			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, ** means significant at 1% level of probability, *means significant at 5% level of probability, DI=Days of intervals, Treat= Treatment, T*DI=Interaction of treatment and day intervals.

Changing pattern of C/N during composting

The changing pattern of C/N at different treatments up to 45 days period was shown in Table 7. There were also found a decreasing pattern in C/N at all treatments with the advancement of composting process in all treatments. There were significant differences in C/N among treatments and day intervals ($p<0.01$) and the interaction of treatments and days intervals ($p<0.05$) over 45 days of composting period. The similar trend was found by Kaushik and Garg (2003) reported that composting resulted in significant reduction in C/N ratio. The organic carbon, chemical oxygen demand and C/N ratio decreased significantly during maturation of the compost irrespective of treatments and method of composting (Jeevan *et al*., 2007). The end product of compost was resembled with humus and used as a means of soil amendment. Composting reduced the volume of the organic waste and destroyed the harmful pathogens as the process was controlled properly (Keener and Elwell, 2000). Wong and Chu (1985) noted that toxicity effects diminished as the time of composting increased, presumably because of lower organic acid concentrations in the material, indicated by reductions in the C/N ratio.

Table 7. Status of C/N during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	23.70^b±0.71	23.18^b±0.13	25.31^a±0.74	**	**	*
15	23.01^b±0.82	21.79^c±0.40	24.23^a±0.21			
30	20.36^a±0.45	19.93^b±0.25	20.69^a±0.25			
45	18.26^b±0.13	16.95^c±0.28	19.41^a±0.15			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, ** means significant at 1% level of probability, *means significant at 5% level of probability, DI=Days of intervals, Treat= Treatment, T*DI=Interaction of treatment and day intervals.

Changing pattern of pH during composting

The changing pattern of C/N at different treatments up to 45 days period was shown in Table 8. On the advancement of the composting period a little change in pH in all the treatments but those treatments were not follow a trend. At the end of the composting, the highest pH found at T_2 and lowest pH found in T_1. There was no significant difference in pH alteration among treatments and days interval. Slightly alkaline pH in the final compost is very effective for acidic soil that helps to neutralize the soil acidity. The pH values changed during composting, due to changes in the chemical composition. In general, the pH fell below neutral in the beginning due to the formation of organic acids and latter rose above neutral because the acids were consumed and ammonium was also produced (Beck-Friis *et al*., 2003). Hernando *et al*. (1989) reported that compost products had a near to neutral or slightly alkaline pH with a high buffering capacity.

Table 8. Status of pH during composting of cattle manure with different bulking materials.

DI	Treatments			Level of Significance		
	T_1	T_2	T_3	Treat	DI	T* DI
0	8.15±0.57	8.29±0.30	8.17±0.43	NS	NS	NS
15	7.79±0.32	8.41±0.45	8.19±0.55			
30	7.78±0.34	8.18±0.60	8.28±0.68			
45	8.18±0.13	8.28±0.53	8.23±0.59			

T_1 = Composting of cattle manure with rice straw, T_2 = Composting of cattle manure with dry tree leaves, T_3 = Composting of cattle manure with saw dust, same superscripts in different treatments groups did not differ significantly, NS means not significant, DI=Days of intervals, Treat= Treatment, T*DI=Interaction of treatment and day intervals.

Conclusions

Development and growth of aerobic microorganisms and their enzymatic action successfully decompose the biomasses. Bulking materials have a significant effect on microbial growth and propagation. The highest CF and OC decomposition was occurred in T_3 among all three treatments indicated that microbial growth and development was optimum in that case. Therefore, it might be concluded that saw dust is an effective bulking material for composting cattle manure.

References

AOAC, (1990). Official methods of analysis (15th Edition). Association of Official Analytical Chemists, Arlington, Virginia.

Ahsan A, M Kamaludin, MM Rahman, AHMF Anwar, MA Bek and S Idris (2014). Removal of various pollutants from leachate using a low cost technique: integration of electrolysis with activated carbon contactor. Water, Air, and Soil Pollution 225: 2163.

Ahsan A, N Ismail, MM Rahman, M Imteaz, ARahman, N Mohammad, MAM Salleh (2013). Municipal solid waste recycling in Malaysia: present scenario and future prospects. Fresenius Environmental Bulletin 22: 3654-3664.

Alam F, MA Hashem, MM Rahman, SME Rahman, MM Hossain and Z Rahman (2013). Effect of bulking materials on composting of layer litter. Journal of Environmental Science and Natural Resources 6: 141-144.

Baset MA, MM Rahman, MS Islam, A Ara and ASM Kabir (2003). Beef cattle production in Bangladesh- A review. Online Journal of Biological Sciences 3: 8-25.

Beck-Friis B, Smars S, Jonsson H, Eklind Y and Kirchmann H (2003). Composting of source-separated household organics at different oxygen levels: Gaining an understanding of the emission dynamics. Compost Science and Utilization 11:41-50.

Begum MAA, MM Hossain, M Khan, MM Rahman and SME Rahman (2007). Cattle fattening practices of selected farmers in Panchagarh district. Bangladesh Journal of Animal Science 36: 62-72.

Chefetz B, Adani F, Genevini P, Tambone F, Hadar Y, and Chen Y (1998). Humic-acid transformation during composting of municipal solid waste. Journal of Environmental Quality 27(4):794-800.

Eggen T and Vethe O (2001). Stability indices for different compost. Compost Science & Utilization 9 (2): 27-37.

Eneji AE, Yamamoto S, Honna T and Ishiguro A (2001). Physico-chemical changes in livestock feces during composting. Communications in Soil Science and Plant Analysis 32(3-4): 477-489.

Ghos PK, Ajoy, KK Bandyopadhyay, MC Manna, KG Mandal, AK Misra, KM Hati. 2004. Comparative effectiveness of cattle manure, poultry manure, phosphocompost and fertilizer-NPK on three cropping systems in vertisols of semi-arid tropics. II. Dry matter yield, nodulation, chlorophyll content and enzyme activity. Bioresource Technology 95: 85-93.

Hernando S, Lobo MC and Polo A (1989). Effect of the application of municipal refuse compost on the Physical and chemical properties of a soil. Science of the Total Environment 81: 589-596.

Jacob JP, RS Kunkle, RS Trevola, RD Miles and FB Mather (1997). Broiler Litter, Part 1: A feed ingredient for ruminants. University of Florida. Cooperative Extension Service. Institute of Food and Agricultural Science. The USA.

Jeevan Rao K, Rama Lakshmi CS and Sreenivasa Raju A (2007). Evaluation of manurial value in urban and agricultural waste composts. Journal of the Indian Society of Soil Science 56(3): 295-299

Kaushik P and Garg VK (2003). Vermicomposting of mixed solid textile mill sludge and cow dung with the epigeic earthworm *Eisenia foetida*. Bioresource Technology 90: 311-316.

Keener HM and Elwell DL (2000). Mortality composting principles and operation. In ohio‟s Livestock and poultry Mortality Composting Manual. Ohio: The Ohio State University Extension. USA.

Lee JE, MM Rahman, CS Ra (2009). Dose effects of Mg and PO_4 sources on the composting of swine manure. Journal of Hazardous Materials 169: 801-807.

Modak M, Chowdhury EH, Rahman MS and Sattar MN (2019). Waste management practices and profitability analysis of poultry farming in Mymensingh district: A socioeconomic study. Journal of Bangladesh Agricultural University 17(1): 50–57.

Rahman MA, MA Hashem, MM Rahman, SME Rahman, MM Hossain, MAK Azad and ME Haque (2013). Comparison of struvite compost with other fertilizers on maize fodder production. Journal of Natural Science and Environmental resources 6: 227-23.

Rahman SME, Islam MA, RahmanMM and DH Oh (2008). Effect of cattle slurry on growth, biomass yield and chemical composition of maize fodder.Asian Australasian Journal of Animal Sciences 21: 1592-1598.

Rahman MM, S Akhter, MS Rabbani and MM Hossain (1999). Indigenous knowledge on livestock practiced by the farmers in Mymensingh district of Bangladesh. Bangladesh Journal of Animal Science 28: 97-103.

Rahman MM, S Akther, MM Hossain (1998). The availability of the livestock feeds and feeding practices followed by the farmers of some areas of Mymensingh District. Bangladesh Journal of Animal Science 27 (1-2): 119-126.

Rahman MM, S Akther, MM Hossain (1997). Socio Economic Aspects of the farmers for livestock keeping in Mymensingh town adjacent areas. Progressive Agriculture 8: 153-157.

Roy BC, MRI Khan, MM Rahman, MAM Salleh, A Ahsan and MR Amin (2013). Development of a convenient method of rumen content composting. Journal of Animal and Veterinary Advances 12: 1439-1444.

Sarker LR, Khan MRI and Rahman MM (2018). Ensiling of Wet Rice Straw using Biogas Slurry and Molasses in Monsoon of Bangladesh. Journal of Animal Sciences and Livestock Production 2: 1-5.

Sarker BC, MA Alam, MM Rahman, AFMT Islam and MGF Choudhury (2009). Waste management of commercial poultry farms in Bangladesh. Journal of Innovation and Development Strategy 3: 34-37.

Sherman R (2005). Large-scale organic materials composting. North Carolina Cooperative Extension Service; USA.pp1-15. Website: https://composting.ces.ncsu.edu/large-scale-composting/

Sullivan DM and Miller RO (2001). Compost quality attributes, measurements and variability. In: Stoffella, P.J., Khan, B.A. (Eds.), Compost Utilization in Horticulture Cropping System. Lewis Publishers, New York, USA. pp. 97-120.

Won SG, JY Park, MM Rahman, CS Ra (2016). Co-composting of swine mortalities with swine manure and saw dust. Compost Science & Utilization 24 (1): 42-53.

Wong MH and Chu LM (1985). The responses of edible crops treated with extracts of refuse compost of different ages. Journal of Agricultural Wastes 14: 63-74.

Young CC and Chou CH (2003). Allelopathy, Plant Pathogen and Crop Productivity. In: Huang, H.C. and Acharya, S.N. (eds). Advances in Plant Disease. pp. 89-105.