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Improvement of compost quality by addition of some amendments

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Abstract

Composting is a biochemical process converting various components in organic wastes into relatively stable humus-like substances that can be used as a soil amendment or organic fertilizer. Even though composting is a proven-technology that can be applied on the spot, there are many aspects that should be improved in the performance of current composting facilities. One of these areas is the conservation and enhancement of the nutrients value of the product by reducing the loss of nitrogen. The aim of the present study was to investigate the effect of some amendments for improving compost quality produced from municipal wastes (MW). Treatments included different amounts of molasses, office paper, sulfuric acid and paper mill sludge added to 20 kg organic wastes at 2 and 4 weeks after composting start (first and second stages). Results showed that the least C/N ratio of compost was obtained by using 4% paper mill sludge (PMS). The use of 4% office paper at second stage increased this ratio to 46. The sulfuric acid is also suitable amendment for increasing the agronomic value of the produced compost quality. It is suggested to investigate the effect of these amendments on compost quality derived from manure and other organic wastes.

Keywords: Municipal Wastes Compost, Molasses, Office paper, Paper mill sludge

Introduction

Composting is a biochemical process which involves conversion of the various components of organic wastes into relatively stable humus-like substances that can be used as a soil amendment or organic fertilizer. Even though composting is a proven-technology that can be applied on the spot, there are many aspects that should be improved in the performance of current composting facilities. One of these areas is the conservation and enhancement of the nutrients value of the product by reducing the loss of nitrogen (Jeong and Kim, 2001). The decreased ammonia loss may lead to an alleviation of the odor problem that is usually encountered in full-scale composting facilities (Switzenbaum et al. 1994). Several factors such as C/N ratio, temperature, mixing and turning and aeration rate can influence the volatilization of ammonia during composting (Morisaki et al. 1989). Gaseous nitrogen losses during composting mainly occur as ammonia, but may also occur as nitrogen and NO_x (Eklind and Kirckman, 2000). Witter and Lopez-Real (1988) reported that total nitrogen loss could amount to 50% of the initial nitrogen in over 33% of the initial nitrogen during composting of poultry manure (Hansen et al. 1989). Ammonia (NH_3) is generated from decomposition of nitrogenous material, i.e. proteins and amino acids. Its emission frequently occurs during the thermophilic stage of aerobic decomposition and tends to be high with low C/N ratio. However, when different types of organic materials are composted, a higher C/N ratio does not necessarily indicate an effective solution for preventing N loss (Baca et al., 1992; Mahimairaja et al., 1994; Brink, 1995; Eklind and Kirchmann, 2000). Both chemical form and particle size of carbon (C) source affect the availability of C to microorganisms. Glucose, a readily available C source, appeared to cause immediate immobilization of N when an appreciable amount was added to soils (Liang et al., 2006). Subair (1995) found that glucose was effective in reducing NH3 volatilization from liquid hog manure, whereas material resistant to decom-position (sawdust) was not. Meyer and Sticher (1983) showed that N loss during composting of cattle manure and straw could be reduced by increasing the proportion of ground straw to chopped straw whilst maintaining a C/N ratio of 31.6. The juice extraction from the cane stalks and the subsequent sugar production from the cane juice provide molasses as a by-product. There is some sugar mills located in the sugar cane cultivation areas of Iran. On an annual basis, the sugar production process releases molasses by-products amounted 30000 tones, only in Haft Tappeh sugar factory. The utilization of molasses is important for the complete realization of the profit obtained by sugarcane cultivation. The market for molasses as a raw material for the domesticated meal, organic acid production and as soil amendment is fast catching up. Currently, an option for molasses utilization is as an amendment for production of organic wastes compost (Liang et al., 2006). Likewise, alkaline sludge is also a by-product of paper mill that is annually produced to the tune of thousands cubic meter in Iran. It can be an environment-

Table 1. Some properties of the used paper mill sludge

Property	Amount
pH	12.75
EC (dS/m)	65.0
$CaCO_3$ (%)	36.5
Ca (g/kg)	30.4
Mg (g/kg)	2.9

Table 2. The compounds of the used cane molasses

Molasses compounds	Kind	Percent
Sugar and non sugar compounds	sugar	27.30
	brix	84.60
	purity	32.27
	sucrose	33.11
	ash	11.82
Organic compounds	starch	0.10
	gum	1.47
	wax	0.20
	Total nitrogen	0.20
Non metallic compounds	Cl^-	1.96
	SO_4^{2-}	2.50
	P_2O_5	0.09
Metallic compounds	Na_2O	0.11
	K_2O	6.10
	CaO	1.22
	MgO	0.66
	SiO_2	0.36

al issue in addition to transportation costs, which is incurred in its disposal. However, there are ample scopes to utilize these organic wastes from industries for their use as compost amendments. The objective of present investigation was to evaluate the effectiveness of these by-products with other amendments including the office paper and the sulfuric acid in reducing N losses and improving the quality of municipal compost.

Materials and methods

The present investigation was carried out during the months of March-October, 2008. In this study, the effects of some amendments in the composting municipal wastes (MW) were investigated. MW and paper mill sludge (PMS) respectively, were collected from the compost factory of Rasht and Choka paper factory of Talesh, Guilan province; while molasses was prepared from Haft Tappeh sugar factory, Khouzestan province, Iran. The molasses and the office paper, the sulfuric acid and the paper mill sludge were respectively used as carbonic amend- ments, the acidic amendment and a lime factor having Ca and Mg ions. Some of the important characteristics of the PMS and molasses employed in this study are presented in Tables 1 and 2, respectively. The used molasses and the office paper had a C/N ratio of 72.3 and 560.3, respectively. The C/N ratio difference of both materials (cane molasses and paper) is related to their nitrogen content; because, they have a similar carbon but the office paper had less nitrogen than molasses. The molasses had an acidic pH (pH=5.5) with electrical conductivity was 25 dS/m. For providing MW, the material discharged from the rotary drum was passed through the trammel screen with the finer size fraction being collected through the screen and the coarser size fraction being collected on the screen. The finer fraction contains mainly biodegradable organic materials and was used for composting and the coarse fraction mainly contains non-biodegradable organic (e.g., plastics) and inorganic (e.g., metals, glass) materials was sent to a landfill. The fines account for 50–55% of the original weight of material and have a moisture content of 55–60%. Some properties of the used MW are shown in table 3. Each treatment combination consisted of 20 kg fresh organic wastes (decomposable MW) and 2%, 4% and 8% of other organic wastes as discussed later. Experiments were laid out in completely randomized design with three replications. Treatments included different amounts of the molasses and the office paper that were added to decomposable organic wastes in 2 and 4 weeks after composting started (first and second stages) as following:

- Control treatment (M_0): Municipal wastes without amendment,
- M_{2-1}, M_{4-1} and M_{8-1} treatments i.e. 2, 4 and 8% molasses-MW at the first stage, respectively.
- M_{2-2}, M_{4-2} and M_{8-2} treatments i.e. 2, 4 and 8% molasses-MW at the second stage, respectively.
- P_{2-1} and P_{4-1} treatments i.e. 2 and 4% office paper-MW at the first stage, respectively.
- P_{2-2} and P_{4-2} treatments i.e. 2 and 4% office paper-MW at the second stage, respectively.
- A_{20} , A_{40} treatments i.e. 20 ml and 40 ml sulfuric acid per 1 kg fresh organic wastes (MW), respectively.
- L_2 and L_4 treatments i.e. 2% and 4% PMS, respectively.

The sulfuric acid and PMS were added to MW at the beginning of the experiment. Molasses, with a composition of mainly sucrose, was chosen as the readily available C source to be added into composting mixture. Increasing dosage of molasses were dissolved in the same amount of water and added in treatments. The office paper, consisting mainly of cellulose, was chosen as a less readily available C source. Standard 216 mm × 280 mm sheets of paper were shredded to approximately 10 mm in width prior to mixing with municipal wastes. Treatments were turned upside down twice a week for aeration, while doing so water was also added to organic wastes for adjusting moisture content. After 50 days, a 100 g sample of every treatment was taken for further analyses. The samples were air dried and ground to pass through a 1 mm sieve. Total kjeldahl nitrogen (TKN) and the total organic carbon (TOC) of the samples were estimated by using a micro-kjeldahl method (Singh and Pradhan, 1981) and Walkey and Blacks Rapid titration method (1934), respectively. The pH and EC were determined on a water extract from compost using compost to water ratio of 1:6 by weight. The microbiological assays (microbial activity detection) were done for bacteria, actinomcetes and fungi plate counting method as described by Storm (1985). The actinomycetes and the fungi were isolated on the agar plates by dilution plating, while mesophilic and thermophilic microbial strains were obtained by plating samples taken from compost and cultivating the plates at 30 and 60°C, respectively (Xi et al., 2005). The data were analyzed by standard ANOVA procedures using MSTATC and SAS software and the significant differences was determined based on P<0.05 level for the least significant difference Test.

Results and discussion

The Table 4 indicates the temperature of the organic wastes during 7 weeks of composting process. In molasses treatments at the first stage, the temperature of organic wastes was maximum at the fourth week, which increased to more than $50°C$. Temperature in M_{8-2} treatment

Table 3. Concentration of the some elements and pH in the used municipal wastes

Parameter	Amount	Parameter	Amount
pH (1:6 dry O.M/water)	6.24	Cl (%)	0.51
N (%)	1.12	Na (%)	0.62
C (%)	16.27	S (%)	0.24
P (%)	0.29	Fe (%)	0.70
K (%)	0.24	Zn (ppm)	302
Ca (%)	1.86	Mn (ppm)	311
Mg (%)	0.22	Cu (ppm)	186

Table 4. Organic wastes temperature (°C) during the composting time in different treatments

Treatments	Time after composting start (week)						
	1	2	3	4	5	6	7
M_0	32	37	42	51	48	39	28
M_{2-1}	30	33	44	52	50	41	27
M_{4-1}	27	37	42	50	47	38	30
M_{8-1}	27	32	49	58	48	37	29
M_{2-2}	29	28	38	49	54	43	32
M_{4-2}	30	37	39	54	58	41	30
M_{8-2}	32	35	42	56	57	42	31
P_{2-1}	25	28	37	52	48	33	26
P_{4-1}	29	35	46	48	46	36	27
P_{2-2}	35	42	48	48	42	34	27
P_{4-2}	32	45	49	51	43	32	26
A_{20}	27	37	49	52	45	32	30
A_{40}	29	32	46	49	41	35	25
L_2	26	36	45	52	40	33	28
L_4	29	34	47	50	38	32	29

reached to maximum at the fifth week. The temperature maximum occurred in forth week for paper, PMS and the sulfuric acid treatments. The results show that the thermophilic stage occurred in the fourth week after composting for the most treatments, but this stage occurred at the fifth week for molasses-second stage treatments. Table 5 shows the total hetrotroph counts in different treatments during the composting (log cfu/g). It is observed that there was a conformity between total hetrotroph counts and the temperature, so that, there were many population of microorganisms in the higher temperature. Therefore, it seems that the maximum growth and activity of microorganism has continued until the fifth week. Similarly, the temperature peak was also attained during this week. The results of the Table 5 corroborate this finding. Use of molasses has promoted microorganisms activity, consequently they have decomposed the organic wastes to obtain carbon for production of microbial biomass, which contributed to the nitrogen immobilization by the microorganisms and a resultant reduced N loss. This is in agreement with the results of Liang et al. (2006).

The Table 6 shows the effect of molasses on the total nitrogen of final compost. At the first stage, the application of 2% and 4% of molasses resulted in increase in the total nitrogen content of the compost than in the control, but the increase owing to addition of 2% molasses was not significant. The greatest increasing total nitrogen is related to M_{8-2} treatment that the total nitrogen 2.82 times increased in comparison to the control. This can be due to the use of further molasses and decrease in pH of organic masses. Addition of organic amendments to compost might have led to production of acidic intermediate compounds due to their metabolism and hence reduction in pH value of the compost, which might have helped in prevention of NH_3 loss. Witter (1986) reported that composting process halted at 40°C and pH fell from 7.5 to 4.5, when adding 4% sucrose (dry weight) to an initial sewage sludge-straw mixture. In our experiment, 2% and 4% molasses at two stages did not significantly increase the pH; however, the use of 8% molasses in both stages led to decrease in pH in comparison to the control, remarkably. Using 8% molasses caused further increase in microbial activity, which led to the production of the higher acidic intermediate compounds. These acidic intermediate compounds caused the decrease in pH of the 8% molasses treatment. Not much variation was observed in ‘C’ content of the product compost; however, the differences in C:N ratio was significant, which could be attributed to differences in nitrogen content. The least C/N ratio was observed in treatments with 8% molasses, which was three times lower than the control. Molasses has increased treatments electrical conductivity compared with the control; however, it should be regarded that this increasing EC can be adjusted by the soil EC, when it is mixed in the soil, since value of EC was not significant to the control.

The Table 6 indicates that the application of 2% and 4% office paper at the first stage caused to increase the total nitrogen of compost that can be due to the increasing microbial biomass and preventing ammonia loss. The effect of 4% paper on nitrogen was more than 2% paper treatment. When 2% and 4% paper were compared with 2% and 4% molasses, it was observed that the office paper effect on total nitrogen was more than molasses. On the basis of their study on effect of carbon and buffer amendment on ammonia volatilization in composting, Liang et al. (2006) indicated that the effect of the office paper as an ammonia suppressant was less than the molasses. On the contrary in the present study, use of paper

Table 5. Total hetrotrophs counts in different treatments during the composting (log cfu/g)

Treatments	Time after composting start (week)						
	1	2	3	4	5	6	7
M_0	6.1	7.4	8.2	9.4	9.3	8.0	6.0
M_{2-1}	8.3	8.7	9.9	10.6	10.5	9.3	7.5
M_{4-1}	7.7	9.3	9.6	10.3	9.5	8.6	7.6
M_{8-1}	7.1	8.6	10.4	11.1	10.1	9.3	6.2
M_{2-2}	6.1	6.3	7.3	10.0	11.2	9.4	8.7
M_{4-2}	8.4	9.0	9.2	11.0	11.4	9.2	7.0
M_{8-2}	8.1	8.6	9.6	10.9	11.0	10.0	7.9
P_{2-1}	6.3	6.8	7.8	9.2	8.7	7.2	6.0
P_{4-1}	7.4	7.7	8.3	9.1	8.0	7.2	5.9
P_{2-2}	7.1	8.0	8.2	9.1	9.2	8.7	7.2
P_{4-2}	6.4	7.2	8.1	8.9	8.2	7.4	6.8
A_{20}	5.9	6.9	8.1	10.1	10.0	9.0	6.8
A_{40}	6.2	6.4	8.2	8.6	7.9	7.6	7.1
L_2	6.7	7.8	8.9	10.6	10.1	8.1	7.3
L_4	6.1	6.8	9.1	10.5	8.8	8.6	7.0

Table 6. Effect of the treatments on the C, C/N ration, pH and EC of produced compost

Treatment	Total nitrogen (%)	Carbon (%)	C/N	pH (1:6)	EC (1:6)
M_0	0.78 ijk	11.80 cd	15.56 cd	8.11 abcd	6.65 hi
M_{2-1}	1.00 hij	11.03 e	11.16 def	8.02 cde	7.56 abcde
M_{4-1}	1.10 gh	11.36 cde	10.40 defg	8.04 cde	7.93 abc
M_{8-1}	1.30 fg	11.26 de	8.80 efg	7.90 ef	8.06 a
M_{2-2}	1.02 ghi	11.26 de	11.00 def	8.02 cde	6.80 ghi
M_{4-2}	1.12 gh	11.20 de	9.96 efg	8.10 abcd	7.50 cdef
M_{8-2}	2.20 ab	12.03 c	5.46 g	7.76 f	8.03 ab
P_{2-1}	1.80 cd	11.50 cde	6.36 fg	8.10 abcd	7.01 fgh
P_{4-1}	2.00 bc	11.73 cd	5.86 fg	8.11 abcd	7.10 defgh
P_{2-2}	1.01 ghi	11.46 cde	11.30 def	8.10 abcd	7.20 defg
P_{4-2}	0.28 i	11.80 cd	41.3 a	8.11 abcd	7.06 efgh
A_{20}	1.89 c	11.20 d	5.96 g	7.46 f	7.60 ab
A_{40}	0.71 hi	11.80 cd	17.00 cd	6.95 g	8.06 a
L_2	1.75 cd	11.40 cd	6.51 a	8.16 ab	7.52 ab
L_4	2.25 a	11.30 cd	5.02 a	8.23 a	8.06 a

LSD (least significant difference) shows the significant difference ($\rho < 0.05$) among the means of treatments.

Values followed by the same letters in each column are not significantly different at the 0.05 level (least significant difference)

resulted in more suppression of ammonia loss and hence led to higher total nitrogen content in the product than the molasses at the first stage. In some studies, the application of cellulosic organic matter such as maize and rice straw affect on nitrogen loss (Nengwu, 2006). XiTao (2004) concluded that the addition of 1% rice straw in the chicken manure could reduce the loss by 2.52%. The total nitrogen content in the treatment, which received the 4% paper at the second stage decreased in comparison to the control. This can be due to the use of paper at the second stage. During this time, microbial activity might have increased to decompose organic wastes. As a result, to support the increasing microbial biomass, utilization of available carbon is inevitable by microbial population. Since paper is a cellulosic compound, microorganisms gradually deco-mpose it, consequently available carbon is utilized for sustaining increased microbial biomass. On the other hand, when paper was used at the second stage, it was still to be decomposed to prepare available carbon for supporting microbial population. Therefore, the large part of nitrogen is lost as ammonia. The molasses as a carbohydrate compound served as a readily available resource of carbon to prepare necessary carbon for microorganisms at both stages. According to the results of Table 6, significant variation in the carbon percent between paper treatments was not observed. The best paper treatments with the view of C/N ratio are related to 2% and 4% treatments at the first stage, although use of the 2% paper is also suitable at the second stage. The application of 4% paper at the second stage because of the increasing C/N ration than control amounted 2.64 times is not proposed. The use of 20 ml sulfuric acid per 1 kg fresh organic wastes (MW) increased total nitrogen than in the control that can be due to decrease in pH of organic mass. Ammonia volatilization can be stopped by decreasing mass pH. The experimental data (Freney et al., 1983; Nakasaki et al., 1993) indicated that severe losses of NH_3 occurred when high pH values were measured. Inorganic chemicals have been used to inhibit ammonia volatilization by increasing the acidity of compost mixtures (Carey et al., 1998; Kithome et al., 1999; Ekinci et al., 2000). Adding 40 ml sulfuric acid decreased the total nitrogen of MW compost. Taking into consider-ation table 6, heterotrophs counts in 20 ml sulfuric acid treatment is more than 40 ml sulfuric acid treatment that this can decreases microorganisms activity. Although, sulfuric acid decreased pH, but it seems the effect of sulfuric acid on microorganisms activity had a more importance in stopping ammonia. Carey et al. (1998) believed that the addition of sulfuric acid reduces ammonia volatilization, but the low pH may have negative influence on heating process. The effect of PMS on total nitrogen of compost is observed in table 6. The use of 2% PMS increased total nitrogen than control and most treatments, remarkably. Increasing total nitrogen by 4% PMS is more than other treatments excluding M_{8-2} treatment. For investigation of the paper mill sludge effects on total nitrogen, we must consider two topics: (1) Increasing pH of organic mass and (2) Ca and Mg ions of PMS. Based on the table 5, there was not a considerable change of compost pH in 50 days duration, but the pH measurements at 24 hr after adding paper sludge denoted to increase in pH (pH was 8.75 and 8.95 for 2% and 4% paper sludge, respectively). Increasing pH of compost increases ammonia volatilization (Jeong and Kim, 2001), but the ammonia volatilization is not very important at the primary stages because many organic compounds have still been decomposed. With increasing microorganisms activity, organic compounds (especially proteins) are gradually decomposed and ammonia is produced, but organic acids are simultaneously produced to reduce pH derived from adding PMS (correction of pH). Consequently, PMS effect on pH and ammonia volatilization decreases during time. Therefore, positive effect of PMS on total nitrogen of final compost can be due to its Ca and Mg ions. Calcium and Magnesium salts have also been added to precipitate ammonia with carbonate and to remove the alkalinity that could prevent a rise in pH (Witter and Kirchmann, 1989). Precipitation of struvite ($MgNH_4PO_4\ 6H_2O$) also is a common phenomenon in anaerobic treatment facilities (Ohlinger et al., 1999). Jeong and Kim (2001) investigated a new method for conservation of ammonia in aerobic composting. They demonstrated that struvite crystals could be formed in aerobic composting, when sufficient Mg and P were added. This crystallization process resulted in a substantial reduction of ammonia loss.

Conclusion

With regard to derived results, molasses as a readily carbon resource is a suitable ammonia suppressant for municipal wastes compost production to increase the total nitrogen of the final compost. The influence of the office paper on total nitrogen and C/N ration of compost is more than molasses, but the use of office paper at the second stage is not proposed, because it is a cellulosic compound and its carbon is not easily available for microorganisms growth in thermophilic stage. Application 8% molasses and 4% office paper respectively at the first and second stages caused to decrease C/N ratio below 6 while the use of 4% office paper at the second stage increase it into 46. The sulfuric acid and paper mill sludge are also suitable amendments for increasing the agronomic value of the produced compost quality. But it should be regarded using sulfuric acid is suitable at fewer amount (20 ml/kg fresh organic wastes; decomposable municipal wastes). The paper mill sludge had a more effect on total nitrogen of the produced compost than the sulfuric acid

References

Baca MT, Fornasier F, De Nobili M (1992) Mineralization and humification pathways in two composting process applied to cotton wastes. J Ferment Bioeng. 74 (3): 179–184.

Brink N (1995) Composting of food waste with straw and other carbon sources for nitrogen catching. Acta Agric Scandinavica-Section B Soil Plant Sci. 45: 118–123.

Carey DS, Keener HM, Elwell DL (1998) The effect of ammonium sulfate addition to partially to composted poultry manure. ASAE paper. No. 98-4099. St. Joseph, MI. 20p.

Ekinci K, Keener HM, Elwell DL (2000) Composting short paper fiber with broiler litter and additives: I. Effect of initial pH and carbon/nitrogen ratio on ammonia emission. Composting Science Utilization. 8: 160-172.

Eklind Y, Kirchmann H (2000) Composting and storage of organic household waste with different litter amendments. II. Nitrogen turnover and losses. Bioresour Technol. 74 (2): 125-133.

Freney JR, Simpson JR, Denmead OT (1983) Volatilization of ammonia. In: Freney, J. R., J. R. Simpson (Eds.), Gaseous Loss of Nitrogen from Plant-Soil Systems. Martinus Nijhoff/Dr. W. Junk Publishers, Hingham, MA, pp. 1-32.

Hansen RC, Keener HM, Hoitink HAJ (1989) Poultry manure composting: Design guidelines for ammonia. ASAE paper, No. 89-4075. ASAE, St. Joseph, MI. 10p.

Jeong YK, Kim JS (2001) A new method for conservation of nitrogen in aerobic composting processes. Bioresour. Technol., 79: 129-133.

Kithom M, Paul JW, Bomke AA (1999) Reducing nitrogen losses during simulated composting of poultry manure using absorbents or chemical amendments. J Environ Qual. 28: 194-201.

Liang Y, Leonard JJ, Feddes JJR, McGill WB (2006) Influence of carbon and buffer amendment on ammonia volatilization in composting. Bioresour Technol. 97: 748-761.

Mahimairaja S, Bolan NS, Hedley MJ, Macgregor AN (1994) Losses and transformation of nitrogen during composting of poultry manure with different amendments: an incubation experiment. Bioresour Technol. 47 (3): 265–273.

Meyer M, Sticher H (1983) The significance of straw content for the retention of nitrogen during the composting of cattle manure. Z Pflanzenernaehr Bodenk. 146: 199–206.

Morisaki N, Phae CG, Nakasaki K, Shoda M, Kubota H (1989) Nitrogen transformation during thermophilic composting. J Ferment Bioeng. 67: 57-61.

Nakasaki K, Yaguchi H, Sasaki Y, Kubota H (1993) Effects of pH control on composting of garbage. Waste Manag Res. 11: 117-125.

Nengwu Z (2006) Composting of high moisture content swine manure with corncob in a pilot-scale aerated static bin system. Bioresource Technology. 97(15): 1870-1875.

Ohliger KN, Young TM, Schroeder ED (1999) Kinetics effects on preferential struvite accumulation in wastewater. J Environ Eng. ASCE, 125 (8): 730-737.

Singh R, Pradhan K (1981) Determination of nitrogen and protein by Kjeldahl method. In: Forage Evaluation Science. Pvt. Publishers Ltd., New Delhi, p. 23.

Storm PF (1985) Effect of temperature on bacterial species diversity in thermophilic solid-waste composting. Appl Environ Microbiol. 50 (4): 899-905.

Subair S (1995) Reducing ammonia volatilization from liquid hog manure by using organic amendment. M.Sc. Thesis, McGill University, Montreal, Canada.

Switzenbaum MS, Holden C, Soares H, Kuter GA (1994) Effect of amendments on nitrogen conservation in

wastewater biosolid composting. Compost Sci Utilization. 2 (2): 35-42.
Walkey JA, Black JA (1934) Estimation of organic carbon by the chromic acid titration method. Soil Sci. 37: 29-31.
Witter E, Kirchmann H (1989) Effects of addition of calcium and magnesium salts on ammonia volatilization during manure composting. Plant and Soil. 115: 53-58.
XiTao C, WeiYi H, ZhiZhou C, HongYing H (2004) Mechanism of nitrogen loss and reduction in nitrogen loss during the compost of chicken manure. Jiangsu J Agr Sci. 20 (2): 106-110.