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Nitrogen transformations during pig manure composting

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Abstract: Composting is now suggested as one of the environmentally and friendly alternative method for disposal of solid organic wastes, as it leads to minimization, stabilization, and utilization of organic waste. Transformations of nitrogen were investigated in co-composting of pig manure with different amendments, such as sawdust and leaves. Samples were analyzed for pH, total-N, soluble NH_4-N, soluble NO_3-N and soluble organic-N. The total-N increased after 63 days of composting, as well as the soluble NO_3-N and soluble organic-N. Soluble NH_4-N increased significantly and showed peak values at day 7, thereafter decreased sharply and gradually to lower levels. Seed germination index (GI) showed that co-composting of pig manure with sawdust reached maturity after 49 days of composting, while co-composting of pig manure with sawdust and leaves required shorter time for 35 days. Soluble NH_4-N was significantly negatively ($P < 0.05$), while soluble NO_3-N and soluble organic-N were significantly positively ($P < 0.05$), correlated with seed germination index (GI). Addition of leaves in co-composting of pig manure with sawdust had no significant impacts on nitrogen transformations, but it was beneficial for maturity of pig manure compost.

Keywords: pig manure; composting; nitrogen; transformation; maturity

Introduction

In recent years, intensive animal production has resulted in high density of animals in small areas, producing large quantities of waste with insufficient nearby land for application. In Hong Kong, the pig industry has seen a steady growth in recent years. It resulted in indiscriminate disposal of animal waste, particularly pig manure (22000 tones annually). This has led to environmental concerns including odor pollution and methane emissions (Tamminga, 1992; 1995; Lopez-Real, 1996). Serious environmental contamination called for environmental and economic feasible technologies for animal waste treatment. Composting is now suggested as one of the environmentally and friendly alternative methods for disposal of solid organic wastes, as it leads to minimization, stabilization, and utilization of organic waste. Most studies show that mature compost application to agronomic soils can increase crop, improve physical properties of the soil, and therefore, can be served as a soil conditioner (McConnell, 1993; Wong, 1996). However, immature compost, when applied to soils, maintains high decomposition activity, which may retard plant growth due to nitrogen starvation, anaerobic conditions and phytotoxicity of NH_3 and some organic acids (Mathur, 1993). Therefore, compost maturity and stability are key factors during composting.

Nitrogen is believed to be one of the most important factors affecting compost quality. Composting of N-rich wastes, such as source-seperated organic household wastes can be associated with substantial gaseous N losses, amounting up to 50% – 60% (Kirchmann, 1994; Brink, 1995). Also during composting of manure, gaseous N losses were reported to be high, up to 77% (Martins, 1992) and during composting of sewage sludge up to 68% (Witter, 1988). Emissions of nitrogenous gases mean loss of an essential plant nutrient but may also lead to environmental pollution. Factors affecting ammonia formation and losses during composting are pH, temperature, aeration level, ammonia and ammonium adsorbing capacity of added materials (Witter, 1989), and presence of available energy, that may lead to immobilization of N (Kirchmann, 1985; 1989). Bhamidimarri and Panday (Bhamidimarri, 1996) described that sawdust has a high ammonia retention capacity in pig manure compost. In this study, the impacts on soluble nitrogen transformations with additional leaves or not in co-composting of pig manure with sawdust have been investigated.

The aims of this study were to investigate the changes and transformations of soluble nitrogen during co-composting of pig manure with sawdust, as well as to evaluate the impacts on the losses of nitrogen and the maturity of compost with additional leaves.

1 Materials and methods

1.1 Composting pile establishment

Pig manure and sawdust were collected from a pig farm and a sawmill located in Taipo, Hong Kong, respectively. A smashing machine was used to break the twigs into smaller size fractions. In order to achieve a C/N ratio of 30, pile A was prepared with pig manure and sawdust at a ratio of 3:2 (w/w, fresh weight), while pile B was mixed with pig manure and sawdust and leaves at a ratio of 3:1:1 (w/w, fresh weight), respectively. The purpose of using sawdust and leaves was to adjust the C/N ratio because of its relatively high C content. Twigs were added to the piles at 10% (v/v) as bulking agent for aeration. Windrow composting piles of approximately 8 m^3 each, were composted for 63 days. The heaps were turned and mixed using a front-end loader at a turning frequency of every 3 days. The moisture content was adjusted to about 60% – 70% at the beginning of composting. At a depth of 60 cm within the composting piles, the temperature was taken daily. Triplicate samples were collected from each pile at day 0, 3, 7, 14, 21, 35, 49 and 63, and stored at 4℃ immediately prior to analysis. Sub-samples were air-dried, ground to pass through a 0.25 mm sieve and stored in a desiccator for analyses. The

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selected physicochemical properties of the experimental materials are shown in Table 1.

Table 1 Selected physicochemical parameters of raw materials

Parameter	Pig manure	Sawdust	Leaves
pH	8.12	5.55	6.68
EC, dSm^{-1}	2.90	0.02	0.83
Moisture content, %	68.3	8.12	61.5
T-C, %	36.6	46.5	23.2
T-N, %	3.24	0.07	1.15
C/N ratio	11.3	664	20.2

1.2 Physicochemical properties of compost

The aqueous compost extracts were obtained by mechanically shaking the fresh samples with double distilled water (DDW) at a solid: DDW ratio of 1:10 (w/v, dry weight basis) for 1h. The suspensions were centrifuged at 12000 r/min and filtered through 0.45 μm membrane filters. The filtrates were used for the following analyses. pH was determined using an Orion 920 ISE pH meter; electrical conductivity (EC) by an Orion 160 conductivity meter; NH_4-N by the Indophenol Blue method; NO_3-N by the copperised cadmium reduction method (Page, 1982). Total organic carbon was determined with air-dried samples by the $K_2Cr_2O_7$ colourimetric method, total N by a Kjeldahl digestion method. Soluble organic-N content was determined by a Kjeldahl digestion method on the soluble extract followed by NH_4-N determination by methods described before (Page, 1982).

1.3 Cress seed germination index test

Seed germination and root length test were carried out on water extracts by mechanically shaking the fresh samples for an hour at a solid: DDW ratio of 1:10 (w/v, dry weight basis). 5.0 ml of each extract was pipetted into a sterilized plastic petri dish lined with a Whatman # 5 filter paper. Ten cress seeds (*Lepidium sativum*, L.) were evenly distributed on the filter paper and incubated at 25℃ in dark for 48h. Triplicates were analyzed for each pile sample. Treatments were evaluated by counting the number of germinated seeds, and measuring the length of the root radical. The responses were calculated by a germination index that was determined according to the following formula (Zucconi, 1981).

$$\text{Germination index}(\%) = \frac{\text{Seed germination index}(\%) \times \text{root length of treatment} \times 100\%}{\text{Seed germination}(\%) \times \text{root length of control}}.$$

2 Results and discussion

2.1 Changes in temperature and pH

As shown in Fig. 1a, temperatures of two piles reached 50℃ and entered the thermophilic phase after 3 days of composting, which indicated active microbial decomposition in the composting piles. The microorganisms consumed the soluble organic matter and ambient nutrients, which then underwent aerobic degradation to generate heat, biomass and carbon dioxide. The thermophilic phase (>50℃) of pile A lasted for 40 days, while pile B lasted for 38 days. The temperature of pile A decreased sharply to 37℃ at day 45, while pile B declined sharply to 38℃ at day 43 after the thermophilic phase and entered a cooling phase. Many reports described that the optimum temperature range for effective decomposition was 50 to 60℃, while others suggested that maximum decomposition of municipal solid waste occurred at temperature between 65 to 70℃ (Bach, 1984; Epstein, 1997). The maximum temperature in this study ranged from 65 to 69℃. Short-term of temperature fluctuation was caused by temperature decline in connection with turning aeration.

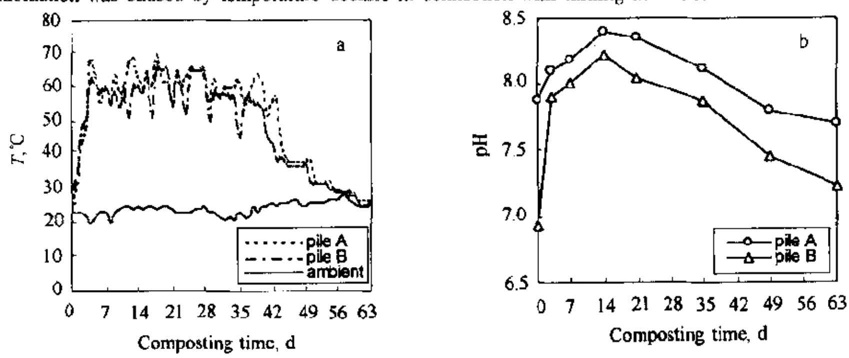

Fig.1 Changes in temperature (a) and pH (b) during composting of pig manure

The changes in pH of two piles followed the same trend with a sharp increase at the beginning but a significant decrease at the end of composting (Fig. 1b). pH of pile A increased sharply from 7.89 at day 0 to a peak value of 8.40 at day 14 as temperature increasing, while pile B increased from 6.94 to 8.22, which may be explained by the presence of NH_3 formed during ammonification and mineralization of organic N through microbial activities (Bishop, 1983). After 35 days of composting, a gradual decrease in pH was observed for two piles. The pH values at the end of composting for pile A and pile B were 7.69 and 7.24, respectively. A decrease in pH consequently coincided with nitrate formation, and probably caused by the volatilization of NH_3 and the H^+-release from the nitrification process later in the composting period by nitrifying bacteria (Eklind, 2000). And also by the decomposition of organic matter and production of organic and inorganic acids by the activities of microorganisms in compost (Mathur, 1991).

2.2 Changes in total-N

Total-N of the two piles increased slightly after 63 days of composting (Fig. 2). Total-N contents of pile A was 1.57% at the beginning of the composting process, which then increased to 2.00% at the end of composting. As well as pile B, increased from initial 1.78% to final 2.11%. The contents of total-N increased after composting for 63 days, which may be due to the net loss of dry mass by volatilization of carbon dioxide during the mineralization of organic matter (Inoko, 1979; Viel, 1987; Fang, 1999). Nitrogen-fixing bacteria may also have contributed to the increase of total-N in the later stage of composting (Bishop, 1983). Pile B with leaves showed higher total-N content as compared to pile A without leaves throughout the composting due to high content of N in leaves.

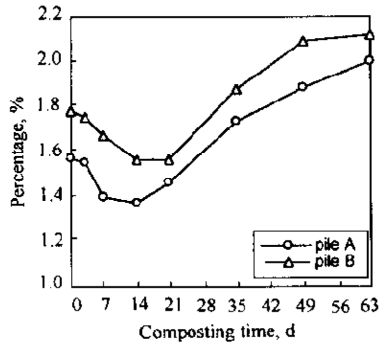

Fig.2 Changes in total-N (as percentage of dry matter) during composting of pig manure

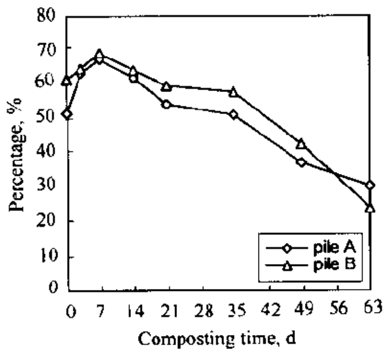

Fig.3 Changes in soluble NH_4-N (as percentage of soluble-N) during composting of pig manure

2.3 Changes in soluble NH_4-N

As shown in Fig. 3, at the first 7 days of composting, soluble NH_4-N (as percentage of soluble-N) of pile A and pile B were increased significantly from initial 52% and 61% to peak values of 67% and 69%, respectively. It may be due to active ammonification with an increase in temperature and pH at the beginning of composting, as well as the mineralization of organic-N compound (Mahimairaja, 1994). Thereafter, soluble NH_4-N decreased gradually to 30% and 24% at the end of composting by volatilization loss and immobilization by microorganisms.

2.4 Changes in soluble NO_3-N

Soluble NO_3-N was almost absent at the beginning of composting and started to increase after the thermophilic phase (Fig. 4). Soluble NO_3-N(as percentage of soluble-N) of two piles remained at low levels closed to 0% in the first 21 days of composting. Thereafter, the percentages increased sharply to 3% of two piles at day 63. Soluble NO_3-N of two piles remained at a low level before a rise at day 21 due to nitrification. It may be explained that little nitrification occurred under thermophilic condition, since high temperature and excessive amount of ammonia inhibited the activity and growth of nitrifying bacteria (Morisaki, 1989; Stevenson; 1986). There was no great difference of soluble NO_3-N between pile A and pile B.

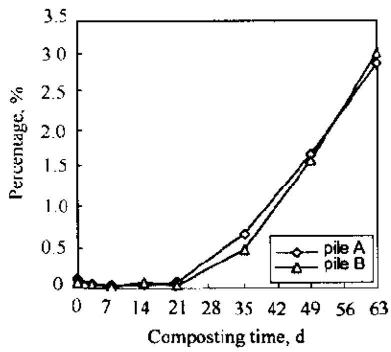

Fig.4 Changes in soluble NO_3-N (as percentage of soluble-N) during composting of pig manure

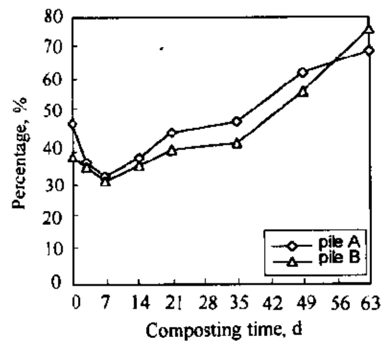

Fig.5 Changes in soluble organic-N (as percentage of soluble-N) during composting of pig manure

2.5 Changes of soluble organic-N

Soluble organic-N (as percentage of soluble-N) decreased in the first 7 days, and thereafter increased gradually in the later stage of composting (Fig. 5). Pile A and pile B decreased from 48% and 38% at day 0 to 33% and 31% at day 7, respectively. It may be due to the mineralization of soluble organic-N compound (Mahimairaja, 1994), for satisfying the consumption of activities and growth of microorganisms at the beginning of composting. And then increased gradually to 70% and 76% at the end of composting, which may be due to the formation of organic-N in the later period of composting.

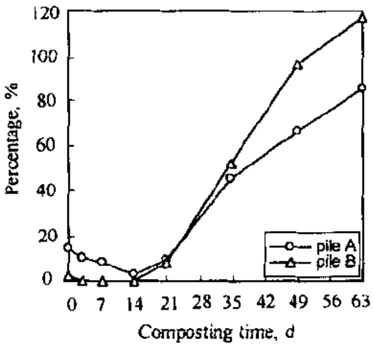

Fig.6 Changes in GI values during composting of pig manure

2.6 Cress seed germination index

The germination index (GI), which combines the measure of relative seed germination and relative root elongation of cress seed (*Lepidium Sativum*, L.), is the most sensitive parameter used to evaluate the toxicity and degree of maturity of compost(Zucconi, 1981). As shown in Fig. 6, the GI values of pile A decreased from an initial level of 14% to the lowest values of 3% at day 14, while GI value of pile B from 2% to 0%. This may be attributed to the release of high concentrations of NH_3 and low molecular weight organic acids (Wong, 1985; Fang, 1999). As the composting process proceeded, the GI values of pile A increased significantly and reached 85% at the end of the composting time, with pile B reached 117%. A germination index of 50% has been used as an indicator of phytotoxin-free compost (Zucconi, 1981). Pile A without leaves was stabilized enough after 49 days of composting, while pile B with leaves required 35 days, according to the GI criterion. Pile B required a shorter time to reach stabilization than pile A, indicated that pig manure amended with leaves was beneficial for maturity.

As shown in Table 2, soluble NH_4-N was significantly negatively ($P < 0.05$), while soluble NO_3-N and soluble organic-N were significantly positively ($P < 0.05$), correlated with cress seed germination index(GI). It could be suggested as good chemical indicators of compost maturity.

3 Conclusion

Table 2 Correlation coefficients between nitrogen and GI values during composting

	Soluble NH_4-N	Soluble NO_3-N	Soluble organic-N
Pile A	-0.9266**	0.9673**	0.9266**
Pile B	-0.9417**	0.9499**	0.9417**

** $P < 0.05$.

The total-N increased after 63 days of composting, as well as the soluble NO_3-N and soluble organic-N. Soluble NH_4-N increased significantly and showed peak values at day 7, and thereafter decreased sharply and gradually to lower levels in two piles. Seed germination index (GI) showed that co-composting of pig manure with sawdust reached stabilization after 49 days of composting, while co-composting of pig manure with sawdust and leaves required shorter time of 35 days. Soluble NH_4-N was significantly negatively ($P < 0.05$), while soluble NO_3-N and soluble organic-N were significantly positively ($P < 0.05$), correlated with seed germination index (GI). Summarily, addition of leaves in co-composting of pig manure with sawdust had no significant impacts on nitrogen transformations, but it was beneficial for maturity of pig manure compost.

References:

Bach P D, Shoda M, Kubota H, 1984. Rate of composting of dewatered sewage sludge in continuously mixed isothermal reactor[J]. Journal of Fermentation Technology, 62: 285—292.

Bhamidimarri S M R, Pandey S P, 1996. Aerobic thermophilic composting of piggery solid wastes[J]. Water Science and Technology, 33: 89-94.

Bishop P L, Codfrey C, 1983. Nitrogen transformations during sludge composting[J]. Biocycle[J], 24: 34—39.

Brink N, 1995. Composting of food waste with straw and other carbon sources for nitrogen catching[J]. Acta Agriculture Sandinaveca, Section B: Soil and Plant Science, 45: 118—123.

Eklind Y, Kirchmann H, 2000. Composting and storage of organic household waste with different litter amendments [J]. Bioresource Technology, 74: 125—133.

Epstein E, 1997. The Science of Composting[M]. A Technomic Publishing Company.

Fang M, Wong J W C, Ma K K *et al*., 1999. Co-composting of sewage and coal fly ash: nutrient transformations [J]. Bioresource Technology, 67: 19—24.

Fang M, Wong J W C, 1999. Effects of lime amendment on availability of heavy metals and maturation in sewage sludge composting[J]. Environmental Pollution, 106: 83—89.

Inoko A, Miyamatsu K, Sugahara K *et al*., 1979. On some organic constituents of city refuse composts produced in Japan[J]. Soil Sci Plant Nutr, 25: 225—234.

Kirchmann H, 1985. Losses, plant uptake and utilization of manure nitrogen during a production cycle[J]. Acta Agriculture Scandinavia Supplementum, 24.

Kirchmann H, Witter E, 1989. Ammonia volatilization during aerobic and anaerobic manure decompostion[J]. Plant and Soil, 115: 35—41.

Kirchmann H, Widen P, 1994. Separated collected organic household wastes, chemical compostion and composting characteristics[J]. Swedish Journal of Agricultural Research, 3: 3—12.

Lopez-Real J, Baptista M, 1996. A preliminary comparative study of three manure composting systems and their influence on process parameters and methane emissions[J]. Compost Science and Utilization, 4(3): 71—82.

Mahimairaja S, Bolan N S, Hedley M J *et al*., 1994. Losses and transformation of nitrogen during composting of poultry manure with different amendments: an incubation experiment[J]. Bioresource Technology, 47: 265—273.

Martins O, Dewes T, 1992. Loss of nitrogenous compounds during composting of animal wastes[J]. Bioresources Technology, 42:103—111.

Mathur S P, 1991. Composting processes[M]. Bioconversion of waste materials to industrial products(Martin, A. M. ed.). New York:

Elsevier. 147—186.
McConnell D D, Shiralipour A, Smith W H, 1993. Compost application improves soil properties[J]. BioCycle, 34:61—63.
Morisaki N, Phae C G, Nakasaki K, Shoda M, 1989. Nitrogen transformation during thermophilic composting[J]. Journal of Fermentation and Bioengineering, 67: 57—61.
Morse D, 1995. Environmental considerations of livestock producers[J]. J Anim Sci, 73: 2733—2740.
Page A L, Miller R H, Keeney D R, 1982. Method of soil analysis, Part 2——Chemical and microbiological properties(2nd ed). Agronomy [M]. No. 9. Madison, Wisconsin, USA : ASA, SSSA.
Stevenson F J, 1986. Cycles of soil[M]. New York: Wiley.
Tamminga S, 1992. Nutritional management of dairy cows as a contribution to pollution control[J]. Journal of Dairy Science, 75: 345—357.
Viel M, Sayag D, Andre L, 1987. Compost: production, quality and use(de Bertoldi, M. *et al*. ed.)[M]. Elsevier Applied Science. 230—237.
Witter E, Kirchmann H, 1989. Peat, zeolite and basalt as adsorbents of ammoniacal nitrogen during manure decomposition[J]. Plant and Soil, 115: 43—52.
Witter E, Lopez-Real J, 1988. Nitrogen losses during the composting of sewage sludge and the effectiveness of clay soil zeolite, and compost in adsorbing the volatilized ammonia [J]. Biology Wastes, 23: 279—294.
Wong M H, 1985. Phytotoxicity of refuse compost during the process of maturation[J]. Environmental Pollution (Series A), 40: 127—144.
Wong J W C, Li G X, Wong M H, 1996. The growth of *Brassica chinensis* in heavy metal-contaminated sewage sludge compost from Hong Kong[J]. Bioresource Technology, 58:309—313.
Zucconi F, Forte M, Monac A *et al*., 1981. Biological evaluation of compost maturity[J]. Biocycle, 22: 27—29.

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