



CHANGES IN PHYSICO-CHEMICAL PARAMETERS DURING FORCED-AERATION STATIC-PILE CO-COMPOSTING OF CATTLE MANURE WITH CALCIUM CYANAMIDE

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Abstract. The goal of this research was to determine the effect of CaCN₂ addition into manure mixed with sawdust on the composting process under forced-aeration static condition, especially on nitrogen (N). The changes in the physical and chemical parameters over the entire composting period were evaluated. The profile of temperature, pH, and NO₃⁻-N was improved in the piles mixed with 2%, 3% and 4% CaCN₂ (the test piles). The NH₄⁺-N met the limit value accepted for mature compost. Finally, the additive contents of not less than 2% but not more than 3% in CaCN₂ were recommended for this system based upon a comprehensive evaluation of the measured parameters.

Keywords: nitrogen, composting, manure, waste management technologies.

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Introduction

Composting is a low-cost, effective and natural way of recycling organic materials, and it is included in sustainable agriculture and recommended for organic agriculture (Peigné, Girardin 2004). Composting has been shown to have some advantages, including pathogen suppression, weed seed killing and improvement of pesticide degradation (Dorahy *et al.* 2009; Karanasios *et al.* 2010), and its end products (composts) have been used as soil amendments due to their high concentration in organic matter (Ohsowski *et al.* 2012). Moreover, compost application in soil has been reported to reduce losses of N (Kelln *et al.* 2012). Despite these benefits, composting also can have several disadvantages. Several studies demonstrated that nutrients would be lost during composting (Venglovsky *et al.* 2011; Webber *et al.* 2009) and possible odors associated with composting would be generated (Li *et al.* 2008; Hanajima *et al.* 2010). Additionally, nutrient losses are an agronomic problem for

organic farmers because they attempt to compensate for N scarce organic farms by their compost (Peigné, Girardin 2004). One of the nutrient losses during composting is N which is mainly lost as ammonia (NH₃) but may also as N₂, N₂O and NO_x (Bueno *et al.* 2009; Velasco-Velasco *et al.* 2011). Fukumoto and Inubushi (2009) noted that most of the N losses resulted from NH₃ emission which was 9.5% of the initial total N (T-N) during active composting of swine manure, when total N₂O emissions were 9.3% of T-N, and total N losses were 27.8% of the initial T-N which was markedly greater than the sum total of NH₃ and N₂O. The N losses during composting can be influenced by several factors including temperature, pH, C/N ratio, and turning (Parkinson *et al.* 2004; Bueno *et al.* 2009).

Calcium cyanamide (CaCN₂) is an environmentally friendly N fertilizer with pesticide effects (Shi *et al.* 2009). And our previous studies showed that manure composting would quickly reach the sanitary standard and the quality of the composting products would be improved with the

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addition of CaCN_2 (Simujide *et al.* 2012ab). Overall, these studies indicated the possibility of use of CaCN_2 as an amendment during manure composting to improve composting efficiency. However, N fate during composting of this kind of compostable mixtures had not been evaluated. Therefore, the aim of this study was to evaluate the effect of CaCN_2 addition on the changes in the physico-chemical parameters during manure composting, paying special attention to the evolution of N, which will provide further information about the feasibility of selection of CaCN_2 for composting.

1. Materials and methods

1.1. Experimental design

The experiment was carried out for 63 d from 21 April to 23 October 2012. Fresh manure of apparently healthy dairy cows from a 900-cow dairy farm was collected and mixed with sawdust (bulking agent) at a ratio of 4:1. Composting was conducted on a concrete apron, subdivided into four separate compartments, each with floor dimensions 50×50 cm. Compartments were isolated from each other by 40 cm high walls, and were all roofed. An iron screen mesh was installed about 10 cm above the reactor bottom to segregate the compost pile from the aeration channel. Sawdust was laid 2 cm thick over the iron screen mesh to distribute air equally, and air was blown to the piles using air pumps (one pump for one pile). Forced-aeration was conducted intermittently every day from the beginning of the composting process to 35 d, and then the piles were turned once a week. In addition, the air supply was enriched by turning of piles after each sampling. Compost piles contained about 25 kg compostable mixtures per compartment at the beginning of the experiment, and were maintained in a roughly conical shape during composting. The piles were classified into three test piles (test I, test II and test III) and control pile. Solid CaCN_2 was respectively mixed with test I, test II and test III at a rate of 2%, 3% and 4% by weight, while was not added into the control pile. Compost samples in duplicate were collected from each pile by using five-spot analyses at days 0, 4, 7, 14, 21, 28, 35, 42, 56, and 63 for the analysis of different parameters. The characteristics of the composting materials are shown in Table 1.

Table 1. Characteristics of composting materials

| | Fresh manure | Sawdust | CaCN_2 |
|-----------------------------------|-------------------------|------------|-----------------|
| Moisture content (%) ^a | 81.42±0.52 ^b | 7.95±0.44 | – |
| C (%) ^a | 33.80±1.60 | 42.43±1.78 | 1.71±0.97 |
| N (%) ^a | 1.71±0.05 | 0.25±0.01 | 21.24±0.08 |
| C/N ratio | 19.78 | 168.43 | 0.08 |

^a On a wet weight basis; ^b Standard deviation.

1.2. Physico-chemical analysis

Ambient temperature around the compost bins and the temperature within each pile were measured daily at 9:00 AM and 16:00 PM. Daily temperature of the pile was the average temperature of the top, middle and bottom layer in the two measurements. The moisture content of the samples was determined after oven drying at 105 °C to a constant weight (Li 1983). The pH was determined by a Mettler-Toledo EL20 pH-meter (Mettler-Toledo international trading (Shanghai) Co., Ltd.). Total nitrogen (T-N) and total carbon (T-C) was respectively measured by kjeldahl method and $\text{K}_2\text{Cr}_2\text{O}_7$ volumetric method (Li 1983). The concentration of $\text{NH}_4^+\text{-N}$ was determined by extracting the sample with 10% NaCl and the extracts were distilled (Nanjing Agricultural College 1980). Phenol-disulfonic acid colorimetric method was used to obtain the concentration of $\text{NO}_3^-\text{-N}$ (Nanjing Agricultural College 1980).

1.3. Statistical analysis

Three replicates were used for each analysis. Data were presented as the mean values of triplicates.

2. Results and discussion

2.1. Temperature

The goal of the temperature control during a composting process is to achieve to the greatest extent the harmlessness and stabilization of the compost materials after composting. Temperature changes reflect microbial activities of the compost pile and the state of the composting process. As shown in Fig. 1, all piles presented a change of temperature rise, temperature drop and maturation. The test piles reached their highest temperature 44.80 °C at 13 d in test I, 55.00 °C at 11 d in test II and 52.00 °C at 14 d in test III, respectively, while the control pile recorded the maximum temperature 43.80 °C at 1 d. The result indicated that the time to reach the high temperatures during composting was delayed with the addition of CaCN_2 resulting from the reduced porosity of the compost piles in the beginning. However, the maximum temperatures in the test piles were higher than the control pile, and the duration of the high temperatures was also longer in the former than in the latter. But generally, the duration time in all piles was not long enough by comparison with the results of others. The temperatures of 55 to 60 °C for 7 to 14 d were regarded as the ideal temperatures for effective composting (Tang *et al.* 2004; Johannessen *et al.* 2005; Syl-la *et al.* 2006). As for lower temperatures, 33.5 to 41.5 °C for 7 d was reported to be enough for efficient inactivation of bacterial populations such as *E. coli* during composting (Larney *et al.* 2003). In other aspect, a number of factors always have an effect on the change of composting

temperature, including the composition of the composting materials, composting method, and environmental condition, etc. (Changa *et al.* 2003; de Guardia *et al.* 2010; Tirado, Michel 2010). The short duration of the high temperatures in the present study were mainly caused by the long ventilation time at the first stage of composting and the poor insulating qualities of small masses of the piles.

2.2. Moisture content

Desirable moisture contents of mixtures at the beginning of composting fall within the range of from 40 to 65% with a preferred range of 50–60% (Agnew, Leonard 2003; Trémier *et al.* 2009). Nevertheless, in fed-batch composting of household biowaste, the optimum moisture content was in the range 30–40%, at which the microorganisms showed the highest protease activity (Narihiro *et al.* 2004a, b). And a successful composting with high initial moisture contents was also reported (Hanajima *et al.* 2006). So, the optimum moisture conditions during composting depend on the nature of the compostable materials. The initial moisture contents in this study were adjusted around 65%. The moisture content in all piles, on the whole, exhibited a declining trend (Fig. 2). The mean moisture content of the test piles decreased from an initial value of 64.69% to a final value of 60.78% in test I, from 64.13% to 58.44% in test II and from 63.77% to 61.94% in test III, respectively. In the control pile, it was from 67.08% to 61.50%. Among them, the evaporation of moisture was highest in test II, which was related to the longest duration of the high temperatures in it.

2.3. pH

The pH in the test piles showed the same change that followed a first sharp decline and then stabilization trend, when it increased greatly at the first 4 days and then went to stabilize in the control pile (Fig. 3). As the additive content of CaCN_2 increased, the pH increased accordingly. The mean pH went respectively from an initial value of 7.40, 9.38, 10.78 and 11.61 to 7.41, 7.71, 8.47 and 8.91 in the control pile, test I, test II and test III at the end of composting. And during the process, the pH was below 9 from 4d in test I and from 14d both in test II and test III, and then almost fluctuated between 8 and 9 which is considered to be the preferred range for a successful composting (Zeng *et al.* 2011). Comparatively, the pH in the control pile was in 8–9 from 4 d to 21 d and then decreased slowly and stabilized around 7.5. This is an acceptable condition but not the ideal one.

2.4. N transformation

Trends in percent T-N were shown in Fig. 4. At the first stage of composting, the T-N changed relatively little in

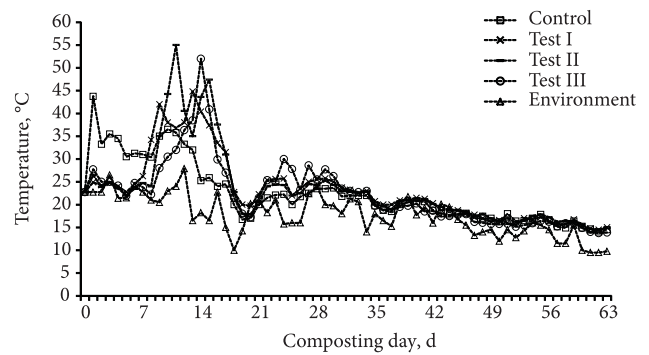


Fig. 1. The temperature profile during composting

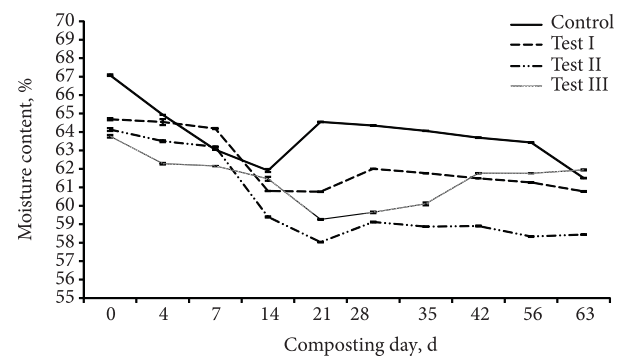


Fig. 2. The moisture content profile during composting

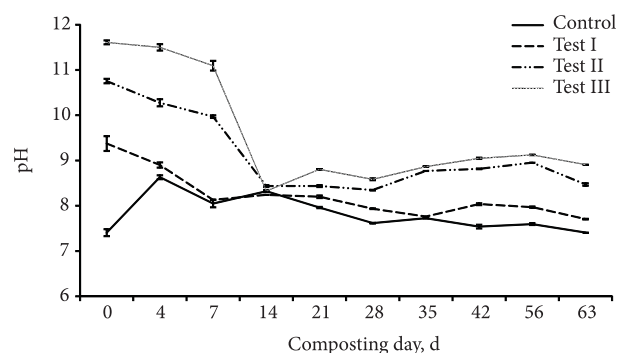


Fig. 3. The pH profile during composting

the control pile when decreased in the test piles, and then all began to increase. The decrease was due to the release of N in the form of NH_3 . With the composting time increasing, organic matters constantly decompose into CO_2 and H_2O and have a continuous loss, and the volume of the composting mixtures decreases accordingly. So, the T-N is condensed and its content always has a slight increase at the end of composting (Rihani *et al.* 2010). The percent T-N increased from an initial value of 0.89%, 2.02%, 2.48% and 2.98% to 1.20%, 2.64%, 3.05% and 3.02% in the control pile, test I, test II and test III after 63d composting that the increasing rate was 34.83%, 30.39%, 22.98% and 1.34%, respectively. This showed that the

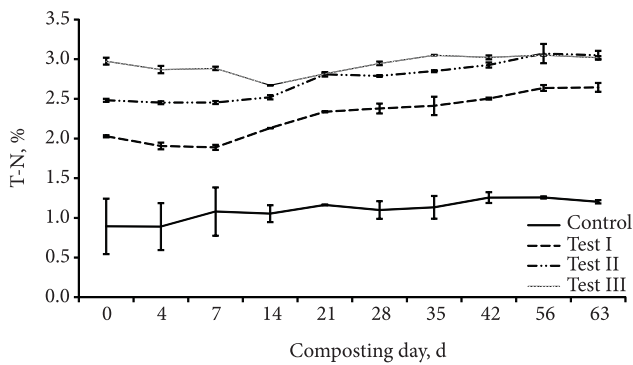


Fig. 4. The T-N profile during composting

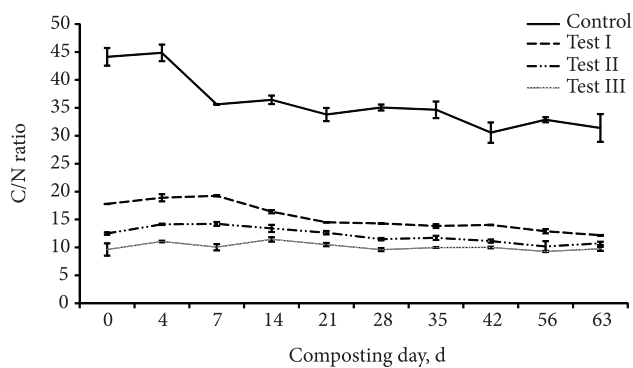
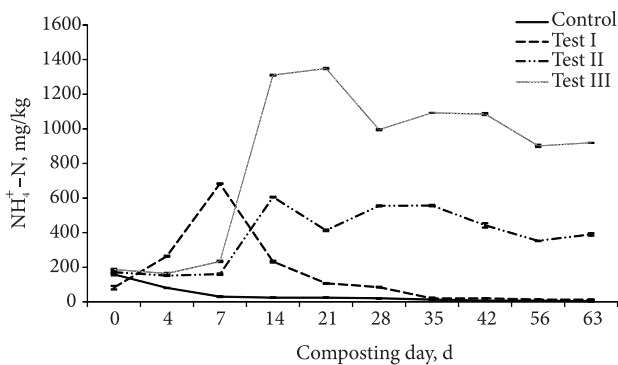
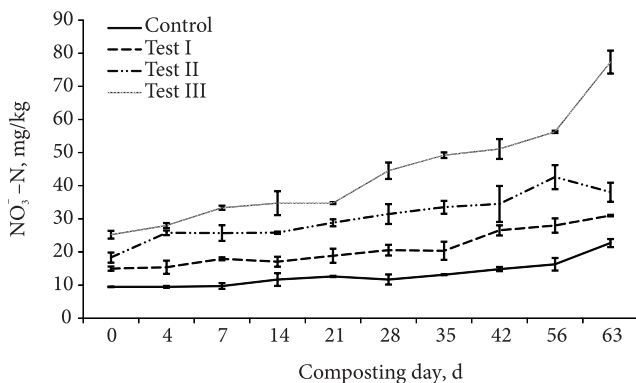


Fig. 5. The C/N ratio profile during composting

Fig. 6. The NH₄⁺-N profile during compostingFig. 7. The NO₃⁻-N profile during composting

increasing rate of T-N dropped with the increase of CaCN₂ additive content, it was because the increase of additive content resulted in the decrease of C/N ratio and when it went low, there was less C available for consumption, whereas N nutrients were relatively excess, causing a part of N to transform into ammoniacal N and have their volatilization losses. Paredes *et al.* (2000) found that during co-composting of olive mill wastewater with solid organic wastes, the high N losses through NH₃ volatilization occurred in the mixtures which had low initial C/N ratios (15.0–21.5), but it was reduced in the pile with the higher initial C/N ratio (31.0). In the current study, the initial C/N ratio was 44.13 in the control pile and 9.63–17.79 in the test piles. Then, it fell sharply in the control pile followed by test I and test II with a relatively little change in test III, before stabilizing and reaching values of 31.40 in the control pile and 9.75–12.17 in the test piles after the maturation phase (Fig. 5). The C/N ratio was so low at the start in these piles that it would not be evaluated by the normal suggested levels.

The concentration of NH₄⁺-N always falls during the composting process (Paredes *et al.* 2000). However, different results have been found in some studies, for instance, Bueno *et al.* (2009) reported that the NH₄⁺-N concentrations increased significantly at the initial stage and then decreased during composting of trimming residues at different levels of moisture and particle size. As shown in Fig. 6, the NH₄⁺-N concentrations in all piles, although occurring at different times, increased significantly at the initial stage and reached their maximum level because of ammonification which is always associated with temperature increase and mineralization of organic N compounds (Bueno *et al.* 2009). Then, the NH₄⁺-N concentrations decreased due to NH₃ volatilization and immobilization by microorganisms (Bueno *et al.* 2009), indicating that the inhibitor was gradually eliminated as composting process continued. Except in test III, the NH₄⁺-N contents in other piles were <400 mg/kg at the end of composting, which is the maximum limit recommended for a mature compost. The NO₃⁻-N contents showed a rising trend. During the thermophilic phase, lower increments were detected with respect to the mesophilic phase because of the inhibitory effect of NH₃ and high temperature on the growth of nitrifying bacteria (Huang *et al.* 2004; Bueno *et al.* 2009). The addition of N-rich CaCN₂ produced the composts with higher NO₃⁻-N concentrations than the control pile (Fig. 7).

Conclusions

1. The forced-aeration static-pile composting process of cattle manure mixed with CaCN₂ is technically feasible,

and it could be considered as an effective way to transform N and inactivate *E. coli* in manure.

2. The addition of CaCN₂ delayed the time to reach the high temperatures during composting, but increased the high temperature levels and duration.
3. With addition of CaCN₂, the pH evolution was improved; the final values of the NH₄⁺-N contents basically met the limit accepted for a mature compost; the final concentrations of NO₃⁻-N were enhanced.
4. With a comprehensive assessment of the physico-chemical parameter values, the addition of not less than 2% but not more than 3% CaCN₂ was recommended.

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