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Short communication

Reducing ammonia volatilization during composting of organic waste through addition of hydrothermally treated lignocellulose

Bakhtiyor Nakhshiniev [a,*], Chamila Perera [a], Muhammad Kunta Biddinika [a],
Hazel Bantolino Gonzales [b], Hiroaki Sumida [c], Kunio Yoshikawa [a]

[a] *Department of Environmental Science and Technology, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, 4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8503, Japan*
[b] *Innovative Platform for Education and Research, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, 4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8503, Japan*
[c] *College of Bioresource Sciences, Department of Chemistry and Life Science, Nihon University, 1866 Kameino, Fujisawa, Kanagawa 252-8510, Japan*

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ABSTRACT

Composting of organic wastes rich in nitrogen suffers from the loss of certain amount of nitrogen into atmosphere, notably through ammonia (NH_3) volatilization. In this study, the addition of hydrothermally treated lignocellulose (180 °C, 1.0 MPa, 30 min) to composting mixture as a new strategy for reducing NH_3 volatilization during the bench-scale composting experiment was tested. The results show that the addition of hydrothermally treated lignocellulose is very effective in reducing NH_3 volatilization during composting process. The effect was mainly due to the presence of high amount of simple sugars in treated lignocellulose, which promoted microbial activity to immobilize more inorganic nitrogen during intensive decomposition of organic nitrogenous compounds. As a result, NH_3 volatilization reduced from 9.61% in Control to 3.37% in Treated composting mixture. The difference in NH_3 volatilization was also reflected by significant difference ($p < 0.05$) in C/N ratio of the final compost products: with 23.89 in Control and 19.47 in Treated compost.

Introduction

Composting is a simple and low-cost method to convert the organic wastes into safer and usable end product. If properly accomplished, composting stabilizes organic waste, kills pathogens and weeds, suppresses unpleasant odor, reduces the volume of the waste and turns it into a nutrient-rich product that can be used as organic fertilizer for plant growth. However, composting of organic wastes rich in nitrogen suffers from the loss of certain amount of nitrogen into atmosphere, notably through ammonia (NH_3) volatilization. The process is the result of activity of microorganisms on organic nitrogenous compounds that are faster in decomposition compared to organic carbon compounds (Bernal et al., 1993; Beline et al., 1998). Substantial loss of nitrogen through NH_3 volatilization, sometimes as high as 40–80% of the initial mass of nitrogen, has been reported previously in the literature (Kirchmann and Witter, 1989; Martins and Dewes, 1992; Kithome et al., 1999; Lee et al., 2009). The consequence of such massive NH_3 volatilization is not only the increase of air pollution but also the decrease of agronomic value of end product.

Several practices such as optimization of initial C/N ratio (Jiang et al., 2011), process temperature (Pagans et al., 2006; Eklind et al., 2007), pH (Nakasaki et al., 1993), aeration (DeGuardia et al., 2008) and moisture regime (Bueno et al., 2008; Jiang et al., 2011) have been found to influence the degree of NH_3 volatilization from compost. However, optimization of these parameters under the practical composting conditions is not always an easy task and moreover, does not always appear to be effective. Notable reductions of NH_3 volatilization and subsequent retention of nitrogen in the final compost product have been achieved after the addition of various mineral absorbents and acidifying agents to the compost (Bernal et al., 1993; Termeer and Warman, 1993; Mahimairaja et al., 1994; Prochnow et al., 1995; Kithome et al., 1999; Boucher et al., 1999; Jeong and Kim, 2001; Zhang and Lau, 2007; Alipour and Torkashvand, 2009). Unfortunately, mineral absorbents are not commonly available and application of acidifiers requires special

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* Corresponding author. Tel.: +81 45 924 5507; fax: +81 45 924 5518.
E-mail addresses: bakhtiyor_nr@yahoo.com, bakhtiyor.n.aa@m.titech.ac.jp (B. Nakhshiniev).

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precaution to avoid overdosing, which may conversely slow down the activity of the microorganisms and/or cause salinity problem (Zhang and Lau, 2007; Lee et al., 2009; Wang et al., 2013).

The simplest technique that could be used to suppress NH_3 volatilization effectively is to add simple sugars, e.g., the forms of carbon that is necessary for immediate immobilization of nitrogen and subsequent suppression of NH_3 volatilization (Reinertsen et al., 1984). Notable reduction in NH_3 volatilization was shown when the fresh hog manure was supplemented with glucose (Subair, 1995). Molasses, rich normally in sucrose, was applied to compost mixture and NH_3 volatilization was remarkably suppressed, which was caused by immobilization (Liang et al., 2006). In the experiments of Li et al. (2013a,b), the addition of sucrose and glucose to sewage sludge, straw and sawdust mixtures led to more than 55% reduction of NH_3 emissions. However, in order to reduce NH_3 volatilization effectively, large amount of expensive sugars must be added (Li et al., 2013a) and recently, application of molasses is becoming uneconomical due to its growing demand from the bio-ethanol production industries.

Previously, a novel hydrothermal treatment technology with mild reaction conditions ($160\ ^\circ C < T < 220\ ^\circ C$, $0.6\ MPa < P < 2.4\ MPa$, 30 min) was investigated as a treatment step in enhancing biodegradability of lignocellulosic residues for organic fertilizer production (Nakhshiniev et al., 2012). Specifically, hydrothermal treatment was performed to disrupt hemicellulose–lignin association and improve susceptibility of cellulose fibers to microbial attack. According to the results, treatment temperature of 180 °C was the most favorable for accelerating aerobic degradation of lignocellulose, and that this improved biodegradability was mainly attributed to the effect of treatment on solubilization of the major portion of hemicellulose polysaccharides into simple sugars. Thus, it was hypothesized that the addition of hydrothermally treated lignocellulose as a carbon amendment might reduce NH_3 volatilization during composting process.

Material and methods

Material

In this research, freshly harvested green kudzu plant (*Pueraria montanavarlobata*) and bamboo tree (*Phyllostachys pubescens*) residues were used as the model composting ingredients. The green kudzu was used as a high-nitrogen material while bamboo was used as a lignocellulose carbon amendment. After the harvest, the residues were chopped into chips (2–3 cm) and oven-dried (55 °C) to constant weight. The oven-dried residues were then, grounded, sieved (<0.25 mm) and preserved for the next experimental procedures. The physicochemical properties of the materials are summarized in Table 1.

Table 1
Physicochemical properties of composting ingredients used in the present research.

Parameters (dry base)	Green kudzu	Raw bamboo	Treated bamboo
Simple sugars[a], %	10.61 (0.18)	1.36 (0.09)	15.70 (0.29)
Hemicellulose, %	18.42 (1.55)	30.83 (0.21)	7.48 (1.47)
Cellulose, %	26.15 (0.73)	38.01 (0.97)	39.22 (1.91)
Lignin, %	16.17 (0.82)	19.15 (0.76)	32.74 (0.44)
OM, %	91.93 (0.12)	98.30 (0.03)	97.02 (0.39)
Total C, %	44.61 (0.04)	47.50 (0.04)	51.30 (0.03)
Total N, %	3.74 (0.01)	0.41 (0.03)	0.44 (0.01)
C:N ratio	11.93	116.59	115.85

A (*B*), where *A* = mean and (*B* = standard deviation) with *n* = 3.
[a] As a glucose and xylose equivalent.

Hydrothermal treatment of bamboo

Hydrothermal treatment of bamboo was conducted in a 0.5 l batch-type hydrothermal reactor (MMJ-500, Japan) equipped with automated stirrer, pressure sensor and temperature controller. The schematic diagram of the experimental set-up was reported previously (Nakhshiniev et al., 2012). The amount of grounded residue and water mixture loaded into the reactor was about 60 g, corresponding to 1:3 mixing ratio. The reactor was then heated to 180 °C (1.0 MPa) at an average heating rate of 7.2 °C/min and a constant stirring speed of 200 rpm. In order to prevent combustion during heating, the air inside the reactor was initially evacuated with a stream of argon gas. After reaching the pre-set temperature, the mixture was further held in the reactor for 30 min. Once the holding time was complete, the reactor was decompressed and the treated bamboo residue was promptly taken out. The effect of hydrothermal treatment on the chemical properties of bamboo is incorporated in Table 1.

Composting system

The bench-scale composting systems were employed in this research. As shown in Fig. 1, composting was carried out in 250 ml perforated polystyrene vessels in which two layers of 1.5 g (dry weight) microbial seeds with 3.0 g (dry weight) starting composting mixture in the middle, were sandwiched between the two porous stratums of 5 g perlite (wetted with 15 mg pure water). The microbial seed was derived from the commercial compost (Wakayama Organic Productive Union, Japan). Prior to use, it was sieved (passed through 2 mm and retained on 1 mm mesh screen) and pre-incubated (27–60 °C) for five days with frequent mixing. This was done to guarantee reproducibility of gaseous emissions from the compost seed, since limited NH_3 and CO_2 productions were expected from the mixtures. The composting mixtures were prepared by adding either hydrothermally treated or raw bamboo residue to green kudzu with a mixing ratio that would produce a C/N ratio close to 25. Thus, the green kudzu and treated bamboo were mixed with 1.36:1.65 ratio and labeled “Treated” mixture, and the green kudzu and raw bamboo were mixed with 1.30:1.70 ratio and labeled “Control” mixture. The moisture content in both mixtures was adjusted to 65%, by adding distilled water. The other properties of the mixtures are shown in Table 2. The vessels were then sealed in 2-l jars and incubated to undergo composting process, including blank vessels that contained only perlite and microbial seeds. The temperature inside the incubation was room temperature during

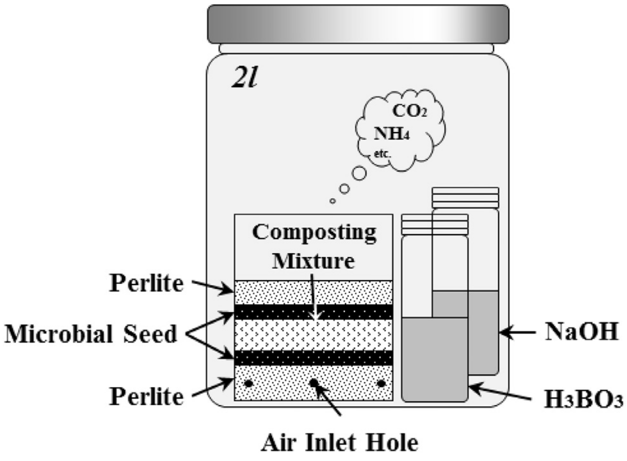

Fig. 1. Biometer jar for simulating aerobic composting.